DEPARTMENT OF TRANSPORTATION

Systems Engineering Analysis for MnDOT Arterial Traffic Management

Concept of Operations

May 2020
Prepared by AECOM

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Introduction

This document presents a ***Concept of Operations*** (*ConOps*) for the Minnesota Department of Transportation (MnDOT) arterial traffic management. This programmatic document is specifically developed for the MnDOT system. Other agencies can use it as a template to modify and customize the document for their projects and systems. This programmatic ConOps should not be adopted without customization for non-MnDOT projects.

The emphasis of this document is on defining the use of Intelligent Transportation Systems (ITS) tools to manage traffic on MnDOT operated arterial roadways. More specifically, 'who' uses or will use the tools, 'why' are (or will be) the tools used, and 'how' are the tools (to be) used. Examples of ITS 'Tools' include Dynamic Message Signs (DMS), Video, and Traffic Management Center (TMC) Software.

Rural Minnesota Perspective

In rural areas of Minnesota, a number of ITS tools are used to help manage traffic on arterials. In rural areas, it is common for these ITS tools to operate as stand-alone systems, fully functioning without connections to other systems. This document describes these ITS tools, including summaries of how they are used today (if they are) and how the use of the tools might change in coming years.

Metro Areas Perspective

In the metro areas of the state (including the Twin Cities as well as smaller cities throughout the state), real-time traffic management activities have traditionally focused on the freeway network. This is evident by the fact that the MnDOT Regional Transportation Management Center (RTMC) currently houses freeway operations personnel, and the workstations designed for arterial operations are typically vacant.

In recent years, MnDOT has begun a number of deployments that will begin a transition towards increased metro area real-time arterial traffic management (initially in the Twin Cities but later expanding to additional cities). This transition will deploy surveillance, information dissemination, remote signal timing control, and other traffic management tools.

However, this shift towards an increased focus on arterial traffic management must go beyond simply deploying technologies, otherwise MnDOT risks a situation where the technology devices will be largely underutilized. The increased arterial ITS deployments will actually require a paradigm shift in the definition of the role of the MnDOT Arterial Operations Group. Currently, the MnDOT Arterial Operations Group consists of traffic engineers who work to deploy and operate systems on the arterials. However, the staff members' positions are not focused on real-time monitoring and response to conditions in the same way freeway operations dispatchers in the RTMC focus on real-time response.

As traffic volumes increase along arterials, and as arterial corridors play an increasing role in the overall traffic network, there is an increasing need for real-time arterial traffic management that is analogous to the freeway traffic management currently performed by the RTMC. While MnDOT has begun this transition by deploying technologies on arterial corridors throughout the metro, there is an equally important need for a transition in the overall approach to arterial traffic management - that is more real-time operations. Later sections of this document describe the likely transition to a more real-time operational management perspective of the MnDOT Metro Area Arterial Operations Group.

Arterial Traffic Management Transitions Described in this Document

This ConOps describes three key transitions likely to occur in arterial traffic management:

- A more formally defined real-time traffic management role for the Arterial Operations Group.
- A migration of the Arterial Operations Group to staff the RTMC when appropriate; and
- A transition towards interconnecting what are now stand-alone arterial traffic management tools.

In addition, as operations of connected and automated vehicles (CAVs) expand, several data exchanges between arterial traffic management and CAVs are anticipated, and these are presented in this document.

Defining New Roles for Metro Arterial Traffic Management

This ConOps describes who uses ITS tools, why the tools are used, and how the tools are used. Throughout the document, the recurring theme is that MnDOT is beginning to increase the number of arterial ITS deployments and increase traffic management needs/capabilities. This increased activity introduces a number of gaps in the operations of the devices. This section first summarizes the questions that must be answered, and then presents a summary table (Table 1) of the suggested roles to be performed in the coming years as arterial ITS deployments increase.

Questions to be Answered as Arterial ITS Deployments Increase:

1. **Video**. Video deployments on arterials should be supported by a formal definition of who will monitor the videos (e.g. MnDOT Arterial Operations, Freeway Operations, Metro Maintenance).
    - Are videos to be monitored during peak periods only or during RTMC hours?
    - Are videos actively monitored (operator sitting watching) or only when triggered by data (e.g. if the arterial travel time algorithm detects a deviation from typical travel times or when an incident is reported to Minnesota State Patrol)?
    - Are videos monitored from within the RTMC or from the MnDOT Arterial Operations office (video can be viewed at Arterial Operations desks but not controlled)?

2. **Websites.** MnDOT is exploring approaches for increased web dissemination of arterial information (e.g. websites that color arterial highways in real-time to represent the speed of traffic on the highway). If deployed, a logical transition will be to also display incidents and events on these website displays. MnDOT's Condition Reporting System allows for arterial incident and event entry, but a formal operations procedure is needed for consistency of event entry.
    - Who will perform the entry (e.g. MnDOT Arterial Operations, Freeways Operations, Metro Maintenance)?
    - What hours will entry be performed (e.g. peak periods, RTMC hours)?

Table 1. Summary of Suggested Roles for MnDOT Metro Area Arterial Traffic Management

<table>
<tr><th>What Tool will be Used?</th><th>Arterial Operations Activity</th><th>Who will Perform it?</th><th>When will it be Performed?</th><th>Where will it be Performed?</th></tr>
<tr><td>Condition Reporting System</td><td>Entry of incidents/ events into Condition Reporting System</td><td>• MnDOT Metro Arterial Operations
• MnDOT Metro Freeway Operations support as needed during times arterial operators are not staffed</td><td>• Peak Periods (as long as less than 50% of the metro arterial corridors are covered)
• RTMC Freeway Operations hours (once more than 50% of the metro arterial corridors are covered)</td><td>RTMC Arterial Operations Workstation</td></tr>
<tr><td rowspan="6">ATMS (Advanced Traffic Management System Software)</td><td>Monitoring Arterial Video (note: video can be viewed at Arterial Operations desks but not controlled)</td><td rowspan="3">• MnDOT Metro Arterial Operations
• MnDOT Metro Freeway Operations support as needed during times arterial operators are not staffed</td><td rowspan="2">• Peak Periods (as long as less than 50% of the metro arterial corridors are covered)
• RTMC Freeway Operations hours (once more than 50% of the metro arterial corridors are covered)</td><td rowspan="3">RTMC Arterial Operations Workstation</td></tr>
<tr><td>Posting Arterial incident messages to Arterial DMS</td></tr>
<tr><td>Posting Freeway incident messages to Arterial DMS</td><td>• Peak periods by Metro Arterial Operations
• Other times by RTMC or Maintenance staff</td></tr>
<tr><td>Posting Arterial incident messages to Freeway DMS</td><td>• MnDOT Metro Freeway Operations</td><td>• All hours RTMC is staffed</td><td>RTMC Freeway Operations Workstation</td></tr>
<tr><td>Implementing Arterial ‘flush’ signal timing plans for Corridor control (e.g. Integrated Corridor Management or ICM)</td><td rowspan="2">• MnDOT Metro Arterial Operations</td><td rowspan="2">• Peak Periods (as long as less than 50% of the metro arterial corridors are covered)
• RTMC Freeway Operations hours (once more than 50% of the metro arterial corridors are covered)</td><td rowspan="2">Arterial Operations Desk/Office
RTMC Arterial Operations Workstation</td></tr>
<tr><td>Real-time Operational Changes (e.g. temporarily extending a signal phase if an approach is not clearing)</td></tr>
</table>

3. **RTMC Radio.** The RTMC radio broadcaster currently announces metro-wide reports every 10 minutes during peak periods. These traffic reports traditionally cover the freeways where videos and data are available. As video and data feeds will increasingly be available for arterials, a policy is needed to define the extent to which the dispatcher reports on arterials (ideally coupled with public outreach explaining the expanded role if there is one).
    - Will the freeways receive priority during reporting times or will radio broadcasters cover the arterial network as well?

4. **DMS.** Increased deployment of DMS on arterials will allow for automatic and manually created messages on arterials.
    - Who will be responsible for posting arterial DMS messages (e.g. MnDOT Arterial Operations, Freeways Operations, Metro Maintenance)?
    - What hours will incident/event messages be posted for arterials?

Intended Use of this Document

The intended uses of this ConOps are:

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

To accomplish these uses, the ConOps first introduces the needs for effective traffic management. The ConOps then introduces the concept of arterial traffic management and describes a likely transition towards increased arterial traffic management. Next, the document 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 (or will use) the tool, 'why' the tool is (or will be) used, and 'how' the tool is (or will be) used.

Consider the following example:

A common deployment of technologies on arterial highways involves signal pre-emption for at-grade rail crossings. When a train is traveling through, a pre-emption signal ensures that cross traffic receives a red light until the train is past (regardless of whether the train system deploys gates). While this deployment has traditionally been a stand-alone technology, if this pre-emption signal at the intersection could be communicated to a central location, this could allow information dissemination to inform travelers of the train passing through the intersection. In the case of emergency vehicles that may be transporting injured people or traveling to crash scenes, knowing that a train is blocking an intersection could allow them to take alternate routes such as a bridge over the train track.

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 Arterial Network

The MnDOT statewide road network consists of approximately 11,895 miles, of which 10,981 miles are not part of the Interstate Trunk Highway system. Many of the MnDOT non-freeway roadways are considered arterials. An arterial roadway is defined as a moderate or high-capacity road which is immediately below a freeway level of service. Arterial roads typically carry large volumes of traffic between regional areas. It is common for arterial roadways to have at-grade intersections, some of which are controlled with traffic signals.

In many instances, arterial roads were established prior to the construction of the Interstate Highway network. Due to this fact, many arterials parallel freeways within the state and serve as alternate routes during incidents or congestion. One such example is US Highway 10 which takes a route approximately parallel to I-94 through much of the state. Some arterials are considered so vital that they were included within the Minnesota State Constitution. Figure 1 depicts the Minnesota Arterial System.

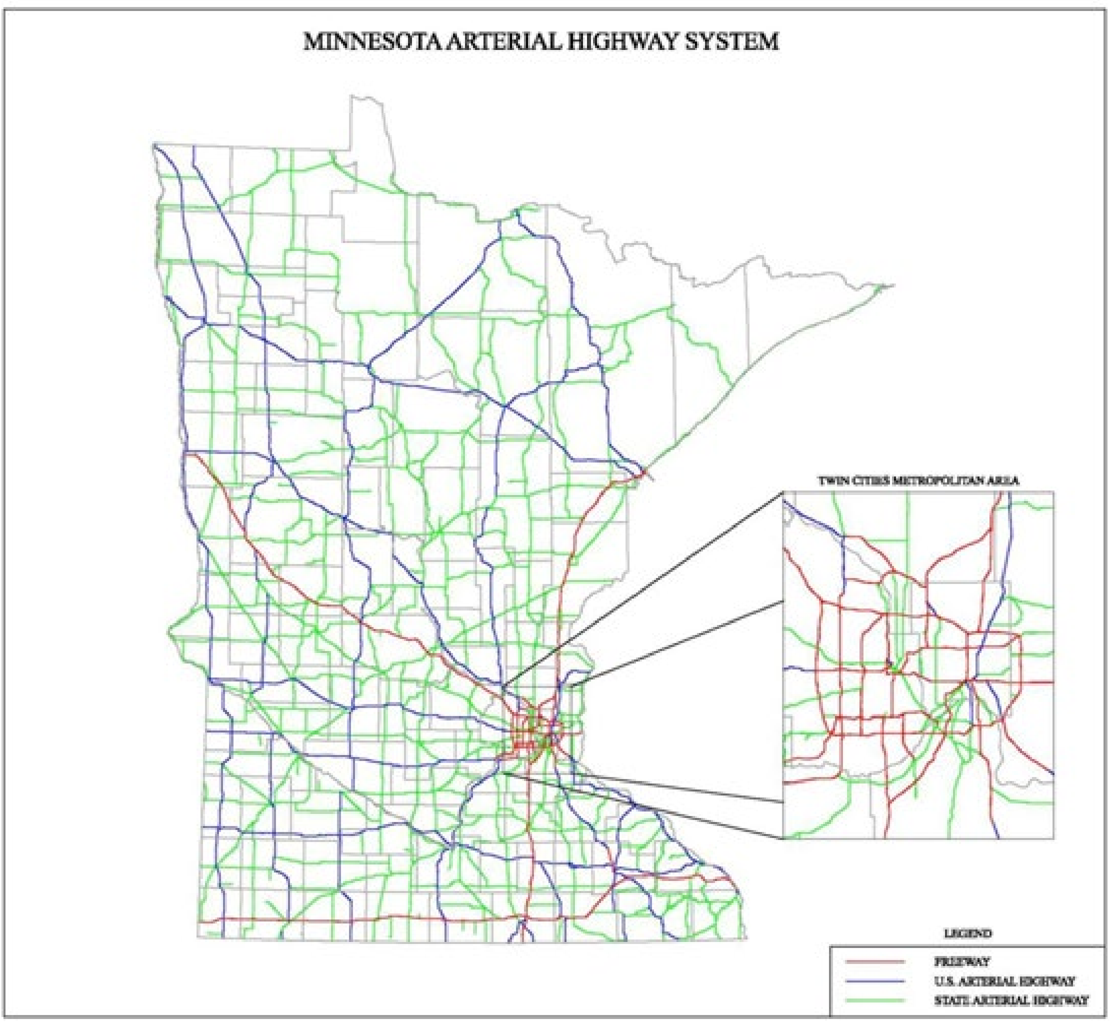

Figure 1. Minnesota Arterial Highway System

The Minneapolis-St. Paul Metro Area (Twin Cities) operates the most complex network of arterials. Major arterial highways include but are not limited to US Highway 10, US Highway 12, US Highway 61, US Highway 169, US Highway 212, MN Highway 7, MN Highway 13, MN Highway 36, MN Highway 47, MN Highway 55, MN Highway 65, and MN Highway 77. In addition, other arterials contribute to the overall network. In summary, the Twin Cities arterial 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 numerous major arterials. In addition to the US Highways mentioned previously, US Highway 2 in northern Minnesota provides a critical east/west route across the state connecting Duluth and East Grand Forks. US Highway 14 in southern Minnesota provides a critical east/west route across the state connecting Rochester to Mankato before continuing west into South Dakota. US Highway 52 in south eastern Minnesota provides a critical north/south route between Rochester and the Twin Cities. Many of the regional population centers in rural areas are located along (or near) major arterial highways. The numerous US and Minnesota Highways crisscross the state connecting regional centers, serving local communities, and support economic development.

Current Traffic Management

The at-grade interactions of vehicles along different paths require full-time traffic management on arterials. The most common 'traffic management' activity performed on arterials is signalized control of at-grade intersections, either as stand-alone or coordinated systems. MnDOT has developed a Concept of Operations document specifically for traffic signal control, and therefore this will not be covered in detail in this document.

Beyond the common traffic signal operations, arterial traffic management supports the needs of emergency vehicles, transit vehicles, pedestrians and bicyclists by facilitating the safest and most efficient progression of traffic along arterial highways. These arterial highways range from rural to metro highways.

Intelligent Transportation Systems

MnDOT has operated ITS since the 1970's. With the exception of traffic signal controllers, the use of ITS for arterial traffic management has not been as comprehensive as that for freeways. However, MnDOT is increasing the number of planned arterial ITS traffic management deployments.

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.

The 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. Arterial 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 arterial 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 arterials 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 2.

Table 2. Arterial Traffic Management Needs

Problem	Needs (As a Result of the Problem)
Incidents and events significantly reduce arterial 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 arterial levels of service that impede traffic flow and limit capacity.	**Need 2: Traffic monitoring** There is a need to monitor traffic volumes and congestion levels.
Travelers unaware of congestion or delays miss opportunities to divert to alternate routes and encounter delays.	**Need 3: 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 planned events (e.g. roadwork, special events) encounter unexpected stopped traffic and delays without the option to divert.	**Need 4: Real-time planned event notification** There is a need to inform travelers en-route and pre-trip of planned events (e.g. special events, roadwork).
Travelers unaware of incidents, isolated inclement driving 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 alert travelers en-route and pre-trip of active unplanned events (e.g. crashes, unusual driving conditions, Amber Alerts, special events, weather condition alerts).
Numerous factors must be considered when formulating traffic management responses to operational problems.	**Need 6: Arterial operational analysis** There is a need for short-term analysis of multiple data sources and for long term performance measurement analyses.
Numerous factors must be considered when planning traffic management adjustments and improvements to operational problems as well as programs and planning projects.	**Need 7: Arterial data storage, archive and access** There is a need to store, archive, and share arterial 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 8: Manual Event Reporting** There is a need for manual incident and event reporting.
Traffic management devices in the field must be controlled by operators without requiring operators to be local to the device.	**Need 9: Device control** There is a need to control arterial management devices remotely.
In metro areas, traffic movement is inefficient if travelers stop at multiple traffic signals along a stretch of road.	**Need 10: Coordinated control** There is a need for coordinated signal control.
Speed differentials contribute to the risk of crashes.	**Need 11: Speed control** There is a need to slow traffic exceeding the speed limit.
Arterials are used by a combination of vehicles, pedestrians, and bicycles.	**Need 12: Multimodal options** There is a need to allow multimodal use of the arterial system.

Problem	Needs (As a Result of the Problem)
During highway and non-highway emergencies, emergency vehicles must reach their destination quickly and safely.	**Need 13: Emergency management** There is a need to provide safe and effective travel for emergency vehicles responding to incidents.
Illegal movements at traffic signals contribute to the risk of crashes.	**Need 14: Enforcement systems** There is a need to enforce and reduce unsafe driving practices at signal systems.
Transit vehicles operating behind schedule cause delays for all riders and deter travelers from selecting the transit mode.	**Need 15: Transit vehicle advantages** There is a need for transit vehicles to have advantages.
In some locations, drivers' lack of attention contributes to a higher rate of crashes.	**Need 16: Warning systems** There is a need to alert drivers to potentially hazardous 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.

Operational Concept

MnDOT is responsible for traffic management along arterial highways. Arterial highways are defined (for the purposes of this document) as all MnDOT maintained roads that are not limited access freeways. Arterial highways include highways with signalized intersections and non-signalized intersections and range from rural, relatively low volume roads to urban high-volume roads.

In many ways, arterial traffic management is very similar to freeway traffic management (e.g. traffic management strategies and supporting technologies are used to promote safe and efficient movement of vehicles). However, unlike freeways, there is a wider range of highway designs for arterials (ranging from rural two-lane arterials with no sidewalks, curbs or gutters; to multi-lane arterials with controlled pedestrian access. Therefore, there is a wider range of traffic management strategies and technologies.

For these reasons, arterial traffic management systems range from simple stand-alone deployments (such as Dynamic Speed Display Signs ('Your speed is' signs) in rural school zones) to complex coordinated signal control systems in metro areas that function to optimize traffic flow and minimize emissions.

The Evolving Operational Concept for Arterial Traffic Management

This section describes the current and evolving operational concept for arterial traffic management by dividing arterial traffic management into three categories:

- Metro Area Comprehensive arterial corridor traffic management
- Locally operated arterial traffic control and alert systems.
- Individual intersection traffic signal control

Note: MnDOT has developed a separate Concept of Operations for individual traffic signal control, therefore while individual intersection traffic signal control is recognized in this report, it is not a primary focus.

The following sections describe the first two bullets above.

Metro Area Comprehensive Arterial Corridor Traffic Management

The MnDOT RTMC is staffed with MnDOT Freeway Operations personnel and MnDOT Metro Area Maintenance dispatchers. However, there are currently no arterial operations staff members regularly in the RTMC (although workstations are available). Based on a brief survey of TMCs around the country, this is not a unique situation. In fact, most TMCs do not have the set aside space for arterial operations in the TMC. This is not simply a discussion of location. For the most part, real-time operator involved traffic management on arterial highways has been considerably less than freeways.

This lack of arterial operations presence can be traced to the following three factors:

1. **High Functioning Traffic Controllers.** The hardware and software that control traffic signals are able to adjust on fixed schedules (time of day and day of week) and in response to local traffic detectors, while remaining coordinated with other signals. Simply put, for a well-timed traffic signal system (and corridor) there is very little that an operations engineer could do manually to improve on these functions without causing other problems (e.g. signal coordination and progression issues). Therefore, there is very little need for an operator manually 'managing' arterial traffic signals in real-time. However, recent emerging strategies and technologies involving corridor management (either stand-alone corridors or integrated corridor management) have defined approaches for changing the role of an arterial corridor when needed (e.g. to help clear a parallel freeway or to disperse event or incident traffic using corridor-wide 'flush' signal timing plans). Therefore, these 'corridor' approaches will likely increase the manual involvement in arterial traffic management.

2. **Traditional Traffic Management Approaches.** Arterial traffic engineers typically use technologies to observe and correct *operational problems* as opposed to real-time *traffic problems*. In other words, arterial operations personnel may observe video images to examine whether signal timing parameters are clearing queues effectively, or to follow-up on traveler complaints, but rarely use video to view current conditions to implement a real-time management strategy.

   Similarly, traffic data collected in the field is most commonly used for signal retiming or validation, as opposed to real-time incident detection or response.

3. **Freeway Focus for Technology Deployments.** Over the past decades, the priority for deployment of technology management tools (such as video and DMS) has initially been focused on the freeways, where incidents impact more travelers and cause greater delays. Therefore, it is not surprising that there is a greater emphasis on real-time freeway monitoring and response than there is on arterials. However, recent deployments (and planned future deployments) will continue to increase monitoring and control capabilities for arterials.

In conclusion, as traffic volumes increase along arterials, and as arterial corridors play an increasing role in the overall traffic network, there is likely to be an increased need for real-time arterial traffic management that is analogous to the freeway traffic management currently performed by the RTMC. While MnDOT has begun this transition by deploying technologies on arterial corridors throughout the metro, there is an equally important need for a transition in the overall approach to arterial traffic management - that is more real-time operations.

The transition towards metro-wide real-time arterial traffic management will likely involve two major transitions, defined as follows:

1. **Definitions of real-time operations roles.** The MnDOT Metro Area Arterial Operations Group currently provides real-time operations of the traffic signals, including field response for operational problems. However, as noted above, there is no staff time dedicated to continuous monitoring of conditions (using video or traffic detectors) to proactively decide to respond to changing conditions. MnDOT may elect to create periods of time when Arterial Operations Group staff members are dedicated to monitoring the video and detectors on the arterials to assess whether real-time response to traffic conditions is warranted.

2. **Migration to RTMC staffing.** Over time, as the amount of time the Arterial Operations Group has staff dedicated to monitoring and responding to traffic conditions increases, it will become more efficient for these staff to sit in the RTMC during some (or all) periods of the time they are monitoring conditions. The RTMC offers increased video control and the support of additional teams. Also, the presence of the Arterial Operations Group in the RTMC will increase efficiencies and coordination of system wide responses to incidents (for example an Integrated Corridor Management approach).

This document describes this impending evolution of arterial traffic management by not only describing what is done now, but also describing what will likely be done as the MnDOT Arterial Operations Group migrates to this new role.

Localized Traffic Control Actions

The nature of arterial highways introduces aspects that are not encountered by freeway highways. The most obvious example is conflicting movements between passenger vehicles, emergency vehicles, transit vehicles, pedestrians, rail traffic and bicycles supported by at-grade intersections that may or may not be signalized. Another example is the fact that arterials encounter nature-related challenges that most freeways do not, such as areas prone to flooding when nearby rivers crest. For these reasons, arterial traffic management involves localized traffic control actions – defined as those actions that do not require integration with other actions (for example a local dynamic speed display sign does not mandate connection to other actions and is locally 'self-contained').

As arterial traffic management evolves in Minnesota, there may be increasing numbers of localized traffic control actions, and there might be coordinated corridor-wide arterial traffic management actions deployed together with the localized systems. Therefore, the localized deployments may transition to exchange data with other systems where they did not before. For example, speed detector data captured by dynamic speed display signs may one day be communicated to a nearby TMC or Transportation Operations Center (TOC) for inclusion in arterial performance analyses. As another example, local flood detectors that activate local warning signs may also communicate this information to centralized traveler information systems for statewide deployment.

Arterial Traffic Management Actions

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

The Comprehensive Arterial Corridor traffic management actions include:

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

The Localized Traffic Control actions include:

- Local (potentially stand-alone) arterial traffic control and traveler alerts.

Figure 2 illustrates the arterial traffic management actions.

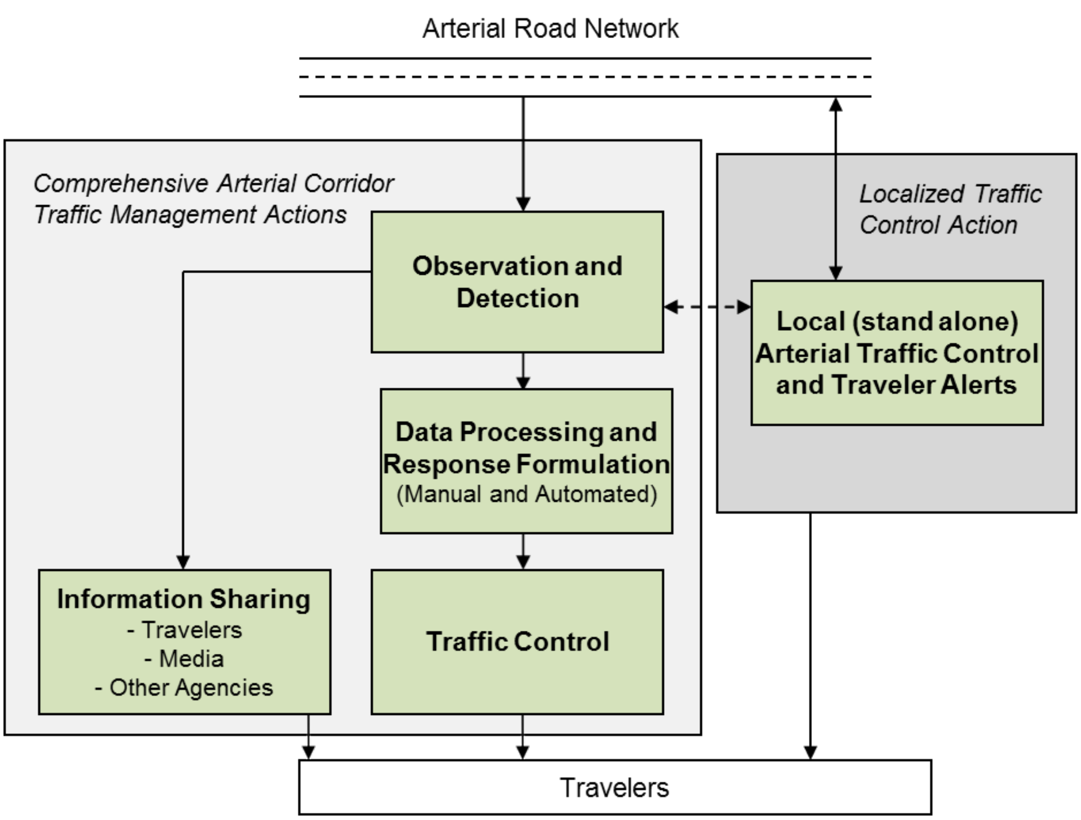

Figure 2. High Level Summary of Arterial Traffic Management Actions

ITS Tools that Support Traffic Management Actions

ITS are technology systems, devices, and applications that work together as ‘Tools’ to support the actions of arterial traffic management. Each ITS tool supports one or more of the actions performed for traffic management. Examples of ITS ‘Tools’ include dynamic message signs, video, and emergency vehicle preemption.

Figure 3 illustrates the ‘Tools’ that support each of the five traffic management actions.

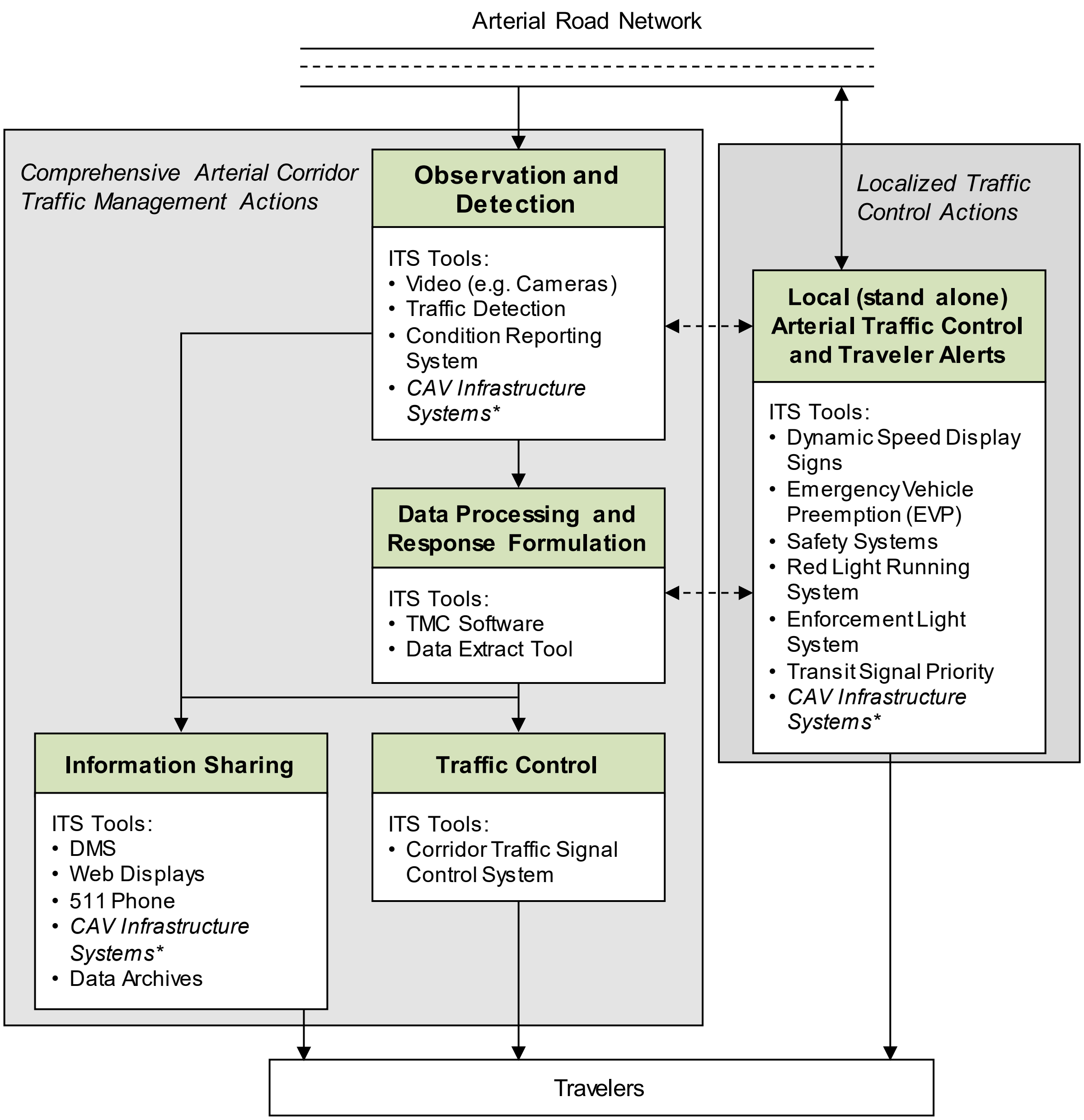

Figure 3. Illustration of ITS Tools that Support Arterial Traffic Management

Mapping of ITS Tools to Needs

Table 3 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 3: Real-time travel time/congestion notification is primarily addressed by three ITS Tools (DMS, web displays, and 511 mobile app). 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 3. Map of ITS Tools to Arterial Traffic Management Needs

Need	ITS Tools														
	Metro Area Comprehensive Arterial Corridor Traffic Management									Local Arterial Traffic Control and Traveler Alerts					
	Observation and detection			Information Sharing			Data Processing & Response Formulation		Traffic Control						
	Video	Traffic Detection	Condition Reporting System	DMS	Web Display	511 Phone and Mobile App	Data Extract Tool	ATMS	Traffic Signal Control Systems	DSDS	EVP	Safety Systems	Red Light Running	Enforcement Light	TSP
Need 1: Incident/event verification	P														
Need 2: Traffic monitoring	P	P													
Need 3: Real-time travel time/congestion notification		C		P	P	P		C							
Need 4: Real-time planned event notification			C	P	P	P									
Need 5: Real-time unplanned event notification	C		C	P	P	P									
Need 6: Arterial operational analysis	C	C	C					P							
Need 7: Data storage, archive and access		C					P	P							
Need 8: Manual Event Reporting	C	C	P												
Need 9: Device control		C						P							
Need 10: Coordinated control		C						P	P						
Need 11: Speed control										P					
Need 12: Multimodal options									P						
Need 13: Emergency management									C		P				
Need 14: Enforcement systems	C												P	P	
Need 15: Transit vehicle advantages									C						P
Need 16: Warning systems												P			
Need 17: Center-to-Center communications					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 arterial traffic management as it provides arterial 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.

Based upon research and feedback, arterial 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 monitoring; and
- Need 8: Manual event reporting.

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

- Video;
- Traffic Detection; and
- Condition Reporting Systems

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 4. Observation and Detection 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 1: Incident/event verification	N/A	There are no interdependencies for the needs addressed by Observation and Detection
Need 2: Traffic monitoring	N/A	
Need 8: Manual event reporting	N/A	

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 arterial 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 arterial traffic volumes and occupancy.

The operational concept of traffic detection for arterial 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).

Condition Reporting System

A Condition Reporting System (CRS) supports the manual and automated creation and assembly of current and planned events to be used to populate traveler information systems. The current MnDOT Condition Reporting System (Condition Acquisition and Reporting System, or CARS) includes all MnDOT state-maintained highways. Therefore, operators have the capabilities to enter events on all arterial highways.

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 5. Observation and Detection Operational Concept: Condition Reporting System

<table>
<tr><th colspan="4">Traffic Management Action: Observation and Detection
ITS Tool: Condition Reporting System (CRS)</th></tr>
<tr><th>Why is CRS Used?</th><th>Who Uses CRS?</th><th>How is the Condition Reporting System Used?</th><th>Condition Reporting System Requirements</th></tr>
<tr><td rowspan="2">Need 8: Manual Event Reporting</td><td>MnDOT Metro Freeway Operations

MnDOT Metro Arterial Operations

MnDOT Metro Maintenance

MnDOT Districts

Minnesota State Patrol (MSP)

MnDOT Construction</td><td>• Currently (2010) the majority of manual event entry on arterials is roadwork or driving condition reporting.
• As video increases in the metro areas, and arterial operations takes a more real-time management role, there could be an increase in the entry of real-time events.
• The 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.</td><td>CRS1: MnDOT Freeway Operators, MnDOT Arterial Operations, MnDOT Metro Maintenance, MnDOT Districts, MnDOT Construction, and MSP 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.</td></tr>
<tr><td>MnDOT Public Affairs</td><td>• Authorized MnDOT Public Affairs Staff enters Amber Alerts into the Condition Reporting System.</td><td>CRS5: The Condition Reporting System shall provide a mechanism for operators to enter Amber Alerts.</td></tr>
</table>

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 Traveler Information (TI) as shown in the table below.

Table 6. 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 • ATIS05 Provide information on roadway construction and maintenance activities • 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 • ATIS17 Determine travel time or traffic condition for major signalized arterials • ATIS22 Include information on local roads in 511	• TI01 Broadcast Traveler Information • TI02 Personalized Traveler Information • TM06 Traffic Information Dissemination

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 (described in Chapter 6) assembles data, and the data processing and response formulation 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 6: Arterial operational analysis;
- Need 7: Arterial data storage, archive, and access;
- Need 9: Device control; and
- Need 10: Coordinated control.

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

- Traffic Management Center (TMC) Software; 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 7. 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 6: Arterial Operational Analysis	Need 2: Traffic monitoring	Observation and Detection
	Need 7: Arterial data storage, archive and access	Data Processing and Response Formulation
Need 9: Device Control	N/A	N/A
Need 10: Coordinated Control	Need 2: Traffic monitoring	Observation and Detection

Traffic Management Center Software

Traffic Management Center (TMC) Software 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 traffic signal control systems. 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 8. 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 ATMS Is or Will Be Used**	**ATMS Requirements**

Need 6: Arterial operational analysis	MnDOT Metro Arterial Operations	• Currently (2010) MnDOT Arterial Operations staff do not regularly monitor arterial conditions in real-time, post DMS messages, or implement real-time signal timing changes.
		• Beginning in summer 2010, limited arterials in the metro area (Hwy 13, Hwy 55, Hwy 7) will be equipped with real- time monitoring and control.
		• As arterials are equipped, MnDOT Arterial Operations will increasingly begin to monitor the highways. Initially, this will most likely consist of monitoring during busy peak periods (e.g. holiday weekends, inclement weather). Real-time monitoring will include:
		  ○ Observing congestion, crashes or obstructions
		  ○ Posting DMS messages
		  ○ Entering events in the Condition Reporting System.
		• As real-time monitoring and response becomes a higher priority, staff may one day be dedicated solely to perform real-time operations and response, either from their desk or from within a workstation at the RTMC.
		• Metro Arterial Operations will operate one or more algorithms to calculate arterial travel times on those corridors equipped with real-time detection and communications.
			N/A

Need 9: Device Control	MnDOT Metro Arterial 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, posting messages to DMS, activating traffic signal timing plans). • 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. • The Travel Times computed by automated algorithms will be sent to the appropriate DMS as a message and posted on the website for travelers to view by the ATMS. • Operators use available data and information (volume, occupancy, video views) to determine if automated traffic signal timing plans should be manual overridden. Timing plans are selected from pre-defined plan options stored in the ATMS and deployed to the system. • Operators use the ATMS to modify traffic signal control system timing parameters. • Operators use the ATMS to control signs on the managed corridors. • The ATMS displays recommended messages to operators for the managed corridors. • Operators use the ATMS to monitor status of field devices	TMC 1: The ATMS shall communicate with detectors, DMS, CCTV, and traffic signal control systems. TMC2: The ATMS shall present operators with a view of current traffic detector data. TMC3: The ATMS shall provide a mechanism for operators to select a DMS 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 the ATMS. TMC5: The ATMS shall provide operators a mechanism to control video. TMC6: The ATMS shall send control commands to field devices that cause the field devices to perform actions (e.g. display messages) either from manual commands or automated algorithm outcomes. TMC7: The ATMS shall report status of field devices connected to the ATMS. TMC8: The ATMS shall be accessible to MnDOT and MSP operators at any location connected to the MnDOT Local Area Network (LAN). TMC9: MSP shall have full entry authority to ATMS. TMC10: The ATMS shall operate algorithms
	MnDOT Metro Maintenance	• Operators control arterial management devices (DMS and video) from their workstations when critical events occur and Arterial Operations staff are not on duty.	
	MnDOT	• State Patrol dispatchers are usually first alerted to crashes or	

Traffic Management Action: Data Processing and Response Formulation **ITS Tool:** ATMS			
Why is ATMS Used?	**Who Uses ATMS?**	**How ATMS Is or Will Be Used**	**ATMS Requirements**
	Districts Minnesota State Patrol	incidents in rural Minnesota. MSP dispatchers will post messages to be displayed on DMS. MnDOT Traffic personnel also have the capability to post messages on DMS.	that execute calculations using data ingested, and control devices automatically based upon the algorithm rules (e.g. calculate arterial travel times and post travel times to DMS automatically). TMC11: The ATMS shall provide a mechanism for operators to override automated algorithms by performing manual controls.
Need 10: Coordinated Control	MnDOT Metro Arterial Operations	• An algorithm automatically determines the traffic signal control system timing plan to be activated based upon time of day. In traffic responsive systems, timing plans may be activated based upon detector data and an internal algorithm. Manual intervention from operators overrides the automated timing plan selection. • An algorithm compares detector data on managed corridors and determines messages to be presented to operators based upon thresholds being met.	TMC12: The ATMS shall provide a mechanism to retrieve, archive, store, and process traffic signal control system detector data. TMC13: The ATMS shall provide a mechanism to remotely upload and download traffic signal control system timing plans with field devices.

Role of ATMS in ITS Architecture

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

Table 9. 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 • TM03 Traffic Signal Control • TM05 Traffic Metering • TM06 Traffic Information Dissemination	• ATMS01 Provide efficient signal timing • ATMS14 Monitor operation and performance of traffic signals • ATMS22 Provide a system-coordinated response for incidents • ATMS24 Operate freeway/expressway/arterial DMS • ATMS25 Operate video monitoring cameras • ATMS36 Implement Integrated Corridor Management (ICM) strategies • ATMS37 Provide safe signal phase transition	• TM03 Traffic Signal Control • TM07 Regional Traffic Management

Data Extract Tool

Beyond the real-time use of detector data, the detector data for arterials 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 Arterial Operational Analysis. However, there are a variety of users and a variety of reasons why arterial 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 10. 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 7: Arterial data storage, archive, and access	MnDOT Metro Arterial Operations	• The data extract is accessed over the internet, reports are downloaded as spreadsheets. • The Data Extract Tool is used to request and receive reports from any combination of detectors on the arterials for any time periods (pending availability of data). • Volume and occupancy data is 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	• The Data Extract Tool is used to access actual traffic data and used as inputs to long term modeling and planning.	DET1: The Data Extract Tool shall be accessible to any agency using Internet connectivity.
	Other Agencies	• The Data Extract Tool allows any user to access historical volume and occupancy data throughout the arterial system. Research agencies and consulting firms 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 11. 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 two real-time traffic management actions that are performed by traffic management personnel:

- Information is shared with travelers and other agencies; and
- Traffic controls are implemented to restrict or allow movement of vehicles.

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 arterial 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 3: Real-time travel time/congestion notification;
- Need 4: Real-time planned event notification;
- Need 5: Real-time unplanned event notification; and
- Need 17: Center-to-Center communications.

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

- Dynamic Message Signs (DMS);
- Web Displays; and
- 511 Phone System and Mobile App.

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

Table 12. Information Sharing Interdependencies of Needs

In Order for Information Sharing to Meet This Need	This Need Mist Be Met (The Dependency)	Action Responsible for Meeting Dependency
Need 3: Real-time travel time/congestion notification Need 5: Real-time unplanned event notification	Need 6: Arterial Operational Analysis Need 9: Device Control	Data Processing and Response Formulation
	Need 1: Incident/Event verification Need 2: Traffic monitoring	Observation and Detection
Need 4: Real-time planned event notification	Need 8: Manual Event Reporting	
	Need 6: Arterial Operational Analysis Need 9: 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 arterial 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).

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 the web pages.

Table 13. Information Sharing Operational Concept: Web Pages

<table>
<tr><th colspan="4">Traffic Management Action: Information Sharing
ITS Tool: Web Pages</th></tr>
<tr><th>Why are Web Pages Used?</th><th>Who Uses Web Pages?</th><th>How are Web Pages Used?</th><th>Web Pages Requirements</th></tr>
<tr><td rowspan="4">Need 4: Real-time planned event notification

Need 5: Real-time unplanned event notification

Need 17: Center-to-Center communication</td><td>MnDOT Metro Arterial Operations</td><td>• 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.
• Arterial Operations staff members will use website video image displays to view conditions on the arterials.</td><td>WP1: MnDOT web pages shall receive data and information describing events, incidents, traffic, 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.</td></tr>
<tr><td>MnDOT Districts</td><td>• Descriptions about roadwork projects are created by District Staff and updated as appropriate.</td><td>WP4: MnDOT web pages shall allow for District-specific ‘pages’ to display local content entered locally.</td></tr>
<tr><td>Public</td><td>• Travelers view traveler information via web pages pre-trip
• Travelers view travel information via web pages using mobile devices such as iPhones and Blackberries.</td><td>WP5: MnDOT web pages shall load quickly using typical Internet connections.
WP6: MnDOT web pages shall provide mobile device specific views.</td></tr>
<tr><td>Information Service Providers</td><td>• Private information service providers may capture data and information from MnDOT websites to rebroadcast on the private website.</td><td>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.</td></tr>
</table>

Role of Web Pages in ITS Architecture

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

Table 14. 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
• TM06 Traffic Information Dissemination • TM01 Infrastructure-Based Traffic Surveillance	• ATMS05 Provide incident and congestion information to travelers • ATMS09 Share video, data, and other information with PSAPs	• TI01 Broadcast Traveler Information • TI02 Personalized Traveler Information • TM06 Traffic Information Dissemination • TM08 Traffic Incident Management System

511 Phone and Mobile App

The 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 operates a 511 mobile app for travel information dissemination.

The following table describes:

- Why 511 Phone and Mobile App are 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 System and the Mobile App.

Table 15. 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 4: Real-time Planned Event Notification Need 5: Real-time Unplanned 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/display to users 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/displayed each time a user uses the system.
	Traveling Public	• Travelers call 511 or use the mobile app for real-time traffic reports and receive route-based reports of the conditions they can expect currently on the highway.	511P3: Public shall have a mechanism to access the 511 Phone and the Mobile App.

Role of 511 Phone and Mobile App in ITS Architecture

511 Phone and Mobile App were identified in the *Minnesota Statewide Regional Architecture* as a need/potential solution for TM as shown in the table below.

Table 16. Role of the 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
• TM06 Traffic Information Dissemination	• ATMS05 Provide incident and congestion information to travelers.	• TI01 Broadcast Traveler Information • TI02 Personalized Traveler Information • TM06 Traffic Information Dissemination

Corridor-wide Traffic Control

Corridor-wide Traffic control describes the action of regulating or guiding traffic on an arterial corridor to optimize throughput while maintaining safety. Corridor traffic management also includes the capability to redefine the function of the corridor as needed for overall network traffic management, as in the case of integrated corridor management.

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

- Need 10: Coordinated Control; and
- Need 12: Multimodal options.

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

- Traffic Signal Control Systems

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

Table 17. Traffic Control Interdependencies of Needs

In Order for Traffic Management to Meet This Need	This Need Must Be Met (The Dependency)	Action Responsible for Meeting Dependency
Need 10: Coordinated Control	Need 2: Traffic Monitoring	Observation and Detection

Traffic Signal Control System

Traffic Signal Control Systems are utilized where arterial highways intersect at-grade with other roadways. Traffic Signal Control Systems are a right-of-way assignment device with a variety of operational schemes and subsystems. Depending on the specific configuration, Traffic Signal Control Systems may include detection (i.e. loop detectors, microwave detection, video detection, push button stations), indications (for vehicles, pedestrians, and/or bicycles), controller for the storage of timing logic and algorithms, communication hardware (for coordination and/or management), and hardware to make the system accessible for pedestrians with disabilities.

The following table describes:

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

Table 18. Traffic Control Operational Concept: Traffic Signal Control Systems

Traffic Management Action: Traffic Control **ITS Tool:** Traffic Signal Control System (TSCS)			
Why are TSCS Used?	**Who Uses TSCS?**	**How are Traffic Signal Control Systems Used?**	**Traffic Signal Control Systems Requirements**
Need 10: Coordinated Control Need 12: Multimodal Options	MnDOT Metro Arterial Operations	• Traffic signal control systems are used to assign right-of-way to one or more movements at an intersection. • Typically, traffic signal control systems are programmed to reduce intersection delay. • Traffic signal control systems can be programmed with one or more timing plans. Plans can be implemented based upon time of day, day of week, or real-time traffic patterns in order to maintain operational efficiency. • Data can be uploaded and downloaded (to/from an external center using ATMS) when a traffic signal control system is connected to a communications system. Data sent to the TSCS includes timing plans. Data returned from the TSCS includes loop detector data, and notifications and/or alerts regarding system performance or issues. • When feasible, several traffic signal control systems along a corridor are interconnected via a communications system. This allows for coordination amongst multiple traffic signal control systems reducing travel times along the corridor and providing efficiencies for all modes. • Traffic signal control systems assist pedestrians in crossing arterials. • Recently, traffic signal control systems are being constructed or retrofitted with devices to better	TSCS1: Traffic Signal Control Systems should be in installed in accordance with guidance provided in the Minnesota Manual on Uniform Traffic Control Devices (MMUTCD). TSCS2: Traffic Signal Control Systems should be designed in accordance with guidance provided in the MnDOT Signal Design Manual. TSCS3: Traffic Signal Control Systems should be installed in accordance with guidance provided in the MnDOT Traffic Engineering Manual (TEM). TSCS4: Traffic Signal Control Systems should be operated in accordance with guidance provided in the MnDOT Traffic Signal Timing and Coordination Manual.

Traffic Management Action: Traffic Control ITS Tool: Traffic Signal Control System (TSCS)			
Why are TSCS Used?	**Who Uses TSCS?**	**How are Traffic Signal Control Systems Used?**	**Traffic Signal Control Systems Requirements**
		accommodate users with disabilities. • Typically, newly constructed or retrofitted traffic control signal systems include pedestrian countdown timer indications to inform pedestrians on the amount of time left they can safely cross the intersection. • Traffic signal control systems are evaluated and prioritized regarding the installation of other subsystem devices in order to make the system more accessible to pedestrians with special needs.	
	Public	• Travelers view signal phase indications en-route. • The traveling public must adhere to green and red lights at traffic signal control systems.	TSCS5: Traffic Signal Control Systems shall display control messages to travelers using understood and unambiguous displays.

Role of Traffic Signal Control Systems in ITS Architecture

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

Table 19. Role of Traffic Signal Control 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
• TM03 Traffic Signal Control	• ATMS01 Provide efficient signal timing; and • ATMS37 Provide safe signal phase transition.	• TM07 Regional Traffic Management

Local Arterial Traffic Control and Traveler Alerts

Local area traffic control and traveler alert strategies are used to manage traffic through scenarios where the safety, mobility, or efficiency of the travelers may be jeopardized at any time. Local traffic control systems typically do not rely on data or manual intervention from outside systems, but rather operate on a 'stand-alone' basis and focus on a very specific portion of the infrastructure.

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

- Need 11: Speed Control;
- Need 13: Emergency Management;
- Need 14: Enforcement Systems;
- Need 15: Transit Vehicle Advantages; and
- Need 16: Warning Systems.

The ITS Tools used to perform Local Arterial Traffic Control and Traveler Alerts, and therefore address the stated needs include:

- Dynamic Speed Display Signs;
- Emergency Vehicle Preemption;
- Safety Systems;
- Red Light Running System;
- Enforcement Light System; and
- Transit Signal Priority.

There are interdependencies between the Action of Traffic Control and the needs addressed by Traffic Control as shown in Table 20.

Table 20. Traffic Control Interdependencies of Needs

In Order for Traffic Management to Meet This Need	This Need Must Be Met (The Dependency)	Action Responsible for Meeting Dependency
Need 11: Speed Control	Need 2: Traffic Monitoring	Observation and Detection
Need 13: Emergency Management	Need 2: Traffic Monitoring	Observation and Detection
	Need 8: Device Control	Data Processing and Response Formulation
Need 15: Transit Vehicle Advantages	Need 2: Traffic Monitoring	Observation and Detection
	Need 8: Device Control	Data Processing and Response Formulation
Need 16: Warning Systems	Need 2: Traffic Monitoring	Observation and Detection
	Need 8: Device Control	Data Processing and Response Formulation

Dynamic Speed Display Signs

Dynamic Speed Display Signs (DSDS) typically consist of a dynamic message sign component, a sensor which detects vehicle speed, and a controller which provides the logic between the dynamic message sign and sensor. DSDS are an interactive type of sign providing motorists with real-time information about vehicle speed in relation to the surrounding environment (i.e. school zone or work zone), roadway conditions that may pose a safety problem (i.e. advisory speed limit on sharp horizontal curve), speed zone transitions, or in areas with a history of excessive speeds. The most common operational procedure is to display the vehicle speed and flash the speed display if the vehicle speed exceeds a threshold. Furthermore, the device usually has the ability to display a blank sign if the vehicle speed is higher than a maximum threshold (to discourage travelers from attempting to cause the sign to display excessive speeds).

The following table describes:

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

Table 21. Traffic Control Concept: Dynamic Speed Display Signs

Traffic Management Action: Traffic Control **ITS Tool:** Dynamic Speed Display Signs (DSDS)			
Why are DSDS Used?	**Who Uses DSDS?**	**How are Dynamic Speed Display Signs Used?**	**Dynamic Speed Display Signs Requirements**
Need 11: Speed Control	MnDOT Construction	• DSDS are used in advance of work zones to reduce vehicle operating speeds. • DSDS are used in work zones to increase driver awareness.	DSDS1: DSDS should be placed so as not to obstruct other regulatory, advisory, construction or guide signage.
	MnDOT Arterial Operations	• DSDS are used in areas of changing geometrics (i.e. four lane highway transitions to two lane highway) to reinforce safe vehicle operating speeds. • DSDS are used in speed transition zones (i.e. reduction in speed at town limit) to reinforce safe vehicle operating speeds. • DSDS are used in school zones to reinforce safe vehicle operating speeds. • DSDS are used in areas where excessive speeds are an issue to increase compliance with regulatory speed limits. • In the future, DSDS may become traffic monitoring stations, recording traffic speeds to be relayed to a central TMC for processing and information dissemination message creation.	DSDS1: DSDS should be placed so as not to obstruct other regulatory, advisory, construction or guide signage. DSDS2: DSDS shall display the vehicles speed to the driver. DSDS3: DSDS shall flash the vehicle speed when it exceeds a threshold value above the speed limit. DSDS4: DSDS shall display blank if vehicles speed exceeds a high-speed threshold. DSDS5: All DSDS thresholds shall be adjustable. DSDS6: DSDS technology selections shall explore the capability of communicating speed readings to a TMC in real-time.

Traffic Management Action: Traffic Control ITS Tool: Dynamic Speed Display Signs (DSDS)			
Why are DSDS Used?	**Who Uses DSDS?**	**How are Dynamic Speed Display Signs Used?**	**Dynamic Speed Display Signs Requirements**
	Law Enforcement	• DSDS are used in school zones to reinforce safe vehicle operating speeds. • DSDS are used in areas where excessive speeds are an issue to increase compliance with regulatory speed limits.	DSDS1: DSDS should be placed so as not to obstruct other regulatory, advisory, construction or guide signage. DSDS2: DSDS shall display the vehicles speed to the driver. DSDS3: DSDS shall flash the vehicle speed when it exceeds a threshold value above the speed limit. DSDS4: DSDS shall display blank if vehicles speed exceeds a high-speed threshold. DSDS5: All DSDS thresholds shall be adjustable. DSDS6: DSDS technology selections shall explore the capability of communicating speed readings to a TMC in real-time.
	Public	• Travelers receive real-time feedback regarding potentially unsafe vehicle operating speeds and may adjust vehicle operating speed. • Travelers' awareness of regulatory or advisory speed limit is increased.	DSDS7: The traveling public shall have an unobstructed view of DSDS from the vehicle.

Role of Dynamic Speed Display Signs in ITS Architecture

DSDS were identified in the *Minnesota Statewide Regional Architecture* as a need/potential solution for TM, and Maintenance and Construction (MC) as shown in the table below.

Table 22. Role of Dynamic Speed Display 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
• TM01 Infrastructure-Based Traffic Surveillance • TM17 Speed Warning and Enforcement • MC06 Work Zone Management	• ATMS15 Provide operating speed/travel time information to travelers • ATMS18 Provide dynamic speed feedback to drivers and enforcement agencies • MCM14 Provide dynamic speed display	• TM01 Infrastructure-Based Traffic Surveillance • TM06 Traffic Information Dissemination • TI01 Broadcast Traveler Information • TM17 Speed Warning and Enforcement • MC06 Work Zone Management

Emergency Vehicle Preemption (EVP)

Preemption is a tool for providing priority through an intersection controlled by a traffic signal control system. Preemption can be provided for different users with railroad and emergency vehicles being the most common uses. Emergency Vehicle Preemption (EVP) almost always consists of a receptor installed at or near the traffic signal control system. Upon detecting a request from an approaching emergency vehicle, the receptor places a request to the traffic signal control system controller. The controller contains logic for EVP and attempts to provide an exclusive green phase for the approach with the emergency vehicle while providing red phases for all other approaches. EVP configurations typically include a confirmation light installed at or near the traffic signal control system which provides information to the approaching emergency vehicle that an EVP request has been received by the controller.

The following table describes:

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

Table 23. Traffic Control Operational Concept: Emergency Vehicle Preemption

Traffic Management Action: Traffic Control **ITS Tool:** Emergency Vehicle Preemption (EVP)			
Why is EVP Used?	**Who Uses EVP?**	**How is Emergency Vehicle Preemption Used?**	**Emergency Vehicle Preemption Requirements**
Need 13: Emergency Management	Emergency Responders	• EVP is used to provide emergency vehicles responding to a call safe and rapid travel through a signalized intersection. • EVP is typically wired into the traffic signal control system. • EVP typically includes sensors to monitor whether an emergency vehicle is approaching. The system is activated when an emergency vehicle's EVP emitter or siren (depending on specific EVP technology) is activated. • Upon activation, a preemption request is placed in the traffic signal controller. The controller contains logic which modifies the signal timing in order to serve the approach with the emergency vehicle a green phase. • EVP has a higher priority than transit signal priority, vehicle phases, bicycle phases and pedestrian phases. • EVP has a lower priority than railroad preemption.	EVP1: Emergency responders shall only activate EVP when responding to an emergency call. EVP2: Installation of confirmation indication(s) shall be included with all EVP deployments. EVP3: Preemption requests shall be logged in order to verify system operational state and monitor system performance. EVP4: Emergency responder agencies shall coordinate and standardize on one EVP technology to be deployed within the coverage area.

Role of Emergency Vehicle Preemption in ITS Architecture

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

Table 24. Role of Emergency Vehicle Preemption in ITS Architecture

Minnesota Statewide Regional ITS Architecture: Service Package	Minnesota Statewide Regional ITS Architecture: Need/Potential Solutions	Associated National ITS Architecture: Service Package
• TM03 Traffic Signal Control	• TM37 Provide safe signal phase transition	• TM03 Traffic Signal Control

Safety Systems

Safety Systems provide warning to motorists of potentially unsafe road conditions. Examples of Safety Systems include collision avoidance systems, curve warning systems, systems that detect flooded roads, animal crossing warning systems, and railroad active warning systems.

The following table describes:

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

Table 25. Traffic Control Operational Concept: Safety Systems

Traffic Management Action: Traffic Control **ITS Tool:** Safety Systems (SS)			
Why are SS Used?	**Who Uses Safety Systems?**	**How are Safety Systems Used?**	**Safety Systems Requirements**
Need 16: Warning Systems	MnDOT Arterial Operations	• Curve warning systems are deployed in locations that experience a high number of run off the road type crashes near horizontal roadway sections. The systems are used to detect vehicles that may be approaching at an unsafe speed and provide a dynamic warning to vehicle operators. • Animal crossing warning systems are deployed in locations that experience a high number of animal-vehicle crashes. The systems detect the presence of animals on or near the roadway and provide a dynamic warning to vehicle operators. • Collision avoidance systems are deployed at intersections that experience a high number of right-angle type crashes. The systems are used to detect approaching vehicles and provide a dynamic warning to vehicle operators who desire to cross or enter the roadway. • Queue warning systems are deployed at locations where sight distance is limited by vertical curvature, horizontal curvature, or other man-made or natural obstructions. The systems detect the presence of stopped vehicles and provide a dynamic warning to vehicle operators in an attempt to reduce rear-end type crashes. • School bus stop warning systems are deployed at rural bus stop locations. The systems detect the presence of an approaching or stopped bus and provide a dynamic warning to vehicle operators in an attempt to reduce rear-end type crashes and/or passing violations when the bus lights and stop arm are activated. • Over height warning systems are deployed at locations where substandard vertical clearance to an overhead structure is present. The system is placed in advance of the structure and is ideally located	SS1: Safety Systems should be placed so as not to obstruct other regulatory, advisory, construction or guide signage. SS2: Safety Systems signs and devices should be in accordance with guidance provided in the Minnesota Manual on Uniform Traffic Control Devices (MMUTCD). SS3: Safety Systems shall consider real-time communications of alerts detected to a central location (e.g. TMC) to support information dissemination of conditions.

Traffic Management Action: Traffic Control ITS Tool: Safety Systems (SS)			
Why are SS Used?	**Who Uses Safety Systems?**	**How are Safety Systems Used?**	**Safety Systems Requirements**
		in advance of an alternative route which would allow for diversion around the structure. The system detects the presence of a vehicle whose height is taller than the vertical clearance provided at the structure. The system provides a dynamic warning to the vehicle operators so that the vehicle can reroute and avoid damage to the structure and/or vehicle. • Flood warning systems are deployed at location where the roadway is periodically covered in water creating a potentially hazardous condition. The systems detect the presence of water on the roadway and provide a dynamic warning to vehicle operators so that the vehicle can reroute.	
	Public	• Travelers receive real-time feedback regarding potentially hazardous conditions and may adjust vehicle speed, perform evasive maneuvers, or reroute as appropriate.	SS4: The traveling public shall have an unobstructed view of Safety Systems from the vehicle.

Role of Safety Systems in ITS Architecture

Safety Systems 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 Safety 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
• TM13 Standard Railroad Grade Crossing • TM17 Speed Warning and Enforcement • TM06 Traffic Information Dissemination • TM03 Traffic Signal Control	• ATMS28 Provide railroad flashing light signals and gates • ATMS32 Provide curve speed warnings • ATMS34 Provide roadway flood warnings • ATMS35 Provide vehicle over height detection/warning systems	• TM14 Advanced Railroad Grade Crossing • VS05 Curve Speed Warning • VS11 Oversize Vehicle Warning

Red Light Running Systems

Red Light Running Systems typically consist of a camera, a sensor which detects vehicle speed, and a controller which provides the logic between the camera and sensor. Red Light Running Systems are an automated enforcement device used for citations.

The following table describes:

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

Table 27. Traffic Control Operational Concept: Red Light Running Systems

Traffic Management Action: Traffic Control **ITS Tool:** Red Light Running Systems (RLRS)			
Why are RLRS Used?	**Who Uses RLRS?**	**How are Red Light Running Systems Used?**	**Red Light Running Systems Requirements**
Need 14: Enforcement Systems	Law Enforcement	• Law Enforcement downloads violation data from red light running system locations and upon observing evidence, law enforcement issues a citation when a violation occurs.	RLRS1: Law Enforcement shall verify and issue citations for violations. RLRS2: Red Light Running Systems shall not directly or indirectly modify or otherwise change traffic signal control system timing parameters.

Role of Red-Light Running Systems in ITS Architecture

Red-Light Running Systems were identified in the *Minnesota Statewide Regional Architecture* as a need/potential solution for TM as shown in the table below.

Table 28. Role of Red-Light Running 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
• TM01 Infrastructure-Based Traffic Surveillance	• ATMS02 Implement red-light running technology	• TM01 Network Surveillance • TM03 Traffic Signal Control

Enforcement Light Systems

Enforcement Light Systems typically consist of a light which is illuminated during the red phase of traffic signal control system. Enforcement Light Systems are typically passive systems requiring observation of the violation by law enforcement agencies.

The following table describes:

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

Table 29. Traffic Control Operational Concept: Enforcement Light Systems

<table>
<tr><th colspan="4">Traffic Management Action: Traffic Control
ITS Tool: Enforcement Light Systems (ELS)</th></tr>
<tr><th>Why are ELS Used?</th><th>Who Uses ELS?</th><th>How are Enforcement Light Systems Used?</th><th>Enforcement Light Systems Requirements</th></tr>
<tr><td>Need 14: Enforcement Systems</td><td>Law Enforcement</td><td>• Law Enforcement is made aware, either through observation or public feedback, of a traffic signal control system with a high occurrence of red-light running violations.
• Law Enforcement and MnDOT collectively agree on enforcement light system locations.
• The enforcement light system is a passive, stand-alone system.
• The enforcement light system does not record or otherwise store information regarding the violation.
• The indication is typically hard wired into the signal system. The indication does not require a separate activation method as it is always lit when the corresponding signal phase is red.
• The enforcement light system is a visual tool which allows law enforcement to simultaneously observe if the signal phase is red (through the enforcement light system indication) and whether a vehicle is committing a violation.
• Law enforcement observes the indication and issues citations when a violation occurs.</td><td>ELS1: Law Enforcement shall not record or otherwise store information regarding the violation.
ELS2: Enforcement Light Systems shall use indications that do not conflict with vehicle and pedestrian indications at the traffic signal control system.</td></tr>
</table>

Role of Enforcement Light Systems in ITS Architecture

Enforcement Light 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 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
• TM01 Infrastructure-Based Traffic Surveillance	• ATMS02 Implement red-light running technology	• TM01 Infrastructure-Based Traffic Surveillance • TM03 Traffic Signal Control

Transit Signal Priority

Transit Signal Priority (TSP) is a tool for providing priority through an intersection controlled by a traffic signal control system. Transit Signal Priority is typically used by transit agencies within the jurisdiction. TSP almost always consists of a receptor installed at or near the traffic signal control system. Upon detecting a request from an approaching transit vehicle, the receptor places a request to the traffic signal control system controller. The controller contains logic for TSP and attempts to modify timing for the approach with the transit vehicle to provide an advantage to transit riders.

The following table describes:

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

Table 31. Traffic Control Operational Concept: Transit Signal Priority

Traffic Management Action: Traffic Control **ITS Tool:** Transit Signal Priority (TSP)			
Why TSP is Used?	**Who Uses TSP?**	**How is Transit Signal Priority Used?**	**Transit Signal Priority Requirements**

Need 15: Transit Vehicle Advantages	MnDOT Arterial Operations	• Intersections and approaches for TSP implementation are selected based on need and potential.
		• Transit Operators and MnDOT collectively agree on TSP methodologies at the location. Considerations include:
		  ○ Whether to activate TSP only when the transit vehicle is behind schedule.
		  ○ Whether to activate TSP only when the transit vehicle is carrying a number of passengers above a set threshold.
		• Traffic Operations staff review performance data (i.e. number of TSP requests and number of TSP requests granted) for transit vehicles.	

<table>
<tr><th colspan="4">Traffic Management Action: Traffic Control
ITS Tool: Transit Signal Priority (TSP)</th></tr>
<tr><th>Why TSP is Used?</th><th>Who Uses TSP?</th><th>How is Transit Signal Priority Used?</th><th>Transit Signal Priority Requirements</th></tr>
<tr><td></td><td>Transit Agency</td><td>

Intersections and approaches for TSP implementation are selected based on need and potential.
Transit Operators and MnDOT collectively agree on TSP methodologies at the location. Considerations include:

Whether to activate TSP only when the transit vehicle is behind schedule.
Whether to activate TSP only when the transit vehicle is carrying a number of passengers above a set threshold.

TSP is provided at or near entrance/exit locations to Park and Ride facilities to provide quick access.
TSP is provided along routes that are frequently delayed or carry major transit traffic.
TSP is used to modify traffic signal timing parameters for transit vehicles that are behind schedule.

The green phase is extended if the transit vehicle is approaching in order to allow the vehicle to proceed through the intersection. The effectiveness of this approach is diminished if a transit stop is located near- side of the intersection.
If the transit vehicle is stopped at the intersection, the red phase is truncated early to reduce the delay the vehicle experiences waiting at the traffic signal.

Transit Operators review performance data (i.e. number of TSP requests and number of TSP requests granted) for transit vehicles.

</td><td></td></tr>
</table>

Traffic Management Action: Traffic Control ITS Tool: Transit Signal Priority (TSP)			
Why TSP is Used?	**Who Uses TSP?**	**How is Transit Signal Priority Used?**	**Transit Signal Priority Requirements**
	Public	• Travelers have no direct interaction with TSP. One goal of TSP however, is the perception that advantages are provided to transit vehicles. Ideally, TSP allows travelers to experience less delay on their daily trips which results in more on-time route services.	

Role of Transit Signal Priority in ITS Architecture

TSP was identified in the *Minnesota Statewide Regional Architecture* as a need/potential solution for Public Transportation (PT) as shown in the table below.

Table 32. Role of Transit Signal Priority in ITS Architecture

Minnesota Statewide Regional ITS Architecture: Service Package	Minnesota Statewide Regional ITS Architecture: Need/Potential Solutions	Associated National ITS Architecture: Service Package
• PT09 Transit Signal Priority	• APTS17 Coordinate transit vehicle movements with traffic control devices	• PT02 Transit Fixed-Route Operations

CAV Infrastructure Systems and CAVs

Table 33 describes the arterial traffic management operational concepts from the perspective of CAV infrastructure systems and CAVs.

Table 33. Arterial 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, traffic signal status, violation 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 and 800 MHz 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. TMC 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

Operations and maintenance of Condition Reporting Systems are detailed in the table below.

Table 34. Condition Reporting System Operations and Maintenance Responsibilities

Condition Reporting System Operations and Maintenance Activities	Metro Area Responsibility	Rural Area Responsibility
24/7 hosting and Operations of Condition Reporting System	• Vendor / Contractor	• Vendor / Contractor
Manual Entry, Edit, and Removal of Events	• MnDOT Metro Area Arterials Operations • 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

The operations and maintenance responsibilities of ATMS are shown in the table below.

Table 35. ATMS Operations and Maintenance Responsibilities

Operational Activities	Metro Area Responsibility	Rural Area Responsibility
Overall operations of software to keep the ATMS running	• MnDOT Metro Area Freeway Operations • MnDOT Metro Area Arterial Operations	• MnDOT Metro Area Arterial Operations • MnDOT District Traffic Office • MnDOT ESS • MnDOT Metro Area Traffic Operations

Operational Activities	Metro Area Responsibility	Rural Area Responsibility
		• MnDOT District Traffic Office • Software Vendor
Operate and maintain communications with field devices and server system	• MnDOT Metro Area Arterial Operations • MnDOT Metro Area Maintenance • MnDOT Metro Area IT • MnDOT Metro Area ESS	• MnDOT District IT • MnDOT District Maintenance • MnDOT ESS
Maintain, support, and update the ATMS Code	• MnDOT Metro Area Freeway Operations • MnDOT Metro Area Arterial Operations • MnDOT Metro Area IT	• MnDOT Metro Area Freeway Operations • Software Vendor

Operations and maintenance of the Data Extract Tool are detailed in the table below.

Table 36. Data Extract Tool Operations and Maintenance Responsibilities

Data Extract Tool Operation and Maintenance Activities	Metro Area Responsibility	Rural Area Responsibility
Software and servers operations and maintenance	• MnDOT Metro Area Freeway Operations • MnDOT Metro Arterial Operations	• MnDOT Metro Arterial Operations • MnDOT District Traffic Office • MnDOT District ESS • MnDOT District Traffic Office • Software vendor

Operations and maintenance responsibilities for Web Pages are shown in the table below.

Table 37. Web Pages Operations and Maintenance Responsibilities

Operational Activities	Metro Area Responsibility	Rural Area Responsibility
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 Arterial Operations • MnDOT Metro Maintenance • MnDOT Metro Construction	• State Patrol • MnDOT District Traffic • MnDOT District Construction • MnDOT District Maintenance

Operational Activities	Metro Area Responsibility	Rural Area Responsibility
Overall Operations and Maintenance of Websites	• MnDOT Metro Arterial Operations (MnDOT site) • Vendor/contractor (statewide site)	• Vendor Contractor
24/7 operations, including monitoring and support to correct system outages	• MnDOT Metro Arterial Operations • 511 Contractor	• 511 Contractor
Monitor bandwidth	• MnDOT Metro Arterial Operations • 511 Contractor	• MnDOT District IT Maintenance • 511 Contractor

Maintenance and operations responsibilities for the 511 Phone system are outlined in the following table.

Table 38. 511 Phone and Mobile App Operations and Maintenance Responsibilities

511 Phone and Mobile App Operations and Maintenance Activities	Metro Area Responsibility	Rural Area Responsibility
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

The operations and maintenance responsibilities for traffic signal control systems are shown in the table below.

Table 39. Traffic Signal Control Systems Operations and Maintenance Responsibilities

Traffic Signal Control Systems Operations and Maintenance Activities	Metro Area Responsibility	Rural Area Responsibility
Operations of Traffic Signal Control Systems	• MnDOT Metro Signals Operations	• MnDOT District Traffic
Maintenance of Traffic Signal Control Systems	• MnDOT Metro Signals Operations • MnDOT ESS	• MnDOT District Traffic • MnDOT ESS

The operations and maintenance responsibilities for dynamic speed display signs are shown in the table below.

Table 40. Dynamic Speed Display Signs Operations and Maintenance Responsibilities

Dynamic Speed Display Signs Operations and Maintenance Activities	Metro Area Responsibility	Rural Area Responsibility
Operations of Dynamic Speed Display Signs	• MnDOT Metro Traffic • MnDOT Metro Construction • State Patrol	• MnDOT District Traffic • MnDOT District Construction • State Patrol
Maintenance of Dynamic Speed Display Signs	• MnDOT Metro Traffic • MnDOT Metro Construction • State Patrol	• MnDOT District Traffic • MnDOT District Construction • State Patrol

The operations and maintenance responsibilities for Emergency Vehicle Preemption are shown in the table below.

Table 41. Emergency Vehicle Preemption Operations and Maintenance Responsibilities

EVP Operations and Maintenance Activities	Metro Area Responsibility	Rural Area Responsibility
Configuration of traffic signal controller timing	• MnDOT Metro Traffic	• MnDOT District Traffic
Maintenance of Emitter Device(s)	• Emergency Responder Agency	• Emergency Responder Agency
Maintenance of Receiver Device(s)	• MnDOT Metro ESS	• MnDOT ESS
Maintenance of Confirmation Light	• MnDOT Metro ESS • Emergency Responder Agency	• MnDOT ESS • Emergency Responder Agency
Activation of Emergency Vehicle Preemption	• Emergency Vehicle(s)	• Emergency Vehicle(s)

The operations and maintenance responsibilities for safety systems are shown in the table below.

Table 42. Safety Systems Operations and Maintenance Responsibilities

Operations and Maintenance Activities	Metro Area Responsibility	Rural Area Responsibility
Repair non-functioning safety system	• MnDOT Metro Traffic • MnDOT ESS	• MnDOT District Traffic • MnDOT ESS

The operations and maintenance responsibilities for red light running systems are shown below.

Table 43. Red Light Running Systems Operations and Maintenance Responsibilities

Red Light Running Operations and Maintenance Activities	Metro Area Responsibility	Rural Area Responsibility
Repair non-functioning red light running system	• MnDOT Metro Arterial Operations • MnDOT ESS	• MnDOT District Traffic • MnDOT ESS

The operations and maintenance responsibilities for enforcement light systems are shown below.

Table 44. Enforcement Light Systems Operations and Maintenance Responsibilities

Operations and Maintenance Activities	Metro Area Responsibility	Rural Area Responsibility
Repair non-functioning enforcement light system	• MnDOT Metro Arterial Operations • MnDOT Metro ESS	• MnDOT District Traffic • MnDOT ESS

The operations and maintenance responsibilities for transit signal priority are shown in the table below.

Table 45. Transit Signal Priority Operations and Maintenance Responsibilities

Operations and Maintenance Activities	Metro Area Responsibility	Rural Area Responsibility
Configuration of traffic signal controller timing	• MnDOT Metro Traffic	• MnDOT District Traffic
Maintenance of Emitter Device(s)	• Transit Agency	• Transit Agency
Maintenance of Receiver Device(s)	• MnDOT Metro ESS	• MnDOT ESS
Activation of Transit Signal Priority	• Transit Vehicle(s)	• Transit Vehicle(s)

Operational Scenarios

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

- Scenario A: Use of the Condition Reporting System
- Scenario B: Use of ATMS
- Scenario C: Use of the Data Extract Tool
- Scenario D: Use of Web Pages
- Scenario E: Use of 511 Phone and Mobile App
- Scenario F: Use of Traffic Signal Control System
- Scenario G: Use of Dynamic Speed Display Signs
- Scenario H: Use of Emergency Vehicle Preemption (EVP)
- Scenario I: Use of Safety Systems
- Scenario J: Use of Red-Light Running Systems

- Scenario K: Use of Enforcement Light Systems
- Scenario L: Use of Transit Signal Priority (TSP)

Scenario A: Use of the Condition Reporting System

There are six distinct use case scenarios for the Condition Reporting System:

1. MnDOT Metro Arterial Operations Perspective

- MnDOT Arterial Operations does not currently enter conditions in a condition reporting system. However, as the deployment of video expands, MnDOT Arterial Operations will have an increased level of real-time knowledge of the status of the road network. In the interim, MnDOT Arterial Operations may request freeway operations personnel to enter real-time reports in the condition reporting system as incidents are detected.
- Over time, a transition might occur where MnDOT Arterial Operations personnel enter arterial incidents and events in the condition reporting system. The Internet nature of the condition reporting system would technically allow for this type of operation. However, operational procedures, training, and other institutional issues would be required to reach full operations of arterial incident/event entry.

2. MnDOT Metro Freeway Operations Perspective

- While the Metro Area Freeway Operations Group will primarily enter crashes and other real-time incidents impacting the metro area freeways, they have the capability (with the condition reporting system) to enter arterial incidents if they are known to the RTMC.

3. MnDOT Metro Maintenance Dispatch Perspective

- Metro Area Maintenance dispatchers input road condition information for freeways into the condition reporting system.
- Metro Area Maintenance enters planned maintenance that will impact travelers, such as lane or road closures for freeways.
- Current operational procedures are for metro maintenance to enter conditions on freeways when the RTMC is not staffed by freeway operations. Metro maintenance could assume a role of entering arterial conditions.
- Road condition data is automatically fed for the Maintenance Decision Support System (MDSS).

4. MnDOT District Perspective

- MnDOT Districts work with the State Patrol to input road condition reports into the condition reporting system.
- State Patrol works with Districts to enter crashes and other incident information.
- MnDOT Maintenance and Construction enter roadwork activities that will impact travelers.

5. MnDOT Construction Perspective

- MnDOT Construction enters planned construction and roadwork activities.

6. MnDOT Public Affairs Perspective

- MnDOT Public Affairs enters Amber Alerts in the Condition Reporting System.

Scenario B: Use of ATMS

There are three distinct use case scenarios for ATMS:

1. MnDOT Metro Arterial Operations Perspective

- *Automated Traffic Controls* – MnDOT Arterial Operations personnel use ATMS to operate a set of algorithms that control timing parameters of traffic signal control systems. Timing parameters can be implemented based on time of day, day of week, or in response to dynamic traffic conditions. ATMS is also used to operate a set of algorithms that calculate Travel Times on selected routes and post the Travel Times on DMS and to a website.
- *Manual Traffic Controls* – Arterial Operations personnel use ATMS to perform a variety of manual traffic management controls. ATMS allows operators to view information about the arterials including volume, occupancy, and status of field devices. ATMS also allows operators to control field devices such as deploying new timing parameters to traffic signal control systems, overriding automated timing parameters in traffic signal control systems with manually specified timing parameters, control the video tools, view the video images at workstations and on the wall display, and post messages to the DMS signs.
- *Efficient Traffic Signal Operations* – ATMS can be used for interconnected traffic signal control systems. Each individual traffic signal control system communicates with nearby systems in order to provide coordinated phase changes. This methodology allows for the clustering of vehicles into platoons and providing a series of green phases on the major intersection approaches. The platoon affect creates efficiency at each individual traffic signal control system by allowing the system to service a high number of vehicles on these approaches in a given portion of the signal cycle. By coordinating green phases along the corridor, efficiency for travelers is created by reducing the delays caused by stopping at several traffic signal control systems. ATMS also allows for time synchronization of all individual traffic signal control systems to one authoritative source. This helps maintain the efficiency of the overall system over time and helps to reduce the need for maintenance activities.

2. MnDOT Metro Maintenance Perspective

- MnDOT Metro Maintenance Dispatchers use ATMS to monitor and observe system outages and system performance. Alerts and/or notifications for traffic signal control system faults can be sent to maintenance personnel. Examples of these issues include a dark system, a system that is in flash, detector(s) continuously placing a request, pedestrian push button(s) continuously placing a request, detector that is not reporting or reporting inaccurate volume information, and Emergency Vehicle Preemption (EVP) activations.
- Metro Area Maintenance Dispatchers use ATMS to post messages to DMS at times when Arterial Operations personnel are not on-duty (typically evenings and weekends). Maintenance dispatchers also use the software to position video tools to observe pavement and/or weather conditions.

3. MnDOT District Perspective

- MnDOT Districts that have ATMS systems use the software to post messages to DMS signs describing construction, crashes, or other events.

Scenario C: Use of the Data Extract Tool

There are four distinct use case scenarios for the Data Extract Tool:

1. **MnDOT Metro Arterial Operations Perspective**
    - MnDOT Arterial Operations personnel uses the data extract tool to analyze data from arterial segments and make data driven decisions for changes to traffic management or needs for infrastructure improvements and adjustments.

2. **MnDOT Metro Planning Perspective**
    - The MnDOT Metro Planning Group uses the data extract tool to analyze detector data to support long term transportation planning.

3. **Research Organizations, Contractors and Consultants**
    - Research organizations (e.g. Universities), contractors and consultants use the data extract tool to examine current and historic data for the available arterials.

Scenario D: Use of Web Pages

There are four distinct use case scenarios for web pages:

1. **MnDOT Statewide Real-time Traveler Information Website Perspective**
    - MnDOT operates a statewide travel information website (http://511mn.org). Information consists of road conditions, video links, roadwork, crashes, and travel weather information as well as broadcasting AMBER Alerts.
    - The statewide website delivers pre-trip and en-route information to travelers about planned roadwork, driving conditions, and real-time crashes and other incidents.

2. **MnDOT Metro Arterial Operations Perspective**
    - MnDOT operates a statewide travel information website with a traffic flow map, video images, travel times, and incidents/events.
    - Arterial Operations Group staff will (at least initially) rely upon MnDOT website displays of video images (still images or full motion) to view conditions. This use of the websites will allow Arterial Operations Group staff to monitor conditions from their desks in lieu of being within the RTMC.

3. **MnDOT Districts Perspective**
    - Some MnDOT Districts operate local web pages as part of the overall MnDOT website (http://www.dot.state.mn.us). Local web pages contain links to project (construction) pages and may include information about projects (e.g. maps, diagrams, budget and schedule). Local information is used to educate and inform local residents about the plans for construction (budget, schedule, impact to traffic). Local sites may link to video images and include real-time event information to assist in planning trips.

4. **Media Outlets / Information Service Providers' Perspective**
   - Numerous private sector information service providers operate websites displaying much of the same information displayed on the MnDOT real-time travel information websites. The private providers' access data through the live MnDOT RSS data feed.

Scenario E: Use of 511 Phone and Mobile App

The following are distinct use case scenarios for 511 Phone and Mobile App:

1. **MnDOT Statewide Perspective**
   - MnDOT provides real-time travel information on MnDOT's 511 Phone System and Mobile App. Information consists of road conditions, travel times, construction detours, road congestion, and travel weather information as well as broadcasting AMBER alerts.
   - All information on the 511 phone system and the 511 mobile app is populated automatically from the Condition Reporting System.

2. **Traveling public Perspective**
   - The traveling public hears traveler information messages through the MnDOT 511 Phone System and Mobile App. The phone messages provide sufficient information about current conditions to assist pre-trip route decision making.

Scenario F: Use of Traffic Signal Control System

There are two distinct use case scenarios for traffic signal control systems:

1. **MnDOT Arterial Operations Perspective**
   - MnDOT uses traffic control signal systems to facilitate the movement of vehicular traffic through at-grade intersections.
   - Traffic control signal systems are frequently designed and constructed to accommodate pedestrian crossings at the intersection.
   - Recently, additional efforts have been made to make traffic signal control systems more accommodating for pedestrians with special needs and bicycles.

2. **Traveling public Perspective**
   - The traveling public must adhere to green and red lights at traffic signal control systems. Pedestrians must adhere to walk/don't walk signs at traffic signal control systems.

Scenario G: Use of Dynamic Speed Display Signs (DSDS)

There are four distinct use case scenarios for DSDS:

1. **MnDOT Construction Perspective**
   - MnDOT utilizes DSDS (generally portable units) in advance and within construction work zone areas to reduce vehicle operating speeds, reinforce regulatory or advisory speed limits, and to improve safety.

2. MnDOT Arterial Operations Perspective

- MnDOT utilizes DSDS in areas where vehicle operating speeds are transitioning. Example areas where dynamic speed display signs are typically used include school zones, speed limit transition zones at municipal boundaries, and changes in roadway geometrics.
- MnDOT utilizes DSDS in locations of substantial pedestrian movements, such as school zones, locations near parks or libraries where pedestrian traffic is prevalent.
- MnDOT utilizes DSDS to mitigate public reports of excessive speeding.

3. Law Enforcement Perspective

- Law enforcement agencies utilize DSDS in areas where excessive speeding is a known issue.
- Law enforcement agencies utilize DSDS to mitigate public reports of excessive speeding.

4. Traveling Public Perspective

- The traveling public utilizes feedback provided by DSDS to adjust vehicle operating speeds.

Scenario H: Use of Emergency Vehicle Preemption (EVP)

There is one distinct use case scenario for EVP:

1. Emergency Responder Perspective

- Emergency responders activate the EVP system as they approach a signalized intersection.
- Upon activation, the emergency responders receive indication the traffic signal control system has received the preemption request and whether the emergency vehicle has priority through the intersection.

Scenario I: Use of Safety Systems

There are two distinct use case scenarios for safety systems:

1. MnDOT Arterial Operations Perspective

- Safety systems are deployed in locations where potentially hazardous conditions exist at unpredictable or isolated times. The systems detect the potentially hazardous condition and provide a dynamic warning to vehicle operators.

2. Traveling Public Perspective

- The traveling public utilizes feedback provided by safety systems to adjust vehicle operating speeds, perform evasive maneuvers, or reroute as appropriate.

Scenario J: Use of Red-Light Running Systems

There is one distinct use case scenario for red light running systems:

1. Law Enforcement Perspective

- Law enforcement uses red light running systems to aide in issuing citations for red light running violations. Red light running systems are an evidence gathering tool which allows law enforcement to observe the evidence at a later date in order to make a determination on whether a vehicle committed a violation.

Scenario K: Use of Enforcement Light Systems

There is one distinct use case scenario for enforcement light systems:

1. **Law Enforcement Perspective**
    - Law enforcement uses enforcement light systems to aide in issuing citations for red light running violations. Enforcement light systems are a visual tool which allows law enforcement to simultaneously observe if the signal phase is red (through the enforcement light system indication) and whether a vehicle is committing a violation.

Scenario L: Use of Transit Signal Priority (TSP)

There are three distinct use case scenarios for TSP:

1. **MnDOT Arterial Operations Perspective**
    - MnDOT does not use TSP directly. Rather, MnDOT works with transit providers to determine locations for TSP and methodologies for how transit signal priority should be implemented.

2. **Transit Agency Perspective**
    - In the Twin Cities Metropolitan Area, Metro Transit uses TSP to reduce delays at traffic signal control systems near park and ride facility entrance/exit locations as well as along signalized arterial highway corridors.
    - In St. Cloud, St. Cloud Metro Bus uses TSP to reduce delays along signalized arterial highway corridors.

3. **Traveling Public Perspective**
    - The traveling public does not use TSP directly. Rather, TSP creates the perception that transit vehicles are provided an advantage. The advantage provided can lead to travelers experiencing less delay on their transit trips and improved schedule adherence.

Risks and Mitigation

Identifying, monitoring for and mitigating risks are essential to the successful implementation and operation of any system. This section presents the risks and constraints that have been identified as most significant for the arterial 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 46. Arterial Traffic Management Tool Constraints

ITS Tools	Constraints	Descriptions of Constraints
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.

ITS Tools	Constraints	Descriptions of Constraints
ATMS	Open Source Software	• MnDOT metro operations are not constrained by any proprietary software (as the metro area ATMS was developed in-house). 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.
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. Inability to communicate to the metro area video may impact the ability to provide video 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.

ITS Tools	Constraints	Descriptions of Constraints
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 and Mobile App. 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 and Mobile App place a constraint on data processing and response formulation, as the functionalities of the 511 Phone and Mobile App are dependent upon the actions performed by data processing and response formulation.
Traffic Signal Control Systems	Traffic Signal Control Systems Location	• Traffic Signal System location and spacing is a factor for the usefulness of the device. • The role of each user and use case scenario should be considered when deploying traffic signal control systems. • Other factors such as natural and man-made obstructions should also be considered.
	Traffic Signal Control Systems Power Source	• The location of the power source for traffic signal control system deployment should be considered.
	Communications with Traffic Signal Control Systems	• Individual use case scenarios for each traffic signal control system should be considered when designing communications (e.g. whether communication to system or amongst several systems is required)
Dynamic Speed Display Signs	Location	• Dynamic Speed Display Sign location is critical on its usefulness. • The role of each user and use case scenario should be considered when deploying a safety system.
Emergency Vehicle Preemption	Emergency Vehicle Preemption Location	• Emergency vehicle preemption location is a factor for the usefulness of the device. • Locations on heavily used routes and those near emergency responders' base locations should receive priority when considering locations. • Other factors such as natural and man-made obstructions should also be considered.
Safety Systems	Safety System Location	• Safety system location is critical on its usefulness. • The role of each user and use case scenario should be considered when deploying a safety system.
Red Light Running Systems	Red Light Running System Location	• Red light running system location is critical on its usefulness. • The role of each user and use case scenario should be considered when deploying a red-light running system. • Other factors such as natural and man-made obstructions should also be considered.

ITS Tools	Constraints	Descriptions of Constraints
	Visual Verification	• Law enforcement utilizes red light running systems to gather evidence when a violation has occurred upon which a citation is issued. • Legislation may require photographic evidence of the driver's face, vehicle identification, signal phase verification, and/or date and time of the violation for adequate enforcement.
Enforcement Light Systems	Enforcement Light System Location	• Enforcement light system location is critical on its usefulness. • The role of each user and use case scenario should be considered when deploying an enforcement light system.
	Visual Verification	• Law enforcement utilizes the enforcement light system to provide visual verification a violation has occurred upon which a citation is issued.
Transit Signal Priority	Transit Signal Priority Location	• Transit signal priority location is a factor for the usefulness of the device. • Other factors such as natural and man-made obstructions should also be considered.
CAV Infrastructure Systems	Information Security and Privacy	• Management, security and maintenance is essential for CAV applications to standard traffic signals. 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.