Model Systems Engineering Document

ITS Application: Traffic Detection

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Prepared by Athey Creek Consultants

Contents

Acronyms

ARC-IT	National Architecture Reference for Cooperative and Intelligent Transportation
ATMS	Advanced Traffic Management Software
ATR	Automated Traffic Recorder
BSM	Basic Safety Message
CAV	Connected and Automated Vehicle
CW	Continuous Wave
DMS	Dynamic Message Signs
FAT	Factory Acceptance Test
FMCW	Frequency Modulated Continuous Wave
HOV	High Occupancy Vehicle
IRIS	Intelligent Roadway Information System
ITS	Intelligent Transportation System
LAN	Local Area Network
MnDOT	Minnesota Department of Transportation
RITIS	Regional Integrated Transportation Information System
RSU	Roadside Unit
SEA	Systems Engineering Analysis
WAN	Wide Area Network
VPN	Virtual Private Network

Purpose and Description of ITS Application: Traffic Detection

Document Purpose

This document is intended to support the Systems Engineering Analysis (SEA) activities for the Minnesota Department of Transportation (MnDOT) and other local transportation agencies within Minnesota as they consider, plan, develop, design, implement, and operate traffic detection. The content of this document will be a systems engineering analysis resource to support project compliance as set forth in 23 CFR Section 940 (Rule 940). This document can be used in conjunction with the Minnesota Statewide Regional Intelligent Transportation System (ITS) Architecture and related systems engineering resources to complete an ITS Systems Engineering project-specific checklist as part of the initial analysis of applications considered for implementation. To access the available checklists for ITS-related deployments, visit the MnDOT Systems Engineering web page at: https://www.dot.state.mn.us/its/systemsengineering.html.

In situations where projects are not consistent with this systems engineering document, the contents of this document may be used as a base to support the development of project specific systems engineering documents, including a concept of operations, functional requirements, and test plans specific to the project.

Traffic Detection Environment/Components

Transportation agencies commonly use traffic detection to collect traffic and vehicle-related data, including but not limited to traffic volume, lane occupancy, speed, vehicle classification, vehicle heading, and vehicle passenger occupancy. This traffic detection data is used by MnDOT for real-time operations and for transportation planning, research, and analysis. Many operations systems, consisting of field devices and related operating systems, also rely on traffic detection data for on-road applications such as ramp metering, MnPASS pricing and display to motorists, and dynamic lane control, to name a few. As operations of CAVs expand, several data exchanges between CAV management systems and CAVs are anticipated, some of which will utilize traffic detection data, and some of which will be a source of traffic data. Traffic detection functions may be completed by field devices, collected from the communications of passing CAVs, or provided to MnDOT by third party traffic detection services.

Table 1 presents the environment/components included in traffic detection and describes the function for each.

Table 1: Traffic Detection Environment / Components

Environment/Component	Function
1. Field Devices for Traffic Detection	Collects one or more aspects of traffic related data (i.e. presence, volume, lane occupancy, speed, vehicle classification, passenger occupancy). Note that CAV infrastructure systems are included as an optional field device for traffic detection.
2. Third Party Traffic Detection Services	Services procured to provide one or more aspects of vehicle related data without the need for field equipment.
3. Traffic Data Management Systems	A software system or systems that enables users to access data, stores and archives data, performs calculations as needed, and summarizes data into useable reports. (e.g. iPEMS, Regional Integrated

	Transportation Information System (RITIS) and/or Intelligent Roadway Information System (IRIS)).
4. Operations Systems	Field devices and related operating systems that utilize traffic detection data to manage on-road traffic operations applications. (Examples of Operations Systems are MnPASS, ramp meters, and travel time systems.)
5. Supporting Communications	The communications infrastructure to allow data communications from traffic detection sources to all related devices and systems. (See details in the *Model System Engineering Document, ITS Application: Communications* document.)
6. CAV Infrastructure Systems	The systems deployed by the DOTs to communicate with on-board units within CAVs. In this context, CAV Infrastructure Systems are expected to receive Basic Safety Messages (BSMs) from passing vehicles (as a field device for traffic detection) and also to be a recipient of data and information from traffic data management systems.
7. CAVs	The vehicles and on-board applications that communicate with CAV Infrastructure Systems and other CAVs. CAVs are expected to be an increasing source of traffic detection as they broadcast BSMs, providing vehicle information (e.g. speed, heading, etc.) to other vehicles and the infrastructure. Also, CAVs will be a recipient of data and information generated from traffic detection.

The primary traffic detection components and related systems are illustrated in Figure 1 below.

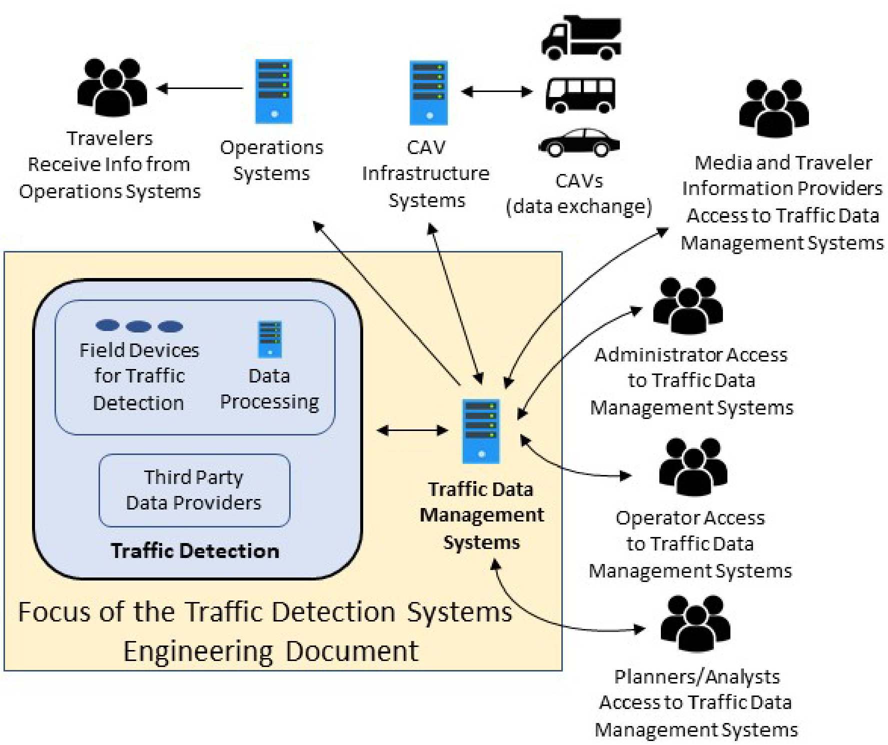

Figure 1: Illustration of Primary Traffic Detection Components and Related Systems/Users

As noted above, traffic detection functions may be completed by field devices or provided to MnDOT by third party detection services. Traffic detection data may be collected by field devices (including intrusive detectors, non-intrusive detectors, and CAV infrastructure systems), or by third party data providers. Table 2 provides an overview of common types of traffic detection.

Table 2: Overview of Common Types of Traffic Detection (sources include: Federal Highway Administration, 2017 [1])

Traffic Detection Type	Description
Field Devices (intrusive, non-intrusive, and CAVs)	
Inductive Loop	Most common detector technology. Consists of one or more turns of insulated loop wire wound in a shallow slot sawed in the pavement.
Road Tubes (piezoelectric tubes)	Detection method for short-duration counts. Long hollow tubes (traditionally rubber) are stretched across the road surface and attached to an air switch. When a wheel (axle) passes over the tube, the depression in the tube forces air into the switch which closes and sends an electrical signal to the recorder.
Magnetometer	Measures changes in both the horizontal and vertical components of the earth's magnetic field. Magnetometers are useful on bridge decks and viaducts, where the steel support structure interferes with loop detectors, and loops can weaken the existing structure. Magnetometers are also useful for temporary installations in construction zones.
Magnetic	Consists of a coil of wire with a highly permeable core. Measures the change in the lines of flux of the earth's magnetic field. Can only detect vehicles moving faster than a certain minimum speed, and therefore cannot be used as a presence detector. Useful where pavement cannot be cut, or where deteriorated pavement or frost activity break inductive loop wires.
Microwave Radar	Transmits microwave energy toward the roadway. Continuous Wave (CW) Doppler radar can only detect flow and speed. Frequency Modulated Continuous Wave (FMCW) radar can also act as presence detector. Certain bridges with large steel structures can cause problems with radar-based systems.
Active Infrared (laser radar)	Transmits infrared energy from detector and detects the waves that are reflected.
Passive Infrared	Does not transmit any energy; detects energy from vehicles, roadway and other objects, as well as energy from the sun that is reflected by vehicles, roadway, and other objects.

[1] Federal Highway Administration. (2017). Descriptions of pavement invasive detectors and non-pavement invasive detectors from "Traffic Control Systems Handbook: Chapter 6 Detectors." Retrieved from https://ops.fhwa.dot.gov/publications/fhwahop06006/chapter_6.htm

Traffic Detection Type	Description
Ultrasonic	Transmits ultrasonic sound energy waves and measures the distance that the reflected wave travels. Can detect vehicle count, presence, and lane occupancy.
Acoustic	Measures vehicle passage, presence, and speed by passively detecting acoustic energy or audible sounds produced by vehicular traffic.
Video Image Processor	Video cameras detect traffic, and the images are digitized, processed, and converted into traffic data. Can replace several loop detectors, and measure traffic over a limited area, rather than just a single point.
CAV Infrastructure Systems	Roadside units that receive and process the secure messages broadcast from CAVs. Typically, the messages received will be the BSM broadcast by on-board applications operating on production or aftermarket vehicles. These may be dedicated “BSM readers” or may be a part of an overall CAV Infrastructure system that also broadcasts data to CAVs.
Vehicle or mobile device Identification and Processing	Approaches that identify vehicles as they pass two or more locations and use the time difference to compute travel times. Examples include the detection of identifiers in mobile devices broadcast using either Bluetooth or wi-fi communications. Identifiers are anonymous as the traffic detection only requires a match to determine the travel time.
Third Party Traffic Detection Services	
Third Party Data providers	Third party data providers may collect data using a variety of approaches, such as probe vehicles, cellular phone data, crowdsourcing, and various other approaches. These providers typically provide data as a service to DOTs, delivering a combination of data and information. Ownership and rights to use and distribute the data vary by contract.

Examples of Communications Technologies Supporting Traffic Detection

The traffic detection application relies upon a number of communications technologies (detailed in a separate document - *Model System Engineering Document, ITS Application: Communications*) to transfer traffic data from field devices to eventual end users. The following table summarizes examples of communications technologies used today.

Table 3: Examples of Current Communications Supporting Traffic Detection Applications

Traffic Detection Application Communications	Communications Technologies Supporting Traffic Detection Applications
Traffic detection field devices to traffic data management systems	• **Long range communications** – Ethernet connections using fiber or copper mediums to communicate traffic data from cabinets in the field and traffic data management systems. • **Short-range wireline or wireless communications** – Ethernet or serial connections using fiber or copper mediums or wireless connections using WiFi, microwave, or FM radio, depending on local conditions, to support two-way communications over the short distances from the traffic detection field devices to cabinets that are connected using long-range communications to traffic data management systems. • **DOT operated Local Area Network (LAN) or Wide Area Network (WAN)** – Private communications network that allows a connection between traffic detection field devices and traffic data management systems with standard security concerns. • **Public internet** – Use of the public internet allows information (e.g. traffic data) to be shared from locations where agency owned communications are not practical. • **Commercial wireless communications** – Services provided by third party providers over commercial networks, such as cellular, allow wireless communications of traffic data from traffic data field devices to traffic data management systems. • **Virtual Private Network (VPN) over public internet** – Secure and encrypted communications over less secure networks and the public internet allow communication of traffic data in locations where agency owned communications are not practical.
3rd party traffic-data sources to traffic data management systems	• **Public internet** – Public internet allows communications of traffic data from third-party data sources agency operated traffic data management systems when agency owned communications are not practical. • **VPN over public internet** – Secure and encrypted communications over less secure networks and the public Internet allow communication of traffic data from third party data sources to traffic data management systems when agency owned communications are not practical.
Traffic data management systems to MnDOT operations systems and CAV infrastructure systems	• **Long range communications** – Ethernet connections using fiber or copper mediums to communicate between traffic data management systems and cabinets in the field that connect locally to CAV infrastructure systems. • **Short-range wireline or wireless communications** – Ethernet or serial connections using fiber or copper mediums or wireless connections using WiFi, microwave, or FM radio, depending on local conditions, to

Traffic Detection Application Communications	Communications Technologies Supporting Traffic Detection Applications
	support two-way communications over the short distances from cabinets in the field to CAV infrastructure systems. • **DOT operated LAN or WAN** – Private communications network that allows a connection between traffic data management systems and CAV infrastructure systems with standard security concerns. • **Commercial wireless communications** – Services provided by third party providers over commercial networks, such as cellular, allow wireless communications of traffic data from traffic data management systems to CAV infrastructure systems. • **VPN over public internet** – Secure and encrypted communications over less secure networks and the public Internet allow communication of traffic data from traffic data management systems to CAVs in locations where agency owned communications are not practical.
Traffic data systems to media and travelers	• **Public internet** – Use of the public Internet allows traffic data to be shared with media providers.

Stakeholders and Typical Conditions

Stakeholders

Table 4 identifies the stakeholder groups that interface with one or more aspects of traffic detection deployment and operations.

Table 4: Traffic Detection Stakeholders/Users

Stakeholder	Description
Travelers	Vehicle drivers and passengers operating traditional vehicles and CAVs.
Operators and Operations Systems	Operators responsible for performing freeway or arterial operations and for managing systems that support operations (e.g. automated ramp metering or travel time systems). Also includes the overall operational activities of the DOT, often performed by automated operations systems, operators, or a combination.
Planners/Analysts	Individuals responsible for analyzing congestion levels, traffic volume, vehicle classification, travel patterns and reporting travel behavior patterns
Administrators	A combination of operators and technical staff responsible for configuring, updating, and verifying agency owned traffic detection equipment or agreements with third party traffic detection service providers.
Technicians and Installers	Technical staff responsible for installing, maintaining, and troubleshooting traffic detection equipment or for integrating traffic detection data from external sources.
CAV Infrastructure Systems and CAVs	External systems that include both CAV infrastructure systems (systems operated by MnDOT) and CAVs (vehicles and on-board units in the vehicles) that support connected and automated vehicle operations. CAVs are expected to broadcast BSMs and CAV Infrastructure systems may receive and process the BSMs as a method of traffic detection.
Media/Traveler Information Providers	External agencies that typically access and redistribute traffic detection data, providing a service to travelers or other consumers of the information.

Typical and Local Conditions

Traffic detection field devices are commonly installed in the pavement or near the roadway, positioned to capture traffic data from all lanes of travel. Third party traffic detection services will also collect traffic data for all lanes of traffic and provide the data to the agency (typically as a procured service). As the number of CAVs operating on the road increase, the BSM messages they broadcast (and potentially other "Event Driven Configurable Messages" from the vehicle) will be received by the agency as a form of traffic detection.

Traffic data management systems and operations systems that utilize traffic data to perform data processing and traffic management functions may reside at MnDOT or may be hosted externally, with access by various users. Typically, a higher density of field detection devices are operational in metropolitan areas, where there is a greater need for higher precision data. Recent trends and private sector services have generally allowed travelers with access to high level reporting of speeds on roadways statewide.

Stakeholder Needs

Table 5 identifies a series of problems or challenges and the related needs for each stakeholder identified above.

Table 5: Traffic Detection Challenges/Problems and Needs

Problem/Challenge	Needs (As a Result of the Problem/Challenge)
Travelers Needs	
- Travelers rely on indicators of travel time or travel speeds when selecting routes or planning departure times.	***Need 1: Public Access to Speed Indicators*** Travelers need access to information describing current conditions such as travel times, speeds, and other information that is derived from traffic detection.
Operators and Operations Systems Needs	
- Some operations systems require detailed volume and lane occupancy data to operate algorithms.	***Need 2: Detailed Volume and Lane Occupancy Data*** Operations systems need detailed volume and lane occupancy data (i.e. "algorithm-rich data") to support algorithms (e.g. travel time calculations, ramp meter rates, etc.) or traffic hazard identification systems (e.g. queue warning, wrong-way vehicle detection, etc.).
- Operators rely on visual representation of volumes and lane occupancy data that can be viewed in real-time to monitor current conditions.	***Need 3: High-Level Volume and Lane Occupancy Data*** Operators and operations systems need high-level volume and lane occupancy data for ingest into systems that use the data to create visual/graphical representation of current conditions.
- Some operations systems require detailed speed data to operate algorithms.	***Need 4: Detailed Speed Data*** Operations systems need detailed speed data (i.e. "algorithm-rich data") for algorithms to compute values such as travel times, generate incident detection alerts, queue warning systems, or to operate other real-time systems.
- Operators rely on visual representation of speed data that can be viewed in real-time to monitor current conditions.	***Need 5: High-Level Speed Data*** Operators and operations systems need high-level speed data (measured or computed from other measured values) as numeric values or categories (e.g. stop and go, slow, normal) for ingest into systems that use the data to create visual/graphical representation of current conditions.
- Visual assessment of passengers in HOV lanes and MnPASS lanes requires multiple on-site law enforcement staff to conduct enforcement.	***Need 6: Passenger Occupancy Data*** Operators and the MnPASS system need accurate passenger occupancy data (e.g. whether there are two or more people in the vehicle) to enhance enforcement efforts.

Problem/Challenge	Needs (As a Result of the Problem/Challenge)
- The data available from traffic detection changes as new data types become available and as data collection techniques become more advanced.	***Need 7: Data Management for Operations*** Operators need to understand all data that is available from traffic detection, to plan for future uses, manage the data currently used, and evaluate new data for use in real-time operations.
- Operators require the traffic data to be in useable formats and through reporting tools.	***Need 8: Traffic Data Processing*** Operators and operations systems need traffic detection data to be processed, assigned to road segments, and needed calculations performed (e.g. calculating speed or traffic density from volume and lane occupancy) for their use in real-time decision-making.
- Analysis of current and historical traffic data or trends in data helps monitor highway performance and refine operational procedures and practices.	***Need 9: Usable Access to Current and Historical Traffic Data*** Operators need to be able to access current and historical traffic data in usable formats and presentation styles to conduct research or performance management.
Planners/Analysts Needs	
- Planning and HPMS reporting require the collection and archive of volume, speed and vehicle classification data. While this need has been traditionally fulfilled by Automated Traffic Recorders (ATRs), planners could benefit from ITS solutions for increased data collection.	***Need 10: Planning Level Traffic Detection*** Planners/analysts need ITS solutions to supplement ATRs in providing planning level data, including but not limited to volume, speed, and vehicle classification data. Tools are needed to post-process historic data to track performance measures such as levels of congestion, travel times, buffer time index, etc.
Administrators Needs	
- It is important to identify issues with devices as early as possible, to implement repairs or replacements in order to minimize disruption in traffic data collection.	***Need 11: Data Assessment Tools*** Administrators need tools to query, review, report, and assess traffic detection data, in order to understand whether devices are operating properly.
- In order to benefit from third party data detection service providers, contractual agreements and management are needed.	***Need 12: Data Procurement Methods*** Administrators need mechanisms that enable them to procure and receive third party data provided by outside services in a way that the agency can rely on consistent ongoing data delivery.
- Data management will help ensure others in the agency benefit from data and manage the long-term storage and access.	***Need 13: Data Management*** Administrators need data management procedures and tools to ensure the benefits of data are maximized and to support administrators in adhering to data archiving and retention policies (e.g. currently volume and occupancy are retained; there is not a current policy on archiving CAV data, but as this is known and understood data management will support it).

Problem/Challenge	Needs (As a Result of the Problem/Challenge)
Technicians and Installers Needs	
- Proper use of field equipment to detect vehicles require communications, power, and installation at the deployment sites.	***Need 14: Field Device Supporting Infrastructure*** Technicians and installers need power, communications, and a support structure to be available at locations where field equipment is used to detect vehicles.
- Devices that are not compatible with existing equipment or systems may not be able to be installed or could require significant staff effort during installation.	***Need 15: Equipment Consistency*** Technicians and installers need consistency and compatibility in the traffic detection devices to achieve efficiencies in procurement, maintenance, and training.
CAV Infrastructure Systems and CAVs Needs	
- CAVs will benefit from data from nearby vehicles.	***Need 16: Vehicle to Vehicle Data Exchange*** CAVs need real-time, low latency data from other CAVs to perform safety and efficiency functions.
- Vehicle data (e.g. acceleration, deceleration, speed, plow activity, material spreading) can offer insight into conditions, traffic patterns, and activities.	***Need 17: Vehicle to Infrastructure Data Exchange*** DOTs need to benefit from the data broadcast by public and private CAVs.
- CAVs will benefit from traffic detection data provided by DOT-owned infrastructure, as additional automated driving systems and capabilities are integrated into vehicles.	***Need 18: Vehicle Use of Infrastructure-Generated Traffic Data*** CAVs may need infrastructure-generated traffic data such as speeds or lane occupancy data derived from real-time and historical traffic detection data.
Media/Traveler Information Providers Needs	
- Travelers benefit if media and other information providers are able to communicate vehicle speeds or other indicators of congestion.	***Need 19: External Access to Traffic Data*** Media and other information providers need access to data representing volume or speed of vehicles.

Operational Concepts

The previous section defined a series of stakeholders that are expected to interact with traffic detection and their needs likely to be addressed by traffic detection. This categorization will be further used in this section to describe the operational concept for traffic detection from each user's perspective. The operational concept is intended to help each user see how their needs have been interpreted and how traffic detection is expected to address their needs. It is presented in a sequential manner from each user's perspective, with the needs included in the tables for reference.

Travelers' Perspective

Table 6 describes the traffic detection operational concepts from the travelers' perspective, and relates each concept to a need, as defined in the previous section.

Table 6: Traffic Detection Operational Concepts – Travelers' Perspective

Need (Travelers' Perspective)	Operational Concept
Travelers' Perspective linked to ***Need 1: Public Access to Speed Indicators***	1.1 Prior to departing on their trips, travelers may access traveler information websites (operated by MnDOT or other partners) to view current traffic speeds or travel times (derived from traffic detection) along their planned routes. 1.2 Travelers en-route to their destination may view travel times or queue warning displayed on Dynamic Message Signs (DMS). 1.3 Travelers watching local news media broadcasts may view speed maps displaying colored roads to indicate the general average speed of travel along key routes.

Operators' and Operations Systems Perspective

Table 7 describes the traffic detection operational concepts from the operators and operations systems' perspective, and relates each concept to a need, as defined in the previous section.

Table 7: Traffic Detection Operational Concepts – Operators' and Operations Systems Perspective

Need (Operators and Operations Systems Perspective)	Operational Concept
Operators and Operations Systems' perspectives related to: ***Need 2: Detailed Volume and Lane Occupancy Data***	2.1 Detailed "algorithm-rich" volume and lane occupancy data collected by traffic detection will be communicated to various traffic data management systems. 2.2 The detailed "algorithm-rich" volume and lane occupancy data will be ingested into various traffic data management systems to support algorithms for freeway and arterial operations systems that require this data (e.g. MnPASS, ramp meters, travel time calculations, wrong-way driver detection or queue detection, etc.).

Need (Operators and Operations Systems Perspective)	Operational Concept
	2.3 Operators may view volume and lane occupancy raw data values (and other derived values) to assist with traffic management activities. 2.4 In situations where advances in traffic detection enable more detailed data collection (e.g. vehicle path/bearing detectors) operators may consider this additional data when selecting operational changes.
Operators and Operations Systems' perspectives related to: ***Need 3: High-Level Volume and Lane Occupancy Data***	3.1 High-level volume and lane occupancy data collected by traffic detection will be communicated to various traffic data management systems. 3.2 High-level volume and lane occupancy data will be ingested into traffic data management systems that post-process the data to create visual/graphical representation of current conditions. 3.3 Operators will view visual/graphic representation of current traffic conditions to monitor traffic congestion and assist with determining response activities.
Operators and Operations Systems' perspectives related to: ***Need 4: Detailed Speed Data***	4.1 Detailed "algorithm-rich" speed data collected by detection devices, procured from third party providers, or computed using other measured values will be communicated to various traffic data management systems. 4.2 Detailed "algorithm-rich" speed data will be ingested into systems that compute travel times to create the travel times to be posted on DMS. 4.3 Traffic data management systems will utilize detailed "algorithm-rich" speed data from traffic detection to run algorithms for freeway and arterial operations systems that require this data (e.g. MnPASS, ramp meters, etc.). 4.4 Operators may view raw speed data values or categories to assist with traffic management activities.
Operators and Operations Systems' perspectives related to: ***Need 5: High-Level Speed Data***	5.1 Speed indicator data generated by traffic detection will be communicated to systems that utilize the data for traveler information. 5.2 Speed indicator data will be ingested into traveler information systems that use the data to create visual/graphical representation of current traffic conditions, for viewing by travelers.

Need (Operators and Operations Systems Perspective)	Operational Concept
Operators and Operations Systems' perspectives related to: ***Need 6: Passenger Occupancy Data***	6.1 Operators and operations systems will rely upon automatically generated alerts to indicate passenger occupancy data, such as less than two passengers in vehicles traveling in MnPASS lanes or High Occupancey Vehicle (HOV) lanes, or as appropriate per future changes in rules and regulations. 6.2 Passenger occupancy data and/or automated alerts will be ingested into systems that monitor MnPASS or HOV lane compliance. 6.3 Operators may communicate passenger occupancy data directly to law enforcement, to assist with MnPASS or HOV lane enforcement efforts.
Operators' perspectives related to: ***Need 7: Data Management for Operations***	7.1 Operators will create data management plans to manage intake, organization, and storage of data from traffic detection. 7.2 Operators will create data management plans to assess traffic detection data needs and plan for future data uses. 7.3 Operators will be presented with new data and collection techniques from traffic detection as they become available and will assess new data types and collection techniques to determine new or enhanced uses for the data in operations. 7.4 Operators will benefit from advanced data collection and/or hybrid approaches (e.g. vehicle path/bearing detection).
Operators and Operations Systems perspectives related to: ***Need 8: Traffic Data Processing***	8.1 Data from traffic detection will be assigned to specific road segments as defined by operators. 8.2 Data from traffic detection will be processed to calculate speed values, if not directly measured by detection. 8.3 Data from traffic detection will be processed to calculate other values such as travel times, if not directly measured by detection. 8.4 Operators will utilize the post-processed data for operational activities and operations systems.
Operators' perspectives related to: ***Need 9: Usable Access to Current and Historical Traffic Data***	9.1 Operators will use traffic data management solutions to view real-time or historical traffic data in useable formats and displays, that may include files, printouts, or screen displays.

Need (Operators and Operations Systems Perspective)	Operational Concept
	9.2 Operators will be able to access historical traffic detection data to perform research that will enhance operations or for performance management. 9.3 Operators will provide access to external parties to download data to support their research or analysis activities on behalf of MnDOT.

Planners/Analysts' Perspective

Table 8 describes the traffic detection operational concepts from the planners/analysts' perspective, and relates each concept to a need, as defined in the previous section.

Table 8: Traffic Detection Operational Concepts – Planners/Analysts' Perspective

Need (Planners/Analysts' Perspective)	Operational Concept
Planners/analysts' perspective related to ***Need 10: Planning Level Traffic Detection***	10.1 Data from traffic detection will include planning-level volume, speed, and vehicle classifications. 10.2 Planners will utilize the data to supplement data from Automated Traffic Recorders (ATRs) to enhance transportation planning activities and outcomes. 10.3 Planners will utilize post-processed data that will allow for tracking of historic travel times, congestion trends, buffer time index, and other related mobility performance measures for planning and developing transportation improvement projects.

Administrators' Perspective

Table 9 describes the traffic detection operational concepts from the administrators' perspective, and relates each concept to a need, as defined in the previous section.

Table 9: Traffic Detection Operational Concepts - Administrators' Perspective

Need (Administrators' Perspective)	Operational Concept
Administrators' perspective related to ***Need 11: Data Assessment Tools***	11.1 Administrators will use computer-based or web-based tools to query, view, report, and assess traffic detection data. 11.2 Administrators will view various reports of data to identify the locations of detection devices that are not working properly.
Administrators' perspective related to ***Need 12: Data Procurement Methods***	12.1 Administrators will assist MnDOT contracting staff with developing materials (e.g. request for proposals) to procure third party providers of traffic detection data.

Need (Administrators' Perspective)	Operational Concept
	12.2 Procurement materials will define requirements for third party data, defining specific formats and delivery methods that are required of all data providers. 12.3 Administrators will be able to rely on consistent data formats and delivery methods from all parties providing third party traffic detection data to MnDOT.
Administrators' perspective related to ***Need 13: Data Management***	13.1 Traffic data will be stored and available for direct access by administrators according to contractual arrangements and limitations of the data (i.e. some data, such as purchased data, may have limitations preventing MnDOT from storing or sharing the data). The term "stored" refers to short-term saving of the data for access directly by users or by systems. 13.2 Traffic detection data will be archived periodically by Administrators in compliance with data retention policies and procedures. The term "archive" refers to packaging and depositing data into databases or data warehouses for long term retention. This may include some processing to reduce storage size and may limit immediate access to the data by all systems. 13.3 As new data retention policies are agreed (e.g. CAV data), Administrators will take steps to archive data in compliance with these policies and may need to develop or procure new tools to support the archive or storage demands. 13.4 Administrators will have the ability to grant access privileges to other data users, including various levels of access. Note: Not all data may be shared; data management and sharing will be within the bounds of contractual agreements.

Technicians/Installers' Perspective

Table 10 describes the traffic detection operational concepts from the perspective of the technicians and installers of traffic detection, and relates each concept to a need, as defined in the previous section.

Table 10: Traffic Detection Operational Concepts - Technicians/Installers' Perspective

Need (Technicians/Installers' Perspective)	Operational Concept
Technicians and Installers' Perspectives related to ***Need 14: Field Device Supporting infrastructure***	14.1 Traffic detection devices will be deployed at locations where they are accessible to power and communications.

Need (Technicians/Installers' Perspective)	Operational Concept
	14.2 Traffic detection devices will be deployed (in-pavement or above ground) so that technicians and installers can access the devices to perform maintenance. 14.3 Non-pavement invasive traffic detection devices that are mounted above ground will be mounted on appropriate support structures.
Technicians and Installers' Perspectives related to ***Need 15: Equipment Consistency***	15.1 In-place traffic detection devices will continue to be used for traffic data collection. 15.2 Procurement of new traffic detection devices will be consistent with in-place devices to the extent possible, so that installers and technicians will be well-trained to install and repair new devices and can interchange parts. 15.3 New traffic detection devices will be compatible with existing equipment and systems such as communications (fiber, etc.) and traffic data management systems (e.g. MnPASS). 15.4 Consistency and compatibility needs will not prevent or inhibit the testing and eventual production use of new products or services. MnDOT will continue to benefit from advances in technology. 15.5 Selection of new equipment or software tools will be done in a way that ensures interoperability and consistency with latest standards and technologies.

CAV Infrastructure Systems and CAVs Perspective

Table 11 describes the traffic detection operational concepts from the perspective of CAV Infrastructure Systems and CAVs, and relates each concept to a need, as defined in the previous section.

Table 11: Traffic Detection Operational Concepts - CAV Infrastructure Systems and CAVs Perspective

Need (CAV Infrastructure Systems and CAVs Perspective)	Operational Concept
CAV Infrastructure Systems and CAVs Perspectives on ***Need 16: Vehicle to Vehicle Data Exchange***	16.1 CAVs (including agency owned CAVs) are expected to broadcast the BSM continuously as they drive the Minnesota roadways. 16.2 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.

Need (CAV Infrastructure Systems and CAVs Perspective)	Operational Concept
CAV Infrastructure Systems and CAVs Perspectives on ***Need 17: Vehicle to Infrastructure Data Exchange***	17.1 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 and volumes. 17.2 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. 17.3 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 Perspectives on ***Need 18: Vehicle Use of Infrastructure-Generated Traffic Data***	18.1 MnDOT may deploy and operate CAV Infrastructure Systems on the roadside to broadcast traffic detection data, such as real-time speeds, expected speeds based on historical data, lane occupancy, or other derived values such as desired gaps between vehicles, that will be received by CAVs. 18.2 CAV Infrastructure Systems may receive traffic data or derived values from traffic data management systems, for use by CAVs. 18.3 CAVs may ingest this traffic data or derived values from the CAV Infrastructure Systems, to support automated driving features.

Media/Traveler Information Providers' Perspective

Table 12 describes the traffic detection operational concepts from the perspective of media / traveler information providers, and relates each concept to a need, as defined in the previous section.

Table12: Traffic Detection Operational Concepts – Media/Traveler Information Providers Perspective

Need (Media/Traveler Information Providers Perspective)	Operational Concept
Media / Traveler Information Providers Perspectives on ***Need 19: External Access to Traffic Data***	19.1 Television media providers may download speed data from MnDOT (or other third-party data providers) and display map representations of the roads color-coded to reflect current speeds. 19.2 Television and radio media providers may download speed data and calculate travel times for pre-defined routes, displaying these travel times to travelers.

Operational Scenarios/Roles and Responsibilities

Roles and Responsibilities

The *Operational Concept* section defined interactions of the primary stakeholders with traffic detection and supporting systems. The table below provides a high-level summary of the roles and responsibilities of the stakeholder groups.

Table 13: Operation and Maintenance Roles and Responsibilities

User Group	Role / Responsibility
Operators	• View and access traffic detection data to monitor real-time traffic conditions and perform traffic-related performance management. • Configure algorithms for any MnDOT-operated traffic data management systems or operations systems, as appropriate. • Monitor the status of traffic detection data; alert technicians or third-party detection services providers to any issues. • Participate in configuring new traffic detection devices, traffic data management systems, and/or operations systems. • Assist with preparing procurement materials for third party traffic detection services. • Assess the emergence of new traffic data types to determine when and where to implement these (e.g. when to deploy additional CAV BSM readers to collect data broadcast by CAVs).
Planners/Analysts	• Access and utilize traffic detection data for transportation planning, research, and related analysis.
Administrators	• Configure new traffic detection field devices and assign them to the appropriate traffic data management systems. • Assign traffic data from third party traffic detection services to the appropriate traffic data management systems and operations systems. • Upgrade traffic detection field devices as appropriate and maintain consistency between field devices, traffic data management system, and operations systems. • Create data management plans, procedures, and reports for effective use of traffic detection data. • Review traffic detection data outputs to assist with trouble-shooting issues with traffic detection. • Monitor the status of traffic detection field devices and determine when upgrades are needed. • Assist with defining requirements for procurement of third-party traffic detection services.

User Group	Role / Responsibility
Technicians/Installers	• Install traffic detection field devices. • Troubleshoot technical issues with traffic detection field devices and make necessary repairs or replacements. • Perform routine maintenance and replacement of traffic detection field devices in accordance with MnDOT ITS maintenance documentation. • Participate in configuring traffic detection data with the appropriate traffic data management systems.
Travelers	• View traffic speeds, travel times, congestion maps, and other traffic conditions via traveler information mechanisms that utilize data from traffic detection.
Media/Traveler Information Providers	• Access and redistribute traffic detection data to travelers and other consumers of the information.

Operational Scenarios

Scenarios are intended to describe how users and systems will interact with traffic detection and related systems, specifically to provide a temporal description of the sequence of events. The following scenarios briefly describe how users will be impacted and how they are expected to respond.

- Scenario A: Ramp Metering
- Scenario B: Traffic Speed Maps
- Scenario C: Performance Management, Research, and Analysis
- Scenario D: Traffic Detection Data Issues
- Scenario E: Connected Automated Vehicle Data Reporting

Scenario A: Ramp Metering

On a typical morning within the Twin Cities, along the limited access freeways, detailed volume and lane occupancy data for each lane of traffic is collected by traffic detection field devices. These volumes and lane occupancies are periodically communicated to IRIS – MnDOT's Advance Traffic Management Software (ATMS), a centrally located traffic data management system. Using the volume and lane occupancy data ingested from traffic detection devices, IRIS continually calculates traffic speeds and densities along the freeway.

As the morning commute period begins, ramp meters activate based on traffic response algorithms. Once activated, the ramp metering algorithm within IRIS uses computed traffic density to determine update ramp meter rates. As traffic densities increase on 169 southbound near 49th Avenue, the ramp meter red indication is extended based on the automated ramp meter algorithm. Travelers view the ramp meter and briefly stop their vehicles during the ramp meter's red indication, until a green indicator allows their vehicle to advance into the freeway stream. At approximately 8:45 AM, as volume and lane occupancy data from traffic detection along 169 southbound near 49th Avenue return to free-flow conditions, the ramp meter algorithm reduces the red indication period. Eventually, as the morning peak concludes, the ramp meters throughout the metro area return to flashing yellow.

Scenario B: Traffic Speed Maps

Speed data from third party traffic detection service providers and traffic data from field devices is ingested into MnDOT-operated traffic data management systems and used to create traffic speed maps (green, yellow, red) in 511 mechanisms. The MnDOT 511 website then displays the speed maps to communicate traffic conditions statewide. A traveler in the Twin Cities metro area is planning a trip from Bloomington to St. Cloud on a Thursday morning during rush hour. In the days leading up to the trip, the traveler views the MnDOT 511 website during the Tuesday and Wednesday morning rush hours and notices red traffic indications between Albertville and Monticello, caused by road construction lane restrictions. The traveler also notices that northbound Highway 169 is typically less congested than I-494 or Highway 100. On the day of the trip, the traveler views traffic maps on the MnDOT website and on a local television station just prior to departure and plans his route accordingly.

Scenario C: Performance Management, Research, and Analysis

Data collected by traffic detection field devices and provided by third party traffic detection services is communicated to iPEMS, a traffic data management system designed to store traffic data and produce various displays of historical data and trends. Planners have identified a need to view historical traffic data, such as volumes, speeds and travel times, along a pre-determined segment of I-694, in order to assess what type of improvements need to be made to the corridor. MnDOT has procured an external engineering consultant to assist with this analysis. Administrators work with planners and iPEMS programmers to determine requirements for exporting and displaying historical traffic data in order to complete the analysis. Administrators also work with iPEMS programmers to define various levels of access for consultants external to MnDOT, following contractual agreements for sharing traffic data provided by third party traffic detection services. Leading up to the analysis, MnDOT planners and external consultants access the data via iPEMS and complete the analysis.

Scenario D: Traffic Detection Data Issues

On a monthly basis, administrators and operators query and review traffic data reports generated through IRIS. They notice a repetitive value of "(-1)" reported for speed, lane occupancy, and volume at various field device locations. Administrators recognize the "(-1)" value as an indication that devices at those locations may not be functioning properly. Administrators then identify the affected device locations from traffic data reports generated by IRIS and alert installers/technicians of these device locations. Installers/technicians go into the field to trouble-shoot the issues with the affected devices. In some cases, technicians determine that communications to the traffic detection field devices has been compromised due to nearby construction. In other cases, installers/technicians determine that the device is no longer operational, and they repair or replace the device.

Scenario E: Connected Automated Vehicle Data Reporting

At a future date, MnDOT has determined that the increasing percentage of CAVs operating on the roads in the Twin Cities has reached a point where roadside devices to receive and process the BSMs being transmitted by the vehicles will contribute to traffic detection. MnDOT places these roadside devices and collects data from passing vehicles. Initially, they have determined that the speed information in the BSM will contribute to (and verify) the overall speed calculations for the metro area freeways.

System Requirements

System requirements are verifiable details that define what a system will do, but not how the system will do it. Requirements can describe the functional, performance, interface, communications, operational, and maintenance conditions of what a system will do.

Requirements for traffic detection (detection and supporting systems) are listed in the table below first by needs (column 1). These represent the needs of all the stakeholders described in the *Stakeholders and Typical Conditions* Section. Based on each need and on the operational concepts presented in the *Operational Concepts* Section, one or more system requirements (column 2). Requirements are all numbered to facilitate traceability back to the original needs and further traceability through design and validation.

Table 14: Traffic Detection Requirements by Need

Need	System Requirement
Travelers	
1. Travelers need access to information describing current conditions such as travel times, speeds, and other information that is derived from traffic detection.	1.1. MnDOT shall collect, process, and disseminate traffic speed data to supplement what travelers have access to from 3rd party information dissemination sources (e.g. additional detail or accuracy in key locations). 1.2. In locations where MnDOT (or other agencies) perform traffic detection, the data collected shall provide traffic speed data in formats that are suitable for map displays, websites, and other publicly-viewed traveler information mechanisms.
Operators/Operations Systems	
2. Operations systems need detailed volume and lane occupancy data (i.e. "algorithm-rich data") to support algorithms (e.g. travel time calculations, ramp meter rates, etc.) or traffic hazard identification systems (e.g. queue warning, wrong-way vehicle detection, etc.).	2.1. Detailed volume and lane occupancy data shall be collected at a maximum spacing of ½ mile in locations where corridor-wide ramp metering, queue warning, or freeway travel time calculations are operational. 2.2. Traffic detection shall record detailed volume and lane occupancy data for all lanes on mainline segments and ramps. 2.3. Traffic detection shall provide detailed volume and lane occupancy data at a precision level that is adequate or higher for processing by algorithms (e.g. MnPASS, ramp metering, travel time calculations, etc.). 2.4. Traffic detection shall provide detailed volume and lane occupancy data in formats (e.g. XML, HTML, Plain Text, etc.) that can be ingested into traffic data management systems. 2.5. Detailed volume and lane occupancy data from traffic detection shall be at least 95% accurate.

Need	System Requirement
	2.6. Traffic detection shall communicate detailed volume and lane occupancy data to a central location for storage and algorithm processing. 2.7. Traffic detection shall record and provide additional types of detailed data (e.g. vehicle path/bearing detectors) as advancements in traffic detection are made.
3. Operators and operations systems need high-level volume and lane occupancy data for ingest into systems that use the data to create visual/graphical representation of current conditions.	3.1. In situations where high-level volume and lane occupancy data are collected by traffic detection applications, the data shall be provided in formats (e.g. XML, HTML, Plain Text) that can be ingested into traffic data management systems that display visual/graphical representation of traffic conditions. 3.2. Traffic detection shall provide high-level volume and lane occupancy data at a precision level that is suitable for post-processing by traffic data management systems that provide visual displays. 3.3. High-level volume and lane occupancy data from traffic detection shall be at least 95% accurate. 3.4. Traffic detection shall communicate high level volume and lane occupancy data to a central location for ingest into traffic data management systems that provide visual displays.
4. Operators need detailed speed data (i.e. "algorithm-rich data") for algorithms to compute values such as travel times, generate incident detection alerts, queue warning systems, or to operate other real-time systems.	4.1. In locations where detailed speed data is required (e.g. for travel time calculations), traffic detection shall record detailed speed data for all lanes on mainline segments and ramps. 4.2. Traffic detection shall provide detailed speed data at a precision level that is adequate or higher for processing by algorithms (e.g. MnPASS, ramp metering, queue warning systems, travel time calculations, etc.). 4.3. Traffic detection shall provide detailed speed data in formats (e.g. XML, HTML, Plain Text) that can be ingested into traffic data management systems. 4.4. Detailed speed data from traffic detection shall be at least 95% accurate. 4.5. Traffic detection shall communicate detailed speed data to a central location for storage and algorithm processing.
5. Operators and operations Systems need high-level speed data (measured or computed from other measured values) as	5.1. Traffic detection shall provide high-level speed indicator data in formats (e.g. XML, HTML, JSON) that can be ingested into systems that display visual/graphical representation of traffic conditions.

Need	System Requirement
numeric values or categories (e.g. stop and go, slow, normal) for ingest into systems that use the data to create visual/graphical representation of current conditions.	5.2. Traffic detection shall provide high-level speed indicator data at a precision level that is suitable for post-processing by visual/graphical display systems. 5.3. High-level speed data from traffic detection shall be at least 95% accurate. 5.4. Traffic detection shall communicate high-level speed indicator data to a central location for ingest into display systems.
6. Operators and the MnPASS system need accurate passenger occupancy data (e.g. whether there are two or more people in the vehicle) to enhance enforcement efforts.	6.1. Traffic detection may detect and record instances of passenger occupancy violations (i.e. less than two people in a vehicle or future changes to rules and regulations), for vehicles traveling in MnPASS lanes or HOV lanes. 6.2. If traffic detection includes passenger occupancy violation, then traffic detection shall generate alerts for instances when passenger occupancy violations occur. 6.3. If traffic detection includes passenger occupancy violation, then traffic detection shall record the time of violation and location of the vehicle that has been detected to have a passenger occupancy violation. 6.4. If traffic detection includes passenger occupancy violation, then traffic detection shall record a vehicle identifier for each vehicle that has been detected to have a passenger occupancy violation. 6.5. If traffic detection includes passenger occupancy violation, then traffic detection shall communicate alerts and other passenger occupancy data (vehicle location, vehicle identifier) in formats suitable for ingest into systems that monitor MnPASS and HOV lane compliance. 6.6. Passenger occupancy data from traffic detection shall be at least 95% accurate.
7. Operators need to understand all data that is available from traffic detection, to plan for future uses, manage the data currently used, and evaluate new data for use in real-time operations.	7.1. Traffic data management systems shall aggregate and organize data collected in a central location. 7.2. Traffic data management systems shall enable users to view data and create data management plans. 7.3. Current systems and approaches used for traffic detection shall not limit the introduction, implementation, integration, and use of innovative approaches, products, or services.

Need	System Requirement
8. Operators and operations systems need traffic detection data to be processed, assigned to road segments, and needed calculations performed (e.g. calculating speed or traffic density from volume and lane occupancy) for their use in real-time decision-making.	8.1. Traffic detection shall collect and process data for specific road segments as defined by operators. 8.2. Traffic detection shall process collected data, as needed, to calculate speed values, if not directly measured by detection. 8.3. Traffic data management systems shall process collected data to calculate travel times, if not directly measured or provided by traffic detection. 8.4. Traffic detection shall combine lane specific data into summary data for the direction of travel at data collection sites. 8.5. Travel times provided by traffic detection or calculated by traffic data management systems shall be at least 95% accurate.
9. Operators need to be able to access current and historical traffic data in usable formats and presentation styles to conduct research or performance management.	9.1. The overall traffic detection application shall include one or multiple traffic data management system(s) that operators can use to access data. 9.2. Traffic data management systems shall ingest and process location traffic data collected by detection devices. 9.3. Traffic data management systems shall receive, process, and store traffic data provided by 3rd party data providers. 9.4. Traffic data management systems shall allow authorized users to view real-time traffic data in useable formats and displays that may include files, printouts, or screen displays. 9.5. Traffic data management systems shall allow users to view historical traffic data in useable formats and displays that may include files, printouts, or screen displays. 9.6. Traffic data management systems shall allow users to query, view, and create reports showing traffic detection data collected. 9.7. Traffic data management systems shall allow users to query, view, and report data using multiple, simultaneous criteria including, but not limited to, data type(s), road segment(s), data precision level, and time period(s). 9.8. Traffic data management systems shall allow users to query, view, and report data by entering thresholds for various data types and numerical ranges, to assist users with identifying issues with traffic detection. 9.9. Traffic data management systems shall allow users external to MnDOT to view and download historical traffic detection data

Need	System Requirement
	from a secure, web-based location, as allowed per contractual arrangements and limitations of the data. 9.10. Traffic data management systems shall allow users to export traffic data in usable formats (e.g. CSV, TXT) for data analysis. 9.11. Traffic data management systems shall allow users to view the locations and statuses of traffic detection devices. 9.12. Traffic data management systems shall allow users to select traffic detection devices and view device parameters and real-time data generated by the devices. 9.13. Traffic data management systems shall store traffic data collected by the traffic detection devices for a length of time that can be configured by a system administrator. 9.14. Traffic data management systems shall have a mechanism for operators to restore connections with traffic detection devices. 9.15. Traffic data management systems shall use appropriate protocols where needed and open standards when available.
Planners / Analysts	
10. Planners/analysts need ITS solutions to supplement ATRs in providing planning level data, including but not limited to volume, speed, and vehicle classification data. Tools are needed to post-process historic data to track performance measures such as levels of congestion, travel times, buffer time index, etc.	10.1. Users shall have access to the traffic data management systems in order to access historical data that (depending upon location and detection method) may include volume, speed, vehicle classification MnPASS data, and other data types.
Administrators	
11. Administrators need tools to query, review, report, and assess traffic detection data, in order to understand	11.1. Traffic detection shall report an error indicator (i.e. a pre-defined error value) for data points when data is not being accurately collected, such as when a detection device is not operating properly or if current conditions are impacting the ability to collect accurate data.

Need	System Requirement
whether devices are operating properly.	11.2. Traffic data management systems shall allow users to view the locations and statuses of traffic detection devices.
12. Administrators need mechanisms that enable them to procure and receive third party data provided by outside services in a way that the agency can rely on consistent ongoing data delivery.	12.1. Procurement materials for procuring third party traffic data (e.g. RFP documents) shall define requirements for consistent data formats that are required of all data providers. 12.2. Procurement materials for procuring third party traffic data (e.g. RFP documents) shall define requirements for consistent delivery methods that are required for all data providers. 12.3. Third party traffic data shall be delivered to MnDOT as processed data, ready to be ingested into traffic data management systems. Examples of the traffic data management systems include iPEMS, RITIS, and/or IRIS. 12.4. Procurement materials shall clearly define MnDOT's rights to the data procured, including the right to share data within and external to MnDOT.
13. Administrators need data management procedures and tools to ensure the benefits of data are maximized and to support administrators in adhering to data archiving and retention policies (e.g. currently volume and occupancy are retained; there is not a current policy on archiving CAV data, but as this is known and understood data management will support it).	13.1. Traffic data management systems shall store data (i.e. save data for short-term access by users and operations systems) according to contractual arrangements and limitations of the data. 13.2. Traffic data management systems shall periodically archive data (i.e. package and deposit data into databases or data warehouses for long term retention) in accordance with data retention policies and procedures. 13.3. Traffic data management systems shall be adaptable to changes in data storage and archival demands, as applicable in accordance with contractual arrangements and limitations of the data. 13.4. Traffic data management systems shall enable administrators to grant access privileges to other data users, including various levels of access, as allowed per contractual arrangements and limitations of the data.
Technicians and Installers	
14. Technicians and installers need power, communications, and a support structure to be available at locations where field equipment	14.1. Traffic detection field devices shall be located such that technicians and installers can access devices to perform maintenance. 14.2. Traffic detection field devices mounted above ground shall only be installed after design and deployment of a support structure.

Need	System Requirement
is used to detect vehicles.	14.3. Traffic detection field devices mounted above ground shall be in accordance with requirements for roadway clearance and crashworthiness (e.g. breakaway structures or protection). 14.4. Traffic detection field device installation design shall include power connections. 14.5. Traffic detection field device designs shall include communications connections. 14.6. Traffic detection field device designs shall include electrical grounding and surge suppression. 14.7. Traffic detection field device designs shall include consideration of obstructions or other interference. 14.8. When utilized, temporary traffic detection devices shall be installed by technicians and installers in approved locations with power and communications.
15. Technicians and installers need consistency and compatibility in the traffic detection devices to achieve efficiencies in procurement, maintenance, and training.	15.1. Traffic detection field devices will be compatible with existing equipment and systems such as communications (fiber, etc.) and operations systems (e.g. MnPASS). 15.2. Newly procured traffic detection devices shall be consistent with in-place traffic detection devices to the extent possible as technicians and installers are well-trained to install and repair these devices and can interchange parts. 15.3. Traffic detection devices, equipment, and software shall be procured to ensure interoperability and consistency with the latest standards and technologies.
CAV Infrastructure Systems and CAVs	
16. CAVs need real-time, low latency data from other CAVs to perform safety and efficiency functions.	16.1. Traffic detection shall provide traffic data (volumes, lane occupancy, and speeds) in formats and precision levels that are consistent with similar traffic data types exchanged by CAVs.
17. DOTs need to benefit from the data broadcast by public and private CAVs.	17.1. Traffic data management systems shall be capable of upgrades to ingest and integrate traffic data (e.g. vehicle speeds) from RSUs as the CAV industry matures. 17.2. Traffic data management systems shall be capable of storing and archiving selected data from RSUs, as data retention policies for CAV-related data are implemented.

Need	System Requirement
18. CAVs may need infrastructure-generated traffic data such as speeds or lane occupancy data derived from real-time and historical traffic detection data.	18.1. Traffic data management systems shall be capable of evolving to communicate real-time and historical traffic detection data (or derived values) to RSUs, for potential use by CAVs. 18.2. Traffic data management systems shall be capable of evolving to generate derived values from real-time and historical traffic detection data, such as target speeds and desired gaps between vehicles, for use by CAVs.
Media/Traveler Information Providers	
19. Media and other information providers need access to data representing volume or speed of vehicles.	19.1. Traffic data management systems shall allow external users from media providers to download (i.e. access and export) speed and volume data for creating displays of traffic conditions to the public, as allowed per contractual arrangements and limitations of the data. 19.2. Traffic data management systems shall allow external users from media providers to download traffic data for pre-defined routes, for displaying travel times to the public, as allowed per contractual arrangements and limitations of the data. 19.3. Traffic data management systems shall allow external users from media providers to download calculated travel times for display to the public, as allowed per contractual arrangements and limitations of the data.

Relationship to the National ARC-IT and Minnesota ITS Architecture

The Minnesota Statewide Regional ITS Architecture presents a vision for how ITS systems work together, share resources, and share information. The 2018 update to the ITS Architecture represents the latest status of Minnesota, as captured through outreach meetings and input from stakeholders statewide. As such, the Minnesota ITS Architecture was a valuable input to the development of this documents, supporting:

- Identification of stakeholders;
- Definition of needs for traffic detection;
- Concepts for the use of traffic detection and
- Overall input to the requirements.

The Minnesota ITS Architecture enabled the Project Team to build upon the content of the architecture and clarify specifics for this document.

In addition to the role of supporting the development of this document, the Minnesota Statewide Regional ITS Architecture and the National Architecture Reference for Cooperative and Intelligent Transportation (ARC-IT) will continue to serve as a resource for the agencies that utilize this document as they prepare for deployment. Table 15 below identifies the needs/potential solutions included in the Minnesota ITS Architecture that are addressed through concepts for the use of traffic detection described in this document, as well as references to service packages and processes as defined in the ARC-IT. Finally, the far right column identifies the traffic detection stakeholder need(s) that were influenced or derived based on each service package.

Table 15: Summary of Local and National ITS & CAV Architecture References Mapped to Traffic Detection Needs

<table>
<tr><th>Minnesota Statewide Regional ITS Architecture:
Need/Potential Solutions</th><th>ARC-IT:
Service Packages</th><th>ARC-IT:
Processes</th><th>Traffic Detection Stakeholder Needs Influenced by each Service Package</th></tr>
<tr><td rowspan="3">• ATIS03 Provide traffic flow maps showing recurring freeway congestion levels
• ATMS05 Provide incident and congestion information to travelers
• ATMS15 Provide operating speed/travel time information to travelers
• ATIS16 Improve quality, consistency and thoroughness of traveler information
• ATIS17 Determine travel time or traffic condition for major signalized arterials
• ATIS18 Provide congestion information to travelers for seasonal or recreational traffic generators
• ATIS 19 Provide different alternatives to travelers for the most appropriate route/mode/time of travel
• ATIS24 Provide web traffic data</td><td>• TI01 Broadcast Traveler Information</td><td>• Collect Traffic Data
• Collect Data for Dissemination</td><td rowspan="3">• Need 1: Public access to speed indicators
• Need 3: High-level volume and lane occupancy data
• Need 5: High-Level Speed Data
• Need 17: Vehicle to Infrastructure Data Exchange
• Need 19: External Access to Traffic Data</td></tr>
<tr><td>• TM01 Infrastructure Based Traffic Surveillance</td><td>• Process Traffic Sensor Data
• Collect Vehicle Speed</td></tr>
<tr><td>• TM06 Traffic Information Dissemination</td><td>• Retrieve Traffic Data
• Process Traffic Sensor Data</td></tr>
</table>

Minnesota Statewide Regional ITS Architecture: Need/Potential Solutions	ARC-IT: Service Packages	ARC-IT: Processes	Traffic Detection Stakeholder Needs Influenced by each Service Package
• ATMS03 Use archived data for traffic management strategy development and long range planning • ATMS47 Study the potential use of ramp meters in larger urban areas outside the Metro	• TM09 Integrated Decision Support and Demand Management	• Collect Vehicle Speed • Process Traffic Data • Retrieve Traffic Data • Provide Traffic Operations Personnel Traffic Data Interface	• Need 2: Detailed volume and lane occupancy data • Need 7: Data Management for Operations • Need 8: Traffic Data Processing • Need 9: Usable Access to Current and Historical Traffic Data • Need 10: Planning Level Traffic Detection • Need 17: Vehicle to Infrastructure Data Exchange
	• DM01 ITS Data Warehouse	• Collect Vehicle Traffic Surveillance Data • Collect Vehicle Roadside Safety Data	
	• DM02 Performance Monitoring	• Manage Roadside Data Collection • Provide Data Collection and Aggregation	
• ATMS07 Provide lane and shoulder control	• TM22 Dynamic Lane Management and Shoulder Use	• Monitor Dynamic Lane Usage • Process Traffic Sensor Data	• Need 2: Detailed volume and lane occupancy data • Need 4: Detailed Speed Data
• ATMS11 Operate reversible lanes	• TM16 Reversible Lane Management	• Process Traffic Sensor Data	• Need 2: Detailed Volume and Lane Occupancy Data • Need 4: Detailed Speed Data

Minnesota Statewide Regional ITS Architecture: Need/Potential Solutions	ARC-IT: Service Packages	ARC-IT: Processes	Traffic Detection Stakeholder Needs Influenced by each Service Package
• ATMS20 Operate dynamic shoulders	• TM22 Dynamic Lane Management and Shoulder Use	• Process Traffic Sensor Data • Collect Vehicle Traffic Surveillance Data	• Need 2: Detailed volume and lane occupancy data • Need 4: Detailed Speed Data • Need 7: Data Management for Operations
• ATMS23 Operate ramp meters	• TM05 Traffic Metering	• Process Traffic Sensor Data	• Need 2: Detailed volume and lane occupancy data • Need 7: Data Management for Operations
• ATMS26 Operate and enforce MnPASS lanes	• ST06 HOV/HOT Lane Management	• Collect Vehicle Traffic Surveillance Data	• Need 2: Detailed volume and lane occupancy data • Need 4: Detailed Speed Data • Need 6: Passenger Occupancy Data • Need 7: Data Management for Operations
	• TM10 Electronic Toll Collection	• Detect Vehicle for Tolls	
	• TM16 Reversible Lane Management	• Process Traffic Sensor Data • Collect Vehicle Speed	
	• TM22 Dynamic Lane Management and Shoulder Use	• Collect Vehicle Traffic Surveillance Data • Process Traffic Sensor Data • Collect Vehicle Speed	

Minnesota Statewide Regional ITS Architecture: Need/Potential Solutions	ARC-IT: Service Packages	ARC-IT: Processes	Traffic Detection Stakeholder Needs Influenced by each Service Package
• ATMS39 Monitor queue length at ramps, incident scenes, and work zones	• TM12 Dynamic Roadway Warning	• Process Traffic Sensor Data • Collect Vehicle Speed • Process Traffic Data • Retrieve Traffic Data	• Need 2: Detailed volume and lane occupancy data
• ATMS47 Study the potential use of ramp meters in larger urban areas outside the Metro	• TM05 Traffic Metering	• Provide Traffic Operations Personnel Traffic Data Interface • Determine Ramp State	• Need 3: High-level volume and lane occupancy data • Need 9: Usable Access to Current and Historical Traffic Data • Need 10: Planning Level Traffic Detection
• ATMS48 Increase enforcement/presence of enforcement	• ST06 HOV/HOT Lane Management	• Detect Vehicle for Tolls	• Need 6: Passenger Occupancy Data
• MCM05 Provide queue detection and advisory to warn traffic of a stopped queue at work zone	• TM12 Dynamic Roadway Warning	• Process Traffic Sensor Data • Collect Vehicle Speed • Process Traffic Data • Retrieve Traffic Data	• Need 2: Detailed volume and lane occupancy data
• MCM11 Notify travelers of delays or travel times through work zones	• MC06 Work Zone Management	• Collect Traffic Data	• Need 1: Public access to speed indicators • Need 5: High-Level Speed Data

Model Test Plan

This section presents a model test plan to support testing and validation activities during the integration and deployment stages of traffic detection to confirm that the system is developed, installed, and operating as specified by the system requirements.

Each traffic detection deployment will be different, and the testing and validation performed will likely vary depending upon the complexity of the system and the familiarity with the vendor products.

The table below provides a series of testing instructions related to the requirements presented above. The intent is that agencies using this model systems engineering document will incorporate these tests into their overall testing and validation plans, adapting them as needed.

Column 3 in the table below describes 'testing instructions' for each requirement. The traffic detection requirements include a range of requirement types and therefore the testing instructions vary.

The following bullet list explains the approach to different testing instructions:

- *Advisory requirement – no testing required:* This is noted for requirements that are primarily operational advice (e.g. the locating and use of traffic detection) and therefore no formal testing is required;
- *Design:* these test instructions are used to describe testing in the form of design reviews or documentation reviews describing traffic detection and traffic data outputs that will be produced by traffic detection. These are typically not physical tests, but rather reviews of processes or documents;
- *Factory Acceptance Test (FAT):* These represent recommendations for FATs to allow the agency deploying the traffic detection to verify the quality assurance/quality control and traffic detection operational parameters at the site of manufacturing and assembly. This can involve the procuring agency on-site at the vendor factory testing the actual equipment to be delivered or the reports of previous tests of components, software, or features;
- *Field:* These represent recommendations for tests to be conducted in MnDOT offices or the field to test the actual deployment and functionality of the traffic detection.

Table 16: Model Test Plan

System Requirement		Testing Instructions	Type of Result	Comments / Notes
1.1	MnDOT shall collect, process, and disseminate traffic speed data to supplement what travelers have access to from 3rd party information dissemination sources (e.g. additional detail or accuracy in key locations).	Advisory requirement – no testing required	N/A	
1.2	In locations where MnDOT (or other agencies) perform traffic detection, the data collected shall provide traffic speed data in formats that are suitable for map displays, websites, and other publicly-viewed traveler information mechanisms.	Field – Confirm that speed data provided by traffic detection is in a consistent format. Field – Establish traffic data with one or more MnDOT-operated traveler information systems (e.g. 511) and confirm that speed data from traffic detection can be: • Ingested into the traveler information systems • Converted to map displays, websites and other viewable mechanisms	Pass/Fail	
2.1	Detailed volume and lane occupancy data shall be collected at a maximum spacing of ½ mile in locations where corridor-wide ramp metering, queue warning, or freeway travel time calculations are operational.	Design – Review design documents to confirm spacing of traffic detection ½ mile spacing in locations where: • Corridor-wide ramp metering is operational • Freeway travel time calculations are operational Field – At time of installation, confirm spacing of traffic at ½ mile spacing for applicable locations.	Pass/Fail	
2.2	Traffic detection shall record detailed volume and lane occupancy data for all lanes on mainline segments.	Field - Confirm that volume and lane occupancy data is being reported for all lanes of mainline segments for which the data is being collected.	Pass/Fail	
2.3	Traffic detection shall provide detailed volume and lane occupancy data at a precision level that is adequate or higher for processing by algorithms (e.g. MnPASS, ramp metering, travel time calculations, etc.)	Field– Compare the reported volumes and lane occupancy data from traffic detection to the minimum precision level of data needed to run algorithms for calculations and operations systems. Confirm that the reported values are at (or exceed) the precision level of data needed to run these algorithms and systems.	Pass/Fail	

	System Requirement	Testing Instructions	Type of Result	Comments / Notes
2.4	Traffic detection shall provide detailed volume and lane occupancy data in formats (e.g. XML, HTML, Plain Text, etc.) that can be ingested into traffic data management systems.	Field – Confirm that reported volumes and lane occupancy data can be ingested into traffic data management systems.	Pass/Fail	
2.5	Detailed volume and lane occupancy data from traffic detection shall be at least 95% accurate.	Field – Perform a series of random checks comparing reported detailed volume and lane occupancy data against known actual values, to verify at least 95% accuracy. This may be done by performing manual vehicle counts in the field, by viewing recorded video at traffic cameras, or by comparing to known values from trusted detection sources.	Pass/Fail	
2.6	Traffic detection shall communicate detailed volume and lane occupancy data to a central location for storage and algorithm processing.	Field – View reports from traffic data management systems to confirm that volume and lane occupancy data is being communicated and received.	Pass/Fail	
2.7	Traffic detection shall record and provide additional types of detailed data (e.g. vehicle path/bearing detectors) as advancements in traffic detection are made.	Field – View reports from traffic data management systems to confirm that any additional detailed data from traffic detection is being communicated and received.	Pass/Fail	
3.1	In situations where high-level volume and lane occupancy data are collected by traffic detection applications, the data shall be provided in formats (e.g. XML, HTML, Plain Text) that can be ingested into traffic data management systems that display visual/graphical representation of traffic conditions.	Field – Confirm that the reported volume and lane occupancy data can be ingested into traffic data management systems that display graphical representation of traffic conditions.	Pass/Fail	

System Requirement		Testing Instructions	Type of Result	Comments / Notes
3.2	Traffic detection shall provide high-level volume and lane occupancy data at a precision level that is suitable for post-processing by traffic data management systems that provide visual displays.	Field – Compare the reported volumes and lane occupancy data from traffic detection to the minimum precision level of data needed for systems that provide visual displays. Confirm that the reported values are at (or exceed) the precision level of data needed.	Pass/Fail	
3.3	High-level volume and lane occupancy data from traffic detection shall be at least 95% accurate.	Field – Perform a series of random checks comparing reported high-level volume and lane occupancy data against known actual values, to verify at least 95% accuracy. This may be done by performing manual vehicle counts in the field, by viewing recorded video at traffic camera, or by comparing to known values from trusted detection sources.	Pass/Fail	
3.4	Traffic detection shall communicate high level volume and lane occupancy data to a central location for ingest into traffic data management systems that provide visual displays.	Field – View reports from traffic data management systems to confirm that volume and lane occupancy data is being communicated and received.	Pass/Fail	
4.1	In locations where detailed speed data is required (e.g. for travel time calculations), traffic detection shall record detailed speed data for all lanes on mainline segments and ramps.	Field – Confirm that speed data from traffic detection is being reported for all lanes of mainline segments and ramps where travel times are boing calculated.	Pass/Fail	
4.2	Traffic detection shall provide detailed speed data at a precision level that is adequate or higher for processing by algorithms (e.g. MnPASS, ramp metering, queue warning systems, travel time calculations, etc.).	Field – Compare the reported speed data from traffic detection to the minimum precision level of data needed for systems that use algorithms. Confirm that the reported values are at (or exceed) the precision level of data needed to run algorithms.	Pass/Fail	

	System Requirement	Testing Instructions	Type of Result	Comments / Notes
4.3	Traffic detection shall provide detailed speed data in formats (e.g. XML, HTML, Plain Text) that can be ingested into traffic data management systems.	Field – Confirm that the reported speed data can be ingested into traffic data management systems.	Pass/Fail	
4.4	Detailed speed data from traffic detection shall be at least 95% accurate.	Field – Perform a series of random checks comparing reported detailed speed data against known actual values, to verify at least 95% accuracy. This may be done by using a radar gun in the field or by comparing to known values from trusted detection sources.	Pass/Fail	
4.5	Traffic detection shall communicate detailed speed data to a central location for storage and algorithm processing.	Field – View reports from central traffic data management systems to confirm that the speed data is being communicated and received.	Pass/Fail	
5.1	Traffic detection shall provide high-level speed indicator data in formats (e.g. XML, HTML, JSON) that can be ingested into systems that display visual/graphical representation of traffic conditions.	Field – Confirm that the reported speed data can be ingested into traffic data management systems that display graphical representation of traffic conditions.	Pass/Fail	
5.2	Traffic detection shall provide high-level speed indicator data at a precision level that is suitable for post-processing by visual/graphical display systems.	Field – Compare the reported speed data from traffic detection to the minimum precision level of data needed for systems that use algorithms. Confirm that the reported values are at (or exceed) the precision level of data needed for visual display systems.	Pass/Fail	
5.3	High-level speed data from traffic detection shall be at least 95% accurate.	Field – Perform a series of random checks comparing reported high-level speed data against known actual values, to verify at least 95% accuracy. This may be done by using a radar gun in the field or by comparing to known values from trusted detection sources.	Pass/Fail	
5.4	Traffic detection shall communicate high-level speed indicator data to a	Field – View reports from central traffic data management systems to confirm that the speed indicator data is being communicated and received.	Pass/Fail	

	System Requirement	Testing Instructions	Type of Result	Comments / Notes
	central location for ingest into display systems.			
6.1	Traffic detection may detect and record instances of passenger occupancy violations (i.e. less than two people in a vehicle or future changes to rules and regulations), for vehicles traveling in MnPASS lanes or HOV lanes.	Design – Review vendor's data output documentation to verify that reported data includes passenger occupancy data, if included in traffic detection. Field – View reported traffic detection data and confirm that it is reporting instances of passenger occupancy violations for vehicles traveling in MnPASS lanes or HOV lanes, if traffic detection includes passenger occupancy violation.	Pass/Fail	
6.2	If traffic detection includes passenger occupancy violation, then traffic detection shall generate alerts for instances when passenger occupancy violations occur.	Field – Perform a series of random tests to confirm that alerts are accurately generated when passenger occupancy violations occur, if traffic detection includes passenger occupancy violation.	Pass/Fail	
6.3	If traffic detection includes passenger occupancy violation, then traffic detection shall record the time of violation and location of the vehicle that has been detected to have a passenger occupancy violation.	Field – If traffic detection includes passenger occupancy violation: • Review reported traffic detection data and confirm that the time of violation and location of vehicles is reported when passenger occupancy violations occur. • Perform a series of random tests to check accuracy of the vehicle location reported.	Pass/Fail	
6.4	If traffic detection includes passenger occupancy violation, then traffic detection shall record a vehicle identifier for each vehicle that has been detected to have a passenger occupancy violation.	Field – If traffic detection includes passenger occupancy violation: • Review reported traffic detection data and confirm that a vehicle identifier is recoded when passenger occupancy violations occur. • Perform a series of random tests to check the accuracy of the vehicle identifier reported.	Pass/Fail	

	System Requirement	Testing Instructions	Type of Result	Comments / Notes
6.5	If traffic detection includes passenger occupancy violation, then traffic detection shall communicate alerts and other passenger occupancy data (vehicle location, vehicle identifier) in formats suitable for ingest into systems that monitor MnPASS and HOV lane compliance.	Field – Confirm the reported passenger occupancy data (alerts, vehicle location, vehicle identifier) can be ingested into systems that monitor MnPASS and HOV lane compliance, if traffic detection includes passenger occupancy violation.	Pass/Fail	
6.6	Passenger occupancy data from traffic detection shall be at least 95% accurate.	Field – Perform a series of field tests by driving vehicles with known vehicle occupancy data and compare the reported passenger occupancy data from traffic detection to the actual values, to verify at least 95% accuracy. • Passenger Occupancy Violation – Drive a series of vehicles with known number of passengers in the vehicle to verify that at least 95% of the vehicles tested generate the appropriate alert when the vehicle is in violation and do not generate "false calls." • Vehicle Identifier – Drive a series of vehicles with known vehicle identifiers (e.g. license plate), to verify accuracy of at least 95% when a violation is detected. • Vehicle location – Equip the test vehicle(s) with GPS to collect a time and location as the vehicle proceeds through the test area. Compare the vehicle location reported by traffic detection when a violation occurs to the test vehicle's GPS time/location data.	Pass/Fail	

System Requirement		Testing Instructions	Type of Result	Comments / Notes
7.1	Traffic data management systems shall aggregate and organize data collected in a central location.	Field – Confirm that the centrally located traffic data management systems can aggregate and organize data received from various traffic detection sources.	Pass/Fail	
7.2	Traffic data management systems shall enable users to view data and create data management plans.	Field – Confirm that users can view traffic data from traffic data management systems. Create a test/sample data management plan from traffic data management systems.	Pass/Fail	
7.3	Current systems and approaches used for traffic detection shall not limit the introduction, implementation, integration, and use of innovative approaches, products, or services.	Design – Review internal (MnDOT) policies and documentation on current systems/approaches that use traffic detection and verify that they do not state limitations on innovative approaches, products, or services for the use of traffic detection.	Pass/Fail	
8.1	Traffic detection shall collect and process data for specific road segments as defined by operators.	Design – Review vendor's data output documentation to verify capability to collect and process traffic data by user-defined road segment. Field – Confirm that traffic data communicated to traffic data management systems is segmented by road user segments.	Pass/Fail	
8.2	Traffic detection shall process collected data, as needed, to calculate speed values, if not directly measured by detection.	Field – Perform a series of random checks of calculated speed data provided against known speed values to verify accuracy of calculated speeds	Pass/Fail	
8.3	Traffic data management systems shall process collected data to calculate travel times, if not directly measured or provided by traffic detection.	Design – If travel times are provided by traffic detection, review vendor's data output documentation to verify that travel times are provided. Field - If traffic data management systems are calculating travel times, verify that the travel times are being calculated using traffic detection data.	Pass/Fail	

System Requirement		Testing Instructions	Type of Result	Comments / Notes
8.4	Traffic detection shall combine lane specific data into summary data for the direction of travel at data collection sites.	Design – Review vendor’s data output to ensure that lane-specific traffic is summarized and reported for the direction of travel.	Pass/Fail	
8.5	Travel times provided by traffic detection or calculated by traffic data management systems shall be at least 95% accurate.	Field – Perform a series of random checks comparing reported travel times against known actual values, to verify at least 95% accuracy. This may be done by comparing to known values from in-place, trusted detection sources.	Pass/Fail	
9.1	The overall traffic detection application shall include one or multiple traffic data management system(s) that operators can use to access data.	Field – Confirm that operators can access data from at least one traffic data management system.	Pass/Fail	
9.2	Traffic data management systems shall ingest and process location traffic data collected by detection devices.	Field – Confirm that the traffic data management systems can ingest and process location traffic data collected by detection devices.	Pass/Fail	
9.3	Traffic data management systems shall receive, process, and store traffic data provided by 3rd party data providers.	Field – Confirm that the traffic data management systems can receive, process, and store traffic data provided by 3rd party data providers.	Pass/Fail	
9.4	Traffic data management systems shall allow authorized users to view real-time traffic data in useable formats and displays that may include files, printouts, or screen displays.	Field – Confirm that the traffic data management systems allow authorized users to view real-time traffic data in useable formats and displays.	Pass/Fail	
9.5	Traffic data management systems shall allow users to view historical traffic data in useable formats and displays that may include files, printouts, or screen displays.	Field – Confirm that the traffic data management systems allow users to view historical traffic data in useable formats and displays.	Pass/Fail	

	System Requirement	Testing Instructions	Type of Result	Comments / Notes
9.6	Traffic data management systems shall allow users to query, view, and create reports showing traffic detection data collected.	Field – Confirm that the traffic data management systems allow users to query, view, and create reports showing traffic detection data collected.	Pass/Fail	
9.7	Traffic data management systems shall allow users to query, view, and report data using multiple, simultaneous criteria including, but not limited to, data type(s), road segment(s), data precision level, and time period(s).	Field – Confirm that the traffic data management systems allow users to query, view, and report data using multiple, simultaneous criteria including, but not limited to, data type(s), road segment(s), data precision level, and time period(s).	Pass/Fail	
9.8	Traffic data management systems shall allow users to query, view, and report data by entering thresholds for various data types and numerical ranges, to assist users with identifying issues with traffic detection.	Field – Confirm that the traffic data management systems allow users to query, view, and report data by entering thresholds for various data types and numerical ranges.	Pass/Fail	
9.9	Traffic data management systems shall allow users external to MnDOT to view and download historical traffic detection data from a secure, web-based location, as allowed per contractual arrangements and limitations of the data.	Field – Confirm that the traffic data management systems allow users external to MnDOT to view and download historical traffic detection data from a secure, web-based location, as allowed per contractual arrangements and limitations of the data.	Pass/Fail	
9.10	Traffic data management systems shall allow users to export traffic data in usable formats (e.g. CSV, TXT) for data analysis.	Field – Confirm that the traffic data management systems allow users to export traffic data in usable formats for data analysis.	Pass/Fail	
9.11	Traffic data management systems shall allow users to view the locations and statuses of traffic detection devices.	Field – Confirm that the traffic data management systems allow users to view the locations and statuses of traffic detection devices.	Pass/Fail	

System Requirement		Testing Instructions	Type of Result	Comments / Notes
9.12	Traffic data management systems shall allow users to select traffic detection devices and view device parameters and real-time data generated by the devices.	Field – Confirm that the traffic data management systems allow users to select traffic detection devices and view device parameters and real-time data generated by the devices.	Pass/Fail	
9.13	Traffic data management systems shall store traffic data collected by the traffic detection devices for a length of time that can be configured by a system administrator.	Field – Confirm that the traffic data management systems store traffic data collected by the traffic detection devices for a length of time that can be configured by a system administrator.	Pass/Fail	
9.14	Traffic data management systems shall have a mechanism for operators to restore connections with traffic detection devices.	Field – Confirm that the traffic data management systems have a mechanism for operators to restore connections with traffic detection devices.	Pass/Fail	
9.15	Traffic data management systems shall use appropriate protocols where needed and open standards when available.	Design – Confirm that the traffic data management systems use appropriate protocols where needed and available open standards.	Pass/Fail	
10.1	Users shall have access to the traffic data management systems in order to access historical data that (depending upon location and detection method) may include volume, speed, vehicle classification MnPASS data, and other data types.	Field – Confirm that users have access to historical data in the traffic data management systems.	Pass/Fail	
11.1	Traffic detection shall report an error indicator (i.e. a pre-defined error value) for data points when data is not being accurately collected, such as when a detection device is not operating properly or if current conditions are	Field – Confirm that traffic detection reports an error indicator for data points when data is not accurately collected.	Pass/Fail	

	System Requirement	Testing Instructions	Type of Result	Comments / Notes
	impacting the ability to collect accurate data.			
11.2	Traffic data management systems shall allow users to view the locations and statuses of traffic detection devices.	Field – Confirm that users can view the locations and statuses of traffic detection devices in the traffic data management system.	Pass/Fail	
12.1	Procurement materials for procuring third party traffic data (e.g. RFP documents) shall define requirements for consistent data formats that are required of all data providers.	Design – Confirm that procurement materials for procuring third party traffic data define requirements for consistent data formats that are required of all data providers.	Pass/Fail	
12.2	Procurement materials for procuring third party traffic data (e.g. RFP documents) shall define requirements for consistent delivery methods that are required for all data providers.	Design – Confirm that procurement materials for procuring third party traffic data define requirements for consistent delivery methods that are required for all data providers.	Pass/Fail	
12.3	Third party traffic data shall be delivered to MnDOT as processed data, ready to be ingested into traffic data management systems. Examples of the traffic data management systems include iPEMS, RITIS, and/or IRIS.	Field – Confirm that third party traffic data is delivered to MnDOT as processed data, ready for ingest into traffic data management systems.	Pass/Fail	
12.4	Procurement materials shall clearly define MnDOT's rights to the data procured, including the right to share data within and external to MnDOT.	Design – Confirm that procurement materials clearly define MnDOT's rights to the data procured, including the right to share data within and external to MnDOT.	Pass/Fail	
13.1	Traffic data management systems shall store data (i.e. save data for short-term access by users and operations systems) according to contractual arrangements and limitations of the data.	Field – Confirm that the traffic data management systems can store data according to contractual arrangements and limitations of the data.	Pass/Fail	

	System Requirement	Testing Instructions	Type of Result	Comments / Notes
13.2	Traffic data management systems shall periodically archive data (i.e. package and deposit data into databases or data warehouses for long term retention) in accordance with data retention policies and procedures.	Field – Confirm that the traffic data management systems periodically archive data by packaging and depositing data into databases or data warehouses for long term retention in accordance with data retention policies and procedures.	Pass/Fail	
13.3	Traffic data management systems shall be adaptable to changes in data storage and archival demands, as applicable in accordance with contractual arrangements and limitations of the data.	Field – Confirm that the traffic data management systems can adapt to changes in data storage and archival demands, as applicable in accordance with contractual arrangements and limitations of the data.	Pass/Fail	
13.4	Traffic data management systems shall enable administrators to grant access privileges to other data users, including various levels of access, as allowed per contractual arrangements and limitations of the data.	Field – Confirm that administrators can grant access privileges to other data users in the traffic data management systems, including various levels of access, as allowed per contractual arrangements and limitations of the data.	Pass/Fail	
14.1	Traffic detection field devices shall be located such that technicians and installers can access devices to perform maintenance.	Design – Confirm that traffic detection field devices are located such that technicians and installers can access devices to perform maintenance. Field – Confirm that technicians and installers can access traffic detection field devices to perform maintenance.	Pass/Fail Pass/Fail	
14.2	Traffic detection field devices mounted above ground shall only be installed after design and deployment of a support structure.	Field – Confirm that traffic detection field devices mounted above ground are installed after design and deployment of a support structure.	Pass/Fail	

System Requirement		Testing Instructions	Type of Result	Comments / Notes
14.3	Traffic detection field devices mounted above ground shall be in accordance with requirements for roadway clearance and crashworthiness (e.g. breakaway structures or protection).	FAT – Confirm that traffic detection field devices mounted above ground meet requirements for roadway clearance and crashworthiness. Field – Confirm that traffic detection field devices mounted above ground meet requirements for roadway clearance and crashworthiness.	Pass/Fail	
14.4	Traffic detection field device installation design shall include power connections.	Design – Confirm that the design for installation of traffic detection field devices includes power connections.	Pass/Fail	
14.5	Traffic detection field device designs shall include communications connections.	Design – Confirm that the design for traffic detection field devices includes communications connections.	Pass/Fail	
14.6	Traffic detection field device designs shall include electrical grounding and surge suppression.	Design – Confirm that the design for traffic detection field devices includes electrical grounding and surge suppression.	Pass/Fail	
14.7	Traffic detection field device designs shall include consideration of obstructions or other interference.	Design – Confirm that the design for traffic detection field devices considers obstructions or other interference concerns.	Pass/Fail	
14.8	When utilized, temporary traffic detection devices shall be installed by technicians and installers in approved locations with power and communications.	Field – Confirm that temporary traffic detection field devices are installed by technicians and installers in approved locations with power and communications, when used.	Pass/Fail	
15.1	Traffic detection field devices will be compatible with existing equipment and systems such as communications (fiber, etc.) and operations systems (e.g. MnPASS).	Design – Confirm that the design for traffic detection field devices is compatible with existing equipment and systems such as communications and operations systems.	Pass/Fail	
15.2	Newly procured traffic detection devices shall be consistent with in-	Advisory requirement – no testing required	N/A	

	System Requirement	Testing Instructions	Type of Result	Comments / Notes
	place traffic detection devices to the extent possible as technicians and installers are well-trained to install and repair these devices and can interchange parts.			
15.3	Traffic detection devices, equipment, and software shall be procured to ensure interoperability and consistency with the latest standards and technologies.	Design – Confirm that procured traffic detection devices, equipment, and software are interoperable and consistent with the latest standards and technologies.	Pass/Fail	
16.1	Traffic detection shall provide traffic data (volumes, lane occupancy, and speeds) in formats and precision levels that are consistent with similar traffic data types exchanged by CAVs.	Field – Confirm that traffic detection provides traffic data in formats and precision levels consistent with similar traffic data types exchanged by CAVs.	Pass/Fail	
17.1	Traffic data management systems shall be capable of upgrades to ingest and integrate traffic data (e.g. vehicle speeds) from RSUs as the CAV industry matures.	Design – Confirm that the traffic data management systems design accommodates future upgrades to ingest and integrate traffic data from RSUs as the CAV industry matures.	Pass/Fail	
17.2	Traffic data management systems shall be capable of storing and archiving selected data from RSUs, as data retention policies for CAV-related data are implemented.	Field – Confirm that the traffic data management systems can store and archive selected data from RSUs.	Pass/Fail	
18.1	Traffic data management systems shall be capable of evolving to communicate real-time and historical traffic detection data (or derived values) to RSUs, for potential use by CAVs.	Design – Confirm that the traffic data management systems design can accommodate future enhancements to communicate real-time and historical traffic detection data to RSUs for potential use by CAVs.	Pass/Fail	

System Requirement		Testing Instructions	Type of Result	Comments / Notes
18.2	Traffic data management systems shall be capable of evolving to generate derived values from real-time and historical traffic detection data, such as target speeds and desired gaps between vehicles, for use by CAVs.	Design – Confirm that the traffic data management systems design can accommodate future enhancements to generate derived values from real-time and historical traffic detection data for use by CAVs.	Pass/Fail	
19.1	Traffic data management systems shall allow external users from media providers to download (i.e. access and export) speed and volume data for creating displays of traffic conditions to the public, as allowed per contractual arrangements and limitations of the data.	Field – Confirm that external users from media providers can download speed and volume data from the traffic data management systems for creating displays of traffic conditions to the public, as allowed per contractual arrangements and limitations of the data.	Pass/Fail	
19.2	Traffic data management systems shall allow external users from media providers to download traffic data for pre-defined routes, for displaying travel times to the public, as allowed per contractual arrangements and limitations of the data.	Field – Confirm that external users from media providers can download traffic data for pre-defined routes from the traffic data management systems for displaying travel times to the public, as allowed per contractual arrangements and limitations of the data.	Pass/Fail	
19.3	Traffic data management systems shall allow external users from media providers to download calculated travel times for display to the public, as allowed per contractual arrangements and limitations of the data.	Field – Confirm that external users from media providers can download calculated travel times from the traffic data management systems for display to the public, as allowed per contractual arrangements and limitations of the data.	Pass/Fail	