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# North Dakota Department of Transportation

# Statewide Transportation Management Center – Concept of Operations

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NDSU | UPPER GREAT PLAINS TRANSPORTATION INSTITUTE
ADVANCED TRAFFIC ANALYSIS CENTER

# Contents

# Executive Summary

The North Dakota Department of Transportation (NDDOT) is pursuing the establishment of a statewide Transportation Management Center (TMC) to better manage the state's network of Intelligent Transportation Systems (ITS) devices and sensors, expand roadway monitoring and condition reporting to a 24/7/365 regime, and streamline the deployment of advanced technologies such as variable speed limits (VSL). TMCs are a proven concept for improving roadway operations and maintenance, coordinating traveler information, and inter-jurisdictional cooperation with partner agencies. Having a successful statewide TMC in North Dakota will help the NDDOT in carrying out its mission "to safely move people and goods".

The purpose of this effort is to present the NDDOT with a concept of operations for deploying a TMC based on existing planning and technical work and stakeholder engagements. The concept of operations is a high-level description of a system that seeks to answer the following questions:

- Who: Who are the stakeholders involved with the system?

  In addition to internal NDDOT stakeholders, the TMC will involve the North Dakota Information Technology Department, the North Dakota Department of Emergency Services and State Radio, and the North Dakota Highway Patrol.

- What: What are the known elements and the high-level capabilities of the system?

  Unified control and operations of the state's network of Intelligent Transportation Systems (ITS) devices and sensors; expanded roadway monitoring and condition reporting to a 24/7/365 regime; and deployment of advanced technologies such as variable speed limits (VSL).

- When: What is the time sequence of activities to be performed?

  The TMC timeline is dependent on funding availability. Once funding is secured and the project is initiated, milestones can be achieved based on this rough schedule:

  Year 1: Architect selection; facility design; bidding; begin construction; hiring and training TMC staff.

  Year 2: Complete facility construction; unified control and operations of field devices and sensors; 24/7/365 roadway monitoring and condition reporting.

  Year 3: VSL demo.

- Where: What are the geographical and physical locations of the system?

  The geographical scope of TMC activities will be the entire state with a focus on interstates and the state highway system. The location of the TMC will be in Bismarck potentially co-located with the State Radio dispatch building at Fraine Barracks.

- Why: What does your organization lack that this system will provide?

  The TMC will consolidate, coordinate, and provide designated staff to perform monitoring and operations activities that are now dispersed among several NDDOT divisions and the NDDOT districts. The TMC will provide the coverage needed for 24-hour operations that will enhance the timeliness and accuracy of roadway condition reporting and traveler information. The TMC

will serve as a central point of contact with partner agencies such as State Radio and North Dakota Highway Patrol, which will enhance cooperation and response to incidents.

- How: What resources are needed to design and build the system?

  Facility, staffing, software, and hardware needs are described at a high level in this document along with a description of resources that are already in place and can be leveraged for the TMC implementation.

The NDDOT has made several efforts and investments towards the establishment of a TMC including the procurement of a central control software (Parsons' Intelligent Networks Advanced Traffic Management System (ATMS)) to unify the control of the state's surveillance cameras, environmental sensing stations (ESS), dynamic message signs (DMS), and radar-based speed and volume sensors. While systems engineering has the principle of delaying technology solutions and vendor choices until the system has been designed and a final decision is made based on evaluation criteria established through the systems engineering process, this is a different situation where the TMC central control software will be an expansion of an existing system. The NDDOT has made significant investment in the ATMS software, has experience in the use of the system, and the vendor has a good track record of product support. With these past efforts and investments, along with this concept of operations, the TMC project is well situated for successful implementation.

# 1. Introduction

This section provides a discussion on the purpose of a concept of operations, the purpose and vision for a North Dakota statewide transportation management center, and defines the scope of the TMC.

## 1.1 Concept of Operations

The purpose of this document is to present the North Dakota Department of Transportation (NDDOT) with a concept of operations for the establishment of a statewide transportation management center (TMC) based on existing planning and technical work and stakeholder engagements conducted throughout this process.

The concept of operations is a high-level description of a system that seeks to answer the following questions:

- Who: Who are the stakeholders involved with the system?
- What: What are the known elements and the high-level capabilities of the system?
- When: What is the time sequence of activities to be performed?
- Where: What are the geographical and physical locations of the system?
- Why: What does your organization lack that this system will provide?
- How: What resources are needed to design and build the system?

## 1.2 Transportation Management Center

A statewide TMC for North Dakota would serve as a centerpiece for roadway control and maintenance operations currently performed through separate NDDOT divisions and NDDOT districts. The envisioned center would operate 24/7 to monitor the transportation network, dispatch maintenance resources, and provide traveler information in a coordinated manner from a centralized location. The TMC would allow the NDDOT to pursue advanced transportation systems such as variable speed limits and connected vehicle technologies. Further, establishing a statewide TMC can enhance coordination and cooperation between the NDDOT and partner state agencies such as the North Dakota Department of Emergency Services and the North Dakota Highway Patrol.

A TMC is the hub where transportation network data are collected, processed, and synthesized to produce information that can be used by system operators to monitor and initiate control and maintenance strategies in response to current conditions. Data collected at the TMC can also be processed to provide timely and accurate traveler information and analyzed to establish performance measures.

## 1.3 Scope

The geographical scope of the TMC would encompass the entire state with a focus on the two interstate freeways in North Dakota and the state highway network.

The TMC planning and development will involve several stakeholders both internal and external to the NDDOT including:

- NDDOT Management
- NDDOT Maintenance Division
- NDDOT Strategy and Innovation Division
- NDDOT Planning and Asset Management Division
- NDDOT Communications Division
- NDDOT Districts
- North Dakota Information Technology Department
- North Dakota Department of Emergency Services
- State Radio
- North Dakota Highway Patrol
- North Dakota Association of Counties
- North Dakota Sheriff's and Deputies Association

The services offered and affected by the TMC implementation fall in the areas of: Data Management, Maintenance and Construction Management, Public Safety, Traveler Information, Traffic Management, and Weather.

## 1.4 Action Plan

NDDOT management have expressed interest in pursuing grants to secure funding for the establishment and operations of the TMC. This effort was leveraged in submitting a proposal for the 2020 USDOT Advanced Transportation and Congestion Management Technologies Deployment Program (ATCMTD), awards are still pending. Meanwhile, other funding opportunities will be monitored and pursued, once funding is available or approval to initiate the project is given, this document will be valuable for the implementation of the TMC.

## 1.5 Document Organization

In addition to the Introduction section, this document will be organized over the following sections:

Section 2. Referenced Documents: provides a listing of various works and documents used as reference in preparing the concept of operations.

Section 3. Background: provides an overview of existing systems and operations as they relate to the TMC.

Section 4. Operational Needs: provides an overview of TMC functions along with the stakeholders' feedback.

Section 5. System Overview: provides a high-level description of key system components and their interfaces.

Section 6. Operational and Support Environment: describes the environment in which the TMC will operate including facilities, equipment, hardware, software, and personnel.

Section 7. Operational Scenarios: describes how the TMC users will interact with the system to perform a task under differing conditions.

Appendix I. Maps of ITS Devices: shows the locations of DMS, cameras, ESS, ATR, WIM, and radio towers deployed throughout the state.

Appendix II. Project ITS Architecture – Service Package Details: provides a detailed description of the service packages included in the TMC project ITS architecture.

## 2. Referenced Documents

The statewide TMC effort and the information contained in this document are the product of several meetings and various supporting projects and documents. This document is based primarily on the following sources:

- Discussions with TMC stakeholders, 2020
- Statewide ITS Architecture, 2019
- Statewide ITS Plan II, 2016
- Site and virtual visits with neighboring state TMCs and a scan of available literature on other state TMCs
- TMC project ITS Architecture, 2020
- FHWA TMC Concept of Operations – Implementation Guide, 1999
- FHWA Developing and Using a Concept of Operations in Transportation Management Systems, 2005
- FHWA Systems Engineering Guidebook for ITS – Concept of Operations Template, 2018

## 3. Background

The NDDOT owns a network of intelligent transportation systems (ITS) devices throughout the state consisting mainly of surveillance cameras, environmental sensing stations (ESS) making up the state's road weather information systems (RWIS) network, dynamic message signs (DMS), automatic traffic recorders (ATR), and weigh in motion (WIM) devices. The TMC is needed to help manage, operate, and maintain the growing number of ITS devices.

The NDDOT has made several efforts and investments towards the establishment of a TMC including the procurement of a central control software to unify the control of the state's cameras, ESS, DMS, and radar-based speed and volume sensors. The NDDOT operates a statewide traveler information system consisting of a web map, 511, and a smartphone application, ND Roads, where roadway conditions are updated during the winter months from 5 a.m. to 10 p.m. The map has layers that display the messages currently active on DMS boards throughout the state, and location tracking information for roughly one third of the snowplow fleet. Information on construction activities and weight restrictions is also provided.

Under normal conditions, the state's freeway and highway networks operate at a high level of service, delays and reduction in travel speed are generally limited to roadway segments in the metro areas during recurring AM and PM peak congestion as these areas continue to experience population growth. Outside of normal conditions, weather has the largest impact on roadway conditions and can create delays and potentially unsafe travel conditions, which highlights the need for robust network condition monitoring, proactive winter maintenance, and timely and accurate traveler information. Currently, there is no designated staff for the function of network monitoring; these activities are performed in an ad hoc manner at varying degrees among the NDDOT districts, the Maintenance division, and the Planning and Asset Management division

## 3.1 Existing Infrastructure

The department utilizes ITS infrastructure in both rural and urban settings. Currently there are 89 DMS units: 57 fixed and 32 portables. A total of 140 cameras are positioned across the state to aid in congestion monitoring, road weather monitoring, and incident response. The state has 30 ESS that provide road weather data to maintenance operators and the traveling public via the maintenance decision support system (MDSS) and the traveler information system, respectively. In addition to these devices there are 3 highway advisory radio (HAR) units, 5 intersection collision warning systems, 16 radar detection sites, 79 ATR's, and 15 WIM's. Parsons' Intelligent Networks Advanced Transportation Management System (ATMS) is used to monitor, poll, and control the DMS, ESS, cameras and radar detectors. Plans are in place to expand the ITS network by adding additional cameras, ESS and DMS to increase coverage and provide more information to the public. The ITS devices operated and maintained by the NDDOT are primarily focused on rural areas. However, NDDOT districts in the state's metro areas of Bismarck, Fargo, and Grand Forks utilize ITS devices to manage traffic in an urban setting as well.

The communications network utilized for interconnecting these devices and systems relies primarily on commercial wireless carriers. Due to the size and rural nature of the state, fiber connected devices are generally limited to locations in or near larger cities. The NDDOT also utilizes radio towers and repeaters to provide connectivity at various locations.

Figure 1 below shows an overview of ITS devices in the state. Detailed maps showing the location of DMS, cameras, ESS, ATR, WIM, and radio towers are available in Appendix I.

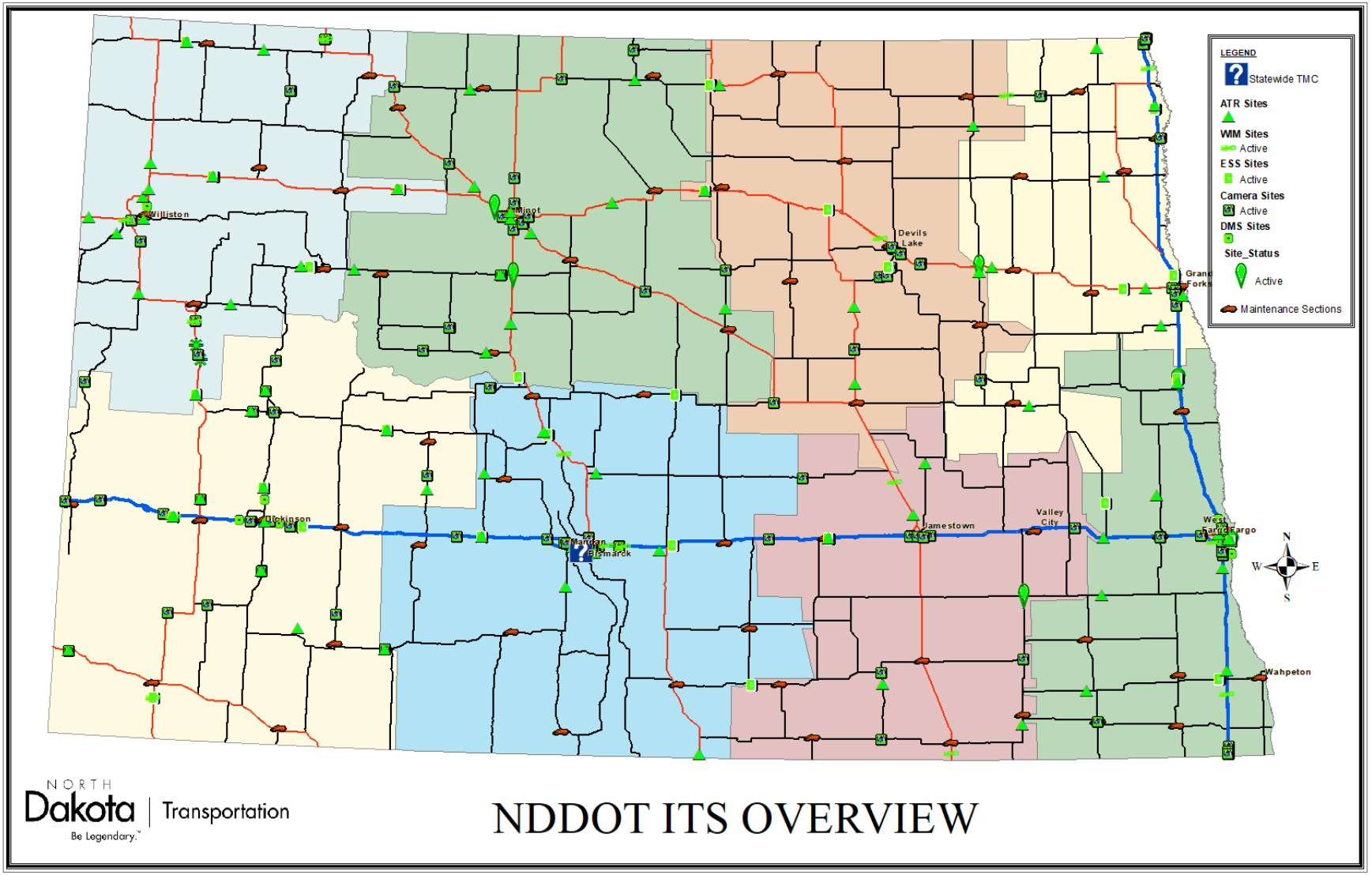



Figure 1. Existing ITS infrastructure

## 3.2 Existing Operations

NDDOT operations, monitoring, and traveler information updates do not occur on a 24/7 basis. Traveler information is updated from 5 a.m. to 10 p.m., seven days a week and holidays. NDDOT operations are based in the central office during regular office hours. Outside office hours, there is generally a staff member available to post messages to DMS, update the traveler information system and create news releases when needed. These functions may be performed virtually from a remote location. Field staff notify the operations staff of the districts' needs and updates are then made to the traveler information map, dynamic message signs, and winter travel alerts are created. Snowplow operators update road conditions directly to the traveler information system from their trucks using connected devices running NDDOT's Road Conditions Reporting System (RCRS) software. Traffic incident information is automatically displayed from NDHP's computer aided dispatch system feed.

Under the current operational scheme, TMC functions are mainly performed by the Maintenance division at the central office and the eight NDDOT districts. With the growth in the number of ITS devices, the expanding scope of ITS functions, and the higher level of expectations for accurate and timely traveler information, a dedicated and appropriately staffed TMC is necessary for the management and operations of the state's roadway network.

The NDDOT Maintenance division and the eight NDDOT districts were polled to establish a baseline for existing operations and practices. A summary of the items discussed along with stakeholders' responses is provided below.

### 24-hour operations

Districts: 24-hour operations occur in Fargo; in Bismarck and Minot they are not standard but do occur during storms. None of the other districts operate on a 24-hour basis.

Maintenance division central office (CO): the division does not operate on 24-hour basis as a standard procedure; however, a staff person from the division receives after hours calls to update the traveler information system.

### Use of DMS and/or HAR

Districts: All districts utilize both fixed and portable DMS in their jurisdictions. Messages are typically handled by the Maintenance division at central office, especially on the fixed DMS. Minot uses their DMS frequently and change the messages from the district office. Fargo manages messages on the DMS during events at the Fargodome.

The number of HAR units available and their usage is limited. The Grand Forks district has one HAR near the Pembina border, but is not used often. Fargo uses HAR in limited situations, such as when traffic is detoured on the interstates.

Maintenance division CO: the division handles the majority of DMS messaging especially during major storms and when travel advisories are issued. After hours, requests for posting messages can come from NDHP.

## Traveler information updates

The NDDOT utilizes several systems to provide and update traveler information. The Road Condition Reporting System (RCRS), a software developed in house, is used for creating road reports and updating the traveler information system (ND Roads web map and mobile application, and 511). The ATMS software is used for posting messages on DMS boards. For Floodgate mass distribution messages on the 511-telephone system, Iteris 511 interface is used by the NDDOT for posting road closures and no travel alerts; it is also used by NDHP for posting AMBER, Silver, and Blue Alerts.

Districts: Roadway condition reports are made daily according to the schedule in NDDOT's Snow and Ice Manual. First reports are issued at 5 a.m. with hourly updates through 8 a.m.; subsequent reports are made throughout the day at set intervals and as conditions change. Last reports are made at 10 p.m. in districts that do not have 24-hour operations.

Maintenance division CO: staff at the division coordinate with the districts and change the traveler information system to reflect road closures and travel advisories across the state.

## Use of MDSS

MDSS is a multifaceted automated system that ingests weather data from ESS sites throughout the state, which is combined with value added meteorology to provide time and location specific weather and roadway condition forecasts. Further, it provides maintenance treatment recommendations for the best course of action to deal with an oncoming weather event.

Districts: MDSS is used extensively by all districts in several ways including: monitoring MDSS feeds for situational awareness, reviewing treatment recommendations before and during storms for proactive response to weather events, and providing feedback reports on actual weather and road conditions to improve the reliability and effectiveness of weather forecasts and treatment recommendations.

Maintenance division CO: staff at the division also monitor MDSS for weather and roadway condition forecasts and use it to view camera images.

## Network monitoring

### *Via video/still images*

Districts: all districts check the surveillance cameras in their jurisdictions and throughout the state for situational awareness such as to ascertain roadway and weather conditions. Most districts limit viewing video streams and look at still images instead to avoid data overages on cameras connected on cellular networks. Bismarck and Fargo districts have fiber-connected cameras within the cities, data overages are not a concern at those sites. Districts have dedicated monitors for viewing images and videos.

Maintenance division CO: staff at the division monitor cameras throughout the state for situational awareness.

### *Via volume, speed, and other sensor data*

Districts: most districts monitor volumes and speeds only occasionally, especially during detours and construction projects. Dickinson monitors speed and road surface friction data often.

Maintenance division CO: staff at the division monitor speed data daily.

### Use of RWIS data

Districts: districts monitor RWIS data such as pavement temperature, wind speed, and road surface friction at individual sites. RWIS sub-surface temperatures are widely used to determine seasonal load restrictions.

Maintenance division CO: staff at the division monitor RWIS data for situational awareness.

Further, RWIS data is fed into MDSS and used by the National Weather Service (NWS).

### Coordination with NDHP

Districts: all districts maintain a high level of coordination with NDHP, in some districts there is daily communication. Road closure decisions and the issuance of travel advisories are done in consultation with NDHP.

Maintenance division CO: the division also coordinates with NDHP during major storm events.

### Coordination with local cities, counties, and neighboring states

Districts: coordination varies and depends on the district's locale and regional conditions and concerns. For example, there is coordination with local agencies in districts that experience spring flooding. Some districts coordinate with their counties for seasonal load restrictions. The Fargo district coordinates with its counterparts at the Minnesota Department of Transportation and the South Dakota Department of Transportation on issues such as road closures on I-94 and I-29 respectively during storm events.

Maintenance division CO: The division communicates with neighboring states and their TMCs during major events and road closures for situational awareness and coordination of the traveler information system messaging.

# 4. Operational Needs

Potential TMC functions were presented to stakeholders to gauge interest in the function, identify needs, and to prioritize the functions over the phased implementation of the TMC.

## 4.1 TMC Functions

The following core and future TMC functions were presented to stakeholders.

### Incident management

Definition: incident management is a TMC function that involves detection, verification, response, and clearance of events including multi-car accidents, vehicle breakdowns, and accidents resulting from road debris or weather conditions.

Incident management is currently handled at the district level. Calls for assistance, maintenance and traffic control resources typically come from State Radio dispatch or the NDHP. Incident command is set up at the scene in collaboration between NDHP troopers and district staff to determine the severity of the incident and the best means to manage and clear it.

Large scale events or disasters, such as major spring flooding, trigger the activation of the ND Department of Emergency Services' (DES) State Emergency Operations Center (SEOC). The SEOC coordinates state support to local and tribal governments utilizing a web system (WebEOC) for reporting, tracking, and coordinating response efforts on a daily basis providing agencies with real-time

situational awareness and a common operating picture of ongoing incidents throughout the state. The NDDOT is represented on the SEOC via the Maintenance division director. The TMC is anticipated to play a supporting role for the SEOC, disseminating emergency and incident information on the traveler information system when needed, such as within the Disaster Traveler Information and the Evacuation and Reentry Management ITS service packages.

### Road closure management

Definition: road closure refers to the decision-making process that guides closing roads due to the weather or other events, the duration of the closure, and reopening.

Road closure management fits under the incident management function.

### Provide travel information

Definition: travel information is a TMC function that involves reporting highway conditions, delays, accidents, scheduled construction or other events, and preferred routes. The information may be disseminated through various means, including dynamic message signs, highway advisory radio, the Internet, and telephone traveler information systems.

NDDOT has a robust system that disseminates traveler information via different means encompassing the ND Roads website and mobile application, 511 traveler information system, and roadside DMS.

District maintenance staff will continue to make roadway condition reports from the field. The districts can update the traveler information system utilizing the RCRS software. The TMC will perform the coordination of messages across the state and update road conditions after hours.

### Special event management

Definition: special event management is a TMC function that involves accommodating non-recurring events (such as sporting events, parades, motorcades, and construction) that are expected to have significant impact on the transportation system.

Special events in North Dakota do not typically span multiple NDDOT districts and can be handled in cooperation between the district and the TMC.

### Records management

Definition: records management is a TMC function that involves archiving and retrieving data about the operations and maintenance activities of the TMC. Activities include entering or recording data, generating and storing reports, and facilitating data warehousing.

It is anticipated that the TMC will expand and enhance the records management function by implementing the ITS Data Warehouse and the Performance Monitoring service packages.

### Emergency management

Definition: emergency management is a function that involves coordinating the response of emergency service providers (such as police, fire, EMS, and towing agencies) to emergency conditions (such as incidents, disabled vehicles, and signal malfunctions).

The emergency management function will remain at the NDDES SEOC and State Radio. The TMC will coordinate with the state's emergency management agencies to streamline response when maintenance and traffic control resources are needed to deal with emergencies.

### Congestion management

Definition: congestion management is a TMC function that involves identifying and responding to recurring congestion resulting from peak travel periods, as well as non-recurring congestion associated with incidents. Responses may include activating ramp meters, posting messages to dynamic message signs and HARs, and adjusting signal timing plans.

Peak period congestion on the state highway system occurs mainly in the Bismarck and Fargo districts. The congestion management function will be shared where the districts deal with recurring and intersection related congestion within their jurisdictions, while the TMC will handle non-recurring congestion on highway mainlines by posting incident information and warning messages on the traveler information system. It is also possible to consider queue warning systems at locations that are prone to have slow or stopped traffic on highways during peak hours.

### System health monitoring

Definition: system health monitoring is a TMC function that involves identifying, responding to, and repairing failures of TMC related field equipment and the communications network.

To streamline the process of monitoring the health of road devices and the communications network that connects them to the TMC, a software system will be utilized to automate the process of identifying failures and network degradation. The health monitoring software will then notify designated staff who will take corrective actions and reduce the overall system downtime.

### Traffic flow monitoring

Definition: traffic flow monitoring is a TMC function that involves viewing traffic data (volume and speed) and video images in real time to evaluate traffic conditions for delays and hazards.

Traffic monitoring will be a TMC function.

### Environmental and RWIS monitoring

Definition: environmental and RWIS monitoring is a TMC function that involves monitoring weather related data (such as pavement temperature and surface conditions, visibility, and wind speed and direction) collected by remote sensors. The data are used to detect and forecast environmental conditions (such as icy roads or dense fog) that may affect travel on the roadway system.

Environmental data from RWIS are used by the districts for situational awareness. The biggest use of the data is feeding it into MDSS for generating weather forecasts and maintenance recommendations for snow and ice control. This will continue after the establishment of the TMC with additional monitoring performed by TMC operators.

### Citizen reporting

Definition: citizen reporting refers to augmenting roadway condition acquisition through crowdsourced reports from the public.

Citizen reporting can help satisfy the need for timelier and more accurate road weather condition information on a 24-hour basis. There are several methods this can be applied, the NDDOT may manage a group of vetted road reporters that would use an application similar to the one snowplow operators currently use to update road conditions, either automatically or after review. A simpler implementation

could add the functionality of uploading a photo of the road conditions utilizing the ND Roads application; TMC operators would update the traveler information system accordingly.

### Variable speed limits

Definition: variable speed limits refers to implementing variable speed limits to manage traffic flow to alleviate congestion or to provide a safe travel speed for varying roadway and weather conditions.

Variable speed limits (VSL) will be demonstrated on a select corridor within the state. The application of variable speed limits will allow the NDDOT to set safe travel speed limits as warranted. An example of VSL use is during adverse weather conditions, especially blowing snow events, where visibility and road surface conditions can vary greatly over relatively small distances. This creates unsafe situations where motorists travel at speeds too high to safely negotiate roadway conditions. Further, VSL creates more uniform and harmonized speeds among motorists to reduce unsafe interactions between vehicles traveling at widely varying speeds.

VSL is an application that has been in consideration for many years, its application can showcase how the TMC can be leveraged for the deployment of advanced technologies.

### Connected vehicle (CV) applications

Definition: CV refers to instrumented vehicles and infrastructure that enable safe, interoperable networked wireless communications among vehicles, the infrastructure, and personal communications devices. This sharing of data creates a connected environment where data can be collected, and information shared freely.

CV applications represent the future of transportation network data collection and traveler information dissemination and offer great possibilities for safety and mobility improvements. CV is the focus of research and funding from FHWA and is another example of an advanced technology that can be pursued by leveraging the establishment of the TMC. There are many CV applications that would be suitable in a rural setting such as real-time location specific warning of unsafe circumstances such as weather and roadway condition.

## 4.2 Summary of TMC Functional Discussion

There was agreement on the core TMC functions presented. The stakeholders saw a need and value in including all the functions above as resources become available. In regard to the roles stakeholders will play in performing various TMC functions, the districts generally would like to remain involved in the operations and decision making for: incident management, road closure, and traveler information functions. Similarly, central office and the Maintenance division view the districts as essential partners in performing these functions and others as the districts know their roads and conditions best.

The TMC will change operations in two main ways: **1) providing coverage after hours for 24-hour operations, and 2) performing overarching coordination of all these functions with a holistic view that considers the entire state.**

The stakeholders' TMC functions discussion is summarized in the table below. If the preference is for a function to be centralized it is marked with a TMC cell, if it is to remain a district function it is marked with a District cell, and if it is to be shared it is marked with a Shared cell.

| Table 1. TMC Functions | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Core Functions | | | | | | | | | | Future Functions | | |
| **District** | Incident management | Road closure | Travel info | Special event management | Records management | Emergency management | Congestion management | System health monitoring | Traffic monitoring | RWIS monitoring | Citizens reporting | VSL | Connected Vehicle Functions |
| Bismarck | TMC | District | Normal hours: dist. 24 hour: TMC | Shared | TMC | TMC | TMC | TMC | TMC | TMC | TMC | TMC | TMC |
| Devils Lake | Shared | Shared | Shared | TMC | TMC | TMC | TMC | TMC | TMC | TMC | TMC | TMC | TMC |
| Dickinson | Shared | Shared (decision from district) | Road reports: district. TMC: disseminate | N/A | TMC | Shared | N/A | TMC | TMC | TMC | TMC | TMC | TMC |
| Fargo | District | District | Shared | District | TMC | TMC | Signals: district Mainline: TMC | District TMC if NDIT issues are resolved | TMC | TMC | No comment | No comment | TMC |
| Grand Forks | Shared | Shared | Shared | TMC | TMC | TMC | TMC | TMC | TMC | Shared | TMC | TMC | TMC |
| Minot | Shared | Shared | Shared | N/A | TMC | TMC | N/A | TMC | TMC | TMC | TMC | TMC | TMC |
| Valley City | Shared | District | Shared | TMC | TMC | TMC | TMC | TMC | TMC | TMC | TMC | TMC | TMC |
| Williston | Shared | Shared | Shared | TMC | TMC | TMC | TMC | TMC | TMC | TMC | TMC | TMC | TMC |
| Central Office Maint. Division | TMC/District | TMC/District | condition reporting: Districts 24 hour: TMC | Shared | TMC | TMC | TMC | TMC | Shared | Shared | Central Office | TMC, with district input | TMC |

# 5. System Overview

This section provides a high-level description of key system components and their interfaces, goals and objectives, and system capabilities.

## 5.1 System Concept Exploration

Several categories, types, and architectures of TMCs exist. The chosen model depends on the agency's needs and available resources. A TMC may be for the management of roadways, traffic signals, or transit operations. A phased development approach is often common where a TMC can grow as funding, experience, and capacities are built over time. The three main TMC architectures are:

- Centralized: a single physical location that houses all traffic operations staff and functions
- Distributed: several centers exist but have unique roles based on operational role or function
- Virtual: there is not a single physical location as a point of activity; all functions exist as network applications and can be accessed in a variety of physical locations. In modern TMCs, virtual capabilities are available under all architectures.

The TMC stakeholders were presented with several functional and operational scenarios, the preferred option is a central facility with the area of operations being the interstates and state highways with a goal to:

- Improve roadway and weather monitoring and reporting
- Enhance maintenance operations and traveler information

With guidance from the NDDOT management, the TMC's main objectives were determined to be:

- Unify the control and operations of all field devices and sensors under one central control software
- Expand the roadway monitoring and condition reporting from the current structure to a 24/7/365 regime
- Implement pilot deployment of advanced technologies, initially VSL with a vision to expand and incorporate more functions in future phases of the TMC

An initial discussion for the TMC location resulted in a potential site for the TMC to be co-located with the state's Department of Emergency Services and State Radio at the North Dakota National Guard's Fraine Barracks in Bismarck, ND. For over two decades, State Radio was engaged as a key stakeholder in the state's ITS plans and ITS architecture development efforts and was always supportive of cooperating and sharing space with a future TMC. State Radio handles communications and dispatch operations for the North Dakota Highway Patrol and is the public safety answering point (PSAP) for 25 counties and is the designated backup for North Dakota's 15 other PSAPs. The location offers several desirable features such as: site security, uninterrupted power supply and backup generators, and hardened buildings to withstand tornadoes and other severe weather threats. The location would also provide for increased cooperation and coordination with the state's emergency management agencies, and the shared facilities would allow synergies to develop between TMC operators and State Radio dispatchers that could streamline response to incidents and resource requests.

The establishment of the TMC and the incorporation of relevant technologies will allow the NDDOT to achieve the following:

- 24/7/365 roadway monitoring and condition reporting coverage
- Space and staff availability for active management and operations
- Enhanced communications and coordination with State Radio, NDHP, and the NDDOT Districts
- Consistency in roadway condition reporting and traveler information throughout the state
- Unification of all sensors and field devices under a single central control system and streamline the expansion of the state's RWIS, video surveillance, and vehicle detection capabilities
- Pilot deployment of variable speed limit application to showcase the safety potential of advanced technologies

## 5.2 System Interfaces

To demonstrate how the TMC will interact with existing systems and how relevant ITS services will be performed with a statewide TMC in place, a project ITS architecture was created within the statewide architecture to showcase the interfaces and information flows needed to perform various TMC functions. An ITS architecture represents the framework for integrating ITS and guiding deployment.

The following table provides a list of ITS service packages from the TMC Project ITS Architecture and their current deployment status. ITS Service Packages are sourced from the FHWA's National ITS Reference Architecture (ARC-IT 9.0) and represent slices of the Architecture's Physical View that address specific services such as Traffic Surveillance, Winter Maintenance, and Traveler information. A service package encompasses several different physical objects (systems and devices) and their functional objectives along with the information flows needed to provide the desired service. The status for each service package is identified as "existing" for services already performed, and "planned" for services that will be deployed through the TMC project. In addition to implementing the planned services, existing services will be enhanced by the establishment of the TMC through the expansion of the scope of the service by the coordinated operations of each service through a unified control system, and the increased monitoring activities that will be performed by designated TMC operators.

**Table 2. TMC Related ITS Service Packages**

| Service Area | Service Package | Name | Status |
|---|---|---|---|
| Data Management | DM01 | ITS Data Warehouse | Planned |
| | DM02 | Performance Monitoring | Planned |
| | | | |
| Maintenance and Construction Management | MC01 | Maintenance and Construction Vehicle and Equipment Tracking | Existing |
| | MC04 | Winter Maintenance | Existing |
| | MC05 | Roadway Maintenance and Construction | Existing |
| | MC06 | Work Zone Management | Existing |
| | MC08 | Maintenance and Construction Activity Coordination | Existing |
| | | | |
| Public Safety | PS01 | Emergency Call-Taking and Dispatch | Existing |
| | PS10 | Wide-Area Alert | Existing |
| | PS12 | Disaster Response and Recovery | Existing |

| | | | |
|---|---|---|---|
| | PS13 | Evacuation and Reentry Management | Existing |
| | PS14 | Disaster Traveler Information | Existing |
| | | | |
| Support | SU01 | Connected Vehicle System Monitoring and Management | Planned |
| | SU07 | ITS Communications | Existing |
| | | | |
| Traveler Information | TI01 | Broadcast Traveler Information | Existing |
| | TI02 | Personalized Traveler Information | Existing |
| | | | |
| Traffic Management | TM01 | Infrastructure-Based Traffic Surveillance | Existing |
| | TM02 | Vehicle-Based Traffic Surveillance | Planned |
| | TM06 | Traffic Information Dissemination | Existing |
| | TM08 | Traffic Incident Management System | Existing |
| | TM12 | Dynamic Roadway Warning | Existing |
| | TM19 | Roadway Closure Management | Existing |
| | TM20 | Variable Speed Limits | Planned |
| | TM23 | Border Management Systems | Planned |
| | TM25 | Wrong Way Vehicle Detection and Warning | Planned |
| | | | |
| Vehicle Safety | VS02 | V2V Basic Safety | Planned |
| | VS03 | Situational Awareness | Planned |
| | VS07 | Road Weather Motorist Alert and Warning | Planned |
| | VS11 | Oversize Vehicle Warning | Existing* |
| | VS13 | Intersection Safety Warning and Collision Avoidance | Existing* |
| | | | |
| Weather | WX01 | Weather Data Collection | Existing |
| | WX02 | Weather Information Processing and Distribution | Existing |
| | WX03 | Spot Weather Impact Warning | Planned |

*Existing service through roadside infrastructure warning devices.

A detailed description of these service packages is provided in Appendix II.

# 6. Operational and Support Environment

This section describes the environment in which the TMC will operate including facilities, equipment, hardware, software, and personnel.

## 6.1 Physical Environment and Hardware

The TMC will require building space to accommodate a dispatch room, office, restroom, breakroom, and a training/meeting space. In the preferred location scenario, the TMC staff will be housed in a new building proposed as a second-floor addition to the existing State Radio dispatch facility. Other locations that meet the above requirements can still be considered, including any available space at the NDDOT central office building. The space above State Radio would be roughly 2319 SF and would allow the TMC to tie into the existing DES generator system for backup power.

In the initial TMC phase, four dispatch operator sit-stand workstations would be installed:

- Two workstations to be operated by the NDDOT
- One spare workstation will be used as backup
- The fourth workstation would be available for NDHP and is expected to be used as needed during events and emergencies

Each workstation will be outfitted with the following:

- A computer console
- 2 or more monitors depending on the need for screen space based on the final configuration of software interface
- A radio console
- A telephone/integrated softphone
- A hands-free headset

The dispatch room will be outfitted with a video wall viewable from all workstations. A budget conscience alternative for a video wall is using several TV monitors mounted to a wall in a grid arrangement, a dedicated computer is used for the monitor operations and running the display. The video wall will be used to display different information including surveillance camera images, MDSS feed, weather, and roadway conditions.

The training/meeting room will be outfitted with chairs and a modular table that can be configured as a conference table or a classroom. The room will have a computer and a projector or a large screen for presentations.

A color network printer will be available in either the dispatch room or training/meeting room.

The NDDOT may choose to publicize a telephone number to be used as a single point of contact for the TMC. The number could be used by the public to report non-emergency situations on the roads such as fallen debris, animal carcasses, or other maintenance issues. The number could also be used for inquiries from other agencies and the media.

## 6.2 Software Systems

### 6.2.1 TMC Control Software

Control system unification of sensors and field devices will occur under the existing Parsons ATMS software. The NDDOT has already made significant investment into this control software for managing surveillance cameras, DMS, ESS, and radar-based vehicle detection. The NDDOT has had a good experience working with the applications and the vendor. The benefits of such modern central control systems include: flexibility through web-based applications that can be run on the NDDOT local network or remotely, configurability of the software through its modular architecture where additional devices and applications can be added as needed, and standardized integration based on the NTCIP ITS standards. The software package is configurable, allowing the addition of modules as needed for the control and operations of the TMC.

While systems engineering (SE) has the principle of delaying technology solutions and vendor choices until the system has been designed and a final decision is made based on evaluation criteria established through the SE process, this is a different situation where the TMC central control software will be an expansion of existing system. The current situation where the NDDOT has made significant investment in the ATMS software, has experience in the use of the system, and the vendor has a good track record of product support does not go against systems engineering practices.

In the current configuration of ATMS, the NDDOT has the following modules as described by Parsons:

**DMS Module:** The DMS module communicates with fixed and portable dynamic message signs (DMS) to disseminate information to motorists. This module allows the system administrator to post messages in real-time, schedule messages for posting at a specific time, or set a message to be sent to one sign, multiple signs, or all signs in the system at once.

**CCTV Module:** The CCTV module provides the functionality for viewing, controlling, and maintaining all the cameras in the system. Using surveillance cameras as part of the ATMS allows users to view real-time traffic and weather conditions. This includes snapshots and streaming images. The module supports all standard digital formats, and it includes the following features:

- Camera controls
- Camera presets
- User priority override
- Video wall configuration

**ESS Module:** The ESS module provides real-time weather conditions. Individual roadside weather stations, referred to as environmental sensor stations (ESS), are set up along highways. The ESS data is transmitted and displayed as color-coded icons on a map to alert users of hazardous conditions. These stations collect the following types of data:

Atmospheric data:

- Air temperature
- Humidity
- Wind speed and direction
- Precipitation type and rate
- Solar radiation

- Visibility distance

Pavement data:

- Pavement temperature
- Pavement condition
- Friction
- Subsurface temperatures

Management of ATR and WIM devices could potentially be added under ATMS.

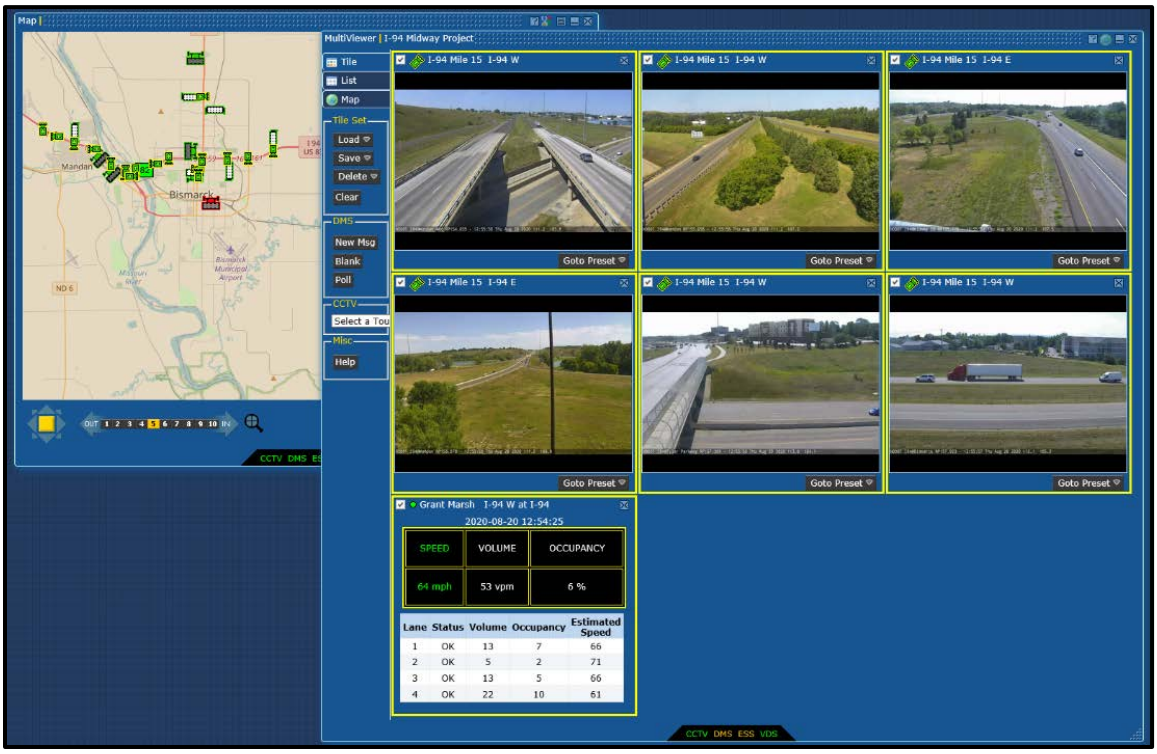


Figure 2. Screen capture from ATMS

### 6.2.2 Additional Software and Computing Needs

Additional software, computing, and server resources will be needed to achieve the following:

- Computer aided dispatch (CAD) integration to tie TMC dispatch into State Radio's CAD software
- Status monitoring software will be needed to keep track of events, activities, calls, citizen reports, etc. This software will have an interface similar to the WebEOC software used by the DES
- Network health monitoring software will be necessary to streamline the process of monitoring the health of roadway devices and the communications network that connects them to the TMC. The health monitoring software will identify failures and network degradation and notify TMC operators or other designated staff so corrective actions are taken to reduce the overall system downtime
- Video/image server will be required to house data from surveillance cameras
- Server systems will be necessary to run the various software described above; some will be physically located at the TMC while others will be cloud computing services

- Staff scheduling software for TMC operator shifts
- Backup systems will be needed for the TMC software and the data they generate
- Software interfacing will be needed to integrate the various systems to present the TMC operators with a concise view

### 6.3 Staffing Needs

The number of TMC staff needed was determined based on the concept of 24-hour operations considering vacation, sick leave, and peak periods. Staffing of the statewide TMC will evolve as the level of ITS devices and operations controlled by the TMC grows. IT support will be required for the various TMC systems; some support tasks will be handled by vendors via service agreements. The NDDOT will determine how other support requirements are met utilizing existing staff, new TMC specific staff, or through NDIT.

Table 3 shows the initial maximum staffing for any one time at the TMC.

| **Table 3. Statewide TMC Operations** | |
|---|---|
| Staffing Requirements | • 1 TMC supervisor<br>• 1 TMC operator<br><br>(10 FTEs dedicated to TMC to cover 24/7 operations) |
| Space Requirements | • 4 operator consoles<br>• 1 supervisor office<br>• video wall<br>• server room<br>• bathroom<br>• training/meeting room |
| Space Needed | 2319 SF* |

* The square footage was calculated based on the option of adding onto the State Radio dispatch center.

During nonpeak periods throughout the year, one workstation will always be staffed. As ITS equipment expand and additional systems and applications come online, additional staff will be needed to operate the statewide TMC.

## 7. Operational Scenarios

Operational scenarios for the statewide TMC will be presented below utilizing the Use Case concept. A use case will show Actors (e.g., TMC Operator, State Radio Dispatcher, etc.) and how they interact with the system (TMC) to perform a task in a particular scenario. When appropriate the task will be shown from the perspective of several actors.

The actors that will be used to show the interaction with the TMC include:

- TMC Manager
- TMC Operator
- IT Technician

- State Radio Dispatcher
- District Engineer
- District Maintenance Supervisor
- Snowplow Operator
- NDHP Trooper
- Driver
- Traveler

## 7.1 Normal Conditions

The following are scenarios that occur day to day during normal operations.

### Camera/RWIS/MDSS monitoring

- The TMC Operator on shift will monitor several camera views both on the computer monitor and video wall
- The TMC Operator on shift will have windows displaying information and dashboards from RWIS and MDSS

### Verifying road conditions

- The TMC operator uses the ATMS camera control interface to choose a camera location
- The TMC operator monitors RWIS data

### Update traveler information system

- Based on information from a call (the call could come from a district, NDHP, or State Radio)
    - TMC Operator will update the traveler information system based on information received
- For external calls, the traveler information system is updated after the conditions are verified
- During off hours, updates are made based on:
    - TMC Operator will update the traveler information system based on observed conditions through surveillance cameras
    - TMC Operator will update the traveler information system based on ESS data

### Debris on the roadway

- TMC Operator receives call reporting debris on the roadway
- TMC Operator dispatches appropriate maintenance resources to clear the road
- TMC Operator updates traveler information system if needed

### TMC management

- TMC Manager coordinates the hiring and training of new TMC Operators
- TMC Manager uses scheduling software to ensure 24/7 coverage while managing equitable shift rotation, vacation and sick leave requests
- TMC Manager assigns tasks for operators to perform during off peak months and down time

## 7.2 Stress and Failure Conditions

The following are extraordinary scenarios that may occur occasionally and cause disruptions on the roadway network or to TMC devices and equipment.

### Device failure

A roadside device goes down requiring repair.

- Health monitoring software detects failure and reports error to TMC Operator
- TMC Operator coordinates repair with IT Technician
- IT Technician performs required corrective action

### Winter storm

A major winter storm requiring the closure of a segment of roadway.

- Snowplow Operators report deteriorating conditions to District office and TMC
- MDSS and NWS forecasts are checked for expected conditions over the short and medium term
- Road closure decision is made in consultation between the district, NDHP, and the TMC
- TMC Operators update the traveler information system to reflect closure
- State Radio is informed of roadway closure
- The TMC coordinates the roadway closure over several districts as needed
- Neighboring states are informed of roadway closures
- Media releases are sent out for the road closures

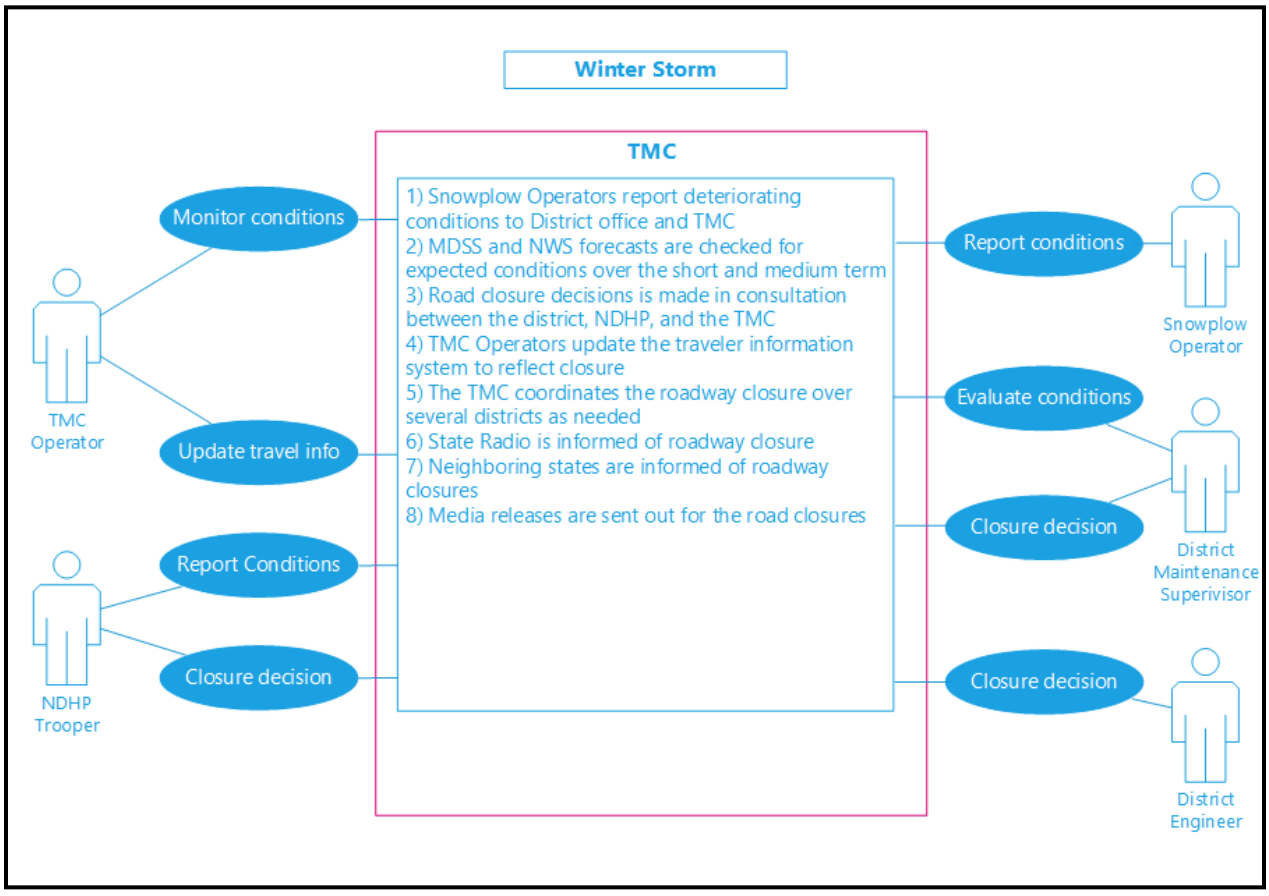



Figure 3. Winter storm use case diagram

### Major incident

An incident that will result in road closure or lane restrictions.

- Incident detection/reporting
    - Incident is reported via 911 call from involved party or from others at scene
    - Incident detection via TMC software based on a drop in observed travel speed
    - State Radio Dispatcher dispatches NDHP, and EMT and Fire/Rescue crews as needed
    - State Radio Dispatcher informs TMC of incident
- Incident evaluation/clearing
    - NDHP Troopers set up incident command, evaluates, verifies/requests Fire/Rescue crews
    - NDHP Troopers request traffic control, maintenance resources, towing and recovery needed for clearing the incident
    - State Radio communicates traffic control and maintenance resources needs to TMC
    - TMC Operator dispatches traffic control and maintenance resources from NDDOT district
    - TMC Operator updates traveler information system with incident information
    - TMC Operator provides incident information for media

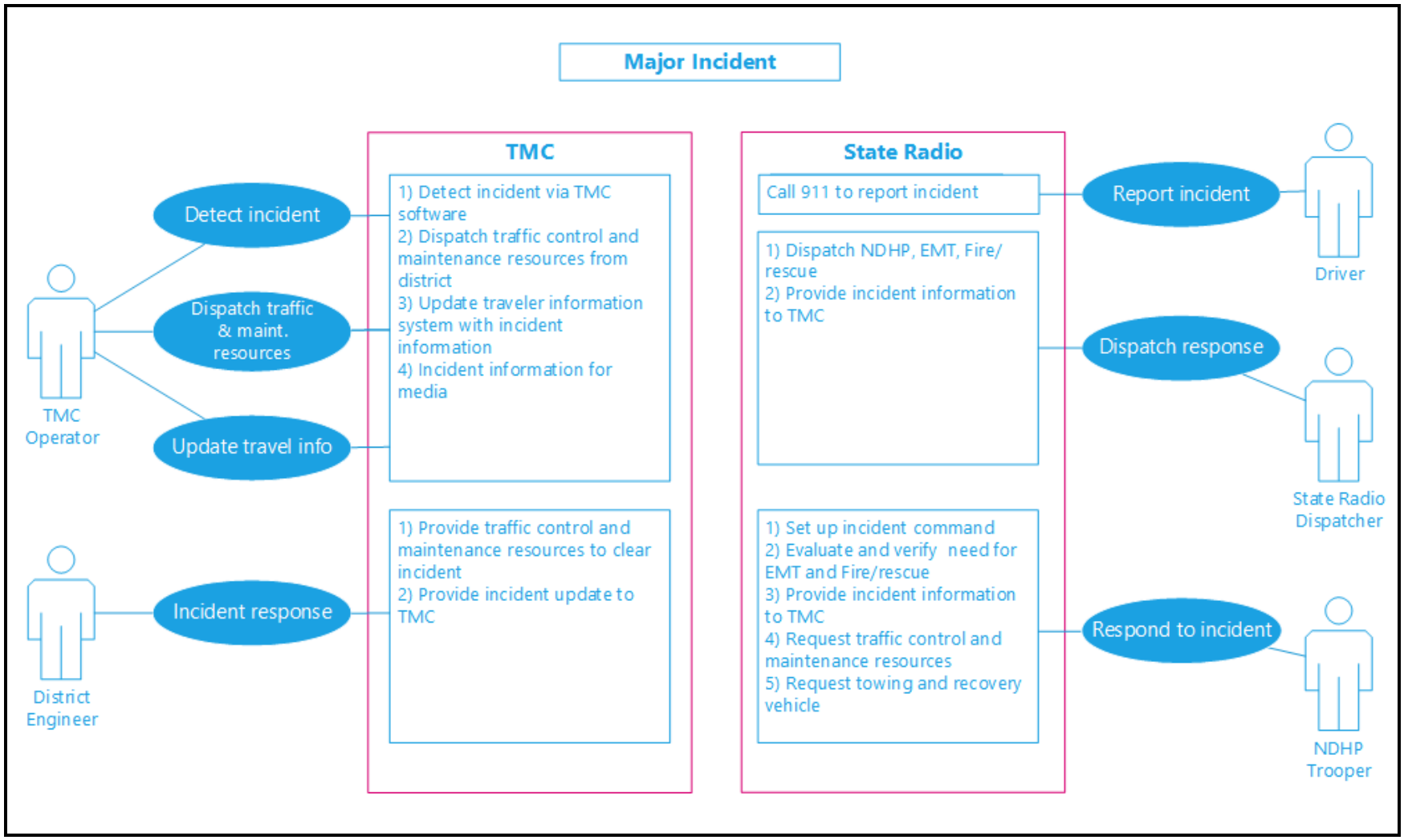



Figure 4. Major incident use case diagram

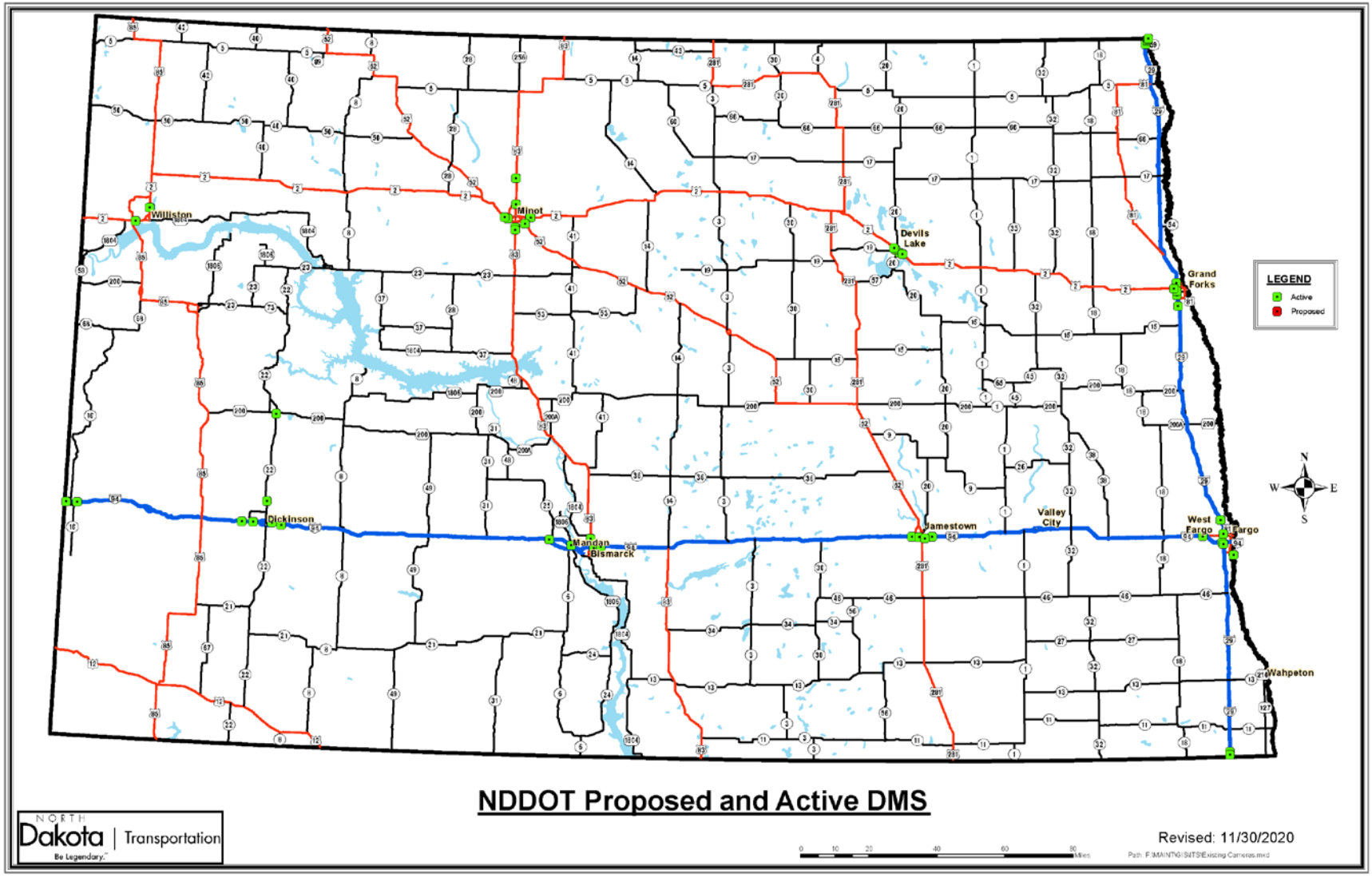
# 8. Summary of Impacts

The establishment of the TMC will improve roadway operations and maintenance activities statewide. The TMC will:

- Provide the space, staffing, and software and hardware systems needed to unify the control of roadway devices and sensors;
- Will move the NDDOT to 24/7/365 operations for network monitoring, and timelier and more accurate traveler information and road condition reporting; and
- Perform overarching coordination of all TMC functions with a holistic view that considers the entire state.

## Appendix I: Maps of ITS Devices

The following figures show the location of DMS, camera, ESS, ATR, WIM, and radio towers in the state.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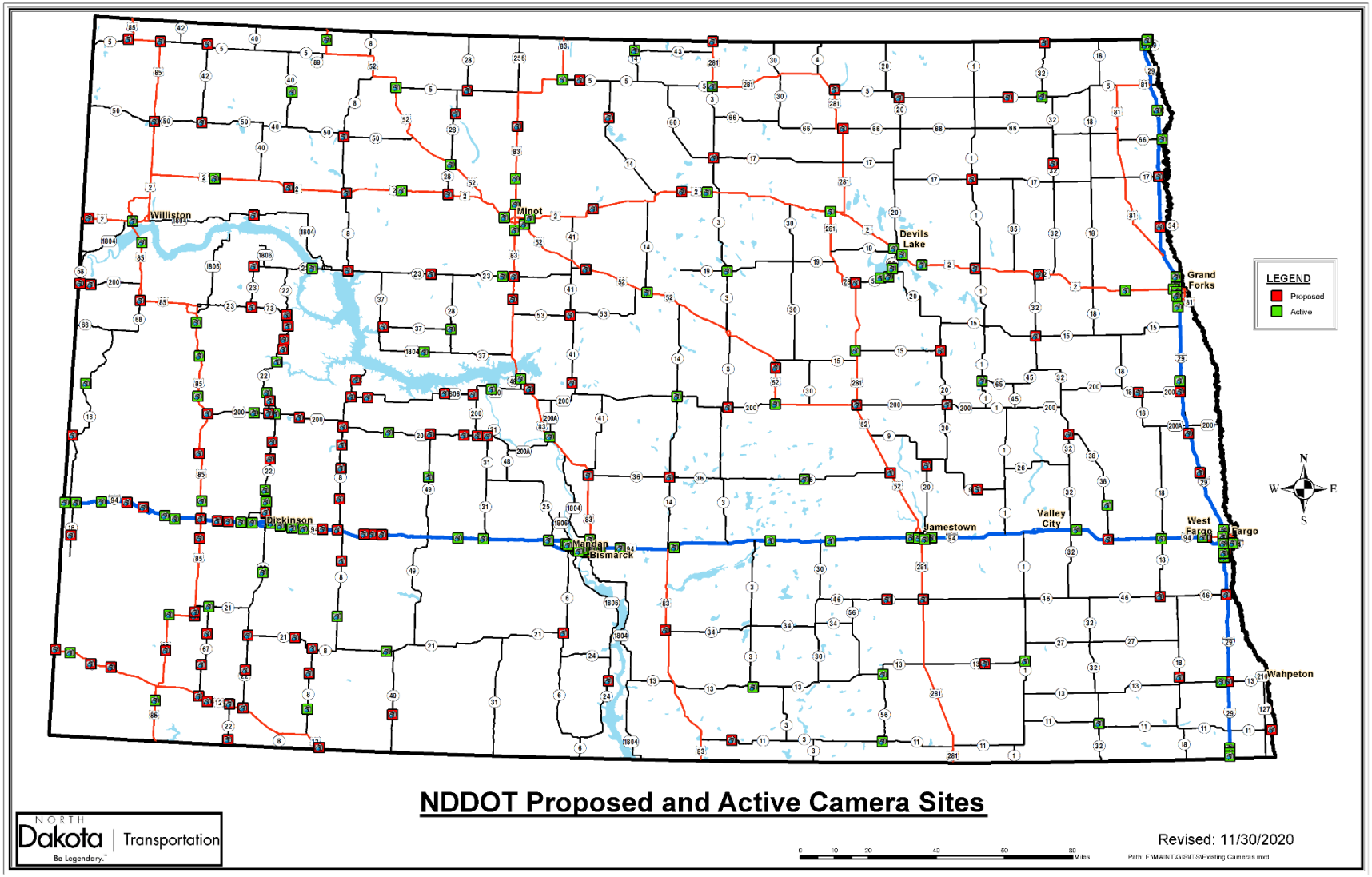
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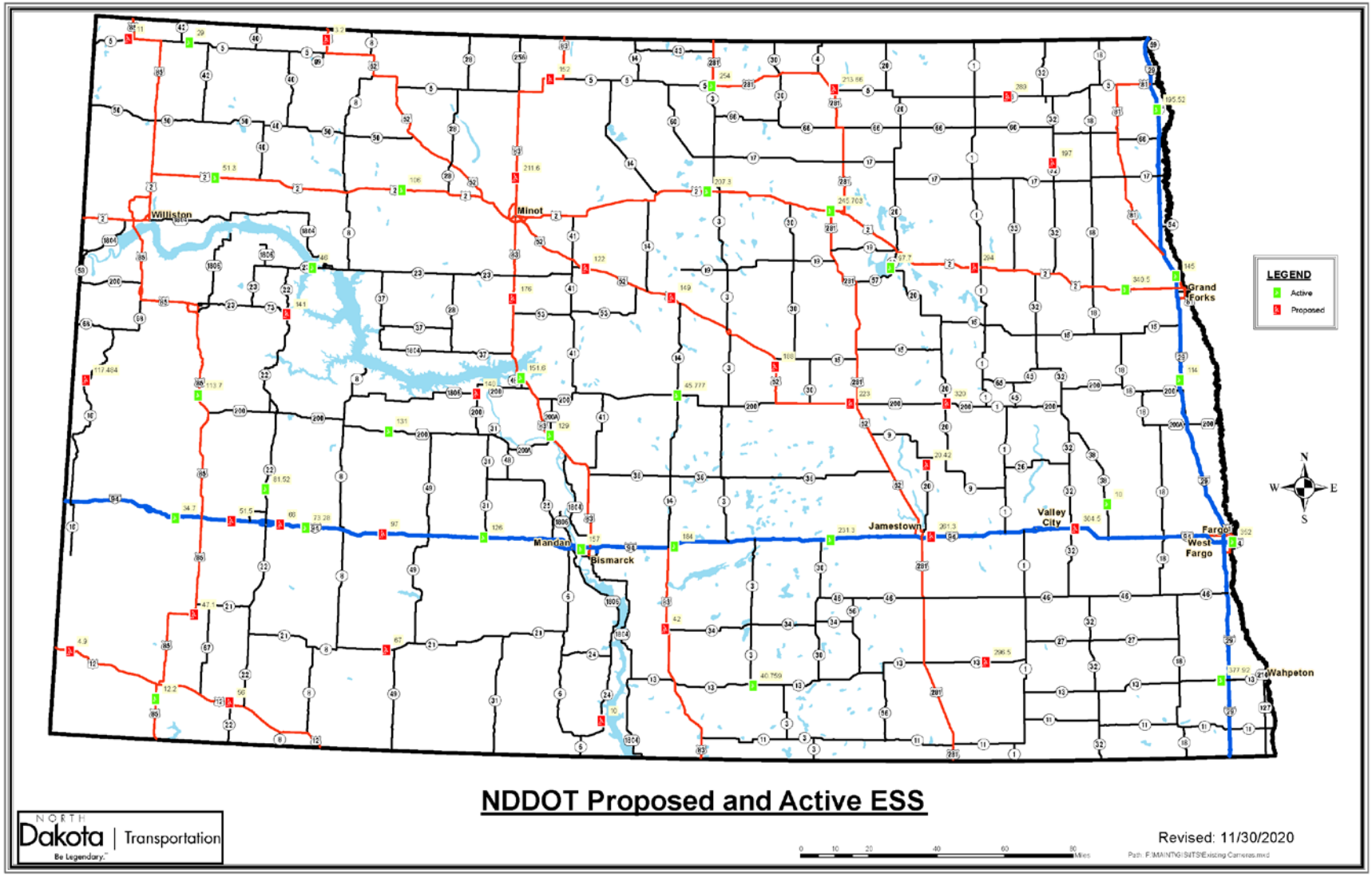
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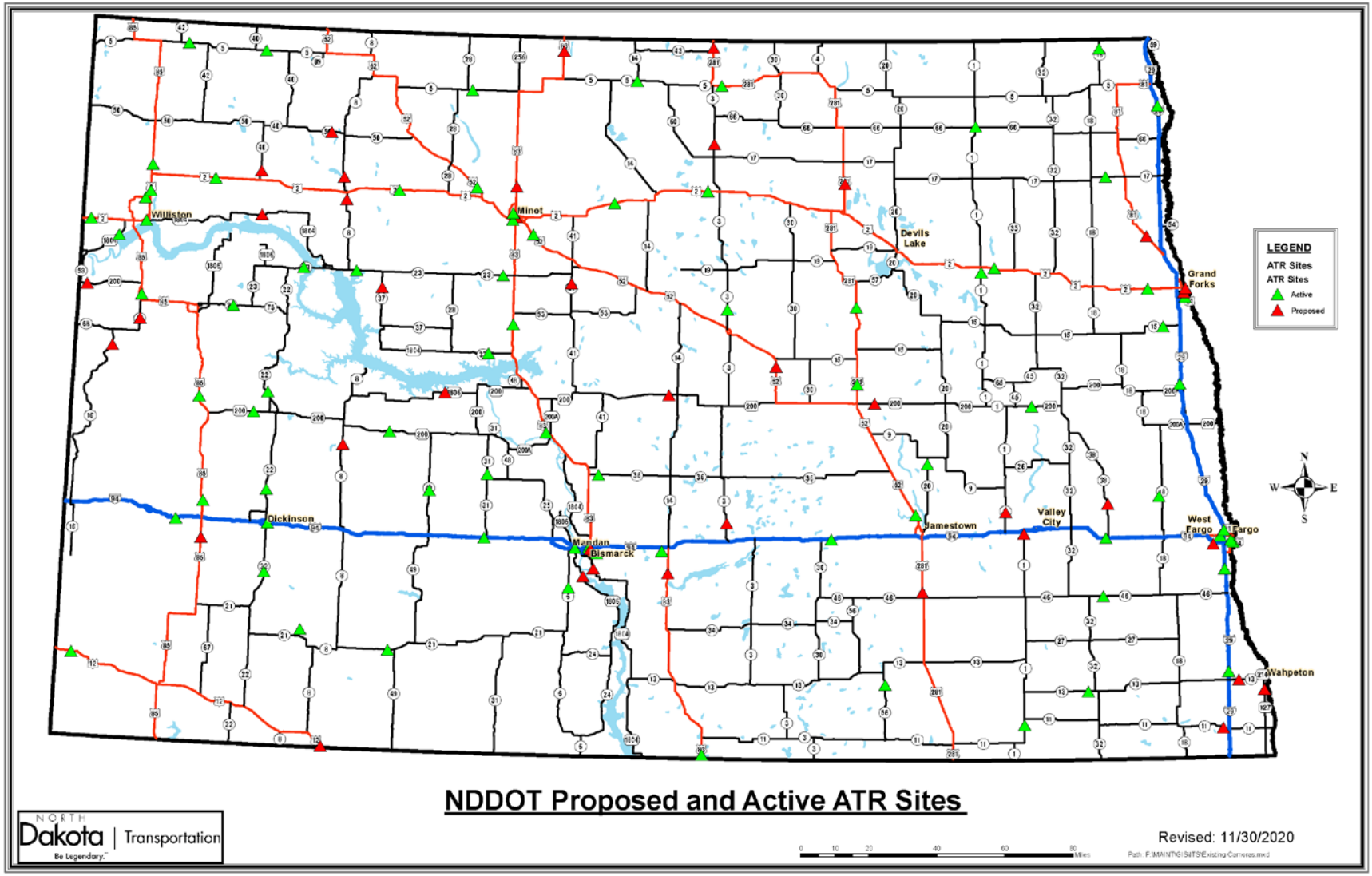
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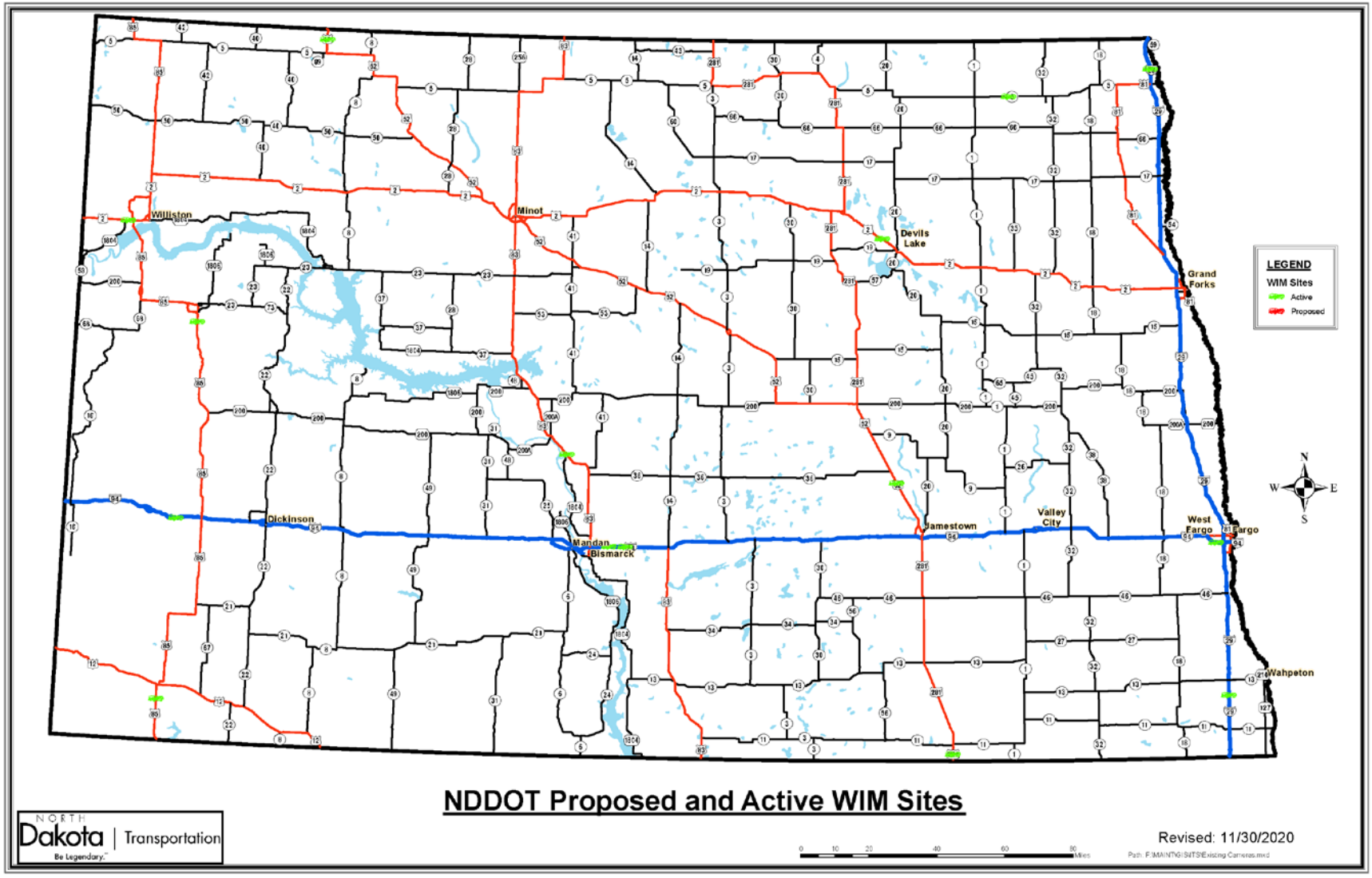
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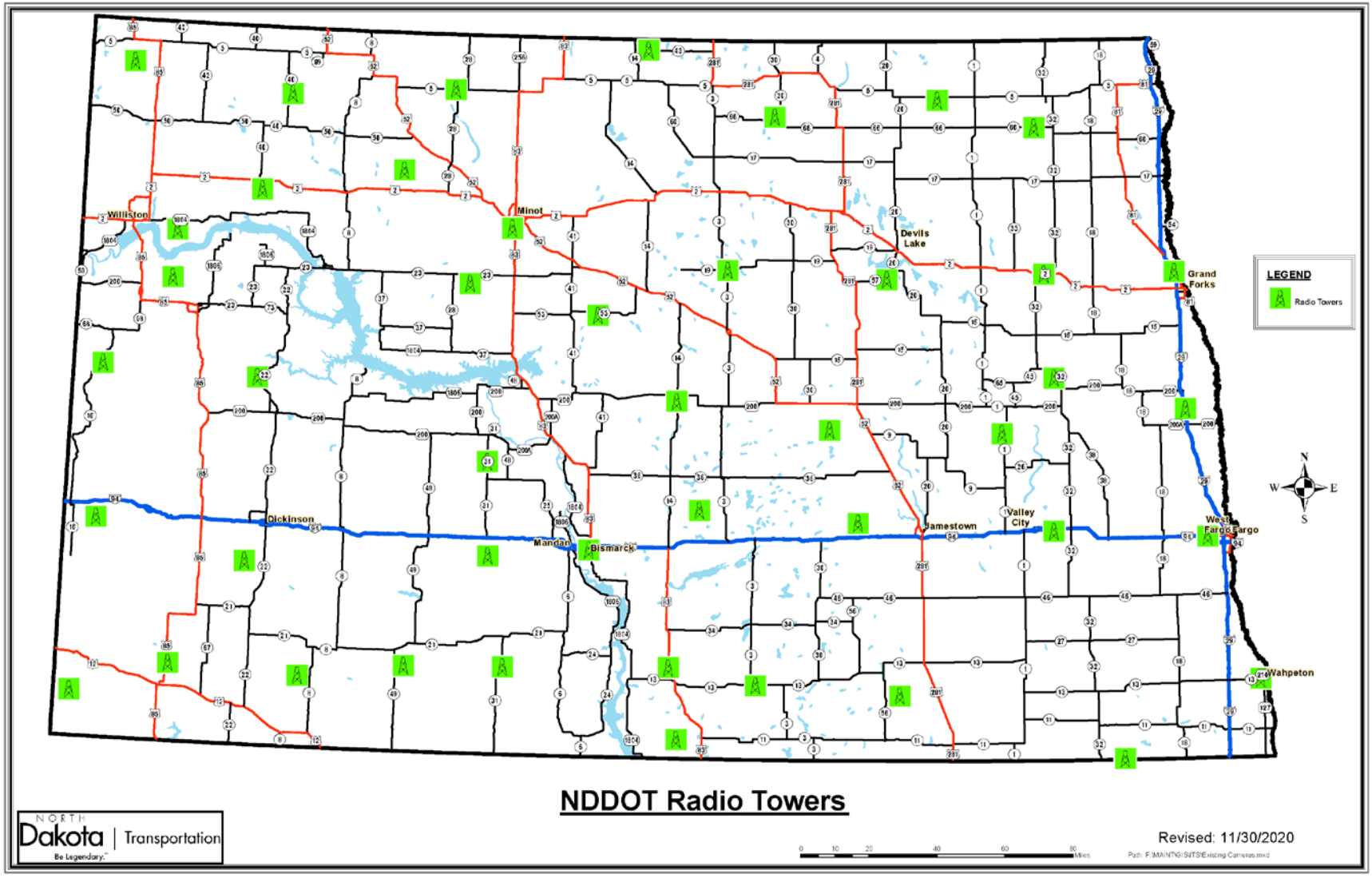
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# Appendix II: Project ITS Architecture – Service Package Details

## Data Management

### DM01 ITS Data Warehouse

This service package provides access to transportation data to support transportation planning, condition and performance monitoring, safety analysis, and research. Configurations range from focused repositories that house data collected and owned by a single agency, district, private sector provider, or research institution to broad repositories that contain multimodal, multidimensional data from varied data sources covering a broader region. Both central repositories and physical distributed ITS data repositories are supported. Requests for data that are satisfied by access to a single repository in the ITS Data Warehouse service package may be parsed by the local repository and dynamically translated to requests to other repositories that relay the data necessary to satisfy the request. The repositories could include a data registry capability that allows registration of data identifiers or data definitions for interoperable use throughout a region.

### DM02 Performance Monitoring

The Performance Monitoring service package uses information collected from detectors and sensors, connected vehicles, and operational data feeds from centers to support performance monitoring and other uses of historical data including transportation planning, condition monitoring, safety analyses, and research. The information may be probe data information obtained from vehicles in the network to determine network performance measures such as speed and travel times, or it may be information collected from the vehicles and processed by the infrastructure, e.g. environmental data and infrastructure conditions monitoring data. Additional data is collected including accident data, road condition data, road closures and other operational decisions to provide context for measured transportation performance and additional safety and mobility-related measures. More complex performance measures may be derived from the collected data.

## Maintenance and Construction Management

### MC01 Maintenance and Construction Vehicle and Equipment Tracking

This service package tracks the location of maintenance and construction vehicles and other equipment to ascertain the progress of their activities. Checks can include ensuring the correct roads are being plowed and work activity is being performed at the correct locations.

### MC04 Winter Maintenance

This service package supports winter road maintenance including snowplow operations, roadway treatments (e.g., salt spraying and other anti-icing material applications), and other snow and ice control activities. This package monitors environmental conditions and weather forecasts and uses the information to schedule winter maintenance activities, determine the appropriate snow and ice control response, and track and manage response operations.

### MC05 Roadway Maintenance and Construction

This service package supports numerous services for scheduled and unscheduled maintenance and construction on a roadway system or right-of-way. Maintenance services include landscape

maintenance, hazard removal (roadway debris, dead animals), routine maintenance activities (roadway cleaning, grass cutting), and repair and maintenance of both ITS and non-ITS equipment on the roadway (e.g., signs, traffic controllers, traffic detectors, dynamic message signs, traffic signals, CCTV, etc.). Environmental conditions information is also received from various weather sources to aid in scheduling maintenance and construction activities.

### MC06 Work Zone Management

This service package manages work zones, controlling traffic in areas of the roadway where maintenance, construction, and utility work activities are underway. Traffic conditions are monitored using CCTV cameras and controlled using dynamic message signs (DMS), Highway Advisory Radio (HAR), gates and barriers. Work zone information is coordinated with other groups (e.g., TIC, traffic management, other maintenance and construction centers). Work zone speeds and delays are provided to the motorist prior to the work zones. This service package provides control of field equipment in all maintenance and construction areas, including fixed, portable, and truck-mounted devices supporting both stationary and mobile work zones.

### MC08 Maintenance and Construction Activity Coordination

This service package supports the dissemination of maintenance and construction activity to centers that can utilize it as part of their operations, or to Transportation Information Centers who can provide the information to travelers. Center to center coordination of work plans supports adjustments to reduce disruption to regional transportation operations.

## Public Safety

### PS01 Emergency Call-Taking and Dispatch

This service package provides basic public safety call-taking and dispatch services. It includes emergency vehicle equipment, equipment used to receive and route emergency calls, and wireless communications that enable safe and rapid deployment of appropriate resources to an emergency. Coordination between Emergency Management Centers supports emergency notification between agencies. Wide area wireless communications between the Emergency Management Center and an Emergency Vehicle supports dispatch and provision of information to responding personnel. This service package also provides information to support dynamic routing of emergency vehicles. Traffic information, road conditions, and weather advisories are provided to enhance emergency vehicle routing. The Emergency Management Center provides routing information based on real-time conditions and has the option to request an ingress/egress route from the Traffic Management Center.

### PS10 Wide-Area Alert

This service package uses ITS driver and traveler information systems to alert the public in emergency situations such as child abductions, severe weather events, civil emergencies, and other situations that pose a threat to life and property. The alert includes information and instructions for transportation system operators and the traveling public, improving public safety and enlisting the public's help in some scenarios. The ITS technologies will supplement and support other emergency and homeland security alert systems such as the Emergency Alert System (EAS). When an emergency situation is reported and verified and the terms and conditions for system activation are satisfied, a designated agency broadcasts emergency information to traffic agencies, transit agencies, information service

providers, toll operators, and others that operate ITS systems. The ITS systems, in turn, provide the alert information to transportation system operators and the traveling public using ITS technologies such as dynamic message signs, highway advisory radios, in-vehicle displays, transit displays, 511 traveler information systems, and traveler information websites.

### PS12 Disaster Response and Recovery

This service package enhances the ability of the surface transportation system to respond to and recover from disasters. It addresses the most severe incidents that require an extraordinary response from outside the local community. All types of disasters are addressed including natural disasters (hurricanes, earthquakes, floods, winter storms, tsunamis, etc.) and technological and man-made disasters (hazardous materials incidents, nuclear power plant accidents, and national security emergencies such as nuclear, chemical, biological, and radiological weapons attacks).

The service package supports coordination of emergency response plans, including general plans developed before a disaster as well as specific tactical plans with short time horizon that are developed as part of a disaster response. The service package provides enhanced access to the scene for response personnel and resources, provides better information about the transportation system in the vicinity of the disaster, and maintains situation awareness regarding the disaster itself. In addition, this service package tracks and coordinates the transportation resources - the transportation professionals, equipment, and materials - that constitute a portion of the disaster response.

The service package identifies the key points of integration between transportation systems and the public safety, emergency management, public health, and other allied organizations that form the overall disaster response. In this service package, the Emergency Management Center represents the federal, regional, state, and local Emergency Operations Centers and the Incident Commands that are established to respond to the disaster. The interface between the Emergency Management Center and the other centers provides situation awareness and resource coordination among transportation and other allied response agencies. In its role, traffic management implements special traffic control strategies and detours and restrictions to effectively manage traffic in and around the disaster. Maintenance and construction provides damage assessment of road network facilities and manages service restoration. Transit management provides a similar assessment of status for transit facilities and modifies transit operations to meet the special demands of the disaster. As immediate public safety concerns are addressed and disaster response transitions into recovery, this service package supports transition back to normal transportation system operation, recovering resources, managing on-going transportation facility repair, supporting data collection and revised plan coordination, and other recovery activities.

### PS13 Evacuation and Reentry Management

This service package supports evacuation of the general public from a disaster area and manages subsequent reentry to the disaster area. The service package addresses evacuations for all types of disasters, including disasters like hurricanes that are anticipated and occur slowly, allowing a well-planned orderly evacuation, as well as disasters like terrorist acts that occur rapidly, without warning, and allow little or no time for preparation or public warning.

This service package supports coordination of evacuation plans among the federal, state, and local transportation, emergency, and law enforcement agencies that may be involved in a large-scale

evacuation. All affected jurisdictions (e.g., states and counties) at the evacuation origin, evacuation destination, and along the evacuation route are informed of the plan. Information is shared with traffic management agencies to implement special traffic control strategies and to control evacuation traffic, including traffic on local streets and arterials as well as the major evacuation routes. Reversible lanes, shoulder use, closures, special signal control strategies, and other special strategies may be implemented to maximize capacity along the evacuation routes. Transit resources play an important role in an evacuation, removing many people from an evacuated area while making efficient use of limited capacity. Additional shared transit resources may be added and managed in evacuation scenarios. Resource requirements are forecast based on the evacuation plans, and the necessary resources are located, shared between agencies if necessary, and deployed at the right locations at the appropriate times.

### PS14 Disaster Traveler Information

This service package uses ITS to provide disaster-related traveler information to the general public, including evacuation and reentry information and other information concerning the operation of the transportation system during a disaster. This service package collects information from multiple sources including traffic, transit, public safety, emergency management, shelter provider, and travel service provider organizations. The collected information is processed and the public is provided with real-time disaster and evacuation information using ITS traveler information systems.

A disaster will stress the surface transportation system since it may damage transportation facilities at the same time that it places unique demands on these facilities to support public evacuation and provide access for emergency responders. Similarly, a disaster may interrupt or degrade the operation of many traveler information systems at the same time that safety-critical information must be provided to the traveling public. This service package keeps the public informed in these scenarios, using all available means to provide information about the disaster area including damage to the transportation system, detours and closures in effect, special traffic restrictions and allowances, special transit schedules, and real-time information on traffic conditions and transit system performance in and around the disaster.

This service package also provides emergency information to assist the public with evacuations when necessary. Information on mandatory and voluntary evacuation zones, evacuation times, and instructions are provided. Available evacuation routes and destinations and current and anticipated travel conditions along those routes are provided so evacuees are prepared and know their destination and preferred evacuation route. Information on available transit services and traveler services (shelters, medical services, hotels, restaurants, gas stations, etc.) is also provided. In addition to general evacuation information, this service package provides specific evacuation trip planning information that is tailored for the evacuee based on origin, selected destination, and evacuee-specified evacuation requirements and route parameters.

## Support

### SU01 Connected Vehicle System Monitoring and Management

This service package provides monitoring, management and control services necessary to other applications and/or devices operating within the Connected Vehicle Environment. This service package maintains and monitors the performance and configuration of the connected vehicle system. This

includes tracking and management of the infrastructure configuration as well as detection, isolation, and correction of infrastructure service problems. It also includes monitoring of performance of the infrastructure and mobile equipment, which includes RSEs, OBEs, the back office applications, as well as the communication links that connect the system.

### SU07 ITS ~~Communications Existing~~Communications Existing

This service package provides secure, reliable communications between ITS devices. It provides the layered protocols and communications services and includes the physical network plant and network hardware that supports ITS communications. It also encompasses security services that protect communications and preserve privacy, and the management services that support network management.

## Traveler Information

### TI01 Broadcast Traveler Information

This service package provides a digital broadcast service that disseminates traveler information to all equipped travelers within range. It collects traffic conditions, advisories, general public transportation, toll and parking information, incident information, roadway maintenance and construction information, air quality and weather information, and broadcasts the information to travelers using technologies such as FM subcarrier, satellite radio, cellular data broadcasts, and Internet streaming technologies.

This service package also provides location-specific or situation-relevant information to travelers in vehicles using Dedicated Short Range Communications (DSRC) infrastructure supporting mobility service packages for connected vehicles. DSRC is used to deliver real-time traveler information including travel times, incident information, road conditions, and emergency traveler information to vehicles as they pass connected vehicle roadside equipment along their route. This service package provides public information that is available to all equipped vehicles in the vicinity of the roadside equipment.

### TI02 Personalized Traveler Information

This service package provides tailored information in response to a traveler request. Both real-time interactive request/response systems and information systems that "push" a tailored stream of information to the traveler based on a submitted profile are supported. The traveler can obtain current information regarding traffic conditions, roadway maintenance and construction, transit services, ride share/ride match, parking management, detours and pricing information. Although the Internet is the predominate network used for traveler information dissemination, a range of two-way wide-area wireless and fixed-point to fixed-point communications systems may be used to support the required data communications with the traveler. A variety of interactive devices may be used by the traveler to access information prior to a trip or en route including phone via a 511-like portal and web pages via smart phone, tablet, personal computer, and a variety of in-vehicle devices.

## Traffic Management

### TM01 Infrastructure-Based Traffic Surveillance

This service package includes traffic detectors, other surveillance equipment, the supporting field equipment, and Center to Field communications to transmit the collected data back to the Traffic Management Center. The derived data can be used locally such as when traffic detectors are connected

directly to a signal control system or remotely (e.g., when a CCTV system sends data back to the Traffic Management Center). The data generated by this service package enables traffic managers to monitor traffic and road conditions, identify and verify incidents, detect faults in indicator operations, and collect census data for traffic strategy development and long range planning. The collected data can also be analyzed and made available to users and the Traveler Information Center physical object.

### TM02 Vehicle-Based Traffic Surveillance

This service package uses probe data information obtained from vehicles in the network to support traffic operations, including incident detection and the implementation of localized operational strategies. Since traffic data is collected from vehicles, travel times and other related traffic performance measures are available. This service package includes the capability to collect data from Connected Vehicles so that "probe" data can be collected from all equipped vehicles, providing access to a large vehicle population as penetration increases. Incident detection enables transportation agencies to determine the location of potential incidents so the agencies can respond more quickly to the incident and mitigate any negative impacts to the transportation network. Vehicle data that can be used to detect potential incidents include changes in vehicle speeds indicating the disruption of traffic flow, when a vehicle's safety systems have been activated or deployed, or sudden vehicle turns or deceleration at a specific location (indicating a potential obstacle in the roadway).

### TM06 Traffic Information Dissemination

This service package provides driver information using roadway equipment such as dynamic message signs or highway advisory radio. A wide range of information can be disseminated including traffic and road conditions, closure and detour information, travel restrictions, incident information, and emergency alerts and driver advisories. This package provides information to drivers at specific equipped locations on the road network. Careful placement of the roadway equipment provides the information at points in the network where the drivers have recourse and can tailor their routes to account for the new information. This package also covers the equipment and interfaces that provide traffic information from a traffic management center to the media (for instance via a direct tie-in between a traffic management center and radio or television station computer systems), Transit Management, Emergency Management, and Transportation Information Centers. A link to the Maintenance and Construction Management Center allows real time information on road/bridge closures and restrictions due to maintenance and construction activities to be disseminated.

### TM08 Traffic Incident Management System

This service package manages both unexpected incidents and planned events so that the impact to the transportation network and traveler safety is minimized. The service package includes incident detection capabilities through roadside surveillance devices (e.g. CCTV) and through regional coordination with other traffic management, maintenance and construction management and emergency management centers as well as rail operations and event promoters. Information from these diverse sources is collected and correlated by this service package to detect and verify incidents and implement an appropriate response. This service package supports traffic operations personnel in developing an appropriate response in coordination with emergency management, maintenance and construction management, and other incident response personnel to confirmed incidents. The response may include traffic control strategy modifications or resource coordination between centers. Incident response also includes presentation of information to affected travelers using the Traffic Information

Dissemination service package and dissemination of incident information to travelers through the Broadcast Traveler Information or Interactive Traveler Information service packages. The roadside equipment used to detect and verify incidents also allows the operator to monitor incident status as the response unfolds. The coordination with emergency management might be through a CAD system or through other communication with emergency personnel. The coordination can also extend to tow trucks and other allied response agencies and field service personnel. This service package is closely related with the Public Safety service packages, which focus on services that support first responders. In particular, local management of the incident using an incident command system is covered by PS02.

### TM12 Dynamic Roadway Warning

This service package includes systems that dynamically warn drivers approaching hazards on a roadway. Such hazards include roadway weather conditions, road surface conditions, traffic conditions including queues, obstacles or animals in the roadway and any other transient event that can be sensed. These dynamic roadway warning systems can alert approaching drivers via warning signs, flashing lights, in-vehicle messages, etc. Such systems can increase the safety of a roadway by reducing the occurrence of incidents. The system can be centrally monitored and controlled by a traffic management center or it can be autonomous.

### TM19 Roadway Closure Management

This service package closes roadways to vehicular traffic when driving conditions are unsafe, maintenance must be performed, and other scenarios where access to the roadway must be prohibited. The service package includes automatic or remotely controlled gates or barriers that control access to roadway segments including ramps and traffic lanes. Remote control systems allow the gates to be controlled from a central location or from a vehicle at the gate/barrier location, improving system efficiency and reducing personnel exposure to unsafe conditions during severe weather and other situations where roads must be closed. Surveillance systems allow operating personnel to visually verify the safe activation of the closure system and driver information systems (e.g., DMS) provide closure information to motorists in the vicinity of the closure. The equipment managed by this service package includes the control and monitoring systems, the field devices (e.g., gates, warning lights, DMS, CCTV cameras) at the closure location(s), and the information systems that notify other systems of a closure. This service package covers general road closure applications; specific closure systems that are used at railroad grade crossings, drawbridges, reversible lanes, etc. are covered by other Traffic Management service packages.

### TM20 Variable Speed Limits

This service package sets variable speed limits along a roadway to create more uniform speeds, to promote safer driving during adverse conditions (such as fog), and/or to reduce air pollution. Also known as speed harmonization, this service monitors traffic and environmental conditions along the roadway. Based on the measured data, the system calculates and sets suitable speed limits, usually by lane. Equipment over and along the roadway displays the speed limits and additional information such as basic safety rules and current traffic information. The system can be centrally monitored and controlled by a traffic management center or it can be autonomous.

### TM23 Border Management Systems

This service package provides international border crossing management for passenger vehicles and other non-commercial travelers crossing the border. This service package manages traffic at the border crossing, provides technology to support expedited processing of trusted travelers, and collects and disseminates border wait times.

### TM25: Wrong Way Vehicle Detection and Warning

This service package detects wrong way vehicles on the main roadway and at the exit of divided freeways, tunnels, and bridges. Wrong way vehicle drivers are immediately warned. If the driver continues onto the roadway, warnings are issued to oncoming drivers of the wrong way entry and traffic management and public safety centers are notified.

## Vehicle Safety

### VS02 V2V Basic Safety

This service package exchanges basic safety messages with surrounding Connected Vehicles to support and augment the safety warning and control automation features identified in VS01. These exchanges support Connected Vehicle safety applications defined in SAE J2945/1: Emergency Electronic Brake Lights, Forward Crash Warning, Blind Spot Warning/Lane Change Warning, Intersection Movement Assist, Left Turn Assist, and Control Loss Warning. It also supports Do Not Pass Warning, Motorcycle Approaching indication, Tailgating Advisory, Stationary Vehicle, and Pre-Crash Actions applications from CVRIA.

### VS03 Situational Awareness

This service package shares information about potentially hazardous road conditions or road hazards with other vehicles to support enhanced driver warnings and control automation. Vehicles broadcast relevant road condition information that is collected by the vehicle, such as fog or icy roads. This service package supports the capability for connected vehicles to share situational awareness information even in areas where no roadside communications infrastructure exists. It can be useful to vehicles that are not fully equipped with sensors, or vehicles entering an area with hazardous conditions. Roadside communications infrastructure, if available, can extend the situational awareness range to cover wrong way vehicles where closing rates can require notification beyond DSRC communications range.

### VS07 Road Weather Motorist Alert and Warning

This service package collects road weather data from connected vehicles and uses that data to develop short term warnings or advisories that can be provided to individual motorists. The information may come from either vehicles operated by the general public and commercial entities (including passenger cars and trucks) or specialty vehicles and public fleet vehicles (such as snowplows, maintenance trucks, and other agency pool vehicles). The raw data will be processed in a controlling center to generate road segment-based data outputs. The processing will also include a road weather motorist alerts algorithm to generate short time horizon alerts that will be pushed to user systems and available to commercial service providers. In addition the information collected can be combined with observations and forecasts from other sources to provide medium (next 2-12 hours) or long term (more than 12 hours) advisories through a variety of interfaces including web based and connected vehicle based interfaces.

### VS11 Oversize Vehicle Warning

This service package uses external measurements taken by the roadside infrastructure, and transmitted to the vehicle, to support in-vehicle determination of whether an alert/warning is necessary. Specifically, the infrastructure data equipment detects and measures the approaching vehicle's height and width. The infrastructure component of the service package transmits the vehicle measurements, along with bridge, overpass, or tunnel geometry, to the oversize vehicle. The vehicle application utilizes this data to determine whether the vehicle can clear the bridge or tunnel. If deemed necessary, the driver is alerted to the impending low height and/or narrow horizontal clearance bridge or tunnel prior to a decision point, enabling the vehicle to reroute and avoid a collision. If the driver ignores the alert and continues along the route, the vehicle will generate a warning indicating an impending collision at a point near the bridge or tunnel approach. To support unequipped vehicles the infrastructure will display warning or reroute information when the measurements indicate that a vehicle does not have adequate height or width clearance. This service package can be expanded to consider weight as well as height and width.

### VS13 Intersection Safety Warning and Collision Avoidance

This service package enables a connected vehicle approaching an instrumented signalized intersection to receive information from the infrastructure regarding the signal timing and the geometry of the intersection. The vehicle uses its speed and acceleration profile, along with the signal timing and geometry information to determine if it appears likely that the vehicle will be able to pass safely through the intersection without violating the signal or colliding with other vehicles. If the vehicle determines that proceeding through the intersection is unsafe, a warning is provided to the driver and/or collision avoidance actions are taken, depending on the automation level of the vehicle.

## Weather

### WX01 Weather Data Collection

This service package collects current road and weather conditions using data collected from environmental sensors deployed on and about the roadway. It also collects data from vehicles in the road network that can be used to directly measure or infer current environmental conditions. It leverages vehicle on-board systems that measure temperature, sense current weather conditions (rain and sun sensors) and also can monitor aspects of the vehicle operational status (e.g., use of headlights, wipers, and traction control system) to gather information about local environmental conditions. In addition, environmental sensor systems located on Maintenance and Construction Vehicles are also potential data sources. The collected environmental data is used by the Weather Information Processing and Distribution service package to process the information and make decisions on operations. The collected environmental data may be aggregated, combined with data attributes and sent to meteorological systems for data qualification and further data consolidation. The service package may also request and receive qualified data sets from meteorological systems.

### WX02 Weather Information Processing and Distribution

This service package processes and distributes the environmental information collected from the Weather Data Collection service package. This service package uses the environmental data to detect environmental hazards such as icy road conditions, high winds, dense fog, etc. so operational centers and decision support systems can make decision on corrective actions to take. The continuing updates

of road condition information and current temperatures can be used to more effectively deploy road maintenance resources, issue general traveler advisories, issue location specific warnings to drivers using the Traffic Information Dissemination service package, and aid operators in scheduling work activity.

### WX03 Spot Weather Impact Warning

This service package will alert drivers to unsafe conditions or road closure at specific points on the downstream roadway as a result of weather-related impacts, which include, but are not limited to high winds, flood conditions, ice, or fog. The service packages is designed to use standalone weather systems to warn drivers about inclement weather conditions that may impact travel conditions. Real time weather information is collected from fixed environmental sensor stations and vehicle based sensors. The information is processed to determine the nature of the alert or warning to be delivered and then communicated to connected vehicles. If the warning includes road closure then diversion information can be provided. For non-equipped vehicles the alerts or warnings will be provided via roadway signage. In addition, the roadway equipment may calculate the appropriate speed for current weather conditions and provide this information to the connected vehicle or on roadway signage.