Connected Vehicle Pilot Deployment Program Phase 1, Concept of Operations (ConOps), ICF/Wyoming

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15. Supplementary Notes

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16. Abstract

The Wyoming Department of Transportation's (WYDOT) Connected Vehicle (CV) Pilot Deployment Program is intended to develop a suite of applications that utilize vehicle to infrastructure (V2I) and vehicle to vehicle (V2V) communication technology to reduce the impact of adverse weather on truck travel in the I-80 corridor. These applications support a flexible range of services from advisories, roadside alerts, parking notifications and dynamic travel guidance. Information from these applications are made available directly to the equipped fleets or through data connections to fleet management centers (who will then communicate it to their trucks using their own systems). The pilot will be conducted in three Phases. Phase I includes the planning for the CV pilot including the concept of operations development. Phase II is the design, development, and testing phase. Phase III includes a real-world demonstration of the applications developed as part of this pilot).

This document presents the concept of operations (ConOps) for the pilot program. The ConOps is a user-oriented document that describes system characteristics for a proposed system from the users' viewpoint. The ConOps has been drafted to communicate the users' needs for and expectations of the proposed system that utilizes vehicle to vehicle and vehicle to infrastructure connectivity to address adverse weather challenges along the I-80 corridor in Wyoming. The ConOps was developed through an intense process of stakeholder engagement and is consistent with the Connected Vehicle Reference Implementation Architecture (CVRIA). In general, the ConOps follows the template recommended by the IEEE Std 1362™-1998 (R2007) but outputs from the Systems Engineering Tool for Intelligent Transportation (SET-IT) are included directly where appropriate. The ConOps will be the guiding document for subsequent planning activities in Phase I including security, safety, human-use and performance management plan development.

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Table of Contents

List of Figures

List of Tables

1 Scope

Wyoming Department of Transportation (WYDOT) is one of the first wave of Connected Vehicle (CV) Pilot sites selected to showcase the value of and spur the adoption of Connected Vehicle Technology in the United States. Connected Vehicle Technology is a broad term to describe the applications and the systems that take advantage of vehicle to vehicle (V2V) and vehicle to infrastructure (V2I) communications to improve safety, mobility and productivity of the users of the nation's transportation system.

As one of the three selected pilots, WYDOTis focusing on improving safety and mobility by creating new ways to communicate road and travel information to commercial truck drivers and fleet managers along the 402 miles of Interstate 80 (I-80 henceforth) in the State. For the pilot project, WYDOT will work in a planning phase through September 2016. The deployment process will happen in the second phase (ending in September 2017) followed by an eighteen-month demonstration period in the third phase (starting in October 2017).

Systems and applications developed in the pilot will enable drivers to have 360-degree awareness of hazards and situations they cannot even see. Specifically, WYDOT hopes to improve operations on the corridor especially during periods of adverse weather and when work zones are present. Through the anticipated outcomes of the pilot, fleet managers will be able to make better decisions regarding their freight operations on I-80, truckers will be made aware of downstream conditions and provided guidance on parking options as they travel the corridor, and automobile travelers will receive improved road condition and incident information through various existing and new information outlets.

1.1 Identification

This document presents a Concept of Operations (ConOps) for the **WYDOT Connected Vehicle Pilot System**. The ConOps describes the proposed system as seen and understood by the stakeholders of interest. The ConOps is based on information gathering effort and a ConOps development workshop, which helped to identify user needs for the system.

1.2 Document Overview

The document is organized to closely mirror the template suggested by IEEE Guide for Information Technology—System Definition—Concept of Operations (ConOps) Document (2007). The purpose of this ConOps is to:

- Capture and document user needs as they relate to pilot demonstration along the I-80 corridor in Wyoming
- Describe the proposed system and applications froma user point of view.

This ConOps does not specify how but rather what should be achieved with a focus on the user needs, the enhancements to current practice enabled by the CV technology, the functionality desired to meet the user needs, and impacts during the development phase. The descriptions of user needs and functionality in this document will be used to develop the system requirements and ultimately drive the design and development of the system.

The primary intended audience of this ConOps document includes stakeholders who work collaboratively today to manage the corridor of interest as well as stakeholders who will become necessary to enable CV technology adoption. These include: WYDOT agency personnel involved in transportation systems management and operations, fleet managers and commercial vehicle operators, fleet management system vendors, equipment vendors, truck drivers, third party application developers, city and local emergency management personnel and the weather service providers. Secondarily, U.S DOT and their team will find the document useful to develop an impact assessment approach that documents the observed benefits and the lessons learned from the pilot project.

The remainder of this document consists of the following sections and content:

- Section 2 (Referenced Documents) describes the external documentation referenced throughout this document.
- Section 3 (Current System or Situation) describes the current situation regarding operations on the corridor
- Section 4 (Justification for and Nature of Changes) describes deficiencies of the existing situation specifically as it relates to the needs of the users of the I-80 corridor.
- Section 5 (Concept for the Proposed System) describes the proposed system and functionality required to meet the user needs and the changes identified in Section 4. This section will describe the key features, the users, and their interaction with the system.
- Section 6 (Operational Scenarios) provide a user-oriented description of how the system works for given contexts and conditions.
- Section 7 (Summary of Impacts) describes the operational impacts of the proposed system on the users, the developers, the maintenance organizations, and the support organizations.
- Section 8 (Analysis of the Proposed System) describes the benefits, limitations, advantages, disadvantages, and trade-offs considered for the system.
- Section 9 (Notes) provides definitions for terms, acronyms, and abbreviations used throughout the document.

1.3 System Overview

As stated earlier, the pilot is intended to develop a suite of applications that utilize V2V and V2I technology to improve truck safety and reduce the impact of adverse weather on, but not limited to, truck travel in the Interstate 80 (I-80 henceforth). Specifically, this pilot will target the 402 mile stretch of I-80 that passes through Wyoming's Maintenance Districts 1 and 3 and will be demonstrated for an eighteen month period in 2017-2018.

Through the pilot, relevant information are made available directly and shared between equipped fleets. Information is also shared through linkages with fleet management centers (who will then

communicate it to their trucks using their own radio systems). The focus on commercial vehicles for the pilot is due to the following reasons:

- Trucks traveling through Wyoming, especially on the I-80 corridor, face real danger during adverse weather. Reducing truck-related incidents can have a dramatic impact on passenger travel as well.
- Truck traffic, which is growing both as a result of the local economy and national trends, depend on the I-80 corridor heavily and have limited and non-ideal alternatives.
- While trucks today are a highly connected vehicle with a significant portion having in-vehicle displays and cellular connectivity with their dispatch centers, adding the ability to relay highly-localized notifications through dedicated short-range communications (DSRC) provides improved situational awareness to drivers when and where they need it most.
- Supporting the applications and the CV environment of roadside, vehicle and back-office infrastructure are core services that allow safe, secure, reliable operations of the system.

1.3.1 System Objects

The following objects are of interest to the system:

- Vehicles – Four categories of vehicles will play a role in the pilot.
  - WYDOT Fleet –This group represents vehicles owned by WYDOT (such as snow plows, highway patrol vehicles and other state-owned vehicles) that will be equipped with on-board equipment (OBE) with DSRC connectivity. The OBE will support communications, generate safety messages, collect and report vehicle, weather and road condition data, store data and provide an interface to communicate safety alerts and advisories. WYDOT fleets also have cellular connectivity with WYDOT centers to support operations
  - Connected Truck – This group represents vehicles owned by commercial vehicle operators that are participating in the pilot. These trucks will be equipped with an OBE with similar functions and capabilities as described for the WYDOT fleet. Similar to WYDOT fleets, connected trucks may have cellular connectivity to their fleet management centers.
  - Private Vehicle – This group of vehicles represent private vehicles who have access to third-party applications on their personal information device
  - Truck – This group of vehicles represent trucks that are connected to fleet management centers but are not equipped with an OBE for this project.
- Infrastructure – Two infrastructure elements are part of the pilot
  - WYDOT Traditional ITS – This object group includes the existing Intelligent Transportation System (ITS) program devices like 511, Dynamic Message Signs (DMS), Highway Advisory Radios (HAR)
  - WYDOT Roadside Equipment (RSE) – This object describes the roadside equipment that will be deployed as part of the system. RSEs include DSRC connectivity, application support, data storage, and other support services to enable CV

applications. WYDOT RSEs can be either fixed or portable equipment depending on the use-case.

- Centers/Systems – Three major centers and systems are part of the pilot.
  - WYDOT Transportation Management Center (TMC) – The TMC is planned to be the hub of operations for the CV Pilot collecting information from WYDOT fleet, and partnering fleet management centers. The TMC supports the integration and fusion of CV and non-CV data to developing warnings and advisories. The TMC also provides traveler information services back to the general public and fleet management centers via various means. The TMC is also responsible for various system services that are necessary for the pilot.
  - Fleet Management Centers – This object represents the partnering fleet management centers that both receive and send real-time information to the WYDOT TMC about their firm's truck operations and corridor conditions.
  - Data Warehouse – A data warehouse capability is planned for the pilot to collect, manage and make available the data collected as part of the pilot for performance management and evaluation.
- External Systems
  - Third Party Information Service Providers (ISPs) – This object represents third-party developers of data and information products for both WYDOT and the end-consumer. These may include weather products that are used by WYDOT TMC to driver-focused applications that use data from the TMC.
  - WYDOT Maintenance Management – This object represents the WYDOT maintenance management systems and functions carried out in the corridor including winter maintenance, work zone management and other non-winter maintenance activities.
  - WYDOT Commercial Vehicle Enforcement- This object represents WYDOT commercial vehicle operations enforcement in the corridor including Port of Entry operations, permitting, and oversize/overweight enforcement.
  - Truck Parking Services – This object represents the public and private parking services available in the corridor.
  - National Weather Service – This object represents the systems and personnel of the National Weather Service (NWS) offices in Wyoming for the I-80 corridor.
  - Adjacent State DOT TMCs – This object represents the systems and personnel at adjacent State DOTs (Colorado, Utah and Nebraska) necessary for coordinated response to conditions on I-80.

1.3.2 Context Diagram and Proposed System Functionality

The context diagram described in Figure 1-1 support various applications that provide actionable information to drivers on I-80. System capabilities are organized by two categories – the pilot system which describes the center-related capabilities and the mobile distribution system which describes the capabilities relating to field to vehicle and vehicle to vehicle interactions. The system, comprising of the pilot system and the mobile distribution element provides the following capabilities.

- Pilot System – Collect Road and Weather Data- The system shall collect road and weather data froma variety of sources including connected trucks, connected WYDOT fleets, fixed infrastructure sensors like RWIS, National Weather Service, maintenance personnel and adjacent State DOTs. The data collected include both directly observed road and weather conditions or other data (such as vehicle telematics) that will help estimate the conditions of road segments along I-80.
- Pilot System – Collect Work Zone Information- The system shall collect work zone information including location, duration and nature of activity reported by maintenance personnel and centers
- Pilot System – Collect Dynamic Travel Information - The system shall collect dynamic travel information such as travel speeds, parking availability, and incident notifications
- Pilot System – Share Integrated and Fused Advisories - The system shall fuse travel information, road condition data and weather data to generate segment-level advisories along I-80. The system shall share advisories with connected vehicles, fleet management centers, traditional ITS channels like DMS/HAR/511 and to partners like truck parking facilities and adjacent State DOTs
- Pilot System – Provide Dynamic Travel Information - The system shall provide dynamic travel information to both vehicles on-road as well as over a wide area to support travel decisions. Dynamic travel information may relate to variable speed limits, road closures, and truck parking availabilities.
- Mobile Distribution – Share Safety and Road Condition Messages - The mobile distribution aspect of the system shall share safety and road condition messages between connected vehicles and between vehicles and the roadside infrastructure. Safety and road condition information shared by connected vehicles to other connected vehicles include situational awareness of downstream conditions, speeds, information on slowing traffic or queues. This information will also be relayed to roadside equipment when connected vehicles pass them in the corridor.
- Mobile Distribution – Collect Messages from Other Connected Vehicles - Connected vehicles shall collect messages from other connected vehicles about situational awareness of conditions and provide the information to the driver in a meaningful format.
- Mobile Distribution – Collect Messages from Infrastructure - Connected vehicles and the pilot system shall collect messages from infrastructure about advisories and alerts including speeds, parking availability, upcoming travel conditions and provide the information to the driver in a meaningful format.
- Mobile Distribution – Generate Emergency Message - Connected vehicles shall have the capability to generate an emergency message while on travel on the I-80 corridor when conditions warrant such a message from that vehicle or about other emergency conditions on the corridor observed by the vehicle.

Where necessary, DSRC Communications will be used to support localized warnings to equipped vehicles as part of the mobile distribution system. This means when connected trucks or WYDOT fleet vehicles approach slowed or stopped traffic, they can receive messages in their vehicle from other equipped vehicles ahead of them to give more reaction time. Or if equipped vehicles pass roadside devices, drivers can receive messages alerting them to hazardous road conditions, crashes ahead, construction zone information, parking recommendations, or other road and travel information. If the

equipped vehicle is stranded, the vehicle can send out an emergency notification to the appropriate center for assistance. The use of DSRC technology in the pilot will be guided by the IEEE 1609.2, 1609.3, and 1609.4 standards for Security, Network Services and Multi-Channel Operation (IEEE, 2013, IEEE, 2010a; IEEE, 2010b), the SAE J2735 Message Set Dictionary (SAE, 2015a), the emerging SAE J2945.1 Communication Minimum Performance Requirements standard (SAE, 2015b). Relevant sections from SAE J3067 (SAE 2014) Information Report will also be reviewed as part of systems development. Weather data collection will also be guided by NTCIP 1204.

The system capabilities and functioned described in the previous paragraphs are implemented through the following seven applications:

- Road Weather Advisories for Trucks - This application provides the capability of collecting road weather data from WYDOT Fleets and Connected Trucks and using that data to develop short term warnings or advisories that can be provided to individual commercial vehicles or to commercial vehicle dispatchers.
- Automatic Alerts for Emergency Responders - This application provides the capability for connected trucks to transmit an emergency message when the vehicle has been involved in a crash or other distress situation.
- CV-enabled Weather-Responsive Variable Speed Limits - This application uses road weather information from connected trucks and WYDOT Fleet vehicles as well as current and historical data from multiple sources to determine the appropriate current safe speed and other traffic management strategies.
- Spot Weather Impact Warning - This application will alert drivers to unsafe conditions or road closure at specific points on the downstream roadway as a result of weather-related impacts (e.g., high winds, flood conditions, ice, and fog).
- Work Zone Warnings - This application provides information about the conditions that exist in a work zone to vehicles that are approaching the work zone.
- Situational Awareness - The application determines if the road conditions measured by other vehicles represent a potential safety hazard for the vehicle containing the application.
- Freight-Specific Dynamic Travel Planning- This application provides both pre-trip and en-route travel planning, routing, and commercial vehicle related traveler information for fleet management centers

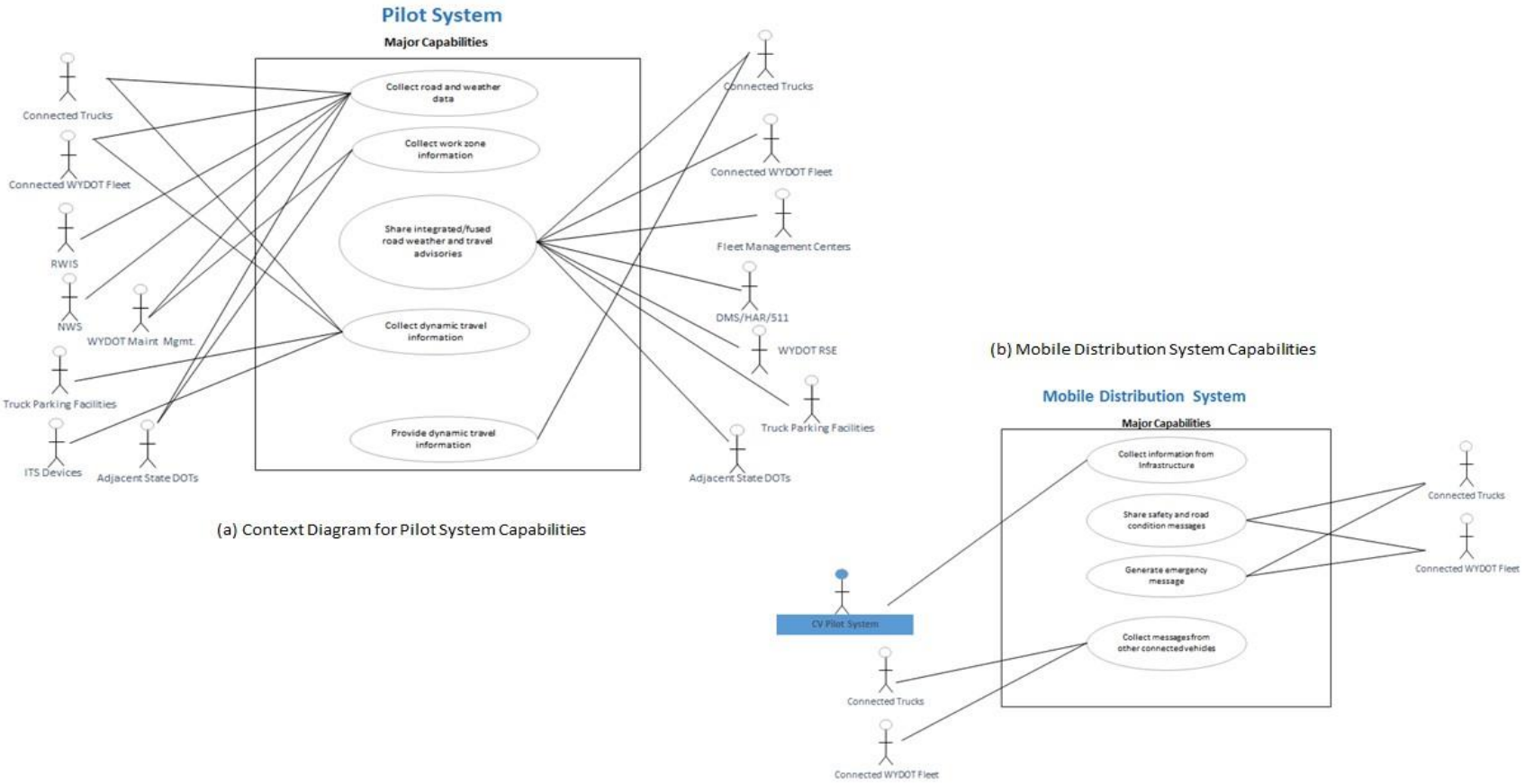

Figure 1-1. Context Diagram for the CV Pilot (Source: ICF/Wyoming)

2 References

The following table lists the documents, sources and tools used to develop the concepts in this document.

Table 2-1. References

#	Documents, Sources Referenced
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3 Current Situation

The Interstate system serves as a vital transportation network across the United States that is closely tied with the economic well-being of the country. In some states, the long distance freight travel served by these interstates constitutes a major portion of the traffic stream. These "bridge" states can have an economic influence that far exceeds their population base. Wyoming is an example of such a state[1], where Interstates serve a critical role in the movement of goods across the country and between the United States and Canada and Mexico. This chapter describes I-80 as it currently exists and highlights the problems and challenges that motivates the development of the proposed system.

3.1 Background and Objectives

Since 2010, Wyoming's Gross Domestic Product (GDP) has increased at an average growth rate of 3.22%, significantly higher than the national average Consumer Price Index(CPI) of 2% for the same time period. The mineral extraction industry (i.e., oil, gas, coal, uranium, and trona) is the primary driver of the state's economy. Transportation has and continues to play an important role in such development, accounting for roughly 6% of the State's GDP, where truck transportation[2] contributes approximately 20% (see Figure 3-1). In this sense, Wyoming is positioned as an important freight corridor and is home to some unique recreational opportunities that draw a significant number of visitors. Interstates 80, 90, and 25 serve a critical role in the movement of goods across the country and between the United States, Canada, and Mexico. Specifically, I-80 in southern Wyoming is a major corridor for east/west freight in the northwest part of the country, as shown in Figure 3-2. This corridor is about 402 miles long and averages more than 32 million tons per year (at 16 tons per truck). The truck volume is 30 to 55% of the total traffic stream on an annual basis and can make up as much as 70% of the traffic stream on a seasonal basis (Wyoming DOT, 2013). Furthermore, the elevation of I-80 in Wyoming is all above 6,000 feet, with the highest point reaching 8,640 feet (2,633 m) above sea level at Sherman Summit, near Buford, which is the highest community on I-80.

[1] Wyoming population was estimated at 584,000 in 2014.

[2] Industries in the Truck Transportation NAICS subsector provide over-the-road transportation of cargo using motor vehicles, such as trucks and tractor trailers. The subsector is subdivided into general freight trucking and specialized freight trucking.

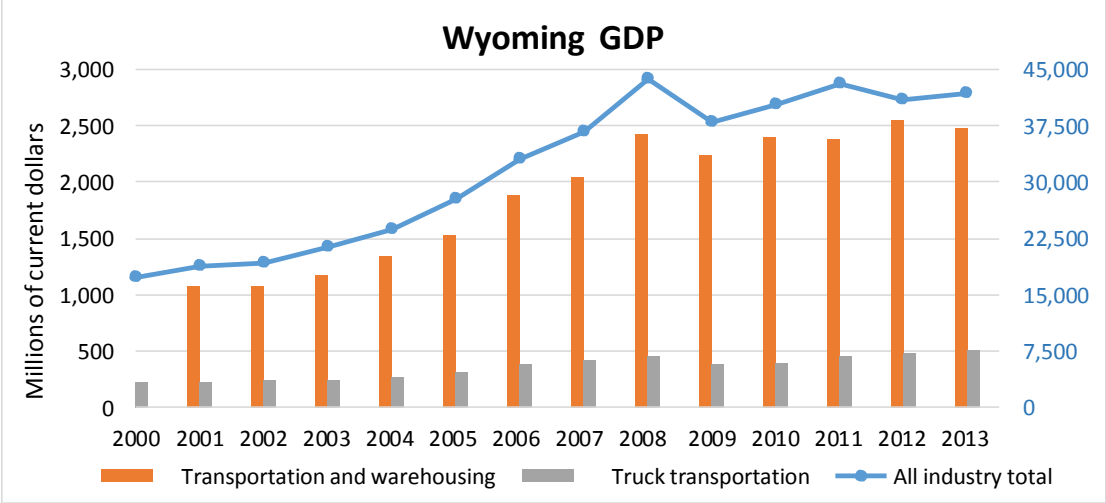


Figure 3-1. Contribution of Truck Transportation to Wyoming's GDP. (Source: U.S. Bureau of Economic Analysis (2014)).

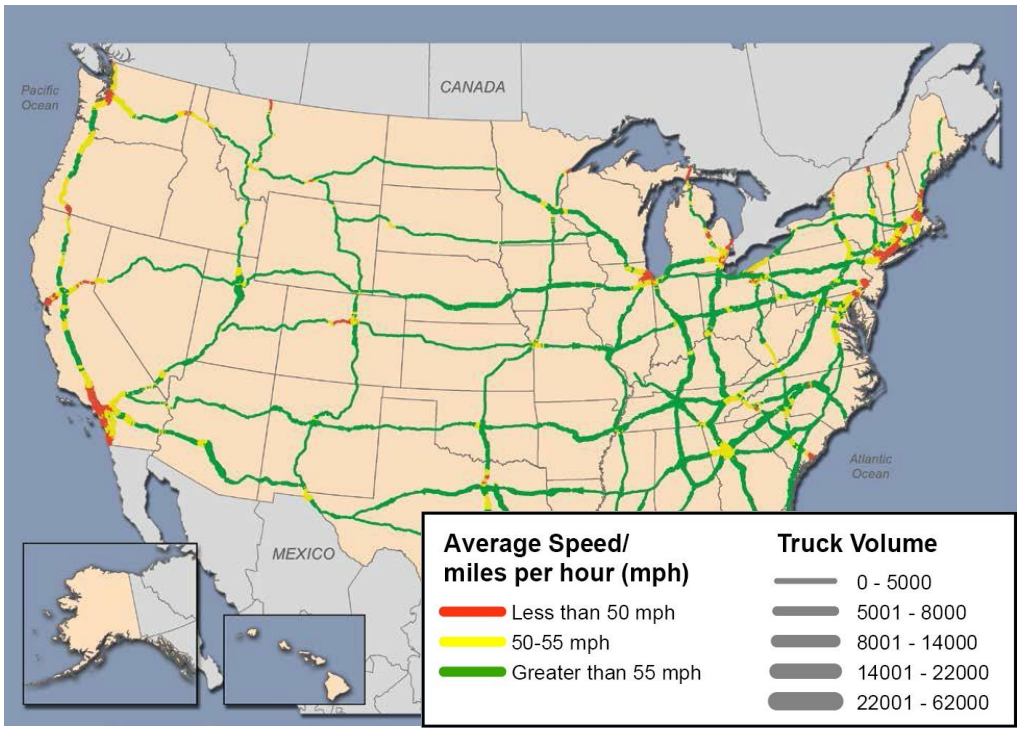


Figure 3-2. Major Freight Corridors in US. (Source: Office of Freight Management and Operations (2013))

The high altitude along the corridor increases the frequency of severe weather events (e.g., ice and snow covered road surfaces, poor visibility from fog and blowing snow, and high wind events), especially during winter season—between October 1st and May 1st of a given year. As a consequence, freight drivers are more exposed to many of the challenges associated with surface travel, such as incidents, frequent road closures, long distances between service centers, reduced availability of truck parking, and lack of alternative routes. The main concerns and desired objectives of WYDOT are addressed next.

3.1.1 High Incident Rate

Crash rates on Wyoming I-80 vary considerably with the highest total crash rates (above 3 crashes per million vehicle miles traveled) located west of Laramie and on the western edge of the state, near the town of Evanston (Offei & Young, 2012). The winter crash rate (October to April) has been found to be 3 to 5 times as high as the summer crash rates (Saha & Young, 2014a). Figure 3-3 shows the differences between summer and winter crashes for the segment of I-80 west of Laramie, known as Elk Mountain. Wyoming's notorious winds result in the nation's greatest concentration of annual blowing snow events and some of the greatest concentrations of vehicle blow overs in the country[3]. With wind speeds frequently exceeding 30 miles per hour (mph) and wind gusts frequently exceeding 65 mph, truck blowovers are a particular concern for high profile freight vehicles that traverse through Wyoming (Young, Offei, & Dai, 2010). On January 5th, 2015 alone, 18 crashes were attributed to the wind. Current operational practice is to recommend no travel for high profile and lightweight trucks when wind gusts exceed 50 mph and to implement a road closure to these vehicles at gusts of 65 mph or higher.

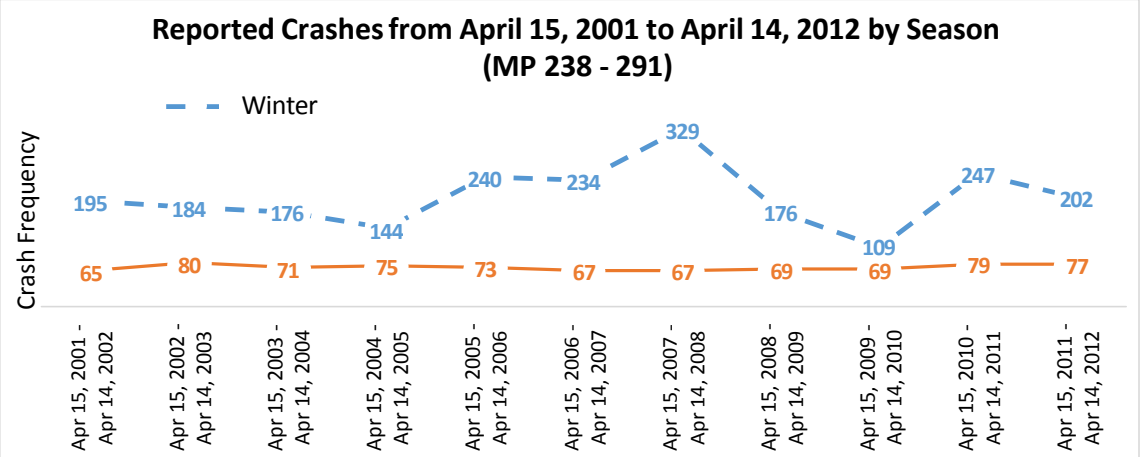


Figure 3-3: Elk Mountain Seasonal Variation of Crash Frequency 2001-2012. (Source: Saha and Young (2014a))

[3] Over 3,470 high-wind crashes have been recorded in the 2002-2012 timeframe.

3.1.2 Economic Impact of Road Closure

Road closures occur when weather conditions and crash hazards become severe and outweigh the significant economic impact these closures cause. For the three years from 2010 to 2012, there were 172 road closures along the Wyoming I-80 corridor. Of these road closures 63% were attributed to weather and another 16% were attributed to weather and crashes (Figure 3-4). For the weather-related closures, the average duration of the closures was over 8 hours long. Based on the analysis performed by Sasha and Young (2014b), considering the truck volume along the corridor and a very conservative value of $370 per truck per hour of closure, there is an economic impact of around $11.7 million per closure. The $370 value considers just the cost associated with the truck being out of service and the driver wage costs. This value would be considerably higher if the impact due to delay of the freight cargo was also considered.

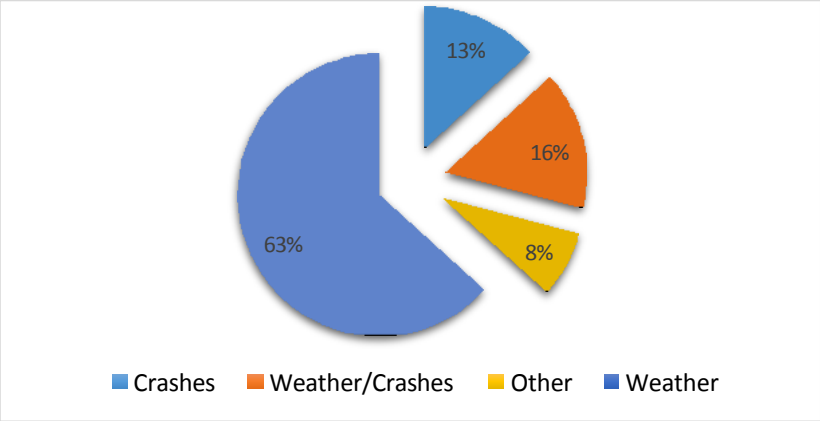


Figure 3-4: Percentage of Road Closures in Mile-hours by Cause, 2010-2012. (Source: Wyoming DOT)

3.1.3 Lack of Service and Parking Locations

The challenges for freight traffic associated with service and parking locations comes from the extremely rural nature of the 402 miles of Wyoming I-80 corridor. Distances between towns along the I-80 corridor range from 60 to 115 miles and typically there are no services between towns[4]. WYDOT has provided truck parking and rest areas in between towns to aid freight traffic in complying with hours of service (HOS) regulations and weather and road closure delays, but it is frequently difficult to find available parking. A WYDOT Truck Parking Study for the I-80 corridor inventoried a truck parking capacity of 3,037 spaces with 18% of those locations being public facilities (e.g., rest areas, truck parking lots, and truck parking turnouts) and the remainder being at private truck service locations. Recent studies have indicated that Wyoming is average in the number of parking spaces provided per 100K Daily Truck Traffic (Office of Freight Management and Operations, 2015). However, this is for

[4] Wyoming Truck Parking Map (2015) http://www.dot.state.wy.us/files/live/sites/wydot/files/shared/Public%20Affairs/Maps/Truck%20parking%20map.pdf

the state as a whole and not specific to I-80. The inability to communicate to drivers the number of available parking spaces is also an issue. Given the heavy truck travel and the frequent road closures and delays along this corridor, lack of available parking is a common occurrence, one that can even extend into adjacent states. During particularly long road closures, the DOTs (Wyoming, Utah, and Nebraska) are sometimes required to extend road closures further upstream to prevent additional trucks from queueing along local streets and highways around interchanges in towns with no available parking capacity. The long distances between reasonable stop locations also becomes an issue when dealing with fast changing weather systems where the roadway conditions can be considerably different at the end of a 60-mile road segment than at the beginning.

3.1.4 Lack of Alternate Routes

With so many challenges to freight traffic the question of alternative routing arises, particularly during road closures. In Wyoming, the highway system beyond the Interstates comprises two-lane rural highways. These highways are unable to handle truck volumes beyond the local freight movement. During extended road closures these two-lane highways are typically closed, along with I-80, to prevent large-scale diversion of freight traffic. Also, these alternate routes are not always built to the same geometric standards as the interstate, increasing the hazards during severe weather events. This leaves the available interstate system to absorb diverted traffic on either Interstate 90 (I-90), approximately 250 miles to the north, or Interstate 70 (I-70), approximately 100 miles to the south, both of which have their own challenges of mountainous terrain and severe weather events. Most freight traffic on I-80 is destined for the central portion of the west (California, Nevada, Utah), as opposed to the northwestern states, so diversion to I-90 through South Dakota and Montana adds considerable travel time to their routes. Diversion to I-70 is better with respect to travel distance but is the most mountainous and is severely congested due to urban traffic in Denver, tourist travel to the Colorado mountain towns and oil and gas development on the western slope of Colorado. The undesirability of diversion to the other interstates can be observed by the willingness of freight trucks to park and wait out the I-80 closures.

3.1.5 Seasonal Constraints

As discussed earlier, the winter crashes on I-80 can be three (3) to five (5) times as high for the six-month period of winter as the six months of summer, but summer travel for freight traffic can have its own challenges stemming from the short, but intense summer construction season. The heavy freight travel on the corridor results in the need for significant maintenance activities which must take place in a relatively short season of moderate weather conditions.

3.1.6 Objectives

I-80's geographic position, with high elevation, combined with its daily freight traffic, provides a safety and economic challenge for Wyoming. The objectives of the Wyoming CV pilot deployment are aimed at addressing these challenges, namely:

Reduce Crash and Road Closure. With respect to safety issues on the corridor, the Wyoming CV pilot deployment aims to continue the crash frequency reduction efforts (e.g., variable speed limit

corridors and improved identification and messaging of hazardous weather conditions). The safety challenge of large multi-vehicle crashes will be a primary safety objective of the pilot deployment. This type of crash requires the real-time connectivity that CV technology can provide to notify drivers of upcoming hazards. The Wyoming CV pilot deployment also hopes to address the frequency and duration of road closures on the corridor through crash reductions and encouraging safer driving behavior.

Improve Emergency Management. Closely related to safety is the management of emergency situations, including large safety events like the multi-car crashes discussed above. The rural nature of the corridor and the extreme weather conditions also make identification of smaller crashes critical since a lone vehicle in a minor crash can become a severe event if the time of exposure to harsh conditions becomes extended. The Wyoming CV pilot deployment has an objective of improving the emergency management of the corridor through early identification of conditions and improved messaging and communication.

Improve Truck Parking. The Wyoming CV pilot deployment has an objective of improving freight driver's ability to locate truck parking locations along the corridor. This objective is safety related as it allows drivers to find safer parking locations in designated areas and to better meet HOS regulatory requirements.

Improve Construction Activity Information. The last objective of the pilot program is improved freight traveler information on construction activities in the corridor. The objective is related to both the safety of the construction zones and the increased efficiency of the freight logistics through improved information for the scheduling of freight movements through the corridor.

3.2 Operational Policies and Constraints

WYDOT's ITS program is geared towards ensuring safety and reliability of travel with an emphasis on the major interstates in Wyoming. Several operational policies and current modes of operation are described in Sections 3.3. In addition, WYDOT shares an operational policy in the form of a Service Level Agreement (SLA) with two other operational divisions that play a critical role in the support of intelligent transportation systems which are used to manage I-80 and other roadways in the State. This SLA defines the priority of devices and the required response times to make repair attempts.

However, WYDOT's most significant constraints relate to manpower issues and budget limitations. It is unlikely that WYDOT's geographic information system (GIS)/intelligent transportation system (ITS) department will be able to create new positions, so any additional workload created as a result of this project must be handled by existing personnel.

3.3 Description of Current Situation

Roadway safety is one of WYDOT's top priorities. To that end, the department operates a Transportation Management Center (TMC) 24 hours a day, 365 days per year to keep the public informed of changing travel conditions. The TMC is the sole source of maintenance dispatching for WYDOT. Operators in the TMC are responsible for statewide maintenance vehicle dispatching,

operating and monitoring ITS devices, obtaining information about road and travel conditions from various sources, and communicating traveler information with the public. For this, TMC operators watch weather conditions via sensors and webcams and they receive reports about crashes, carcasses/debris on the roadway and a multitude of other potential hazards that they relay to maintenance personnel that spurs appropriate action.

WYDOT's roadside ITS infrastructure includes the use of highway advisory radios, dynamic message signs (DMS) and variable speed limit (VSL) zones. I-80 is heavily instrumented with road-weather information systems, web cameras and traffic speed sensors. When operators notice a problem with a device or are notified of a problem by a monitoring software, they inform one of two ITS technicians who are responsible for the repair and maintenance of devices along I-80, as dictated by the SLA.

WYDOT also maintains Weigh-In-Motion (WIM) traffic counting and clarification equipment at five ports of entry throughout the State. These ports of entry are operated twenty-four hours a day.

TMC operators obtain road condition information from a number of different sources, as shown in Figure 3-5. Some of the information sources are also shared directly with the public—data sources marked with a "*" change the Information Output without intervention from the TMC.

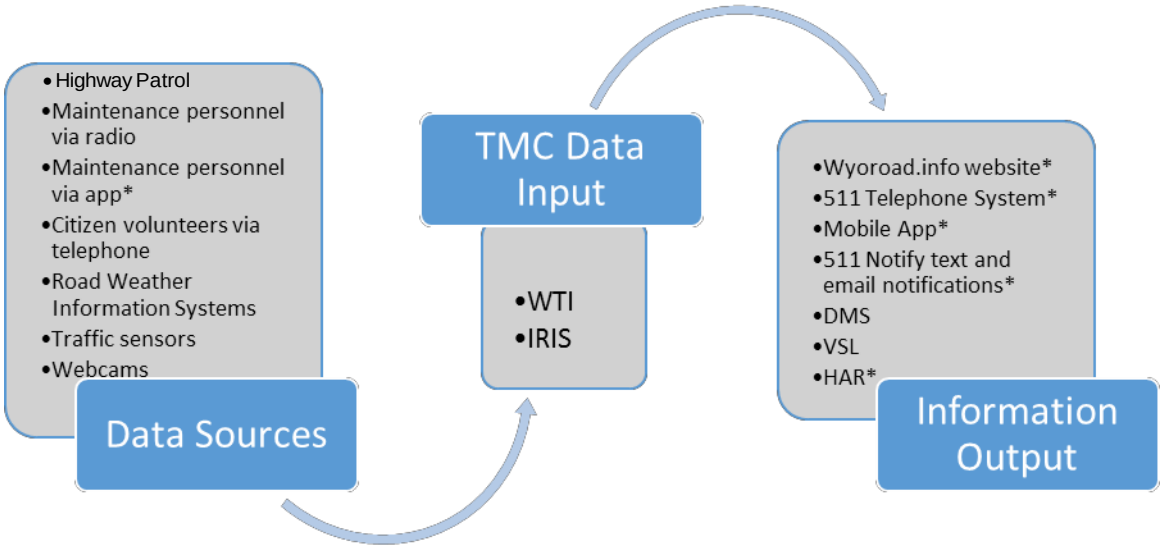


Figure 3-5. TMC's sources of information. (Source: Wyoming DOT)

TMC operators receive information from three primary sources: telephone calls, radio calls, and data feed to the Transportation Reports and Action Console (TRAC), a software program developed by WYDOT that serves as a task list for operators. TRAC currently receives information and informs the TMC about "Call before you dig" requests, conditions reported by the road condition reporting (RCR) app and events from the Wyoming Highway Patrol's computer aided dispatch (CAD) system. Future plans will allow for the TRAC system to receive information from trained volunteer reporters, crowd-sourced information providers such as WAZE, and WYDOT's mobile app.

There are two primary software programs used to disseminate information: i) the Wyoming Travel Information (WTI), a program developed in-house that updates the traveler information website, compiles information to update the 511 phone system, provides information to update Highway Advisory Radios (HARs), sends out text and email notifications; and ii) the Intelligent Roadway Information System (IRIS), which was developed by the Minnesota DOT and modified by WYDOT, which is used to update DMS and VSL signs.

In order to increase security, and because the TMC is co-located with Wyoming Highway Patrol dispatch, all operators must pass a fingerprint-basedbackgroundcheck conducted by the Wyoming Division of Criminal Investigation. Additionally, the TMC systems are all located behind two firewalls that insulate the center from the Internet and from other WYDOT/state users.

3.3.1 Inventory of Assets and Capabilities

Recognizing the challenge faced by travelers on their main interstate through the State, WYDOThas taken a proactive approach to mitigating the impacts of adverse weather. Many of the initiatives and processes are considered best practices in the country and are being replicated by other States. These systems are detailed next.

1. A 24x365 TMC in Cheyenne with a heavy focus on weather management. As discussed earlier, the TMC is collocated with the Wyoming Highway Patrol and utilizes a plethora of roadside ITS devices to monitor weather and traffic conditions.
2. A commercial vehicle operator portal (CVOP) that currently provides forecasted road condition information on common commercial vehicle routes (shown in Figure 3-6). This information focuses on the elements most important to commercial carriers: Forecasted surface conditions, forecasted wind speeds and forecasted visibility estimates. The site is intended to help drivers and dispatchers make decisions like whether a truck should travel ahead of a storm, wait for a storm to pass or choose an alternate route. More than 150 different companies have signed up to be part of this system. The Wyoming Trucking Association has given its support to the project. Currently the CVOP is restricted to forecast information.

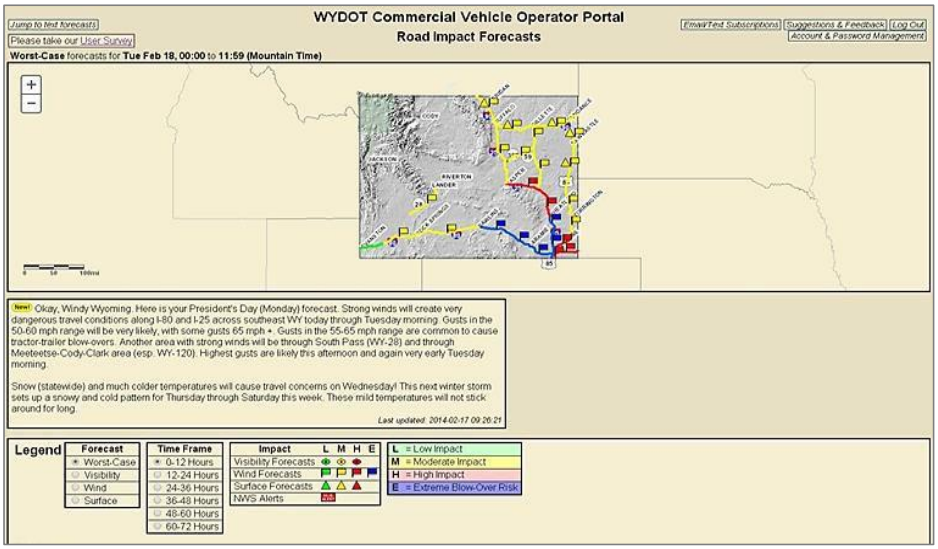


Figure 3-6. CVOP interface. (Source: Wyoming DOT)

3. In 2009, WYDOT started implementing VSL zones along I-80 in order to improve traveler safety. The VSL zones utilize changeable yet enforceable speed limits in 143 miles along four (4) segments; Figure 3-7 shows the locations of these segments. The Elk Mountain Corridor was Wyoming's first VSLsystem in February 2009, whereas the remaining three were implemented in 2011.

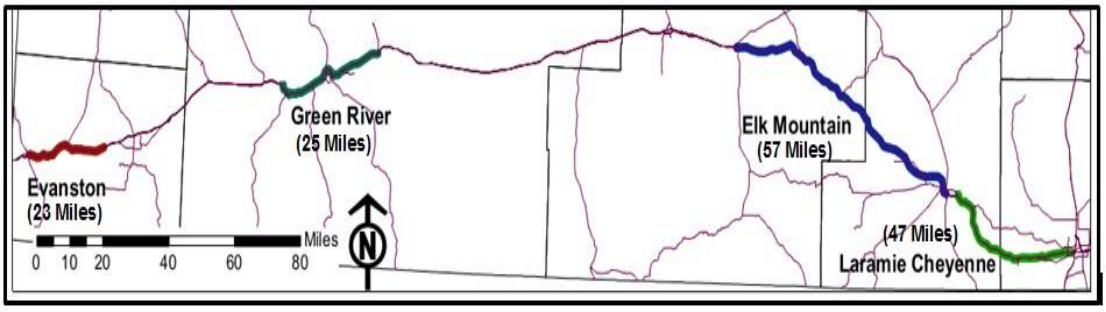


Figure 3-7: Map of Wyoming's VSL Segments. (Source: Wyoming DOT)

4. A secure WyoLink Radio Network throughout the corridor (Figure 3-8). WyoLink is a statewide digital trunked very high frequency (VHF) P-25 compliant public safety communications system. The system is used for voice traffic and secondarily for low-speed mobile data communications; it provides radio service to public safety entities at all levels (city, county, state and federal agencies as well as commercial emergency medical responders and hospitals). The WyoLink system is maintained by WYDOT's Telecommunications Program. Point to point wireless microwave communications are used to communicate between WyoLink radio sites, which also support a parallel IP backhaul

communication system used by intelligent transportation systems. Using point-to-multipoint wireless communications to extend from the backhaul system to roadside service points, GIS/ITS and Telecom have also been able to set up a network of roadside Wi-Fi hotspots along the I-80 and Interstate 25 (I-25) corridors. Using low-cost antennas, WYDOT has been able to achieve Wi-Fi signal range of more than a mile in some locations.

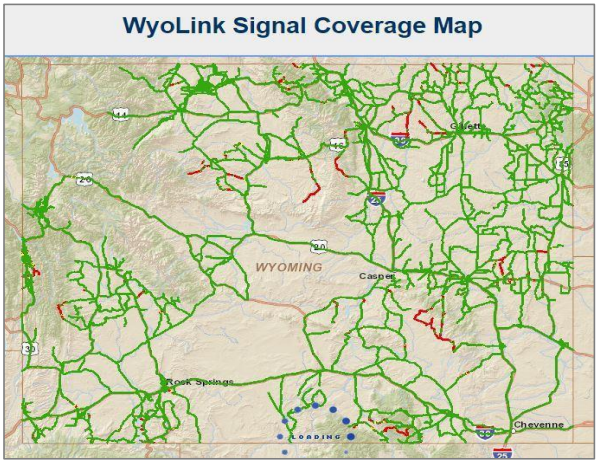


Figure 3-8. WyoLink Coverage Map. (Source: Wyoming DOT)

5. A traveler information system operated by Wyoming. All road condition information is entered into the WTI application by the TMC operator. Upon completing a WTI update, the information is immediately disseminated without manual intervention from the TMC. WYDOT disseminates information through several travel information services: www.wyoroad.info, map.wyoroad.info, 511 Phone system, 511 Notify Text/Email Messaging, CVOP, and Custom Displays for Smart TVs. As of November 2015, there were over 35,000 subscribers to text and email alerts. Of those, 68 percent opened or clicked a link in a bulletin sent within the previous 90 days. Over the 12-month period ending in November, subscribers opened or clicked in a link a bulletin 2 million times.
6. Road impact forecasts are written and updated daily by WYDOT's on-site meteorologist. All forecasts are tailored specifically for commercial vehicles and the common challenges faced by commercial drivers in the state. Weather conditions in Wyoming can vary dramatically based on location and terrain. Hence, all routes have been divided into several forecast sections in order to expose common trouble spots and provide more accurate forecasts with more detail. Forecasts are provided for a 72-hour period, in 12-hour increments for visibility and road surface conditions and in three-hour increments for wind. Each forecast has a specific impact level (low, moderate, or high). Definitions for each forecast type and impact level are provided on the forecast page.
7. A multi-source Road Condition Reporting System. In the winter of 2014-2015, WYDOT piloted a new RCR application for maintenance personnel on I-80 and limited areas of I-25. Funded by a federal Weather Responsive Traffic Management grant, the RCR application is an Android-based mobile application (app) that is being used on 10-inch tablets mounted in

the plows, see Figure 3-9. The app allows maintenance personnel to update WYDOT's public facing traveler information systems directly from the field. Once road condition information is sent through the tablet it immediately enters the database and is disseminated to WYDOT's information systems. Communication with the tablet takes place over the WyoLink Radio Network or Wi-Fi hotspots where available. As part of the contract for app development, WYDOTspecified the agency would own the code so it could be shared with other public agencies.

Figure 3-9. RCR vehicle equipment. (Source: Wyoming DOT).

3.4 Modes of Operation for Current System

WYDOT's TMC operates in several modes that are described below.

Normal Weather Operations – Traffic Management: During normal weather operations, the TMC may be staffed with a contract meteorologist and a balanced mix of less experienced operators and very experienced operators. During the quietest times, this can be as few as two people. All operators are responsible for dispatching maintenance employees, updating road condition and incident reports, and operating roadside intelligent transportation systems. They are also required to check on the health of systems and to create trouble tickets for devices that fail to function properly.

Each shift is also staffed with a floor supervisor, called a "Lead Operator", who is required to provide guidance and expert advice when unusual situations arise. The Lead Operator must be consulted each time a unique weather forecast is delivered via pre-trip and roadside systems.

Normal Operations – Call Before You Dig: During normal operations, the TMC acts to respond to approximately 20,000 "Call before you dig" activities that involve DOT rights of way (ROWs). The TMC is responsible for a system that allows field technicians to receive, investigate and clear the "Call before you dig tickets". Most of the normal operations to call a cleared dig request have been automated.

In the event of an emergency dig request, the TMC must immediately get in touch with responsible people in each district so that utilities can be cleared. This might be necessary when a fiber optic cable is cut or some other critical public utility is affected.

Normal Weather Operations – Work Zone Management: All operators are responsible for dispatching maintenance employees and updating construction zone information. The TMC acts as the central point of contact and will call construction engineers, contractors or sub-contract traffic control personnel in the event of an after-hours need. Each shift is also staffed with a floor supervisor, called a "Lead Operator", who is required to provide guidance and expert advice when unusual work zone situations arise.

Normal Weather Operations – Incident Management: All operators are responsible for responding to incidents, coordinating with the Wyoming Highway Patrol, maintenance employees and any other party that is involved with an incident, and updating all pre-trip and roadside information systems to alert the public in a timely fashion. The TMC acts as the central point of contact for incidents that occur all hours of the day and night. Each shift is also staffed with a floor supervisor, called a "Lead Operator", who is required to provide guidance and expert advice when unusual incidents arise. The Lead Operator is the only person on the floor who is allowed to perform some functions, such as adding phrases to the library for dynamic message signs and handling AMBER Alert functions.

Adverse Weather Operation – Traffic Management: During adverse weather operations, the TMC is staffed with a contract meteorologist and as many as 10 operators and other staff. This can include a balanced mix of less experienced and more experienced operators, quality control personnel, a Lead Operator and one or more engineers. A variety of strategies are possible from the TMC including speed limits, wide area advisories, road closures, vehicle restrictions and lane closures. The TMC uses a very active system of variable speed limits, currently located in six locations around the state, to harmonize traffic. WYDOT's protocol for changing the VSLs allows for maintenance employees, troopers and TMC operators to raise or lower the speed limits. WYDOT uses a research-based algorithm that employs weather sensors and speed sensors to make speed adjustments. Any one of the TMC operators is authorized to recognize and make speed adjustments. During adverse weather, WYDOT TMC updates various traveler information sources through the WTI system such as 511 web/phone, HAR, DMS and an app.

Adverse Weather Operation – Maintenance Management: During adverse weather operations, the TMC is staffed with a contract meteorologist and as many as 10 operators and other staff. This can include a balanced mix of less experienced and more experienced operators, quality control personnel, a Lead Operator and one or more engineers. The TMC is required to monitor environmental sensors, web cameras and speed sensors in an effort to recognize adverse weather conditions and other events that require the attention of maintenance employees. The TMC must then call the responsible maintenance employees so they can go on site to address the problems.

Adverse Weather Operation – Incident Management: All operators are responsible for responding to incidents, coordinating with the Wyoming Highway Patrol, maintenance employees and any other party who is involved with an incident and updating all pre-trip and roadside information systems to alert the public in a timely fashion. The TMC acts as the central point of contact for after-hour incidents and reports major incidents to the Federal Highway Administration (FHWA) and WYDOT's Executive Staff.

Adverse Weather Operation – Parking Management: At this point, WYDOT does not play a major role in parking management. The TMC keeps and provides an on-line list of available public and commercial parking facilities, complete with available resources and private facilities.

Alternate Site Operations: WYDOT maintains redundant critical systems necessary for the TMC to control devices in a community that is approximately 45 miles from the primary Cheyenne facility. Depending on the criticality of the system, the system is operated in either "active-active" or "active-passive" mode.

In the event of an outage to WYDOT's primary TMC located in Cheyenne, a smaller facility located in Laramie, WY, can be staffed with a reduced number of TMC operators. If such operations are necessary, the facility can be staffed at a reduced level in approximately two hours.

3.5 User Classes

A user class is distinguished by the ways in which users interact with the system. Factors that distinguish a user class include common responsibilities, skill levels, work activities, and modes of interaction with the system. Different user classes may have distinct operational scenarios for their interactions with the system. In this context, a user is anyone who interacts with the existing system, including operational users, data entry personnel, system operators, operational support personnel, software maintainers, and trainers.

Table 3-1 includes a brief description of the users previously identified in the *Task 2.2 User Needs* deliverable. Three categories of user groups - centers, field and wide-area – are critical to the pilot:

- Centers – These users and entities represent personnel associated with systems management and control centers including traffic, maintenance, emergency response, private-sector fleet management, parking that will need to be involved in the pilot.
- Field – These users and entities represent personnel and travelers who need to engage with the pilot while en-route. These include not only personal autos, truckers, snowplow operators but also maintenance staff, highway patrol officers, and local law enforcement who are responsible for safe operations on the I-80 corridor in Wyoming.
- Wide Area – This category represents travelers and other entities who engage with the system for general advisories and alerts.

Table 3-1. Identified User Groups for the WYDOT CV Pilot.

User Group	Owner	Short Description
		Centers
1. Traffic Management Center - Operators	WYDOT	Traffic Management Operators responsible for managing advisory, control strategies from the TMC in Cheyenne. Responsible for VSL, DMS, Traffic Incident Management etc.

User Group	Owner	Short Description
2. Traffic Management Center - Traveler Information	WYDOT	Traffic Management Center personnel responsible for updating WTI system and generating travel advisories. Some users in this group may also be operators
3. Traffic Management Center - Weather Providers	WYDOT	Contracted personnel located in the Traffic Management Center who are responsible for developing route-specific forecasts of road and weather conditions
4. Highway Patrol - Dispatch	WYDOT	Personnel providing the dispatch and center capability for highway patrol on I-80. Includes port of entry operations. For the purpose of user needs, this group also includes State homeland security systems and personnel who are involved in emergency response when event-scale warrants emergency operations protocols. This group also manages the port-of entries and are responsible for commercial vehicle safety enforcement.
5. Maintenance - Dispatch	WYDOT	Personnel providing dispatch capability for maintenance fleets on I-80. Includes both work zones and winter maintenance
6. ITS Maintenance	WYDOT	WYDOT maintenance staff specifically for Intelligent Transportation System (ITS) devices
7. Adjacent State DOT Centers	Colorado, Utah and Nebraska	Personnel and systems at statewide TMCs in Colorado, Utah and Nebraska that need information on I-80 conditions
8. Fleet Management Centers - CVOP Only	Various	Personnel and systems at participatingfleet management centers who will receive information only from the CVOP. These entities receive CV-enabled information through the CVOP but otherwise do not participate in the pilot.
9. Fleet Management Centers - Pilot Users	Various	Personnel and systems at Fleet Management Centers who will participate directly in pilot (such as Trihydro, Dooley and maybe others). These users receive and transmit CV information to/from vehicles to/from WYDOT.
10. Truck Parking Facility Operators	Various	Private truck parking facility managers along I-80 corridor
11. National Weather Service (NWS) Forecast Offices	NWS	Systems and personnel at the NWS Forecast Offices in the I-80 Corridor who are responsible for generating weather alerts, warnings and watches.

User Group	Owner	Short Description
12. TMC – Performance Management	WYDOT	Systems and personnel required to support performance management, data archiving, and system evaluation needs during the pilot
13. Wyoming Telecommunications and IT Programs	State of Wyoming	Systems and users responsible for statewide communication linkage through WyoLink Radio Network system and other radio-based systems. Also includes the IT systems and personnel that need to integrate with CV Pilot requirements both within the DOT and through the State government.
14. Special Event Venues	Various	Systems and personnel at arenas, universities and major employers that receive or provide information as part of the CV Pilot.
		Field
1. Maintenance Supervisors	WYDOT	Maintenance supervisors in districts who are responsible for tactical operations during adverse weathers. These personnel are responsible for crew call-ups, shift assignments, and treatment decisions during an event.
2. Snow Plow Operators	WYDOT	Operators of snow plow vehicles who are on the frontlines of weather event response. Personnel are also responsible for providing road condition updates and situational awareness of travel conditions on I-80.
3. Highway Patrol - Field	WYDOT	Operators of highway patrol cars on I-80 who are on the frontlines for incident response, traffic control and enforcement on I-80. From a user needs perspective, this group also includes local police, fire and medical crews that provide first responder capability along the I-80 corridor. This group also manages the port-of entries and are responsible for commercial vehicle safety enforcement.
4. Commercial Truck Drivers	Various	Commercial truck drivers who travel the I-80 corridor as part of their freight movement. A subset of them will be on trucks that are connected (i.e include an OBE with DSRC connectivity)
5. Personal Auto Travelers	Various	Personal auto travelers who travel the I-80 corridor as part of the trip.
		Wide area users
1. 511 Phone, App and Website Users and Media	Various	General users of WYDOT's travel information system services. This group includes users of various WYDOT pre-trip traveler information services including 511 phone, website and app. Also

User Group	Owner	Short Description
		includes media partners of WYDOT who support the wide area dissemination of travel conditions and advisories.

3.5.1 Interactions between Users

Most of the users identified in the previous table interact with each other as part of operations of the I-80 corridor. However, the nature of interactions in some cases (especially from the agency to the vehicle-related users) is minimal and related to the use of traditional ITS devices such as HAR, DMS and 511. Currently, there is limited coordination between the State DOT entities and the private sector parking services in the corridor. Other agency users are actively involved in day to day management of the corridor.

3.6 Support Environment

The GIS/ITS Program is WYDOT's primary division responsible for ITS. Critical pre-trip and roadside control systems are maintained with redundancy and with geographic separation of approximately 45 miles. Depending on the criticality of the system, they are either redundant in "active-active" or "active-passive" mode. The division is currently working to improve the geographic separation of pre-trip and control systems by employing cloud services.

Additional divisions, such as WYDOT's Telecom Program, responsible for the statewide radio network and roadside Wi-Fi hotspots, as well as the state's Enterprise Technology Services, responsible for the primary network routers, play a significant role in providing communication services. The Telecom Program has employees who are experts in various radio technologies and electronics.

All three divisions share a SolarWinds tool for monitoring the health of roadside ITS, power systems, communication devices and network equipment. In general, the three responsible groups provide annual preventative maintenance to the equipment for which they have ownership, and field technicians have experience to troubleshoot, repair or replace failed equipment.

All three divisions further share responsibility for a SLA that details the criticality of various devices and the required time to respond. In order to satisfy the required response time and maintain the service level, adequate inventories of commonly used parts are maintained by the technicians and are available in their vehicles or in their storage facilities.

WYDOT's ITS and Telecommunications Program share a common goal and are committed to assisting each other whenever possible. With the large geographic areas of responsibility, technicians of the two groups rely on each other and work together to expedite repairs.

WYDOT maintains a strong relationship with the trucking community and constantly engages with the Wyoming Trucking Association and carriers, freight operators to ensure that freight needs are being met by the department.

4 Justification For and Nature of Changes

Adverse weather conditions have been shown to have significant impacts on the safety, mobility, and productivity of transportation system users and roadway operators. This chapter describes the shortcomings of the current system, situation that motivates the modification of the existing system and the development of new CV road weather applications.

4.1 Justification of Changes

Gathering and disseminating reliable and accurate information has proven to be an effective and valuable strategy to manage traffic during extreme events, lowering the risk and probability of incidents. For instance, since its implementation in 2011, the VSL corridor between Cheyenne and Laramie has achieved statistically significant reduction of crashes (Saha & Young, 2014b), see Figure 4-1.

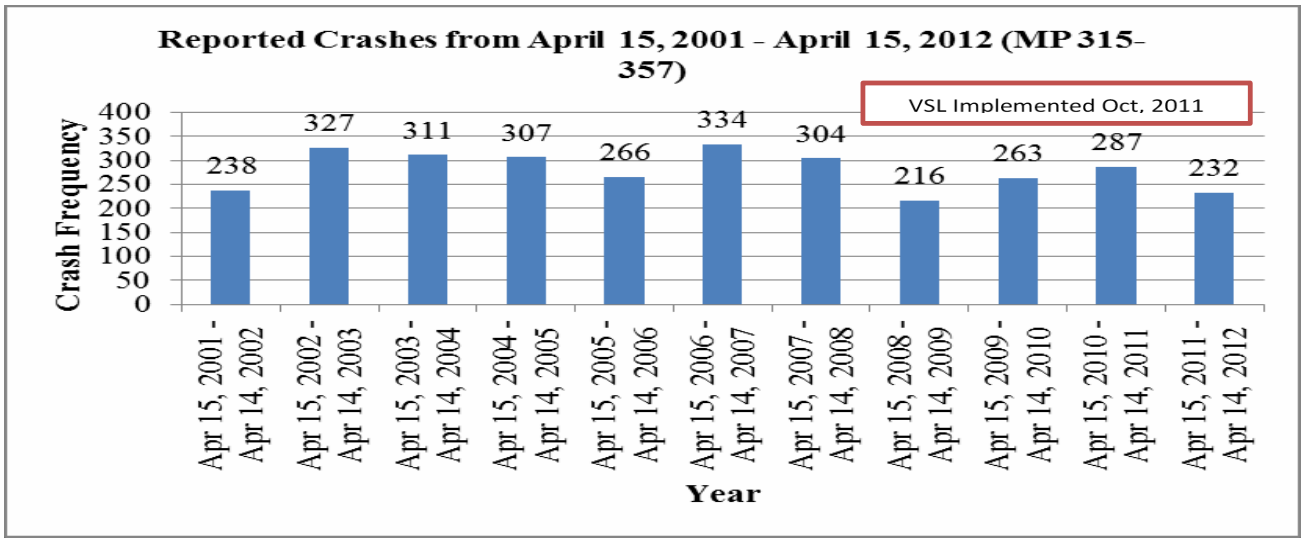


Figure 4-1: Laramie-Cheyenne Corridor Crash Frequency. Source: Wyoming DOT.

Wyoming is one on the nation's leaders in proactive approaches to mitigate the impacts of adverse weather. As described in Section 3.3, WYDOT implements: i) 24x365 TMC operations; ii) a CVOP that provides forecasted road condition information on common commercial vehicle routes; iii) WyoLink, a

statewide, multi-agency, digital trunked VHF P-25 compliant public safety communications system; iv) a combined 143 miles of variable speed limit corridors along I-80; v) a traveler information system; vi) active use of all information systems, including electronic message boards, to provide road forecasts following the NWS/FHWA Pathfinder concepts; vii) a road condition reporting system for maintenance personnel on I-80; and viii) use of trained volunteers to make condition reports. Around 35% of the length of I-80 is covered by variable speed limit signs, and there are weather sensors and Web-Cameras in 40 and 54 locations, respectively, as well as three travel information centers and four rest areas along I-80[5].

Despite the efforts to increase such capabilities along Wyoming's roadways, there are still significant gaps in determining road and weather conditions. The distances between the fixed detection sensors and the restricted ability to communicate actionable information to travelers already on the roadway are still limiting factors that reduce the effectiveness of many information-based strategies.

There is a clear need for expanding the communication system and providing hyper-local alerts, that is, real-time geocoded and continuous information throughout the entire length of the corridor. In this sense, WYDOT continues to look for ways to improve the efficacy and actionable nature of their traveler information systems.

The proposed system offers the opportunity to greatly expand the scope of mobile data collection from equipped vehicles (i.e., snow plows and fleets that operate on the corridor) and develop new applications that provide in-vehicle advisories on wind, speed limits and even parking availability for trucks. By having significantly more situational awareness, emergency response and recovery times can be improved. Because of the relationships that WYDOT has with over 150 fleet operators, applications will have immediate widespread utility since most of the trucks have at least a nomadic device which can receive the advisories wirelessly. Table 4-1 provides a summary of the expected benefit (i.e. new or improved capability) for the system's users.

Table 4-1. Summary of expected benefits by beneficiary due to changes in current system.

User	Receiving/Gaining
WYDOT	Improved capability for road weather advisory and warning for motorists and freight carriers by reducing latency and increasing coverage of road condition reports along the I-80 corridor based on data from equipped snow plows and trucks.
Fleet Management Agencies	Current and forecasted road conditions information along I-80, improving road weather information and routing support for emergency responders.

[5] Number of weather sensors and webcams obtained from www.wyoroad.info. Number of rest areas and information centers obtained from WYDOT's Public Affairs Office (November 2011): Wyoming Rest Areas.

Road Users (Truck drivers)	In-vehicle and in-route information on speed, detours, parking and presence of maintenance and emergency vehicles.

4.2 User Needs

IEEE standard 1362 defines user need as: "a user requirement for a system that a user believes would solve a problem experienced by the user." The standard notes that the word “requirement” does not imply system requirements. Through the process of identification of user needs, the team has identified what the project stakeholders want from the intended system. The following guidance from the ITS-JPO Standards Training[6] were used to provide common context to defining and identifying user needs for stakeholders in Wyoming:

- Generally user needs tend to remain stable over the course of the project and it is this inherent stability in the user needs that binds the scope of the system interface.
- Well written needs describe one or more system features and the intent of the said need in addressing a user problem or responsibility.
- User needs then drive the requirements definition and allow development of complete and correct requirements.
- The user needs document (this document) provides input for the (System) Requirements.
- Another distinction between the user needs and requirements is that ultimately verification is done against the Requirements, while validation is done against the User Needs. Validation answers, "Have we built the right system?" While the verification answers "Have we build the system right.
- It is very important that the user needs be developed with all users involved. Creating user needs might involve several iterations to resolve conflicts. After it is complete, agreed upon, and approved, the user needs help manage the expectations of users and the rest of the development process.

Furthermore, the following Systems Engineering criteria are used to define user needs for the pilot[7]:

- Uniquely Identifiable: Each need must be uniquely identified (i.e., each need shall be assigned a unique number and title).
- Major Desired Capability (MDC): Each need shall express a MDC in the system, regardless of whether the capability exists in the current system or situation or is a gap.
- Solution Free: Each need shall be solution free, thus giving designers flexibility and latitude to produce the best feasible solution.
- Capture Rationale: Each need shall capture the rationale or intent as to why the capability is needed in the system.

The next sections present the user needs identified for the CV Pilot. All user needs are described in a consistent format and include a unique user need ID, title and a statement associated with the user need. These user needs will inform the development of the proposed concepts in the overall ConOps

[6] https://www.pcb.its.dot.gov/StandardsTraining/mod07/sup/m07sup.htm
[7] https://www.pcb.its.dot.gov/StandardsTraining/mod07/sup/m07sup.htm

document. The final list of user needs will also be used to validate the system design. The relevant user needs, particular those associated with safety and evaluation needs, will also be addressed going forward in the Performance Measurement and Evaluation Support plan and the SyRS.

4.2.1 Identified User Needs – Centers

The following sections present the user needs by each identified user group relating to management, monitoring center (and center staff) that will be involved in the pilot. A short description of the user group is also provided.

4.2.1.1 *TMC – Operators*

WYDOT Transportation Management Center operators provide the public with road condition information for most state-maintained routes. The TMC is staffed with operators 24 hours a day, seven days a week. They are responsible for maintenance dispatching and serve as the information hub for all road condition reporting (RCR) activities — including during weather events and road construction activity. The TMC is the hub of transportations systems management in Wyoming and is co-located with the dispatch functions of highway patrol and maintenance. The following table provides the user needs for this group.

Table 4-2. User Needs for TMC – Operators (TMCO).

User Need ID	User Need Title	User Need
TMCO-1.0 Integrated Enhanced Road Condition information		
TMCO 1.1	Gather road condition Information	Need quality-checked information of current road conditions (precipitation, visibility, grip) for areas not covered by traditional Road Weather Information System (RWIS) sensors
TMCO 1.2	Gather vehicle impacts	Need current information on how current road conditions are impacting drivers in terms of traction and similar measures that affect vehicle operations
TMCO 2.0 Monitor Traffic Conditions		
TMCO 2.1	Support precise crash location	Need geotagged information about traffic crashes on I-80 to provide timely and correct notification of incident to Wyoming travelers
TMCO 2.2	Monitor traffic flow	Need real-time information about changes to typical traffic flow patterns in terms of volume, speeds and speed distribution
TMCO 3.0 Plan for Forecast Conditions		
TMCO 3.1	Generate forecast information on travel conditions on I-80	Need capability to generate route-specific forecasts at pre-determined durations (3-hour, 6-hour) or as needed.

TMCO 3.2	Determine timing and nature of proactive actions	Need capability to support use of forecasts in decision making including deciding on event-response tactics
TMCO 4.0 Perform Weather Responsive Traffic Management		
TMCO 4.1	Actively manage speed on I-80	Need to improve the capability to determine timing and location of speed reductions for the I-80 Variable Speed Limit System to better match conditions and travel speeds
TMCO 4.2	Actively manage closures on I-80	Need to improve the capability to determine timing and location of closures along I-80 to better match conditions and traffic demand.
TMCO 4.3	Actively manage warnings on I-80	Need to improve capability and quality of messaging (DMS, HAR) on I-80 to match conditions observed (and forecast) in the corridor.
TMCO 4.4	Monitor device outages and performance	Need remote monitoring and quality-checking capabilities for ITS devices used in winter weather response.
TMCO 5.0 Coordinate Event Response		
TMCO 5.1	Coordinate maintenance dispatch	Need improved capability to coordinate with maintenance dispatch operations. This may include receiving current field reports from maintenance and providing alerts to field personnel about traffic conditions.
TMCO 5.2	Support highway patrol operations and emergency	Need enhanced capability to coordinate with highway patrol operations. This may include support to incident management, reporting road conditions and providing forecast information for event response strategy planning
TMCO 5.3	Generate wide area traveler information report	Need enhanced capability to generate operator-led alerts and advisories based on reported or forecast conditions (that are gathered through both traditional and CV sources) that can be communicated through WYDOT's traveler information.
TMCO 5.4	Parking availability Status	Need to continuously monitor parking lot capacity availability and communicate with key partners
TMCO 5.5	Provide wayfinding	Need capability to inform parking space availability communicated to commercial vehicles

4.2.1.2 *TMC - Traveler Information*

The TMC strives to improve safety and efficiency on Wyoming's highway system by providing timely and accurate information to the traveling public. General trends show that the TMC's efforts have paid off in reducing crashes, decreasing the impacts of closures and improving the coordination of highway maintenance operations statewide. Information is shared through the www.wyoroad.info traveler

information website, 511 phone system, text and email alerts, and smartphone apps for Android and iOS, Twitter, a website tailored to commercial vehicle operators and TV displays. In contrast to the previous user group, this group represents the capability to create tailored, route-specific information for wide-area consumption as well as gathering information from the traveling public. The following table provides the user needs for this group.

Table 4-3. User Needs for TMC - Traveler Information (TMCT).

User Need ID	User Need Title	User Need
TMCT-1.0 Generate Current Conditions Alerts and Advisories		
TMCT-1.1	Develop segment-specific reports of current travel conditions	Need capability to fuse existing (sensor, field personnel reports) and new CV sources of data to generate segment-specific motorist alerts and advisories. Capability includes an ability to use surrogate sources of weather data (like wiper usage or ABS activations) to determine alerts
TMCT-1.2	Distinguish between road condition types	Need capability to use CV data to differentiate between different types of road condition (black ice, blowing snow, rain, patchy ice etc.)
TMCT-1.3	Determine return to normal	Need capability to determine when previously assessed condition no longer exists on the roadway
TMCT-2.0 Generate Traffic Information Reports		
TMCT-2.1	Improve incident verification and location	Need improved capability to verify incident location and nature of incident in locations with limited WYDOT visibility (cameras and sensors). Ability of vehicles to report locations under duress can greatly enable faster incident verification
TMCT-2.2	Share incident location and nature of incident	Need improved capability to report traffic flow information to warn upstream drivers about potential stopped and slowed traffic
TMCT 2.3	Share work zone location and information	Need capability to alert travelers to downstream work zones and any changing lane configurations.
TMCT 3.0 Provide Forecast Condition Reports		
TMCT 3.1	Share segment-specific forecasts and advisories	Need capability to fuse atmospheric data, CV data and models to generate short-term forecasts for segments along I-80 for wind, visibility and snow fall
TMCT 4.0 Tailor Information to User Groups		
TMCT 4.1	Tailor information to freight communities	Need capability to support growing freight community needs and demands for current and forecast traveler information on -80, especially related to high-wind risk and closures.
TMCT 5.0 Gather Citizen Reports and Feedback		

TMCT 5.1	Ingest citizen reports into traveler information framework	Need capability to ingest and appropriately weight citizen reported conditions vis-à-vis traditional and CV data in generating alerts and advisories

4.2.1.3 *TMC - Weather Providers*

The TMC weather providers use a variety of information sources to forecast weather and road weather conditions. The TMC works closely with a contract weather provider, DayWeather, who has a daily presence in the TMC and with five offices of the NWS. The NWS offices in Salt Lake City, UT as well as Riverton and Cheyenne, Wyoming provide forecasts along the I-80 corridor. DayWeather is contracted with WYDOT to provide weather forecasting to the TMC to enhance their ability to dispatch maintenance forces and alert motorists of current and pending dangerous driving conditions. Information sources used by the weather providers include national and local weather models, local observations, and field data (such as from RWIS and maintenance staff reports). Recently, DayWeather and the NWS offices have been cooperating on forecasts using concepts from the FHWA/NWS Pathfinder project. The following table provides the user needs for this group.

Table 4-4. User Needs for TMC - Weather Providers (TMCW).

User Need ID	User Need Title	User Need
TMCW-1.0 Ingest Directly Reported Road Weather Data		
TMCW 1.1	Use mobile observations of weather and road weather data to update forecasts	Need capability to integrate directly reported weather and road weather data from mobile sources (equipped fleets) into the forecast models. Data needs include air temperature, humidity, precipitation, visibility etc. that are directly measured by sensors on equipped vehicles.
TMCW 1.2	Conduct quality check on data generated from mobile sources	Need capability to adequately identify the validity of mobile data sources including identifying erroneous data feeds
TMCW-2.0 Ingest Field Observations		
TMCW 2.1	Use field reported conditions to update forecasts	Maintenance personnel field observations of weather conditions identified by location and timestamp to provide to weather providers
TMCW-3.0 Ingest Surrogate Weather Data		
TMCW 3.1	Use surrogate measures of weather and road condition to update forecasts	Need capability to translate vehicle sensor data that could be road weather alert surrogates to be translated into weather observations to enable forecasts.
TMCW 3.2	Develop quality checks for surrogate data	Need capability to define quality checks for surrogate data sources
TMCW-4.0 Develop Protocol for Data Fusion		

TMCW 4.1	Develop protocol to fuse field observations with mobile data	Need protocol to balance conflicting information between field reports and reported conditions from mobile data including relative time validity of data sources.
TMCW 4.2	Develop protocol to fuse traditional fixed observations with mobile data	Need protocol to balance conflicting information between fixed sensors (RWIS) and mobile data including relative time validity of data sources.

4.2.1.4 *Highway Patrol – Dispatch*

Wyoming Highway Patrol dispatch is part of the WYDOT. Highway patrol dispatch communicates with troopers in the field and is the first point of communication for incident response. Dispatch is staffed 24 hours a day, seven days a week. Dispatchers cover the entire state from a single location in Cheyenne and communicate with dispatchers from local law enforcement and emergency services agencies. Highway Patrol is also responsible for the ports of entry in Wyoming and manage the road closures during adverse weather as well. The following table provides the user needs for this group.

Table 4-5. User Needs for Highway Patrol Dispatchers (HPD).

User Need ID	User Need Title	User Need
HPD-1.0 Respond to incidents		
HPD 1.1	Improve remote notification of incidents to Highway Patrol	Need capability to remotely notify dispatch of incidents that occur in remote areas of I-80 where communication is a problem
HPD 1.2	Improve safety at incident sites	Need capability to better stage incident sites during periods of low visibility or adverse road conditions to ensure both traveler and responder safety. For dispatch, this could include better identifying what resources are needed for the incident.
HPD 2.0 Enforce travel restrictions		
HPD 2.1	Manage highway closures	Need capability to provide en-route guidance to manage road closures and communicate to those already on the road about road closures
HPD 2.2	Manage speed and lane restrictions	Need capability to more effectively enforce speed and lane restrictions
HPD 2.3	Remotely report current route impacts	Need capability to coordinate with traffic management to understand how hazardous weather is currently impacting the roadway in terms of pavement temperature, roadway visibility, and accumulation of water/snow/ice on the roadway to be able to prepare to respond to accidents with the appropriate equipment
HPD 3. Situational Awareness		

HPD 3.1	Strategic support to field highway patrol officers	Need capability to monitoring how the forecasted hazardous weather is expected to impacting the roadway in terms of pavement temperature, roadway visibility, and accumulation of water/snow/ice on the roadway to disseminate to the field audience to be able to prepare to respond to accidents with the appropriate equipment.

4.2.1.5 *Maintenance – Dispatch*

The WYDOT maintenance dispatch function allocates maintenance field resources (i.e., snowplows and personnel) to best address the current and forecasted road conditions. Direction to the maintenance field resources could come from the TMC or directly from field supervisors who are the frontline of the response. WYDOT's Transportation Management Center performs the function of dispatching all maintenance vehicles. The TMC maintains a list of maintenance employees to call for every road section in the state and they alert maintenance employees when weather conditions meet criteria for roadway treatment. WYDOT's maintenance teams rely on forecasts heavily for strategic decision-making around winter event response but have not yet fully migrated to a Maintenance Decision Support System. While maintenance functions (treatment strategies, material usage) are not part of the proposed pilot, they play an important role in gathering of field conditions through the RCR system that influences operations and traveler information. They also will be important consumers of CV data to adjust their maintenance practices. The following table provides the user needs for this group.

Table 4-6. User Needs for Maintenance Dispatchers (MD).

User Need ID	User Need Title	User Need
MD-1.0 Alignment of Maintenance Responses		
MD-1.1	Adjusting responses based on CV data	Need capability to use mobile data from equipped fleets into maintenance decision-making including determining spot-specific concerns, timing of crew call-ups, treatment strategies based on reported road weather and traffic conditions
MD-2.0 Gather Field Observations		
MD-2.1	Supplementing manual observations with CV data	Need capability to fuse snow plow operator reported information with mobile data to create maintenance plan

4.2.1.6 *ITS Maintenance Staff*

ITS and telecommunications field technicians maintain, repair, install, and troubleshoot all roadside ITS devices and to ensure they are operational at all times. They make timely and precise repairs, bound by the WYDOTITS Devices-Basic Service Level Agreement, to devices statewide in order to reduce downtime and provide accurate data. These tasks are performed with minimal supervision.

The ultimate goal is to provide reliable real time information concerning travel conditions in Wyoming, ensuring the safety of the traveling public. In the project area, technicians are based in Laramie, Rawlins and Rock Springs. However, technicians in other parts of the state routinely travel to assist when needed. For this particular pilot, in addition to the traditional ITS devices, they will likely be responsible for the maintenance of the DSRC roadside equipment (RSEs). The following table provides the user needs for this group.

Table 4-7. User Needs for ITS Maintenance Staff (ITSM).

User Need ID	User Need Title	User Need
ITSM 1.0 System Reliability		
ITSM 1.1	Ability to monitor field device systems health remotely	Need capability to monitor field devices system health (up-time, communication strength, device status) remotely during normal and adverse weather conditions
ITSM 1.2	Diagnosis of faults	Need capability to determine cause of failure or degradation in performance
ITSM 2.0 Device Safety		
ITSM 2.1	Ensure device safety in operations	Need capability to adequately ensure physical safety of devices as they are exposed to adverse conditions and natural elements
ITSM 3.0 System Security		
ITSM 3.1	Ensure roadside systems are secure and tamper proof	Need capability to ensure security of roadside devices to ensure that they are tamper-proof
ITSM 3.2	Ensure roadside systems are protected fromcyber threats	Need capability to safeguard center, field and vehicle systems fromcyber threats

4.2.1.7 *Adjacent State DOT Centers*

Utah and Nebraska are on the two ends of the I-80 corridor and are natural partners in the effort to manage travel on the roadway. Similarly, Colorado marks the southern boundary of Wyoming and includes a major connecting route to I-80, which is I-25. Information on road closures necessarily needs to be communicated with Utah and Nebraska but even adverse weather condition information need to be shared between the three States and Wyoming. The following table provides the user needs for this group.

Table 4-8. User Needs for Adjacent State DOT Centers (ADOTC).

User Need ID	User Need Title	User Need
ADOTC 1.0 Data Sharing on Corridor Conditions		

ADOTC 1.1	Improved data sharing on closures and adverse weather conditions	Need capability to share data and information gathered from CVs to adjacent State DOTs especially as it relates to closures and adverse weather
ADOTC 1.2	Early notification of unusual demand patterns	Need capability to provide early notification to adjacent State DOTs on unusual traffic conditions or demand levels encountered

4.2.1.8 *Fleet Management Centers - CVOP Only*

Wyoming DOT has developed a CVOP that provides forecasted road condition information on common commercial vehicle routes. This information focuses on the elements most important to commercial carriers: Forecasted surface conditions, forecasted wind speeds and forecasted visibility estimates. The site is intended to help drivers and dispatchers make decisions like whether a truck should travel ahead of a storm, wait for a storm to pass or choose an alternate route. More than 150 different companies have signed up to be part of this system. For a vast majority of these companies, the primary benefit of the pilot would be the improved information in the CVOP through CV-enabled data collection and processing. The following table provides the user needs for a commercial vehicle operator in this group.

Table 4-9. User Needs for Fleet Managers – CVOP.

User Need ID	User Need Title	User Need
CVOP 1.0	**Tailored Alerts and Advisories**	
CVOP 1.1	Receive current driving conditions summary	Need a richer set of information on current driving condition with reduced gaps in coverage. Information of interest includes current speed limits, pavement conditions, wind speeds, parking availability, chain restrictions and other services.
CVOP 1.2	Receive predicted and forecast driving conditions	Need reliable forecasts of road weather that have multiple and long-term time scales
CVOP 1.3	Ability to customize information	Need ability to customize information based on preferred segments and routes along I-80

4.2.1.9 *Fleet Management Centers - Pilot Users*

This second group of fleet management centers represent partners in the pilot demonstration project whose vehicles and centers will be connected as part of this demonstration. These Fleet Management Centers oversee private and commercial fleet management by tracking and monitoring vehicles and drivers. The centers compile data about the driver, vehicle performance and environmental conditions. The centers also manage the routes and locations for the fleet drivers by communicating any change in conditions or events that affect the vehicle's route. For example, two such fleet

managers are Trihydro Corporation and Dooley Oil that manage fleet vehicles that travel the I-80 corridor daily. The following table provides the user needs for this critical group.

Table 4-10. User Needs for Fleet Management Center - Pilot Users (FMC).

User Need ID	User Need Title	User Need
FMC 1.0 – Improve Truck Safety		
FMC 1.1	In-vehicle alerts	Need to provide in-vehicle alerts of upcoming adverse road weather conditions, end of queue, desired action (speeds, detours, parking)
FMC 1.2	Improve situational awareness	Need to enable V2V communication between equipped fleets to support local spot-specific warnings and applications
FMC 1.3	Minimize distracted driving	Need to develop human machine interface that minimizes the distraction and does not pose a burden on the work load of the driver.
FMC 2.0- Improve truck and driver productivity		
FMC 2.1	Optimize routing	Need to be able to use data from TMC to optimize route choices for trucks in the fleet
FMC 2.2	Optimize timing	Need to be able to use data from TMC to optimize time choices for trucks in the fleet
FMC 2.3	Optimize driver performance	Need to be able to use data from trucks to optimize driver performance and compliance
FMC 2.4	Support truck parking	Need to be able to provide guidance to truckers about parking availability especially as conditions are forecast to worsen
FMC 3.0 Manage Driver Concerns		
FMC 3.1	Minimizing privacy concerns	Need to alleviate driver concerns around "big brother" by promoting value. In general, fleet managers are already collecting significant information, however, need to be cautious of new data elements and any perceptions of privacy
FMC 4.0 Protect Sensitive Data		
FMC 4.1	Competitive advantage	Need to ensure safeguards of any data shared with the DOT that might present a competitive advantage when released to the public.

4.2.1.10 *Truck Parking Facility Operators*

The Truck Parking Facility Operators are comprised of private and public facilities along the I-80 corridor. Operators are highly affected during the highway closure events. These facilities fill up quickly during an I-80 closure and the operators need the ability to communicate the available capacity of their facility. From their standpoint, early notification of closures would allow them to plan

their resources better during the event. The private entities are concerned about their competitive advantage as well particularly sensitive to lost revenue. Balancing both the maximal utilization of the facility while minimizing the consequences of overflow or unavailable parking is at the crux of the user needs for this group. The following table provides the user needs for this group.

Table 4-11. User Needs for Truck Parking Facility Operators (TPFO).

User Need ID	User Need Title	User Need
TPFO 1.0 Road Closure Status Notifications		
TPFO 1.1	Road Closure Status	Need advanced notification of road closure received from TMC in order to begin preparations for parking availability
TPFO 2.0 Incoming Truck Notifications		
TPFO 2.1	Type/Number of Trucks	Need incoming truck information (type and number) to prepare for parking availability

4.2.1.11 *NWS Forecast Offices*

The NWS is an organization under the National Oceanic and Atmospheric Administration (NOAA), part of the Department of Commerce (DOC). The mission of NWS is to provide weather, water, and climate data, forecasts, and warnings for the protection of life and property and to enhance the national economy. Each NWS Weather Forecast Office (WFO) is responsible for issuing 10-day weather forecasts for their assigned County Warning Area (CWA) as well as issuing watches, warnings, and advisories for hazardous weather, along with many other tasks related to their mission.[8] For this project, relevant user groups are the three WFOs whose CWAs encompass part of I-80 in Wyoming: Salt Lake City, Riverton, and Cheyenne. The majority of the route is located in the Cheyenne CWA. User needs for this group are similar to the Section 4.3 with the emphasis on how CV data can improve forecast practices and impact estimation for alerts and advisories issued in the State of Wyoming.

Table 4-12. User Needs for National Weather Service Forecast Offices (NWS).

User Need ID	User Need Title	User Need
NWS 1.0 Impact Estimation		
NWS 1.1	Forecasted Route Impacts	Need capability to ingest mobile and fixed data to determine how the forecasted hazardous weather is expected to impacting the roadway in terms of pavement temperature, roadway visibility, and accumulation of water/snow/ice on the roadway.

[8] http://www.weather.gov/about

NWS 1.2	Current Route Impacts	Need capability to ingest mobile and fixed data to determine how the hazardous weather is currently impacting the roadway in terms of pavement temperature, roadway visibility, and accumulation of water/snow/ice on the roadway.
NWS-2.0 Improve Forecasting		
NWS 2.1	Ingest Vehicle-based Observations	Need capability to use weather-related data from CVs to fill in observation gaps
NWS 2.2	Translate surrogate vehicle data	Need capability to aggregate weather-related data at stationary points and derive traditional weather observations from observations unique to the vehicle (e.g., wiper status to rain rate)

4.2.1.12 *Transportation Management Center – Performance Management*

Performance management during the CV Pilot is critical to demonstrate success but also to continuously improve operations. Closely related to performance measurement are requirements for data archiving and evaluation being conducted by the U.S DOT. The TMC will be crucial in determining both the performance metrics and the data collection approach required to quantify them. The TMC will also provide the data capture support to the independent evaluation planned by U.S DOT.

Table 4-13. User Needs for Performance Measurement.

User Need ID	User Need Title	User Need
PM 1.0 Measuring Outcomes		
PM 1.1	PM Framework	Need a performance management framework that defines the success metrics for the pilot.
PM 1.2	Baseline development	Need a capability to establish the baseline in terms of safety, mobility and reliability outcomes
PM 1.3	Target Setting	Need to determine clear targets for pilot demonstration
PM 2.0 Data Plan		
PM 2.1	Data Logging	Need capability through the pilot of logging time-stamped data for various pilot elements
PM 2.2	Data Management	Need a capability to collect and manage data collected from equipped fleets as part of the pilot
PM 2.3	External Data	Need capability to collect, house and manage external data collected for this pilot
PM 3.0 Reporting Plan		
PM 3.1	Dashboards	Need capability for dashboards that highlight key metrics during the course of the pilot

4.2.1.13 *Wyoming Communications and IT*

Wyoming Communications is available over public and private methods to facilitate data communications. These data networks will be utilized to send and receive data in the CV Pilot. DSRC radios will be added both to vehicles and roadside equipment for V2V and V2I communications. The DSRC radios could use WYOLINK, WiFi hotspots, and Cellular backhauls to connect to the TMC and other cloud resources. Current data networks available along the I-80 corridor are:

1) The WYOLINK statewide digital trunked VHF P-25 compliant public safety communications system, which is very available, but are very low bandwidth and have restricted access to government agencies and emergency responders.
2) WiFi hotspots provide high bandwidth access over a limited area. These connections have restricted access to government agencies.
3) Cellular access is represented by multiple carriers along the I-80 corridor at differing coverage areas.
4) Satellite communications are generally available in WY to public and private users.

WYDOTIT and systems engineers in the GIS/ITS group provide network infrastructure to include routers and firewalls and help coordinate internal software programs to ensure new data fits seamlessly in existing workflow. Some services are provided through contracts with specialists.

The following table provides the user needs for this group.

Table 4-14. User Needs for Wyoming Communications (WYC).

User Need ID	User Need Title	User Need
WYC-1.0 V2I Data Use		
WYC-1.1	Data Access	Need to be able to transmit data to/from RSE, the cloud and the TMC in both real-time and non-real time for various CV applications.
WYC 1.2	Data Protection	Need to ensure that data transfer is secure. Non-reputable, signed, and secured data sent and received by vehicles in this pilot
WYC 1.3	Data Sharing	Need to ensure that existing WYOLINK functions are not compromised by new CV data applications

4.2.1.14 *Special Event Venues*

Special event venues can be arenas, universities, or even employers who may hold events when many people in attendance. The people may be local, or may be from out-of-town and not familiar with the local roads. Special event venues often have visiting events that required large trucks to deliver equipment for the event (musical performances, sporting games, etc.). It is necessary for the delivery managers of the special event venues to understand how road and traffic conditions may impact deliveries. In Wyoming, these event venues include facilities in Cheyenne, Casper, and Laramie (at the University of Wyoming). The following table provides the user needs for this group.

Table 4-15. User Needs for Special Event Venues (SEV).

User Need ID	User Need Title	User Need
SEV-1.0 Travel Impacts		
SEV-1.1	Forecasted Route Impacts	Need updates on how forecasted hazardous weather is expected to impact roadways leading to the special event venue so delivery trucks can plan their delivery routes.
SEV-1.2	Current Route Impacts	Need updates on how current hazardous weather is impacting roadways leading to the special event venue so delivery trucks can plan their delivery routes.
SEV-1.3	Road Closures	Need updates on current status and extent of road closures on the corridor including estimated duration of closure and designated alternatives

4.2.2 Identified User Needs – Field

The following sections present the user needs by each identified user group relating to field and roadside staff and vehicles that will be involved in the pilot. A short description of the user group is also provided.

4.2.2.1 *Commercial Truck Drivers*

Commercial truck drivers on the project corridor vary from independent operators to drivers for large fleet operators and constitute 50 to 75% of the traffic on the corridor, depending on the season and time of day. Commercial truck driver's user needs are based on driver needs to adhere to route schedules and maintain compliance with hours of service regulations in the most safe and efficient manner. The following table provides the user needs for this group.

Table 4-16. User Needs for Commercial Truck Drivers (CTD).

User Need ID	User Need Title	User Need
CTD-1.0 Improve Truck Safety		
CTD-1.1	Support low-visibility operations	Need to provide end of queue or low visibility warning systems to trucks entering low visibility area
CTD 1.2	Support movement during high-wind advisories	Need to provide customized warning for trucks entering area with high-winds
CTD 1.3	Support movement during heavy precipitation	Need to provide cautions and speed advisories for trucks entering precipitation zone.
CTD 2.0 Improve truck and driver productivity		

CTD 2.1	Parking	Need to provide parking availability and wayfinding for trucks during winter seasons
CTD 2.2	Size and Weight Restrictions	Need to provide alerts when truck size and weight exceed route parameters
CTD 2.3	Chain law restrictions	Need to provide current status of chain law restriction level including estimated duration of restriction (if at Level 1 or Level 2).
CTD 2.4	Closures and Alternatives	Need to provide information for closures and alternatives at right decision points.
CTD 2.5	Impact assessment	Provide an assessment of impacts due to current and forecast road conditions including travel time and travel reliability.
CTD 3.0 Maintain connectivity with centers		
CTD 3.1	Communication with Centers	Maintain real-time communication capabilities with fleet management centers to update progress of freight movement
CTD 4.0 Minimize impact to driving operations		
CTD 4.1	Minimize interaction with in-vehicle system	Need the system to require minimal interaction or input from the driver to receive notifications while on the road
CTD 4.2	Manage language barriers	Need to system have capability to provide notifications in non-textual format for non-native English speakers

4.2.2.2 *Personal Auto Travelers*

Personal Auto Travelers are comprised of the traveling public, or all those roadway users outside of governmental and commercial drivers. The Personal Auto Travelers drive a variety of different vehicles, have a variety of different skill levels for driving in hazardous weather conditions, and have unique decision processes when deciding whether or not to travel or take an alternate route when hazardous weather is forecast or occurring. The following table provides the user needs for this group.

Table 4-17. User Needs for Personal Auto Travelers (PAT).

User Need ID	User Need Title	User Need
PAT-1.0 Support Safe Operations		
PAT-1.1	Current Hazardous Weather	Need information about current hazards affecting the roadways so decisions can be made on what route to take, and how to modify driving behavior to increase safety
PAT-1.2	Forecast Hazardous Weather	Need information about forecast hazards that might affect the roadways so decisions can be made on which route to take, and how to modify driving behavior to increase safety

PAT-1.3	Traffic Information	Need information on where traffic is slowed or stopped, accidents have occurred, and roads that are closed allow a driver to plan which route to take and how to modify their driving behavior
PAT-1.4	Hazard Notification	Need to provide data on upcoming road hazards to the driver while they are on the road allows the driver to take evasive action (slowing down, alternate routes, etc.) to avoid the hazard

4.2.2.3 *Maintenance Supervisors*

WYDOT Maintenance Supervisors are responsible for the performance of maintenance field personnel and dispatchers in their specific area of operation. Maintenance Supervisors utilize weather and road weather information to make judgments about allocation of resources and scheduling to address the most urgent road conditions. WYDOT maintenance supervisors are responsible for overseeing those tasked with keeping highways maintained for safe travel. There are supervisors assigned to specific departments and supervisors who oversee multiple departments. The following table provides the user needs for this group.

Table 4-18. User Needs for Maintenance Supervisors (MS).

User Need ID	User Need Title	User Need
MS-1.0 Weather and Road Weather Information from Weather Providers		
MS-1.1	Weather Information Integration with Providers	Need to provide a full complement of current and forecast weather and road weather information from weather providers to maintenance supervisors
MS-2.0 Weather and Road Weather Information from Maintenance Field Personnel		
MS-2.1	Weather Information Integration with Field	Need to provide maintenance supervisors with weather and road weather conditions reported by maintenance field personnel

4.2.2.4 *Snow Plow Operators*

Snow plow operators conduct winter road clearing and treatment strategies within WYDOT guidelines and performance goals. In association with the WYDOT TMC they do much more including reporting weather and road conditions by designated highway segments, recommending speed limits for observed road conditions, reporting traffic incidents (if observed), and reporting damaged WYDOT infrastructure (i.e., signs, guard rail, etc.). In the past year, a select group of snow plow operators participated in a demonstration project to report road conditions using a tablet application (RCR App) directly to the TMC. RCR App enabled the reporting of all the information listed above automatically to TMC operators through a revised TRAC system. The RCR App also provided weather and road weather information to the snow plow operations such as RWIS readings and weather radar images. The following table provides the user needs for this group.

Table 4-19. User Needs for Snow Plow Operators (SPO).

User Need ID	User Need Title	User Need
SPO 1.0 Reports of Road Condition		
SPO 1.1	Information from other maintenance personnel	Need to provide snow plow drivers current road condition information for their highway segment and neighboring highway segments
SPO 1.2	RWIS data to plow drivers	Need to provide snow plow drivers RWIS data for atmospheric and pavement conditions relevant to their area of operations
SPO 1.3	Weather radar information to plow drivers	Need to provide snow plow drivers weather radar images relevant to their area of operations
SPO 1.4	Incidents to plow drivers	Need to provide snow plow drivers with any reported incidents relevant to their area of operations
SPO 2.0 V2V Alerts		
SPO 2.1	Do not pass warning	Need to broadcast a warning for vehicles not to pass snow plows while in motion
SPO 2.2	Enhanced Safety Message broadcast	Need to broadcast enhanced safety message for other equipped vehicles to support spot-specific warnings
SPO 3.0 Traffic Management Support		
SPO 3.1	Speed management by snow plow operators	Need to enable snow plow drivers to view current posted speeds for their location and suggest revisions
SPO 3.2	Messaging by snow plow operators	Provide snow plow drivers with DMS messages for signs relevant to their area of operations
SPO 4.0 Mobile Data Collection		
SPO 4.1	Mobile data collection	Need to be able to collect both direct data (weather and road weather) as well as surrogate weather data from snow plows
SPO 4.2	Mobile data transmittal	Need to be able to transit mobile data at required latency for various pilot applications

4.2.2.5 *Highway Patrol – Field*

The Wyoming Highway Patrol is part of WYDOT. Highway patrol troopers are responsible for enforcing traffic laws and crash investigations. They are also responsible for incident management. Employees at ports of entry are responsible for enforcing weight restrictions and collecting appropriate user fees. The following table provides the user needs for this group.

Table 4-20. User Needs for Highway Patrol – Field (WHPF).

User Need ID	User Need Title	User Need

WHPF-1.0 Emergency notification information		
WHPF-1.1	Remote notification and Mayday alerts	Need capability for notification and mayday alerts including the use of on-board vehicle sensor information that suggests a crash may have occurred, including airbag deployment and rapid speed changes
WHPF-1.2	Geo-tagged Location information	Need capability to determine location of vehicles when an incident is notified
WHPF-2.0 Safety Enforcement		
WHPF-2.1	Vehicle size management	Need capability to enforce dimensions of vehicles for use (including high-profile) in determining safety risks related to bridge heights, construction zones and high-wind events
WHPF-2.2	Vehicle weight management	Need capability to enforce weight restrictions of vehicles for use in determining safety risks related to construction zones and high-wind events
WHPF-2.3	Enforcement of applicable commercial vehicle restrictions	Need capability to verify compliance with existing commercial vehicle regulations and applicable restrictions. Chain laws, restrictions on light and high-profile vehicles, hazardous material transport are examples
WHPF 3.0 Incident Scene Management		
WHPF 3.1	Incident scene staging	Need capability to improve staging of incident scene especially during periods of low visibility to minimize risk to responders
WHPF 3.2	Incursion Alerts	Need capability to be alerted of incursion or runaway drivers when responding to an incident scene.
WHPF 4.0 Closure and Restriction Management		
WHPF 4.1	Managing road closures in field	Need capability while in the field to warn drivers up-stream of impending closures or stopped traffic

4.2.3 Identified User Needs – Wide Area

The following sections present the needs by each identified user group relating to end-users and travelers that will be receiving alerts and advisories in the pilot. A short description of the user group is also provided.

4.2.3.1 *511 Phone, App and Website Consumers and Media*

Travel information provided by WYDOT is very popular. During an average winter day, more than 70,000 people visit WYDOT's road condition website and more than 870,000 phone calls are fielded by the 511 phone system each year, and I-80 is the most popular route for condition requests. Because there are few alternate routes in the state and there are large distances between cities, it is important for travelers to receive pre-trip information to determine whether it is safe to travel and to make sure they won't become stranded. The following table provides the user needs for this group.

Table 4-21. User Needs for 511 Phone, App and Website Consumers (CONS).

User Need ID	User Need Title	User Need
CONS 1.0 Road condition information		
CONS 1.1	Current road conditions	Need accurate and timely information to make travel decisions without coverage gaps
CONS 1.2	Current weather conditions	Need accurate and timely information to make travel decisions at the segment level along I-80
CONS 1.3	Forecasted weather conditions	Need consistent, high-quality messages between the NWS and WYDOT forecasters that can be relied upon for making travel decisions
CONS 2.0 Incident information		
CONS 2.1	Geo-tagged Crash location	Need faster and accurate information about crashes so they can avoid areas where there could be travel stoppage or delay
CONS-3.0 Construction zone information		
CONS 3.1	Work zone location and impact	Need accurate information about the location of construction zones and the impact of work zones
CONS 3.2	Speed limit/delay information	Need accurate information about construction zone speed reduction and delays

4.3 Description of desired changes

WYDOT hopes to improve safety and reliability on the I-80 corridor especially during periods of adverse weather and when work zones are present. To achieve this primary objective, several new or modified capabilities, functions, processes, interfaces, and other changes are needed to respond to the previously identified factors:

1. Capability changes: The proposed system will:
    a) Add capability to collect highly-localized event, weather and road condition information from equipped commercial, specialty and public fleet vehicles
    b) Add capability to use collected information effectively to generate localized, timely notification both to fleet managers and to truckers on the road about adverse weather conditions
    c) Add capability to support V2V communication of situational awareness that will take the management center out of the loop and improve timeliness and accuracy of alerts and advisories
    d) Add capability to provide parking availability and status information to truck on the road during adverse weather conditions
    e) Add capability to provide customized alerts and advisories to trucks based on their location along the I-80 corridor using roadside infrastructure

f) Add capability to provide targeted alerts and advisories to trucks based on their vehicle size and weight characteristics along specific locations in the corridor

2. System processing changes: The proposed system will:
    a) Ingest, quality-check and process data gathered from connected vehicles and generate segment-level alerts and advisories
    b) Provide capability for fleet management centers to request alerts and advisories, parking availability based on location
    c) Store data generated from vehicles and controlling systems for performance measurement and evaluation
3. Interface changes: New interfaces will be developed to support activities and to manage, gather, compile and share data related to:
    a) Interfaces between vehicles, roadside, WYDOT centers and U.S DOT services for Core Services for the CV environment
    b) Interfaces between host and remote vehicles for V2V Situational Awareness (SA)
    c) Interfaces between vehicles and infrastructure for Work Zone Warnings
    d) Interfaces for integration of CV applications with existing Wyoming Traveler Information Systems
    e) Interfaces with fleet management centers for freight dynamic planning and routing through the CVOP interface as well as directly to equipped trucks
    f) Interfaces with in-vehicle systems and third party applications for road weather advisories for motorist, freight, maintenance and emergency response vehicles
4. Personnel changes: No new personnel are expected to be added as a result of the proposed system but roles and responsibilities of existing WYDOT staff and pilot participants are expected to evolve during the course of system development and demonstration. Changes are expected in the following areas:
    a) TMC Operator roles and responsibilities – TMC operators have additional responsibilities in terms of monitoring alerts and advisories generated by the proposed system for accuracy and effectiveness
    b) Weather providers/in-house meteorologist – In-house meteorologists will have new data sources to incorporate into advisory and forecast models
    c) Specialty and public fleet drivers – Snow plow drivers and highway patrol troopers who are part of the proposed system will need training on how to interpret in-vehicle alerts and advisories
    d) Truck drivers – Truck drivers who are part of the proposed system will need training on how to interpret in-vehicle alerts and advisories
    e) External personnel such as parking management operators, WYDOT port of entry operators will need to be trained on the requirements and their roles in the proposed system

f) Fleet management center personnel will need training on how to use the new services developed as part of the proposed system in their operations

g) System developers and maintainers – WYDOT's GIS/ITS group along with external support consultants will be responsible for the maintenance of the proposed system adding to their current roles and responsibilities

5. Environment changes: No significant changes are expected in the high-level operational environment of the I-80 corridor due to the proposed system.
6. Operational changes – Some operational changes are expected to occur at WYDOT TMC as a result of the proposed system:
    a) WYDOT's policies on variable speed limits, road condition advisories, incident response are expected to change as result of the proposed system
    b) Additionally, WYDOT TMC's role in parking management activities will increase beyond its current limited scope.
7. Support changes
    a) The inter-site backhaul communication capability offered by the Telecommunications Program will become more critical to support the changes in the new proposed system. These changes may require an analysis of data transfer capabilities at various locations in the corridor prior to deployment to ensure that the communications channel can support the data exchanges required for the CV applications. Where the proposed system uses WyoLink's P25 standard low speed data capability to communicate with WYDOT vehicles, analysis will also be needed to check that the proposed system does not overload capacity and result in unacceptable latency.

4.4 Priorities among changes

All the identified changes in Section 4.3 are essential to the CV Pilot demonstration. The absence of the changes identified in Section 4.3 would greatly compromise the ability to showcase the value of V2V and V2I connectivity to deliver meaningful applications in a real-world context. Essential changes include the ability to develop a critical mass of connected vehicles that are able to engage in both V2V and V2I communication to support various application needs identified in Section 3.3. The second essential change is the ability at the TMC to ingest mobile data collected by connected vehicles, quality-check them and generate segment-level localized weather advisories. More detailed traceability of user needs to requirements will be done in Task 6 in Phase I.

4.5 Changes considered and not included

Several changes were considered and not included as part of the proposed system. Four major ones include:

- Installing additional fixed infrastructure devices for road weather monitoring - There is a significant amount of detection and road condition monitoring in the corridor. However, significant gaps remain due to the sheer length of the corridor and the cost to install and operate such systems. One of the main motivators towards connected and mobile data collection of road condition stems from the reduced reliance on fixed infrastructure.
- Adding capabilities to the maintenance decision-support systems for winter maintenance treatment decisions– While the collection of road condition data will be enhanced through the pilot, one change not included in the pilot is integration of such data in WYDOT's maintenance decision support system (MDSS) to support winter maintenance activities like treatment recommendations for material use and route optimization. This change was not included because the use of MDSS is limited and treatment recommendations from the MDSS are still not used by maintenance supervisors yet. However, the information from the proposed system will be shared with maintenance staff both in the field and at supervisory levels to influence and improve winter decision-making processes.
- Adding truck productivity focused applications– The pilot focuses on minimizing the safety impacts due to adverse weather both by improving travel guidance to freight operators and by providing localized information on spot-specific weather concerns. However, the pilot does not include additional freight optimization techniques like freight drayage optimization, truck loading strategies, and driver workload optimization. These, while important, are considered outside the scope of the system as envisioned. However, the information from the pilots may be used by individual freight operators to achieve their productivity goals.
- Truck platooning applications – While truck platooning applications have been shown to have demonstrable fuel savings and are desired future capabilities on the corridor, the pilot does not include any applications that demonstrate automated cooperative vehicle following behavior. Current levels of technology maturity were deemed inadequately mature to support such operations during adverse weather conditions, which is the focus of the pilot.

5 Concepts for Proposed System

This section will describe the key concepts for the proposed system focusing on the new concepts and features that are required to support the user needs and changes identified in Chapter 4.

5.1 Background, objectives and scope

As noted previously, the proposed site corridor is the length of the I-80 in the State of Wyoming. With the new system, WYDOT hopes to:

- Reduce the latency and increase the coverage of road condition reports along the I-80 corridor by gathering data from equipped snow plows and trucks.
- Support in-vehicle dissemination of advisories to support speed management, detours, parking, and presence of maintenance and emergency vehicles.
- Support fleet management center operations by providing current and forecasted road conditions along I-80.
- Support V2V communication of road condition and posted speeds along the I-80 corridor especially in the variable speed limit zones.

System development and deployment will occur in three Phases. Phase I includes the planning for the CV pilot including the development of ConOps. Phase II is the design, development, and testing phase. Phase III includes a real-world demonstration of the applications developed as part of this pilot. The main scope elements of the pilot to be accomplished in Phase II and Phase III are follows:

- Deploy and operate of a set of vehicles that are equipped with on-board equipment (OBE) with DSRC connectivity. These vehicles will be a combination of snow plows, maintenance fleet vehicles, emergency vehicles and private trucks. These vehicles will broadcast a basic safety message, collect vehicle, weather and road condition data, and provide it remotely to the WYDOT Transportation Management Center. These vehicles will also receive in-vehicle alerts from various applications developed as part of the pilot.
- Deploy roadside equipment (RSEs) with DSRC connectivity that are able to transmit advisories and alerts to equipped vehicles along I-80.
- Leverage the data provided from the equipped vehicles to develop and demonstrate a suite of V2V and V2I applications. As part of the pilot, several applications will be developed to support wide area travel advisories, variable speed limit postings, forecast road condition information, spot-specific warnings, detours, emergency alerts, and parking notification.

- Support performance management and evaluation of pilot through detailed data capture and management of vehicle data throughout the demonstration.

The site map presented in Figure 5-1 highlights the various roadside elements of the CV Pilot and identifies the potentials zone of interest for applications along the corridor. However, the zones, specific number and placement of RSEs, and the number of equipped vehicles (commercial, specialty, and public fleet vehicles) will be finalized through planning activities in Phase I.

5.2 Operational Policies and Constraints

Some key assumptions and constraints are made in defining the features for the proposed system. As for the assumptions, these include the following:

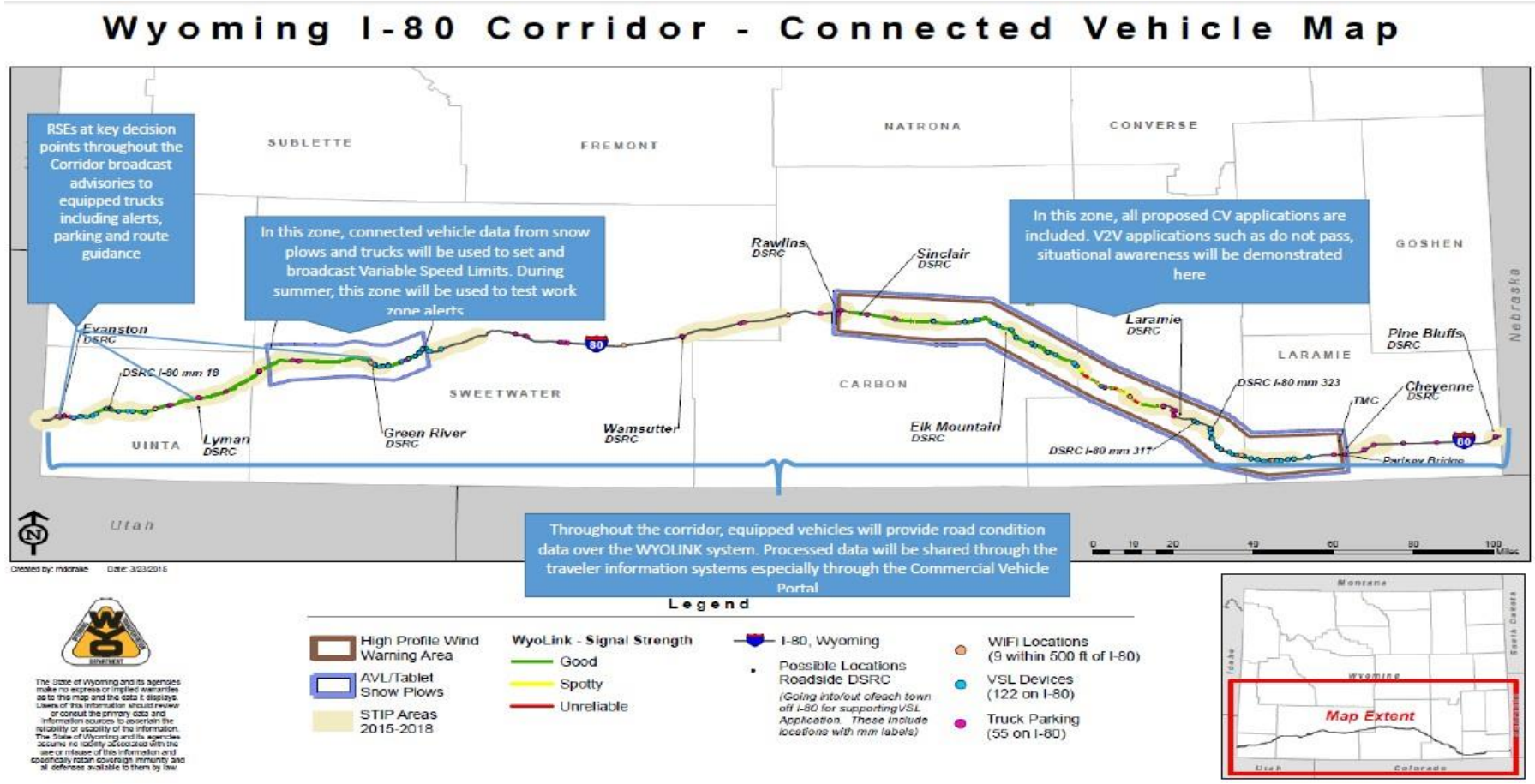
- During the pilot design and demonstration, the number of connected vehicles is expected to be a fraction of the I-80 truck traffic. However, as the rate of connectivity grows, the system needs to be able to add new on-board equipment on vehicles and new roadside equipment to the CV environment along with the back-end systems to support data collection and use.
- Road weather forecasts by segment still will likely rely on a human meteorologist who is able to assimilate disparate datasets to generate a travel advisory. This does not apply for current observations or short-term alerts of impending conditions which may be based on reported conditions by connected vehicles directly.
- Cost-effective real-time monitoring of truck parking availability across the state of Wyoming can be accomplished to support CV Pilot objectives.
- U.S DOT-developed Security Credentialing Management Systems (SCMS) can support secure communications as part of a larger security management framework developed for the proposed system.

While it is very early in the process to be detailing operational policies or identifying constraints, the following constraints were also identified during the conceptualization of the system and will need to be addressed as part of the proposed system:

- Polices regarding the responsibilities of various WYDOT divisions that play a role in supporting CV equipment.
- New agreements or modifications to existing SLAs to support CV technology and prioritize maintenance and support of the CV environment during the demonstration phase.
- Evaluation of WYDOT Executive Staff and Legislative priorities is necessary to continue budgetary support and buy-in from decision makers.
- WYDOT's manpower constraints require a careful analysis of job function changes due to the new system.

- WYDOTand fleet operators who are participants in the proposed system need to develop clear memorandums of understanding on roles and responsibilities of each parties.
- Fleet management systems are expected to proprietary with limited data availability due to competitiveness concerns. Froma functional standpoint, this implies that performance requirements that rely on data collected from fleet management centers may be limited. However, the immediate evaluation needs may be greater than the requirements for day-to-day operations and these needs should be reflected in partnership agreements with fleets.
- Testing and demonstration of a majority of the pilot applications can occur only during winter seasons in 2017 and not through the year.
- Minimizing distraction to truck drivers is critical to any advisories and alerts issued by the system. Any in-vehicle advisory needs to be balanced with the demands of the driving tasks required of the truck driver during stressful conditions.
- Many important highway locations lack reliable, cost effective commercial power and communications services.
- Commercial fleets' data proprietary concerns require a careful analysis (i.e., commercial vehicles may have limitations on the data they want to share versus data they are unwilling to share).
- The use of DSRC technology in the pilot will be guided by the IEEE 1609.2, 1609.3, and 1609.4 standards for Security, Network Services and Multi-Channel Operation (IEEE, 2013, IEEE, 2010a; IEEE, 2010b), the SAE J2735 Message Set Dictionary (SAE, 2015), and the emerging SAE J2945.1 Communication Minimum Performance Requirements standard (SAE, 2015).

Figure 5-1. CV pilot location and zones (Source: ICF/Wyoming)



5.3 Description of the Proposed System

The following sections describe the proposed system to meet the user needs and the desired changes identified in Section 4. This section is organized as follows:

- Major System Components – This sub-section describes the major system components that are part of the system. The section provides a context diagram that shows how the major components interface with each other.
- Capabilities and functions of the proposed system – This sub-section describes the capabilities and functions provided by the system highlighting the applications that will be created as part of this pilot.
- Interfaces to external systems – Several external systems will be involved in the pilot and interface with the proposed system. This sub-section describes the necessary interfaces at a high-level.
- Operational risk factors – This sub-section identifies several operational risk factors that need to be managed during the course of operating the proposed system
- Performance characteristics – This sub-section identifies the performance characteristics of the proposed system.
- Safety, Security and Continuity of Operations – This sub-section describes the safety, security and continuity of operations requirements for the proposed system.

5.3.1 Major System Components

Major system components are described in the following categories:

1. Vehicles
2. Roadside Infrastructure
3. Centers
4. Personnel
5. Communications Infrastructure

5.3.1.1 *Vehicles*

Four categories of vehicles will play a role in the pilot. The first two categories of vehicles are also referred in various sections of the ConOps as “equipped vehicles” since they will an OBE installed or modified as part of the pilot, The Vehicle OBE provides the vehicle-based processing, storage, and communications functions necessary to support CV operations. The radio(s) supporting V2V and V2I communications are a key component of the Vehicle OBE. The OBEs are also capable of generating an SAE J2735 Basic Safety Message (BSM). This communication platform is augmented with processing and data storage capability that supports the CV applications. In addition, the OBE will include an interface with to the vehicle databus (e.g., Controller Area Network (CAN), Local Interconnect Network (LIN), Ethernet/IP, FlexRay, and Media Oriented Systems Transport-MOST) that may enable communication between the Vehicle OBE and other vehicle systems to support CV

applications. The OBE also contains capabilities to monitor vehicle systems to support maintenance of

the vehicle itself and include sensors that monitor environmental conditions such as road condition and surface weather information.

- **WYDOT Fleet Vehicles** –This group represents vehicles owned by WYDOT(such as snow plows, highway patrol vehicles and other state-owned vehicles) that will be equipped with on-board equipment (OBE) with DSRC connectivity. The OBE will support communications, generate safety messages, collect and report vehicle, weather and road condition data, store data and provide an interface to communicate safety alerts and advisories. WYDOT fleets also have cellular connectivity with WYDOT centers to support operations,

- **Connected Truck** – This group represents vehicles owned by commercial vehicle operators that are participating in the pilot. These trucks will be equipped with an OBE with similar functions and capabilities as described for the WYDOT fleet. Similar to WYDOT fleets, connected trucks may have cellular connectivity to their fleet management centers.

The following two categories of vehicles do not have any equipment installed as part of the project. However, impact evaluation requirements may require temporary data collection from these vehicles as well.

- **Private Vehicle** – This group of vehicles represent private vehicles who have access to third-party applications on their personal information device

- **Truck** – This group of vehicles represent trucks that are connected to fleet management centers but are not equipped with an OBE for this project.

5.3.1.2 *Roadside Infrastructure*

Two major components are identified in this category.

WYDOT Traditional ITS – This physical object includes traffic detectors, environmental sensors, HARs, dynamic message signs, CCTV cameras and video image processing systems. Variable speed limit, lane management systems and barrier systems that control access to transportation infrastructure such as roadways are also included. This object also provides environmental monitoring including sensors that measure road conditions, surface weather, and vehicle emissions. Work zone systems including work zone surveillance, traffic control, driver warning, and work crew safety systems are also included. This category also includes speed monitoring devices like loop detectors and non-intrusive radar detectors, size and weight monitoring systems that gather truck weight and size information while in motion. While 511 is not a roadside infrastructure, it is included as part of the traditional ITS infrastructure maintained by WYDOT.

- **WYDOT Roadside Equipment (RSE)** – This object describes the roadside equipment that will be deployed as part of the system. RSE represents the CV roadside devices that are used to send messages to, and receive messages from, nearby vehicles using DSRC or other alternative wireless communications technologies. Communications with adjacent field equipment and back office centers that monitor and control the RSE are also supported. This device operates froma fixed position and may be permanently deployed or a portable device

that is located temporarily in the vicinity of a traffic incident, road construction, or a special event. It includes a processor, data storage, and communications capabilities that support secure communications with passing vehicles, other field equipment, and centers.

5.3.1.3 *Centers*

Three major components and respective sub-components are identified under this category

- **WYDOT Transportation Management Center (TMC)** – The TMC is planned to be the hub of operations for the CV Pilot collecting information from WYDOT fleet, and partnering fleet management centers. The TMC supports the integration and fusion of CV and non-CV data to developing warnings and advisories. The TMC also provides traveler information services back to the general public and fleet management centers via various means. The TMC is also responsible for various system services that are necessary for the pilot. The TMC includes the following key sub-systems and components of interest:
    - **Vehicle Data Translator (VDT) -** The VDT sub-system is data ingest engine that quality-checks CV and non-CV data, processes the multiple sources of data and presents a fused picture of road conditions for specific segments (roadway portions with starting and ending mileposts) on I-80.
    - **Alerts and Advisory Generator –** The Alert and Advisory Generator subsystem uses the outputs from VDT, other weather models to generate appropriate alerts and advisories that are communicated to the CV environment. The subsystem is responsible for determining the nature of the alert and the location-specific dissemination methods. In general, current conditions that cross a determined threshold will automatically generate an alert or advisory. For longer-term forecasts, the WYDOT TMC Weather Operator (see personnel section) will provide a "human-in-the-loop" assessment of the forecasts and make adjustments as necessary.
    - **Wyoming Traveler Information (WTI) –** The subsystem interfaces with all public facing traveler information services such as 511 phone and web system, social media, information kiosks, WYDOT traffic app, and the Commercial Vehicle Operator Portal. This subsystem takes information from the alerts and advisory generator and presents them to the traveling public through various dissemination media.
    - **System Services –** This group of subsystems represent various functions necessary for ensuring the proper and safe operation of the proposed system. These include the following:
        - The **Object Registration and Discovery Service (ORDS)** represents one or more center-based applications that provide registration and lookup services necessary to allow objects to locate other objects operating within the CVE. These registration and discovery services are support services that enable other applications to provide transportation services
        - The **Security Credentialing and Monitoring System (SCMS)** is operated by the USDOT capable of producing IEEE 1609.2 certificates with associated keys suitable for signing and encrypting messages. The SCMS ensures secure message transfer between various applicable objects in the CV environment.

- The '**Service Monitor'** represents one or more center-based systems that provide monitoring, management and control services necessary to other applications and/or devices operating within the CVE. These support services enable other applications to provide transportation services.
- '**Field Support Equipment'** represents the portable equipment used by field personnel to locally troubleshoot, initialize, reprogram, and test infrastructure equipment. It may include a laptop, specialized diagnostics tools, or any other general purpose or specialized equipment that is interfaced locally to infrastructure equipment to support maintenance and repair.
- **Location and Time Store** - 'Location and Time Data Source' provides accurate position information for mobile and field devices. While a Global Positioning System (GPS) Receiver is the most common implementation, this physical object represents any technology that provides a position fix in three dimensions and time with sufficient accuracy.

- **Fleet Management Centers** – This object represents the partnering fleet management centers that both receive and send real-time information to the WYDOT TMC about their firm's truck operations and corridor conditions. This object represents the systems (and associated personnel) that are responsible for the dispatching and management of Commercial Vehicle fleets (e.g. traditional Fleet Managers) and Freight Equipment assets. It may be many people in a large tracking organization or a single person (owner driver) in the case of single vehicle fleets. The Fleet Management Center provides instructions and coordination for Commercial Vehicles and Freight Equipment and receives the status of the vehicles and freight equipment in the fleet that they manage.

- **Data Warehouse** – A data warehouse capability is planned for the pilot to collect, manage and make available the data collected as part of the pilot for performance management and evaluation. The "Data Warehouse" is a Data Distribution Service that collects, processes, and distributes CV data, connecting data producers with data consumers and facilitates data exchange in the CVE. It focuses on data that is relevant for a period beyond the immediate (10 minutes or more, roughly), and distributes that data to interested parties using a "publish and subscribe" mechanism. It stores data for a period long enough to satisfy the utility of that data. It may discard data when it is no longer relevant. The data warehouse supports performance measurement dashboards and the impact assessment.

5.3.1.4 *Personnel*

The following objects represents the personnel-related objects involved in the proposed system.

- **WYDOT TMC Weather Operator –** The 'WYDOT TMC Weather Operator' represents the on-site weather support service that exists in the WYDOT TMC. The function provides weather, hydrologic, and climate information and warnings of hazardous weather. It provides an analysis of atmospheric weather observations and derives forecasts that are an ensemble of NWS, private sector providers, and various research organizations. The service provides

formatted weather data products suitable for on-line processing and integration with other ITS data products.

- **WYDOT TMC Operations Personnel -** This object represents the WYDOTITS Personnel that operate a traffic management center. These personnel interact with traffic control systems, traffic surveillance systems, incident management systems, and work zone management systems. They provide operator data and command inputs to direct system operations to varying degrees depending on the type of system and the deployment scenario.
- **WYDOT Maintenance Field Personnel-** This object represents the people that perform maintenance and construction field activities including vehicle and equipment operators, field supervisory personnel, field crews, and work zone safety personnel. Information flowing from the Maintenance and Construction Field Personnel will include those system inputs specific to maintenance and construction operations, such as information regarding work zone status, or the status of maintenance actions. The field personnel are also monitored within the work zone to enhance work zone safety.
- **WYDOT Highway Patrol Personnel -** This object represents the personnel that perform incident management and enforcement related activities on I-80. Information flowing from Highway Patrol personnel will include those inputs specific to incident management, commercial vehicle enforcement and emergency management.

5.3.1.5 *External Systems*

The proposed system interfaces with several external systems. The nature of the interfaces is described in Section 5.3.3.

- **Third Party Information Service Providers (ISPs)** – This object represents third-party developers of data and information products for both WYDOT and the end-consumer. These may include weather products that are used by WYDOT TMC to driver-focused applications that use data from the TMC.
- **WYDOT Maintenance Management** – This object represents the WYDOT maintenance management systems and functions carried out in the corridor including winter maintenance, work zone management and other non-winter maintenance activities.
- **WYDOT Commercial Vehicle Enforcement**- This object represents WYDOT commercial vehicle operations enforcement in the corridor including Port of Entry operations, permitting, and oversize/overweight enforcement.
- **Truck Parking Services** – This object represents the public and private parking services available in the corridor.
- **National Weather Service** – This object represents the systems and personnel of the National Weather Service (NWS) offices in Wyoming for the I-80 corridor.
- **Adjacent State DOT TMCs** – This object represents the systems and personnel at adjacent State DOTs (Colorado, Utah and Nebraska) necessary for coordinated response to conditions on I-80.

5.3.1.6 *Communications Infrastructure*

A secure WyoLink Radio Network exists throughout the corridor. WyoLink is a statewide digital trunked very high frequency (VHF) P-25 compliant public safety communications system. The system is used for voice traffic and secondarily for low-speed mobile data communications; it provides radio service to public safety entities at all levels (city, county, state and federal agencies as well as commercial emergency medical responders and hospitals). The WyoLink system is maintained by WYDOT's Telecommunications Program.

Point to point wireless microwave communications are used to communicate between WyoLink radio sites, which also support a parallel IP backhaul communication system used by intelligent transportation systems. Using point-to-multipoint wireless communications to extend from the backhaul system to roadside service points, WYDOT have also been able to set up a network of roadside Wi-Fi hotspots along the I-80 and Interstate 25 (I-25) corridors. Using low-cost antennas, WYDOThas been able to achieve Wi-Fi signal range of more than a mile in some locations.

DSRC communications between RSEs and vehicles and cellular linkages between fleet management centers are included in the communications infrastructure as well.

5.3.1.7 *Physical Context Diagram*

The following figure provides a context diagram for the connectivity between various components mentioned in the previous section. (Figure 5-2)

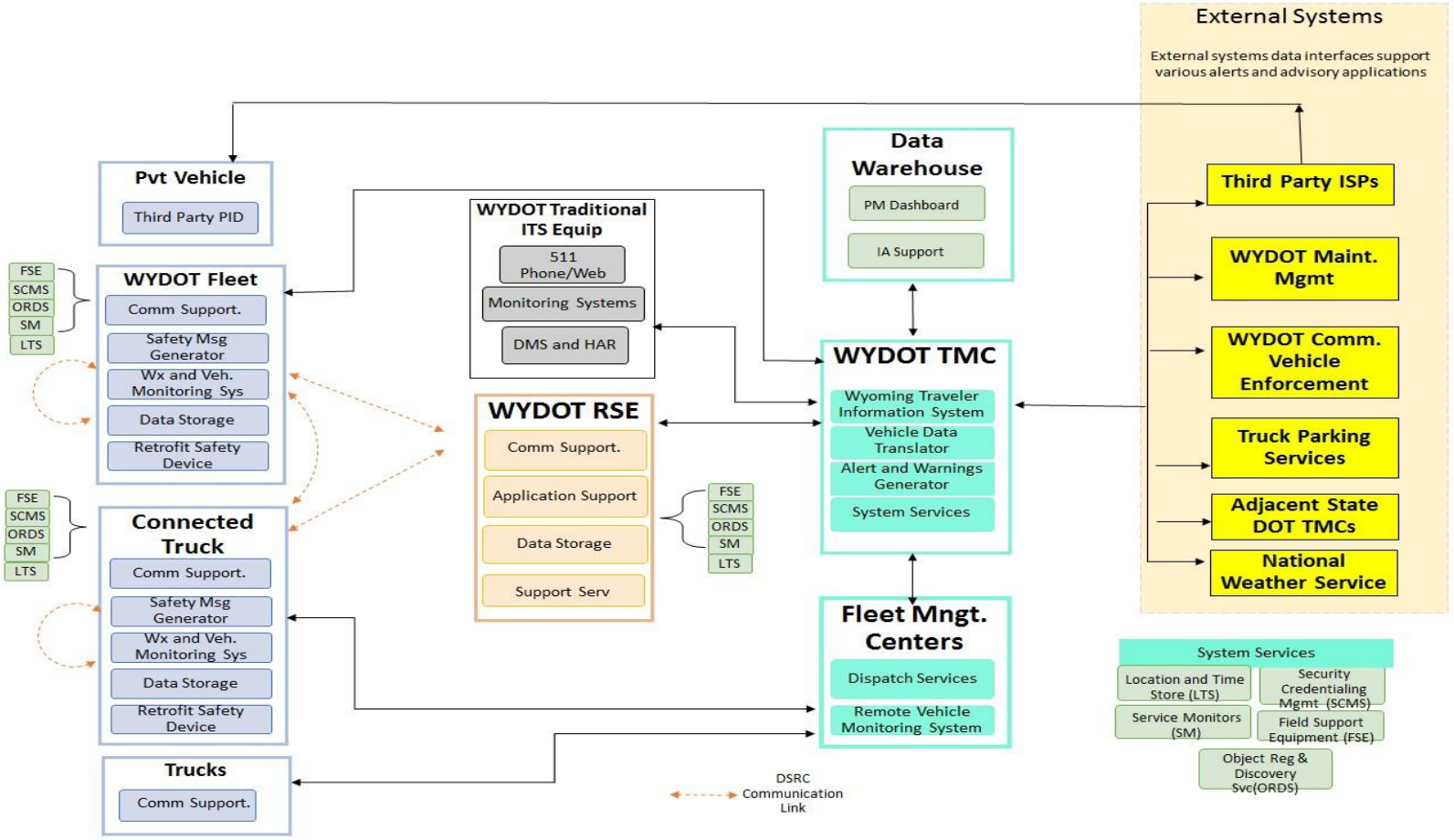


Figure 5-2. Physical Object Diagram for Proposed System (Source: ICF/Wyoming)

5.3.2 Capabilities and Functions of Proposed System

Figure 5-3 provides the context diagram for the proposed system. The following sections describe the capabilities and functions of the proposed system. System capabilities are organized by two categories – the pilot system which describes the center-related capabilities and the mobile distribution system which describes the capabilities relating to field to vehicle and vehicle to vehicle interactions.

5.3.2.1 *Pilot System – Collect Road and Weather Data*

The system shall collect road and weather data from a variety of sources including connected trucks, connected WYDOT fleets, fixed infrastructure sensors like RWIS, National Weather Service, maintenance personnel and adjacent State DOTs. The data collected include both directly observed road and weather conditions or other data (such as vehicle telematics) that will help estimate the conditions of road segments along I-80.

5.3.2.2 *Pilot System – Collect Work Zone Information*

The system shall collect work zone information including location, duration and nature of activity reported by maintenance personnel and centers along I-80.

5.3.2.3 *Pilot System – Collect Dynamic Travel Information*

The system shall collect dynamic travel information such as travel speeds, parking availability, and incident notifications along I-80

5.3.2.4 *Pilot System – Share Integrated and Fused Advisories*

The system shall fuse travel information, road condition data and weather data to generate segment-level advisories along I-80. The system shall share advisories with connected vehicles, fleet management centers, traditional ITS channels like DMS/HAR/511 and to partners like truck parking facilities and adjacent State DOTs

5.3.2.5 *Pilot System – Provide Dynamic Travel Information*

The system shall provide dynamic travel information to both vehicles on-road as well as over a wide area to support travel decisions. Dynamic travel information may relate to variable speed limits, road closures, and truck parking availabilities.

5.3.2.6 *Mobile Distribution – Share Safety and Road Condition Messages*

The mobile distribution aspect of the system shall share safety and road condition messages between connected vehicles and between connected vehicles and the roadside infrastructure. This information include basic safety messages, road conditions, speeds, and indications of stopped traffic ahead. The same information will also be shared with by connected vehicles when they pass an RSE in the corridor.

5.3.2.7 *Mobile Distribution – Collect Messages from Other Connected Vehicles*

Connected vehicles shall collect messages from other connected vehicles about situational awareness of conditions and provide the information to the driver in a meaningful format.

5.3.2.8 *Mobile Distribution – Collect Messages from Infrastructure*

Connected vehicles and the pilot system shall collect messages from infrastructure about advisories and alerts including speeds, parking availability, upcoming travel conditions and provide the information to the driver in a meaningful format.

5.3.2.9 *Mobile Distribution – Generate Emergency Message*

Connected vehicles shall have the capability to generate an emergency message while on travel on the I-80 corridor when conditions warrant such a message from that vehicle or about other emergency conditions on the corridor observed by the vehicle.

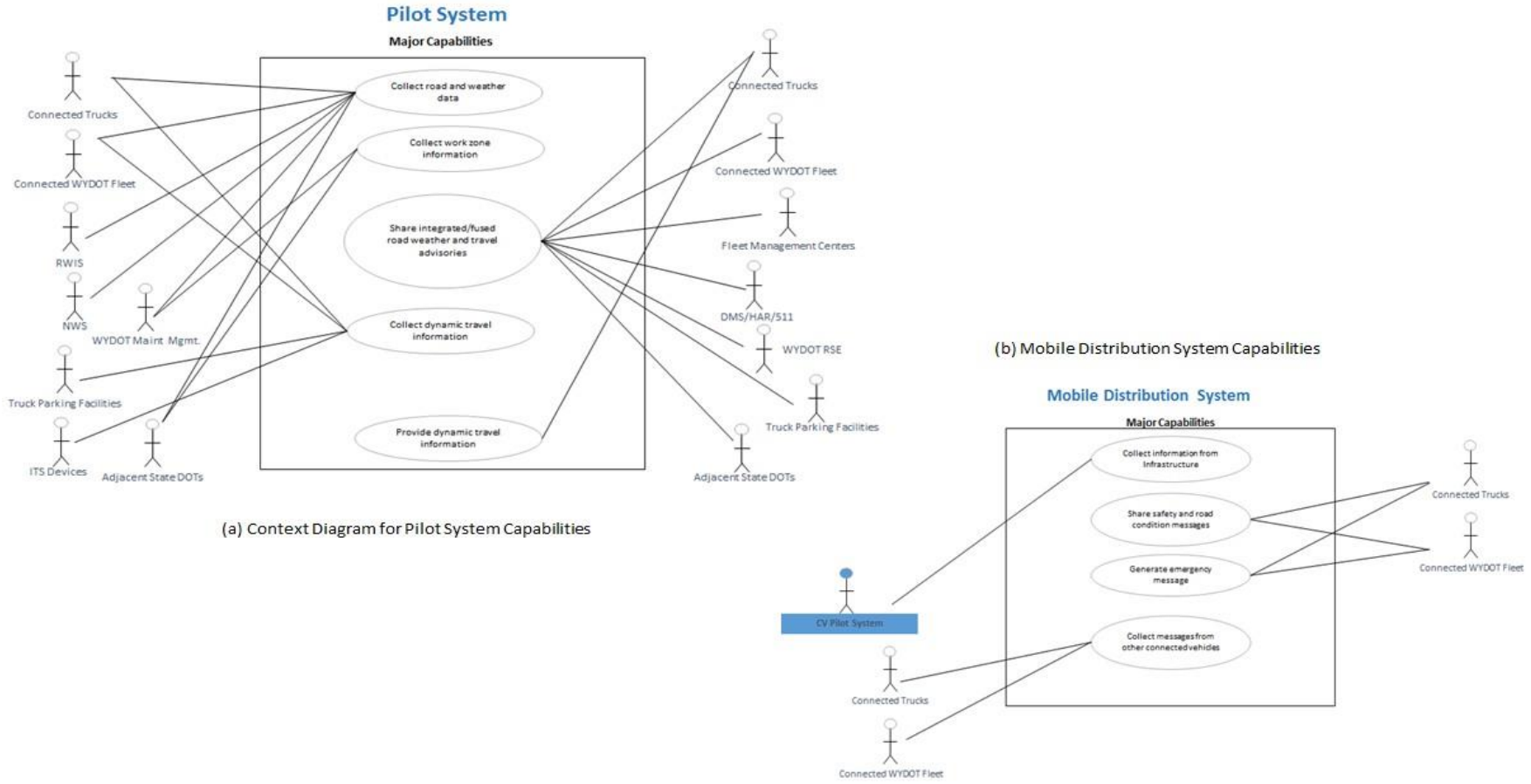


Figure 5-3. Context Diagram for Proposed System (Source: ICF/Wyoming)

5.3.3 Proposed Applications

Figure 5-4 illustrates the relationship between the user needs identified in Section 4, system capabilities defined in Section 5.3.2 and the use-cases (identified in Section 6) with the applications which represent the implementable bundles of functionality. User needs drive system capabilities that support a variety of use-cases. These use-cases are implemented through deployed applications. The following seven applications are proposed as part of the pilot.

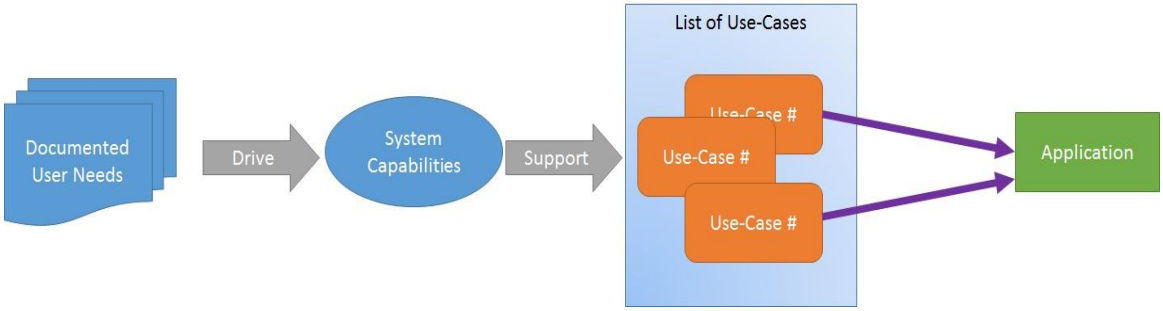


Figure 5-4. Relationship between User Needs, System Capabilities, Use-Cases and Applications (Source: ICF/Wyoming)

5.3.3.1 *Road Weather Advisories for Trucks*

This application provides the capability of collecting road weather data from WYDOT Fleets and Connected Trucks and using that data to develop short term warnings or advisories that can be provided to individual commercial vehicles or to commercial vehicle dispatchers. The raw data will be processed in a controlling center (WYDOT TMC) to generate road segment-based data outputs. The processing will also include a road weather commercial vehicle alerts algorithm to generate short time horizon alerts that will be pushed to fleet management systems and available to commercial vehicle dispatchers. 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 CV-based interfaces. While these advisories are generated for trucks, through existing traveler information portals, road weather advisories can be shared with the general traveling public.

5.3.3.2 *Automatic Alerts for Emergency Responders*

This application provides the capability for connected trucks to transmit an emergency message when the vehicle has been involved in a crash or other distress situation. In addition to driver initiation, an automatic crash notification feature transmits key data on the crash recorded by sensors mounted in the vehicle (e.g. deployment of airbags) without the need for involvement of the driver.

Connected trucks would attempt to provide notification via cellular communication in the corridor. In areas with inadequate cellular coverage, the emergency message is broadcast to passing CVs, who can relay the message to other CVs as well as roadside "hotspots." Once received by WYDOT TMC (either through emergency vehicles or through the roadside equipment), the appropriate response to

the vehicle situation can be carried out by emergency response services. This application allows a vehicle to forward mayday requests even in areas where no V2I infrastructure exists.

5.3.3.3 *CV-enabled Weather-Responsive Variable Speed Limits*

This application uses road weather information from connected trucks and WYDOT Fleet vehicles as well as current and historical data from multiple sources to determine the appropriate current safe speed and other traffic management strategies. The application provides real-time information on appropriate speeds for current conditions and warn drivers of coming road conditions both through traditional ITS as well as RSEs.

5.3.3.4 *Spot Weather Impact Warning*

This application will alert drivers to unsafe conditions or road closure at specific points on the downstream roadway as a result of weather-related impacts (e.g., high winds, flood conditions, ice, and fog). The application 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 via Road Weather Information System (RWIS) or via vehicle-based probe data from commercial, specialty or public vehicles. The information is processed to determine the nature of the alert or warning to be delivered and then communicated to CVs. 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 or through third-party applications.

5.3.3.5 *Work Zone Warnings*

This application provides information about the conditions that exist in a work zone to vehicles that are approaching the work zone. This application provides approaching vehicles with information about work zone activities that may result in unsafe conditions to the vehicle, such as obstructions in the vehicle's travel lane, lane closures, lane shifts, speed reductions or vehicles entering/exiting the work zone.

5.3.3.6 *Situational Awareness*

The application determines if the road conditions measured by other vehicles represent a potential safety hazard for the vehicle containing the application. To enable this application other vehicles broadcast relevant road condition information, such as fog or icy roads or slowing speeds or brake lights. This application supports the capability for CVs to share situational awareness information even in areas where no roadside communications infrastructure exists. This application can be useful to vehicles that are not fully equipped with sensors, or vehicles entering an area with hazardous conditions.

5.3.3.7 *Freight-Specific Dynamic Travel Planning*

This application provides both pre-trip and en-route travel planning, routing, and commercial vehicle related traveler information. Both real-time and static can be provided directly to fleet managers, to

mobile devices used by commercial vehicle operators, or directly to in-vehicle systems as commercial vehicles approach roadway exits with key facilities such as parking. The application also supports advisories to specific categories of advisories (restrictions on lightweight or high-profile vehicles for example).

5.3.4 Interfaces to external systems

The proposed system depends on a few key interfaces to external systems described here:

- Truck Parking Systems – An electronic interfaceto an external system or systems that provides an estimated or measured real-time availability of parking at specific locations in the corridor to the WYDOT TMC.
- WYDOT Maintenance Management – An operator interface that communicates information about current and forecast conditions and incident notifications with the maintenance management personnel.
- WYDOT Commercial Vehicle enforcement – An operator interface that shares information about port of entry operations, road closures, and size and weight restrictions to WYDOT commercial vehicle enforcement personnel.
- Adjacent State DOT TMCs – An operator interface that shares information between State DOTs in Utah, Nebraska and Colorado.
- National Weather Service – An operator interface that coordinates messaging between the NWS and the WYDOT TMC as is currently being occurring due to the FHWA weather enterprise project.
- Third Party ISPs – A traveler information data service that can be consumed by third party application developers needs to be provided

5.3.5 Operational risk factors

Several operational risk factors are identified for the proposed system including the following:

- Critical mass of vehicles is not available reducing the efficacy of use-cases that depend on vehicle to vehicle connectivity
- Data quality from equipped vehicles is poor leading to an inability to generate improved alerts and advisories.
- Risk of data or system breaches in the CV environment resulting in hacked message transfers within the CV environment, loss of data or intrusions into personnel privacy
- Algorithms for several applications are untested in terms of the correct thresholds, message locations and nature of alerts in the Wyoming context
- In-vehicle driver interface for advisories and alerts is ineffective leading to poor compliance and frustration from system users
- Lack of training for various involved personnel leads to limited use of CV data and applications
- Evolving CV technology and emerging solutions and standards create risks in terms of technology obsolescence for the proposed system

- Changes in political or policy environments may change the availability of the communications infrastructure for the proposed system

These operational risks will continue to be managed through the course of planning activities in Phase I of the pilot.

5.3.6 Performance characteristics

Performance of the proposed system will be guided by the performance measurement and evaluation plan developed in Phase I. Overall system outcomes are described in Section 8. However, performance requirements for various system components will be specified during the systems requirement phase including the minimum performance requirements of RSEs, OBEs involved in the proposed system. The requirements will take into account the emerging SAE J2945.1 Communication Minimum Performance Requirements standard (SAE, 2015). Performance requirements will also be set for the VDT, alert and advisory generator in terms of data quality and timeliness of alerts.

Performance characteristics also include assessment of algorithm performance

5.3.7 Safety, Security and Continuity of Operations

5.3.7.1 *Safety*

Safety of all personnel involved in the proposed system will be maintained following the Safety Management Plan developed as part of the planning activities in Phase I. The safety management plan will look at risks associated with equipment failure, application error and user error and define a mitigation approach based on criticality.

5.3.7.2 *Security*

Security of the CV environment will be supported by use of the U.S DOT SCMS and be guided by the security and privacy operating concept developed as part of the planning activities in Phase I. The security and privacy operating concept will identify the various threats to the CV environment and develop a mitigation plan to ensure that messages within the CV environment are secure and privacy of users is maintained.

5.3.7.3 *Continuity of Operations*

Continuity of TMC operations is maintained based on WYDOT protocols. In case of CV equipment failures, the TMC will rely on traditional ITS devices and systems to replicate the capabilities of the new system.

5.4 Modes of Operations

This section describes the following modes of operation for the proposed system.

5.4.1.1 *Normal Operations*

During normal operations, the full suite of CV applications described in Section 5.3.2 is available. Objects in the CV environment are being monitored by the service monitor and are functioning normally.

5.4.1.2 *Degraded Mode*

In a degraded mode, some of the vehicle or infrastructure objects in the CV environment are not functioning as intended. Depending on the nature of the degradation, different functions and processes are available. For example, OBE malfunctions would limit operations to wide area advisories via 511 and the use of traditional ITS (DMS and HAR) for roadside communications. On the other hand, failure of specific RSEs in the proposed system can be managed with redundancy in RSE deployment.

5.4.1.3 *Back-up Mode*

In a back-up mode, some of the center systems like the VDT, Alerts and Advisory Generator or core system services are not functioning as intended. Due to the risk associated with malfunctioning center system, all CV-related use-cases would be suspended and the proposed system would revert back to pre-CV state of operations described in Section 3.

5.5 User Classes and Other Involved Personnel

The following sections represent the user classes and other involved personnel in the proposed system.

5.5.1 Stakeholders

The following are the stakeholders, in no particular order, for the proposed system:

- U.S Department of Transportation
- WYDOT – Traffic, Construction, Maintenance, GIS/ITS, IT, Telecom Programs
- Wyoming Highway Patrol
- Fleet Managers
- Wyoming Trucking Association
- City managers and local traffic and law enforcement officials (Rawlins, Laramie, Cheyenne, Green River, Rock Springs, Evanston)
- National Weather Service
- County Emergency Management
- Private Truck Parking Services
- Adjacent State DOTs
- Third party application developers
- System integrators and vendors

5.5.2 User Profiles

In general, the user classes do not change significantly from the description provided in Table 3.1. However, there are changes in user responsibilities and interactions which are described in these section. Some of these impacts are also elaborated in Section 7 of this document.

Table 5-1. User Profiles in the Proposed System

User Group	Owner	Short Description	Changes to responsibilities and interaction with the system
		Centers	
1. Traffic Management Center - Operators	WYDOT	Traffic Management Operators responsible for managing advisory, control strategies from the TMC in Cheyenne. Responsible for VSL, DMS, Traffic Incident Management etc.	Personnel will have to factor new sources of data and information into their decision making. Particularly, they need to understand how best to use the capability provided by the RSEs for weather responsive traffic management.
2. Traffic Management Center - Traveler Information	WYDOT	Traffic Management Center personnel responsible for updating WTI system and generating travel advisories. Some users in this group may also be operators	More frequent information is now available at a greater geographic fidelity from the system. These need to be reflected adequately in the traveler information system in use today. Personnel also have to develop a public data feed for consumption by third party information service providers
3. Traffic Management Center - Weather Providers	WYDOT	Contracted personnel located in the Traffic Management Center who are responsible for developing route-specific forecasts of road and weather conditions	Have new sources of data and information to include in their sources to create ensemble road condition information about a segment to include into the traveler information systems.
4. Highway Patrol - Dispatch	WYDOT	Personnel providing the dispatch and center capability for highway patrol on I-80. Includes port of entry operations. For the purpose of user needs, this group also includes State homeland security systems and personnel who are involved in emergency response when event-scale warrants emergency operations protocols. This group also manages the port-of entries and are responsible for commercial vehicle safety enforcement.	Will see increased communication about road conditions and incident notifications from the TMC systems involved in the CV environment.
5. Maintenance - Dispatch	WYDOT	Personnel providing dispatch capability for maintenance fleets on I-80. Includes both work zones and winter maintenance	Will see increased communication about road conditions and incident notifications from the TMC systems involved in the CV environment.
6. ITS Maintenance	WYDOT	WYDOT maintenance staff specifically for Intelligent Transportation System (ITS) devices	ITS maintenance will be responsible for a new set of devices that need to be maintained as per the performance requirements
7. Adjacent State DOT Centers	Colorado, Utah and Nebraska	Personnel and systems at statewide TMCs in Colorado, Utah and Nebraska that need information on I-80 conditions	Additional information may be shared as needed with these centers.

User Group	Owner	Short Description	Changes to responsibilities and interaction with the system
8. Fleet Management Centers - CVOP Only	Various	Personnel and systems at participating fleet management centers who will receive information only from the CVOP. These entities receive CV-enabled information through the CVOP but otherwise do not participate in the pilot.	These management centers will see new capabilities realized though improvements in the CVOP.
9. Fleet Management Centers - Pilot Users	Various	Personnel and systems at Fleet Management Centers who will participate directly in pilot (such as Trihydro, Dooley and maybe others). These users receive and transmit CV information to/from vehicles to/from WYDOT.	These management centers will have to establish new interfaces with WYDOT TMC to support real-time data transfer from connected trucks to the TMC. They will have access to new data from their vehicles which they need to factor into their decision-making as well.
10. Truck Parking Facility Operators	Various	Private truck parking facility managers along I-80 corridor	Truck parking facility operators will see additional responsibilities to monitor parking availability and communicating such availability with the TMC.
11. National Weather Service (NWS) Forecast Offices	NWS	Systems and personnel at the NWS Forecast Offices in the I-80 Corridor who are responsible for generating weather alerts, warnings and watches.	Personnel will see their interaction with WYDOT TMC weather operators grow. New sources of weather and road condition data will be available to the NWS forecast offices
12. TMC – Performance Management	WYDOT	Systems and personnel required to support performance management, data archiving, and system evaluation needs during the pilot	New performance dashboards need to be created to understand the performance of the proposed system.
13. Wyoming Telecommunications and IT Programs	State of Wyoming	Systems and users responsible for statewide communication linkage through WyoLink Radio Network system and other radio-based systems. Also includes the IT systems and personnel that need to integrate with CV Pilot requirements both within the DOT and through the State government.	The addition of the CV components will create new requirements of the existing communications and IT platforms that will need the attention of personnel in these programs.
14. Special Event Venues	Various	Systems and personnel at arenas, universities and major employers that receive or provide information as part of the CV Pilot.	No change in their interaction with the system
		Field	
1. Maintenance Supervisors	WYDOT	Maintenance supervisors in districts who are responsible for tactical operations during adverse weathers. These personnel are responsible for crew call-ups, shift assignments, and treatment decisions during an event.	No change to their responsibilities but may receive information from WYDOT TMC about road conditions and alerts through the CV environment.
2. Snow Plow Operators	WYDOT	Operators of snow plow vehicles who are on the frontlines of weather event response. Personnel are also responsible for providing road condition updates and situational awareness of travel conditions on I-80.	Snow plow operators will see additional in-vehicle advisories and alerts. They will also continue their road condition updates

User Group	Owner	Short Description	Changes to responsibilities and interaction with the system
3. Highway Patrol - Field	WYDOT	Operators of highway patrol cars on I-80 who are on the frontlines for incident response, traffic control and enforcement on I-80. From a user needs perspective, this group also includes local police, fire and medical crews that provide first responder capability along the I-80 corridor. This group also manages the port-of entries and are responsible for commercial vehicle safety enforcement.	Field patrol officers will see additional in-vehicle advisories and alerts. They will also be responsible for setting up portable RSEs around incidents and work zones.
4. Commercial Truck Drivers	Various	Commercial truck drivers who travel the I-80 corridor as part of their freight movement. A subset of them will be on trucks that are connected (i.e include an OBE with DSRC connectivity)	Drivers of Connected trucks will see a significant change to their driving environment including in-vehicle alerts and advisories through a new interface. Drivers of regular trucks may see an increased amount of communication with their fleet managers and more location-specific information communicated to them.
5. Personal Auto Travelers	Various	Personal auto travelers who travel the I-80 corridor as part of the trip.	Additional third party applications may be available using data from the proposed system
		Wide area users	
1. 511 Phone, App and Website Users and Media	Various	General users of WYDOT's travel information system services. This group includes users of various WYDOT pre-trip traveler information services including 511 phone, website and app. Also includes media partners of WYDOT who support the wide area dissemination of travel conditions and advisories.	No change

5.5.3 Interactions among user classes

Most interactions between user classes remain as described in Section 3. However, a greater degree of interaction between the WYDOT TMC user groups and fleet management centers is expected to occur in the proposed system. Similarly, a greater degree of communication is required between WYDOT field personnel (maintenance and highway patrol) and the TMC to support truck advisories and warnings. Building on existing initiatives, the interaction between the National Weather Service, the WYDOT TMC weather operator is expected to grow as a result of this system. Lastly, interfaces between truck parking services and WYDOT TMC need to be created that allow for communicating parking availability.

5.5.4 Other involved personnel

The following personnel are also involved in the operations of the proposed system:

- U.S DOT SCMS Operators – Personnel responsible for operating the SCMS

- U.S DOT Impact Evaluation Contractor – Personnel involved in U.S DOT-sponsored impact evaluation
- Third party application developers – Application developers with interest in using data products created by the proposed system.
- System vendors and integrators – Private sector system vendors and integrators involved in the development and operation of the proposed system

5.5.5 Support environment

The support environment listed in Section 3.6 will continue to be used for the proposed system. In addition, U.S DOT evaluation support will help develop a rigorous impact evaluation of the system. New agreements between various stakeholders will be developed to formalize the support environment for the pilot phase as part of the partnership development activity in Phase I.

6 Operational Scenarios

This section is intended to provide an overview of the major operational uses for the proposed system. Each scenario begins with a brief description followed by one or more use-cases that describe a series of related interactions between a user (or more generally, an "actor") and the proposed system that enables the user to achieve a goal pertinent to the scenario. While many scenarios can be created, this section addresses the following six (6) scenarios and sixteen (16) use-cases which are critical to demonstrate the capabilities and desired functionality of the proposed system:

1. Corridor Monitoring and Operations Support (4 use-cases)
2. Truck Advisories (3 use-cases)
3. Truck Warning (3 use-cases)
4. Incident Notification (2 use-cases)
5. Dynamic Travel Planning Support (2 use-cases)
6. Performance Management (2 use-cases)

Each use-case is defined consistently and includes a unique and numbered name, a short description, definition of the use-case goal, constraints and geographic scope. Each use-case also identifies the actors involved and provides examples of how the use-case would work. Alternatives to the main method of operations are also identified. Pre- and Post- conditions for the use-case are also identified along with the information requirements. Any issues and unknowns with each use-case are also highlighted in the description.

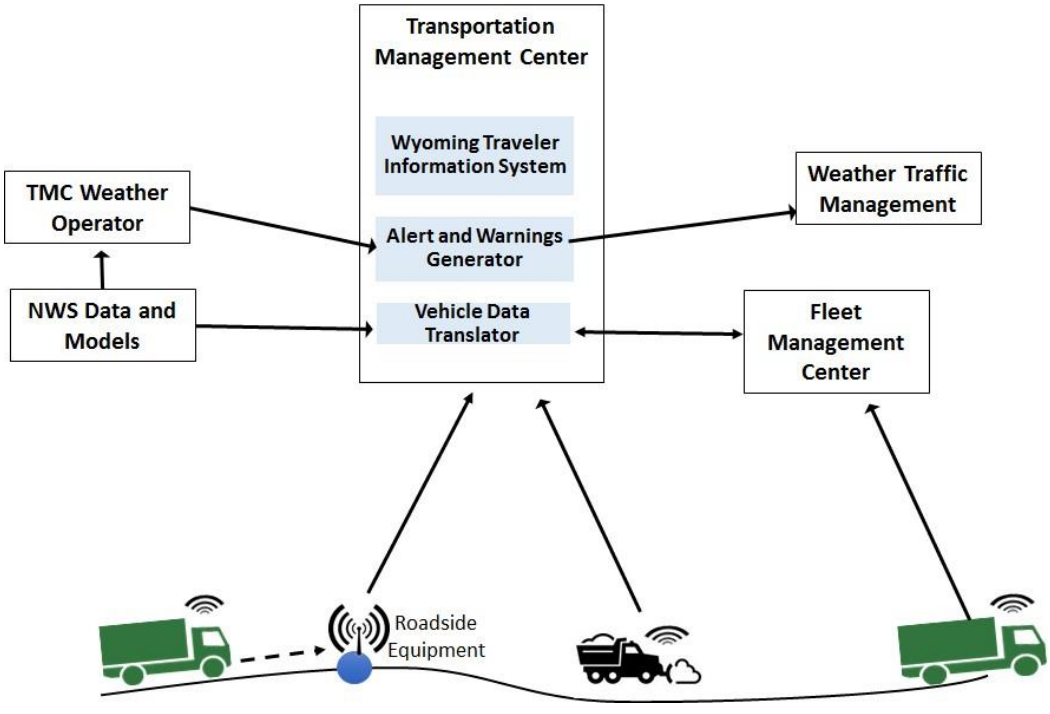
6.1 Corridor Monitoring and Operations Support

This scenario describes the how the new monitoring capabilities from the pilot will be used by WYDOT. Through the pilot, WYDOT will leverage data collected from mobile platforms (WYDOT Fleets and Connected Vehicles), fuse them with existing data sources and develop segment level advisories and warnings. Based on the information received from the field, WYDOT will also initiate several actions that improve the operations of the corridor includingdelivering segment-level advisories and alerts, managing road closures, utilizing other control strategies like variable speed limits and dispatching maintenance and incident response personnel. Four specific use-cases are identified:

- 6.1.1 Road Weather Data Collection
- 6.1.2 Data Fusion and Segment Advisories
- 6.1.3 Weather Responsive Traffic Management
- 6.1.4 Adjacent State DOT coordination

6.1.1 V2I Road Weather Data Collection

Table 6-1. Use Case #1 – V2I Road Weather Data Collection.

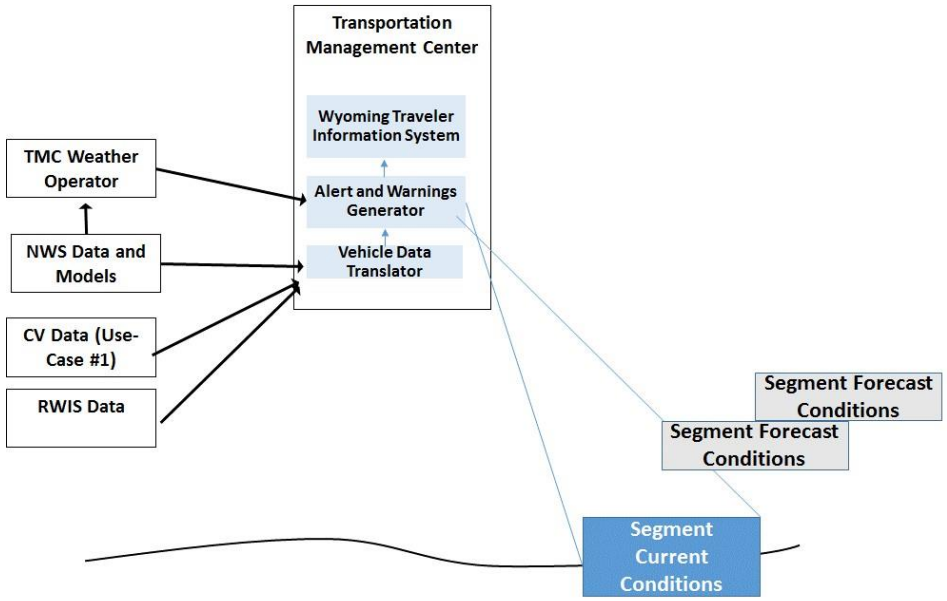
Use Case Name	V2I Road Weather Data Collection
Short Description	This use-case identifies how weather and road weather data collection occurs during the pilot using both connected vehicles, existing road weather infrastructure, and atmospheric weather models. These various streams of data are monitored for quality by an on-site meteorologist as part of the TMC weather operations.
Goal	Improve collection of road condition data along I-80 corridor using connected vehicle technology
Constraints	Gaps in cell coverage require local on-board storage of data before transmitting to WYDOT TMC
Geographic Scope	Corridor-wide
Actors	WYDOT Fleet Vehicles, Connected Trucks, WYDOT TMC, Fleet Management Centers
Illustration	

Preconditions	Equipped vehicles with OBE that includes a sensor package for weather and road condition, ability to collect vehicle operations data and cellular and DSRC capabilities.
Main flow (example)	1. OBE-equipped WYDOT fleet vehicle continuously monitors vehicle operating conditions, weather data and road condition as it drives along the corridor. 2. At a specified time interval, the OBE-equipped WYDOT fleet vehicle transmits the location-based data to WYDOT TMC over a cellular communication link
Alternate flow	1. An OBE-equipped WYDOT fleet vehicle passes by a RSE unit and transmits data to the RSE which then communicates with the TMC 2. An OBE-equipped truck collects weather data and transmits the data over a cellular link to their fleet management center. Fleet management centers then shares the data with the TMC over a center to center data connection.
Post-Conditions	If weather-related data transfer does not occur within a prescribed time period from an equipped vehicle, the data will be deleted from the OBE. Lack of weather and condition reports from vehicles will be flagged by the system monitor.
Information Requirements	Weather and road condition data include temperatures (air and pavement), precipitation, visibility, wind levels and surface conditions. Vehicle operating data includes wiper status, ABS activation and headlight usage.
Issues	Quality of weather and road condition data from mobile platforms like connected vehicles varies based on the parameter being measured. Conflicting information from vehicles and from other fixed infrastructure needs to be managed.

6.1.2 Data Fusion and Segment Advisories

Table 6-2. Use Case #2 – Data Fusion and Segment Advisories Generator

Use Case Name	**Data Fusion and Segment Advisories Generator**
Short Description	This use-case defines how WYDOT TMC personnel, WYDOT TMC Weather providers, and the vehicle data translator system fuse various sources of atmospheric and road weather data, quality-checks the data, and develops segment level advisories and forecasts of conditions.
Goal	Improve segment-level advisories and forecasts along the I-80 corridor.
Constraints	Quality of advisories limited by data quality levels. Developing advisories and forecasts still requires a strong “human-in-the-loop” element.
Geographic Scope	Corridor-wide with some statewide elements.

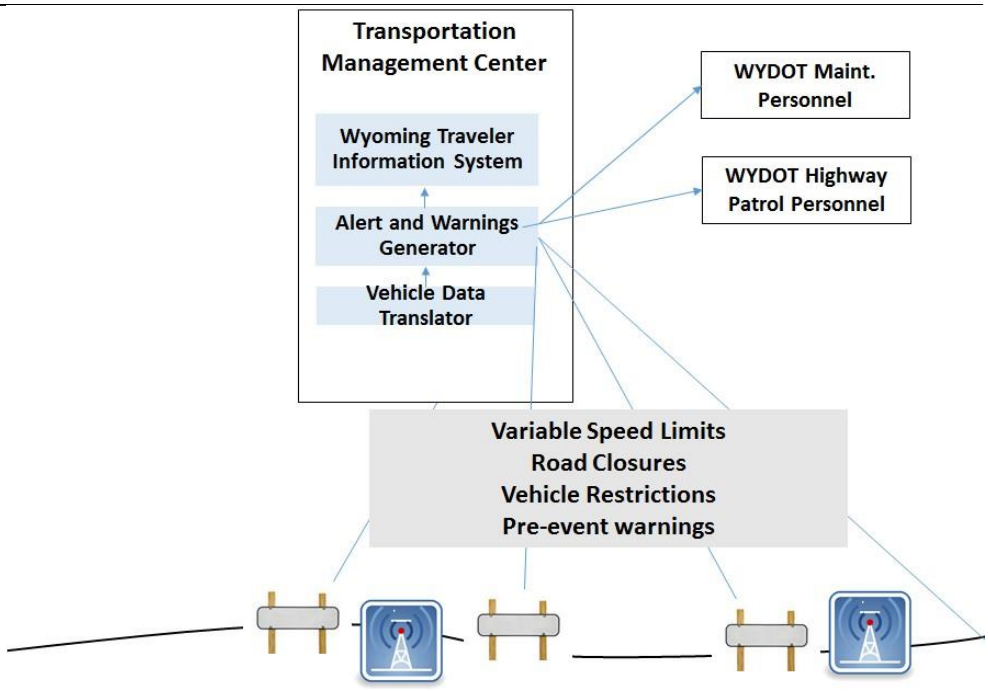
Actors	WYDOT TMC, National Weather Service, WYDOT TMC Weather Provider
Illustration	
Preconditions	Multiple sources of weather and road condition data including CV and non-CV data. Weather models integrated into TMC operations and experienced meteorologists are available to translate data into actionable information.
Main flow (example)	1. CV data is quality checked by the Vehicle Data Translator (VDT) sub-system at the WYDOT TMC for accuracy, latency and suitability. 2. Quality checked CV data is fused with fixed observations (from RWIS) and other NWS data by segments on I-80 by the VDT. 3. Current and valid observations are shared with the Alerts and Advisory Generator system and then passed on to the Wyoming Traveler Information (WTI) sub-system at the TMC. 4. "Human in the loop" in form of WYDOT TMC Weather provider reviews outputs from VDT and combines them with NWS weather models to produce segment-level forecasts of driving conditions. Forecast information is shared with the WTI sub-system.
Alternate flow	None
Post-Conditions	Data that fails quality checks are discarded and a data quality report is generated daily WYDOT TMC Weather provider updates forecasts on a periodic basis determined by WYDOT TMC

Information Requirements	CV weather and road condition data, data from fixed infrastructure (RWIS, other sensor sources), NWS data and models, and meteorological forecasting capability.
Issues	Conflicting information from vehicles and from other fixed infrastructure needs to be managed. Validity criteria of reported data needs to be established and older data need to be factored out of segment-level alert generation. Return to normal conditions is harder to establish.

6.1.3 Weather Responsive Traffic Management

Table 6-3. Use Case #3 – Weather Responsive Traffic Management

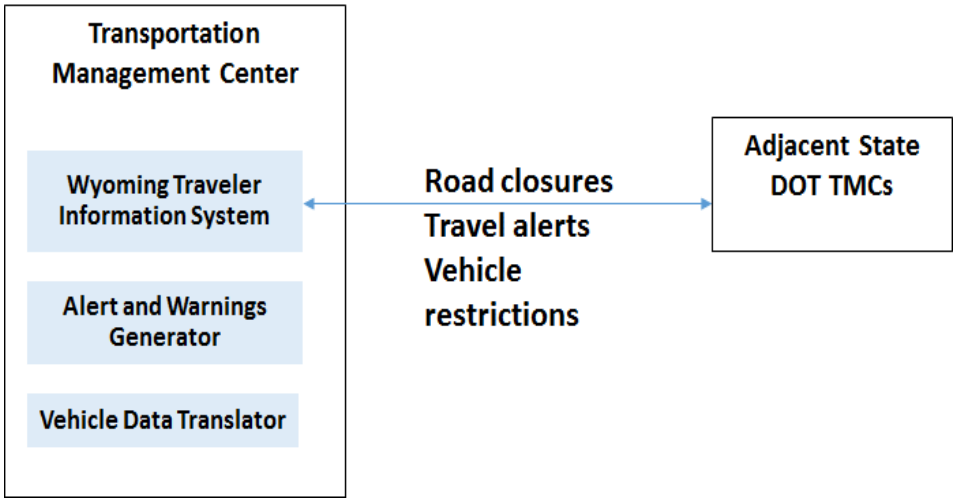
Use Case Name	**Weather Responsive Traffic Management**
Short Description	This use-case defines the various actors and their interactions to manage the traffic conditions during adverse weather. This use-case defines how the WYDOT TMC proactively manages traffic conditions by a combination of advisory, control, and treatment strategies. Advisory strategies include a variety of CV-enabled applications, traditional tools, and HAR. Control strategies in use along the I-80 corridor include variable speed limits, warnings on DMS, and full or partial road closures. Treatment strategies include the ability to dispatch maintenance personnel to address specific sport-specific concerns. Proactive approaches include pre-event messaging of weather conditions and segment forecasts as well.
Goal	Improve responsiveness of traffic management response during adverse weather on I-80
Constraints	While the corridor is well instrumented with ITS devices including DMS and HAR, there are still gaps in coverage for traffic management
Geographic Scope	Corridor-wide
Actors	WYDOT TMC Operations Personnel, WYDOT Maintenance Personnel, WYDOT TMC, WYDOTITS Field Equipment, WYDOT Highway Patrol
Illustration	



Preconditions	Existing policies and field infrastructure to communicate weather responsive traffic information to travelers on I-80.
Main flow (example)	1. WYDOT TMC systems alert WYDOT TMC operators of segment-level alerts and conditions. 2. WYDOT TMC Operators issue appropriate response to alert. Appropriate responses include adjusting speed limits, initiating road closures, issuing travel advisories including vehicle restrictions. 3. WYDOT TMC Operators communicate changes in conditions with WYDOT TMC maintenance field personnel and WYDOT Highway Patrol personnel.
Alternate flow	1. WYDOT Maintenance or highway field personnel request a change in speed limit or a traffic management strategy like closure or vehicle restrictions.
Post-Conditions	WYDOT TMC Operators monitor conditions and remove traffic management strategy implementation once initiating road condition is no longer present.
Information Requirements	Segment-level weather and road condition information .
Issues	None. Traffic management practices are well established and understood by the users of the system.

6.1.4 Adjacent State DOT coordination

Table 6-4. Use Case #4 – Adjacent State DOT Coordination

Use Case Name	Adjacent State DOT Coordination
Short Description	This use-case defines the coordination with the State DOTs adjoining Wyoming with an interest in operations on the I-80 corridor. Primarily, the use-case describes how closure and road condition information is communicated from the WYDOT TMC to similar operating partners in Colorado, Nebraska and Utah.
Goal	Improve coordination between State DOTs along I-80 corridor to manage demand entering the I-80 in Wyoming.
Constraints	None
Geographic Scope	Statewide
Actors	WYDOT TMC, WYDOT TMC Operations Personnel, Adjacent State DOT TMCs
Illustration	
Preconditions	Existing center to center connections with adjoining State DOTs.
Main flow (example)	1. WYDOT TMC operations personnel shares road closures, travel alerts, and vehicle restrictions generated by the WYDOT TMC systems with Adjacent State DOTs. 2. Adjacent State DOTs acknowledge receipt of information and share corresponding response plan with WYDOT TMC operators.

Alternate flow	1. Adjacent State DOTs request WYDOT TMC to issue road condition alerts based on conditions in their State.
Post-Conditions	WYDOT TMC operations personnel and Adjacent State DOT personnel monitor event response and communicate changes to plan with each other. When event is closed, for large-scale events, an after action review is conducted.
Information Requirements	Road closures Existing travel alerts and vehicle restrictions
Issues	None.

6.2 Truck Advisories

This scenario describes how the proposed system alerts truck drivers on I-80 about affected area or segments of the highway so they can optimize their route selection and overall travel time. It should be noted that the advisories do not demand immediate action from drivers. Advisories in this system convey information to the truck driver at a location and time of their travel where an immediate action is not required. In contrast, warnings (described in Section 6.3), require an immediate response from the driver.

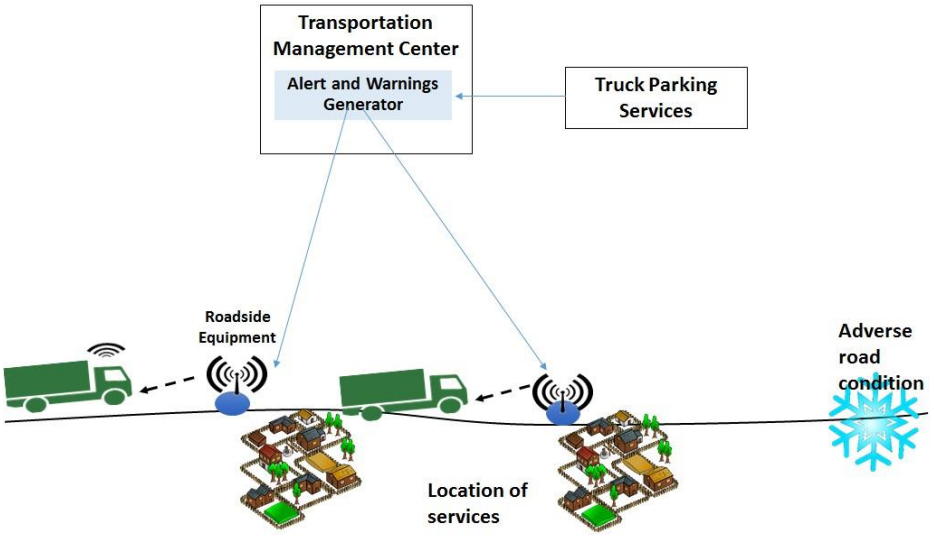
Three use cases are identified under this scenario:

- Infrastructureto Vehicle (I2V) advisory
- Wide-Ara Advisory
- V2V Advisory

6.2.1 I2V Advisory

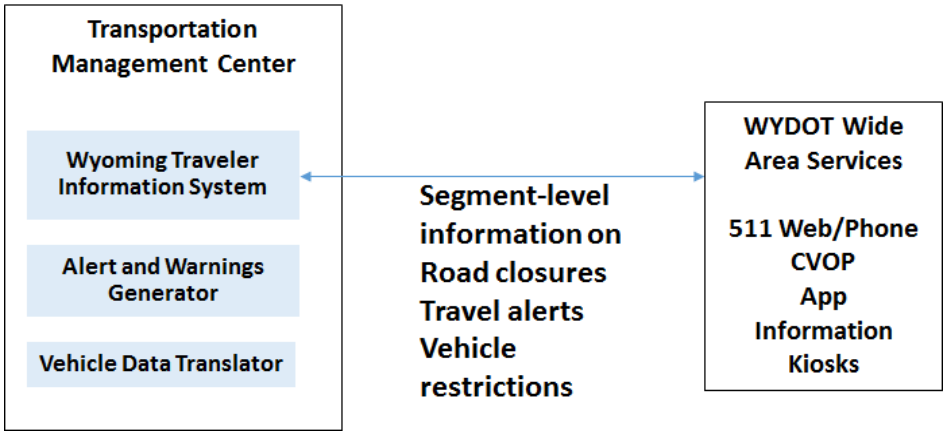
Table 6-5. Use Case #5 – I2V Advisory

Use Case Name	**I2V Advisory**
Short Description	This use-case represents advisories provided by RSE to connected vehicles as they pass by specific locations on the corridor. Information provided by the advisory includes closure and work zone notifications, parking guidance, and posted diversions. Message advisories will be tailored based on the location of the RSE and the available choices to the driver.
Goal	Improve messaging to on-road vehicles about downstream road conditions.
Constraints	The impact of advisories is dependent on the options available to the on-road truck at the time of the advisory. The effectiveness of the use-case is dependent on the careful placement of the RSE and the appropriateness of the message transmitted.

	Efficacy of parking advisories are constrained by available information from parking services.
Geographic Scope	Corridor-wide with special focus on locations along the corridor with access to facilities. (parking, restaurants, lodging)
Actors	WYDOT TMC, WYDOT RSE, Connected Trucks, Truck Parking Services
Illustration	
Preconditions	Availability of parking information and other locations of services such as lodging, restaurants, etc. Location of an RSE upstream of event condition.
Main flow (example)	1. WYDOT TMC sends an advisory to an appropriate set of RSEs upstream of event condition. 2. WYDOT RSEs transmit advisories to passing connected trucks with an OBE.
Alternate flow	None
Post-Conditions	RSE advisories are removed once the downstream conditions are no longer in effect.
Information Requirements	Parking locations Location of other services Location of road condition event
Issues	Human interface to communicate advisories is still uncertain especially for advisories which are more complex in nature for information processing (e.g., parking guidance).

6.2.2 Wide Area Advisory

Table 6-6. Use Case #6 – Wide Area Advisory

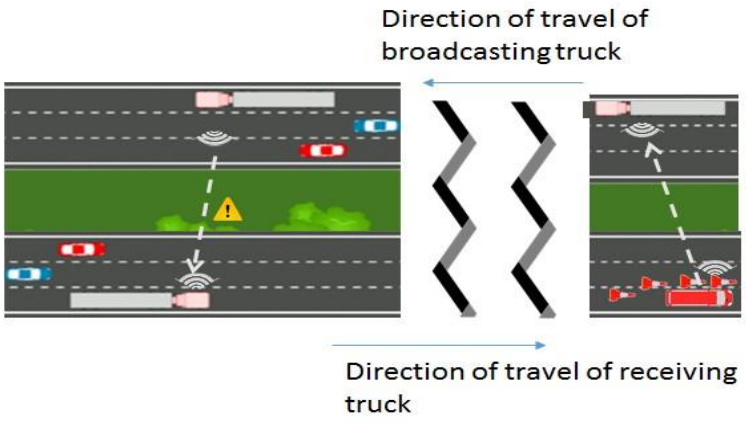
Use Case Name	Wide Area Advisories
Short Description	This use-case defines the wide-area advisories generated by the WYDOT TMC to support operations during adverse weather in the corridor. These include advisories via 511 web and phone systems, information kiosks at special event locations, and WYDOT's traffic application. Wide area alerts can include closure information, pre-event messaging to travelers and information on current conditions.
Goal	Manage demand on the I-80 corridor during adverse weather conditions.
Constraints	None
Geographic Scope	Statewide
Actors	WYDOT Traveler Information subsystem, WYDOTWide Area Services, CVOP
Illustration	
Preconditions	Existence of a 511 web or phone system that has a road weather element.
Main flow (example)	1. WYDOT alerts and advisories subsystem populates the Wyoming Traveler Information (WTI) subsystem with current conditions and forecasts. 2. WYDOTWTI populates WYDOT's wide area services such as the 511 web and phone system, WYDOT informational kiosks, WYDOTtraffic app and the CVOP with segment-level information of conditions.

	3. Users of WYDOT wide area services navigate through appropriate menus to find information on segments of their interest. For users with established profiles, information on pertinent segments is prioritized.
Alternate flow	None
Post-Conditions	WYDOTWTI subsystem updates the wide area services when conditions change or if the original condition is no longer present.
Information Requirements	Current segment-level road weather conditions.
Issues	None. Existing sources of information are well established and used in Wyoming.

6.2.3 V2V Advisory

Table 6-7. Use Case #7 – V2V Advisory

Use Case Name	**V2V Advisory**
Short Description	This use case provides a V2V advisory between equipped trucks and WYDOT fleet vehicles, especially between vehicles traveling in opposite directions. Advisories may include information on stopped vehicles on shoulder, or advisories on work zone or winter maintenance activity observed by equipped vehicles in opposite direction of their travel and shared with vehicles traveling in that direction.
Goal	Improve situational awareness in locations where RSEs and cell coverage are lacking along the corridor.
Constraints	Critical mass of vehicles is required to ensure that V2V advisories are transmitted when desired.
Geographic Scope	Corridor-wide
Actors	WYDOT Fleet Vehicles, Connected Trucks

Illustration	
Preconditions	Equipped vehicles with OBE and DSRC connectivity on the corridor. Adequate critical mass of vehicles in both directions of travel.
Main flow (example)	1. An equipped vehicle or an RSE broadcasts a warning of the event. 2. An equipped vehicle traveling on the opposite direction of travel picks up the message and broadcasts it to other vehicles for a calculated distance based on the speed of the vehicle and the anticipated duration of the event. 3. An equipped vehicle traveling in the direction of the event picks up the advisory at a sufficient distance from the event. 4. Once the calculated distance has been reached, the equipped vehicle that initially broadcast the message will stop broadcasting.
Alternate flow	None
Post-Conditions	Once the calculated distance has been reached, the equipped vehicle that initially broadcast the message will stop broadcasting.
Information Requirements	Information on the duration of the event is critical to ensure that that advisories are only broadcast to vehicles that have the potential risk of exposure to the event scene based on their location and travel speed.
Issues	Due to the nature of the use-case, there is a high-likelihood of false positives unless the nature of the advisory is restricted to long-term events or carefully calibrated by duration. The condition that may been observed by the broadcasting vehicle may have dissipated by the time the receiving vehicle approaches the scene leading to false positives.

6.3 Truck Warning

The CV application is intended mitigate the effects of incidents by warning drivers approaching an affected area or segment of the highway so they can take immediate action to optimize their route

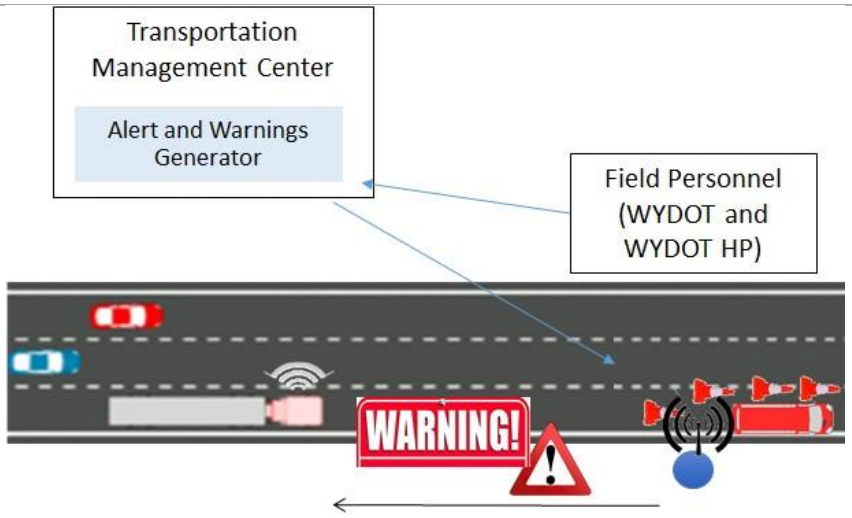
selection and avoid a potential incident. Compared to advisories, these warnings require an immediate action from the driver (reduce speed, stop, pull-over, take exit etc). The timing of the immediate action may vary depending on that action and will be defined as part of the system design. Three specific use-cases are identified under this scenario:

- Infrastructureto Vehicle (I2V) warning- General
- Infrastructureto Vehicle (I2V) warning- Custom
- V2V Warning

6.3.1 I2V Warning-General

Table 6-8. Use Case #8 – I2V Warning - General

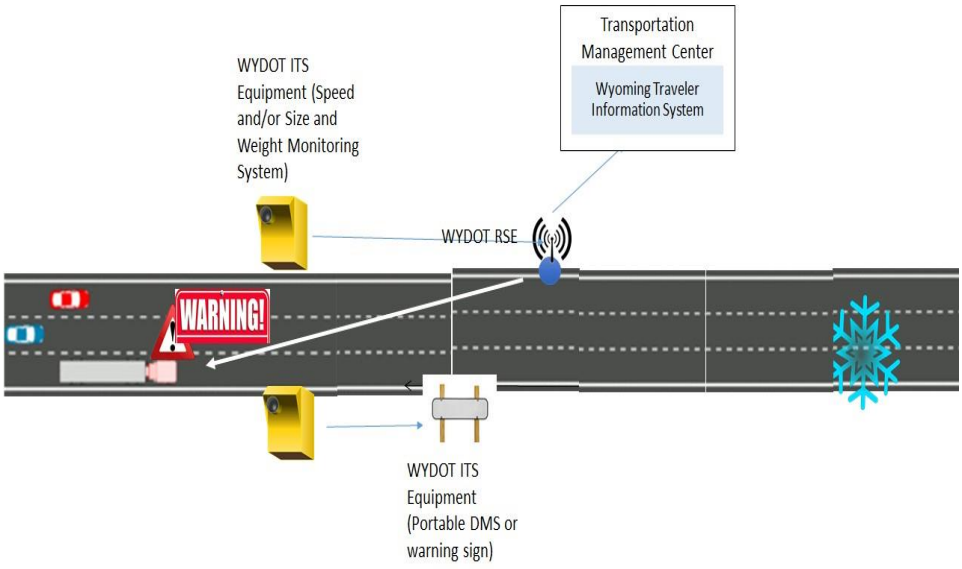
Use Case Name	I2V Warning – General
Short Description	This use-case describes howa RSE communicates with equipped vehicles about immediate threats to driving conditions. Warnings may require a driver to take an immediate action (reduce speeds, stop, pull over, or take an exit) in response to conditions downstream of the RSE. Warnings are not customized to vehicles and all equipped vehicles will receive the same message.
Goal	Improve situational awareness of equipped vehicles in the traffic stream.
Constraints	The use-case depends on the ability for RSEs to be conveniently situated to where the warning is required. Sincethe locations of incidents and events are uncertain, mobile RSE installations are a constraint and required for this use-case.
Geographic Scope	Corridor-wide with a special focus on Cheyenne to Laramie section of I-80.
Actors	WYDOT RSEs, WYDOT TMCs, WYDOT Maint. Field Operations Personnel, WYDOT Highway Patrol, WYDOT Fleets and Connected Trucks
Illustration	



Preconditions	Mobile RSEs with DSRC communications capability. Equipped vehicles with OBE and DSRC communications capability.
Main flow (example)	1. WYDOT Maintenance and Field Operations Personnel arrive at the scene of the event and set up a response plan. 2. Field personnel set up mobile RSEs at prescribed distances from the event to adequately warn drivers upstream. 3. WYDOT TMC activates RSEs to broadcast warnings to equipped vehicles. 4. Equipped vehicles with OBEs receive warnings from mobile RSEs and take evasive action.
Alternate flow	None
Post-Conditions	Field personnel clear the event scene and disassemble the mobile RSEs for future use.
Information Requirements	Nature of event, type of evasive action required by the driver, and immediacy of the action required is critical to this use-case.
Issues	Human interface (timing, nature of alert) to communicate warnings and advisories is still uncertain. The immediacy of the action (response within seconds or minutes) would depend on the situation.

6.3.2 V2I Warning-Custom

Table 6-9. Use Case #9 – I2V Warning Custom

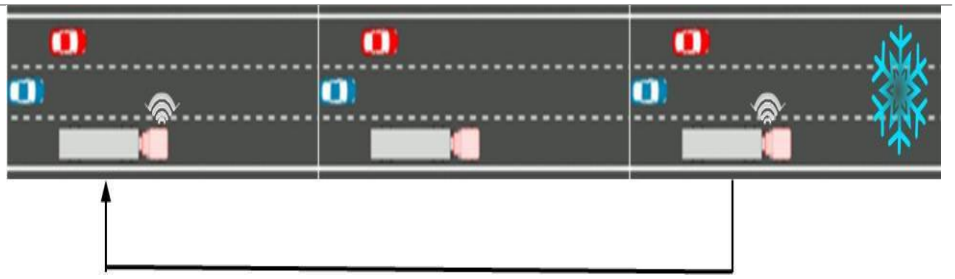
Use Case Name	I2V Warning Custom
Short Description	This use-case describes howa RSE communicates with equipped vehicles about immediate threats to driving conditions. Warnings may require a driver to take an immediate action (reduce speeds, stop, pull over, or take an exit) in response to conditions downstream of the RSE. In contrast to the Use-Case #8, warnings are generated based on the receiving vehicle's type or traveling speed.
Goal	Generate custom alerts for traveling vehicles on the I-80 corridor
Constraints	Requires ITS systems to differentiate between vehicle types and conditions. For example, two types of systems are required for this use-case: speed monitoring systems and size and weight monitoring systems.
Geographic Scope	Corridor-wide with a special focus on near port of entry operations.
Actors	WYDOT Traditional ITS Equipment, WYDOT RSEs, WYDOT TMCs
Illustration	
Preconditions	Existence of speed monitoring systems and size and weight monitoring systems.
Main flow (example)	1. A vehicle passes through a section of roadway with size and weight monitoring system. 2. The size and weight monitoring system determines that the vehicle height or weight is not suitable for the direction of the travel.

	3. A traditional ITS device (like a side-mounted DMS or a warning sign) will activate indicating that a warning has been issued. 4. The size and weight monitoring system sends an alert to a nearby and downstream RSEs. 5. The RSE begins broadcasting a warning message. 6. The RSE communicates the alert to the WYDOTWTI sub-system. 7. If the vehicle is equipped with an OBE, the vehicle receives the warning through the in-vehicle interface and driver takes immediate action.
Alternate flow	The same system can be applied to develop custom alerts based on vehicle speed as well.
Post-Conditions	None
Information Requirements	Speed measurements, size and weight measurements are two additions necessary to support the use-case.
Issues	The availability of external systems that can measure vehicle characteristics like size and weight are limited to a few locations on the corridor. However, speed-based warnings can be more broad-based. Also, the linkage between vehicle types and risk is not well established. Lastly, the immediacy of the action (response within seconds or minutes) would depend on the situation.

6.3.3 V2V Warning

Table 6-10. Use Case #10 – V2V Warning

Use Case Name	V2V Warning
Short Description	This use-case describes vehicle to vehicle communications to alert drivers of deteriorating conditions in front of the lead vehicle. Warnings provided by the lead vehicle are relayed backward in the traffic stream to other equipped vehicles. Warnings include specific condition information (slick ice, incident) or changing driving conditions (slowing speed, emergency brake light).
Goal	Improve situational awareness between equipped vehicles of downstream conditions.
Constraints	Critical mass of vehicles is required to ensure that V2V advisories are transmitted when desired.
Geographic Scope	Corridor-wide
Actors	WYDOT Fleet Vehicles, Connected Trucks

Illustration	
Preconditions	Equipped vehicles with OBE and DSRC communication capabilities.
Main flow (example)	1. Lead vehicle broadcasts safety message as it travels the corridor. 2. Following vehicle OBE is able to receive the safety message, take immediate action, and process the information to provide warnings to other drivers using driver interface. 3. Receipt of safety message from other vehicles and the warning generated is stored locally on the following vehicle OBE. 4. As other vehicles receive the warning, those vehicles provide warning to other drivers even further downstream.
Alternate flow	None
Post-Conditions	None
Information Requirements	Safety message from lead vehicle. Information on the duration of the event is critical to ensure that that advisories are only broadcast to vehicles that have the potential risk of exposure to the event scene based on their location and travel speed.
Issues	Human interface (timing, nature of alerts) to communicate warnings and advisories is still uncertain. Also, the immediacy of the action (response within seconds or minutes) would depend on the situation. Due to the nature of the use-case, there is a high-likelihood of false positives unless the nature of the advisory is restricted to long-term events or carefully calibrated by duration. The condition that may been observed by the broadcasting vehicle may have dissipated by the time the receiving vehicle approaches the scene leading to false positives.

6.4 Incidents Notification

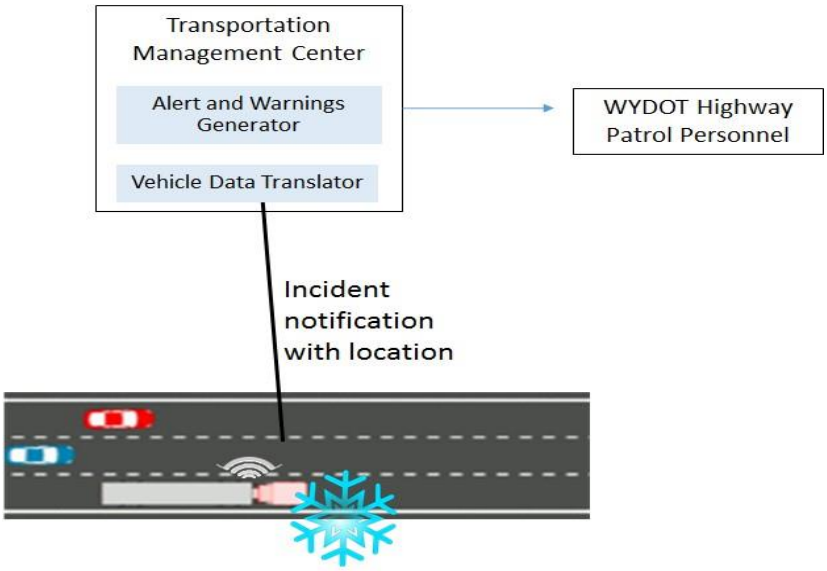
This scenario illustrates the use of the proposed system to improve notification of incidents to appropriate agencies within Wyoming. Due to the large geographic scope, limited landmarks and significant distances between cities, precise location and nature of the crash will help dispatchers make right decisions about the nature of the response. Where communications are not present,

connected vehicles also serve as a relay to collect and distribute emergency notification. Two use-cases are identified under this scenario:

- Incident Notification
- Emergency Relay

6.4.1 Incident Notification

Table 6-11. Use Case #11 – Incident Notification

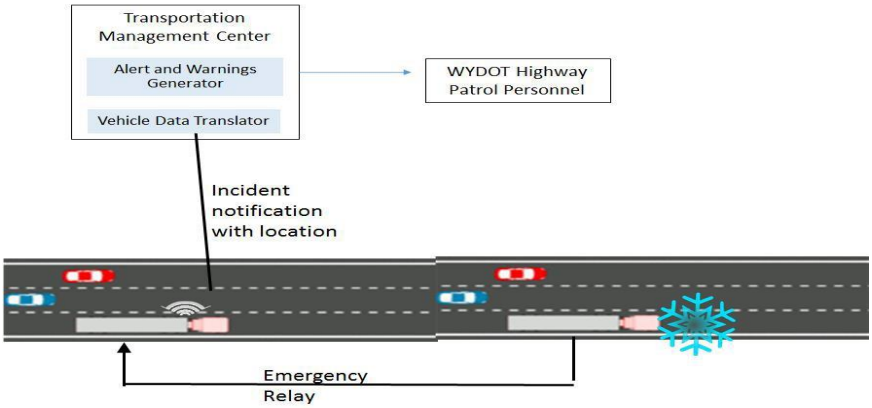
Use Case Name	Crash Notification
Short Description	This use-case describes a location-based notification process from an equipped vehicle involved in a crash in the corridor to the WYDOT TMC. The WYDOT TMC will then notify emergency response personnel based on location.
Goal	Improve emergency response times in the corridor.
Constraints	Cellular communication coverage gaps will constrain this use-case.
Geographic Scope	Corridor wide with potential for statewide expansion.
Actors	WYDOT Fleets, Connected Trucks, WYDOT TMC
Illustration	
Preconditions	Equipped trucks have both DSRC and cellular connectivity.

Main flow (example)	1. When an equipped vehicle is an incident requiring assistance, the driver is able to request assistance through the OBE unit. 2. When assistance is requested, the OBE transmits an incident notification message to the WYDOT TMC. 3. If unable to send the notificationvia cellular communications, the OBE also begins transmitting the notification on a DSRC channel. 4. The WYDOT TMC will receive the information and send an acknowledgment back to the OBE, which will then cease notification actions. 5. The WYDOT TMC will dispatch appropriate response personnel based on the location of the incident.
Alternate flow	When certain vehicle conditions are met (like airbag deployment), the OBE will issue an incident notification automatically, without driver assistance to the WYDOT TMC.
Post-Conditions	None
Information Requirements	Vehicle operating conditions, location source
Issues	None

6.4.2 Emergency Relay

Table 6-12. Use Case #12 – Emergency Relay

Use Case Name	**Emergency Relay**
Short Description	This use-case describes relay of emergency and crash information between equipped vehicles to ultimately notify WYDOT TMC when communication is available.
Goal	Improve emergency response times in the corridor.
Constraints	Critical mass of vehicles is necessary for the relay to work in an efficient manner.
Geographic Scope	Corridor wide with potential for statewide expansion.

Actors	WYDOT Fleets, Connected Trucks, WYDOT TMC
Illustration	
Preconditions	Equipped trucks have both DSRC and cellular connectivity.
Main flow (example)	1. When an equipped vehicle is an incident requiring assistance, the driver is able to request assistance through the OBE unit. 2. When assistance is requested, the OBE transmits an incident notification message to the WYDOT TMC. 3. If cellular coverage is not available, the OBE begins transmitting the notification on a DSRC channel. 4. A following truck or a truck on the other direction of travel picks up the notification message. 5. If the message is received by a WYDOT fleet vehicle, the driver will be notified to reach the WYDOT TMC via radio. 6. The receiving truck then transmits the message when in an area with cellular coverage.
Alternate flow	When certain vehicle conditions are met (like airbag deployment), the OBE will issue an incident notification automatically, without driver assistance to the WYDOT TMC.
Post-Conditions	None
Information Requirements	Vehicle operating conditions, location source
Issues	None

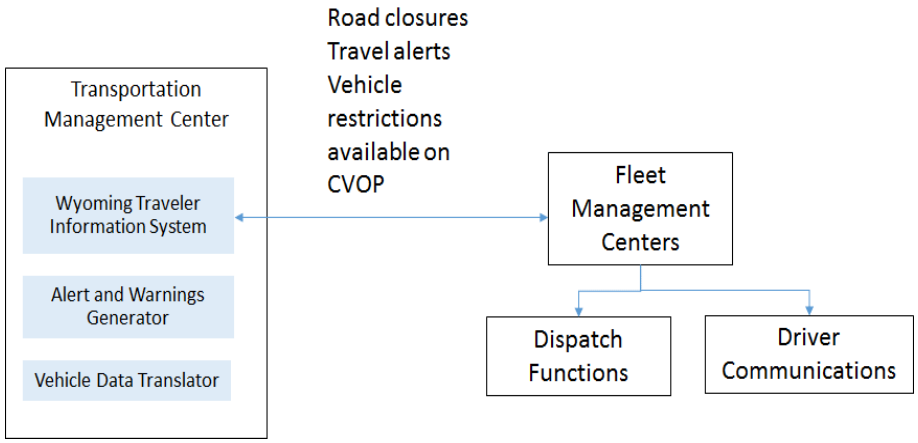
6.5 Dynamic Travel Planning Support

This scenario illustrates how the proposed system provides travel planning support to third parties including freight management centers and third party application developers. Two use-cases are identified:

- Freight Travel Planning Guidance
- Third Party Application Developer Support

6.5.1 Freight Travel Planning Guidance

Table 6-13. Use Case #13 – Freight Travel Planning Guidance

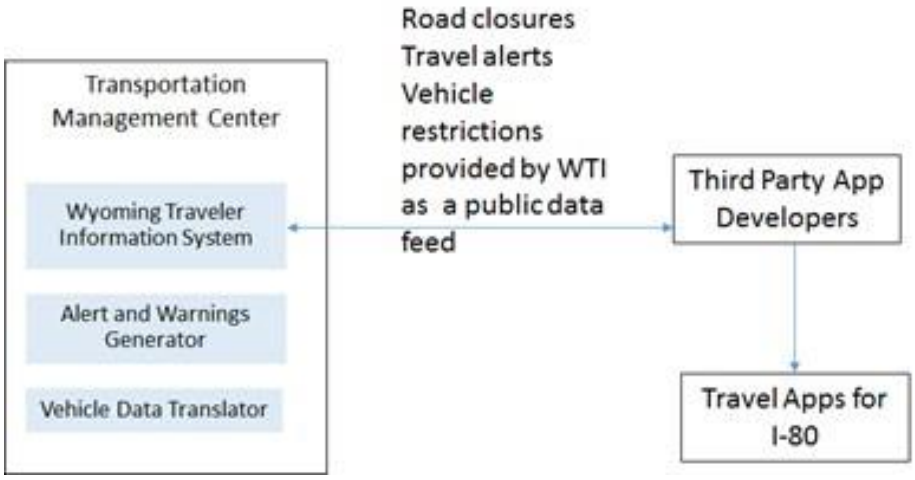
Use Case Name	Freight Travel Planning Guidance
Short Description	This use-case describes how WYDOT TMC and fleet management centers exchange information about travel conditions and forecasts on I-80 through the CVOP and other connections enabled by the proposed system.
Goal	Improve capability of fleet managers to plan their trucking operations on the I-80 corridor.
Constraints	None
Geographic Scope	Statewide with focus on I-80 corridor.
Actors	WYDOT WTI, Fleet Management Centers, WYDOT CVOP, Trucks
Illustration	
Preconditions	Fleet managers subscribe to WYDOT Freight-specific services offered through CVOP.

Main flow (example)	1. WYDOTWTI updates the CVOP portal on a periodic basis with current and forecast conditions for pre-determined segments on I-80. 2. Fleet managers who subscribe to CVOP data feed will receive freight-specific information on driving conditions, forecasts for the entire corridor of interest. 3. Fleet managers can customize their CVOP profile to only obtain information on segments of interest. 4. Fleet managers then communicate to their drivers on road or make dispatch decisions to suit their business needs based on information provided by CVOP.
Alternate flow	None
Post-Conditions	None
Information Requirements	Segment-level current and forecast conditions, freight-specific information like size and weight restrictions.
Issues	While the value of the data can be qualitatively obtained by interview of fleet managers, quantitative data on fleet optimization practices may be harder to obtain from fleet managers who are consumers of the data feed. More information may be available from partnering fleet partners who will be made aware of the evaluation requirements as a contingency on their participation.

6.5.2 Third Party Application Developer Support

Table 6-14. Use Case #14 – Third Party Application Developer Support

Use Case Name	Third Party PID Support
Short Description	This use-case describes how WYDOT TMC supports access to CV data feeds to third-party application developers to use segment alerts and advisories generated by the proposed system in their user-facing applications. Applications developed by third-parties will be used by private vehicles to manage their own travel decisions. Such applications can include value-added services that are created by the third party to incentivize use of their application. Depending on the nature of the partnerships with the third party, information from the user base of the application can be shared back with the WYDOT TMC to supplement the CV data environment.
Goal	Improve capability of general public to plan their trucking operations on the I-80 corridor.
Constraints	Limited number of third party application developers in Wyoming.

Geographic Scope	Statewide
Actors	WYDOTWTI, Third Party Application Developers, Private Vehicles
Illustration	
Preconditions	None
Main flow (example)	1. The WYDOT WTI subsystem makes a data feed available for third party developers. 2. Third party developers sign a data use agreement for use of the public feed. 3. Third party developers incorporate the data feed in their applications.
Alternate flow	Depending on the partnerships, third party developers provide aggregated information back to the WYDOT TMC to support additional data collection on travel conditions in the corridor.
Post-Conditions	None
Information Requirements	Public data feed with current and forecast conditions on I-80
Issues	Since WYDOT TMC is primarily a data feed provider, the impact of these feeds to the driver-user of the third party applications is harder to measure. Data on driver behavior and use of these third party systems may be proprietary and not available for impact evaluation.

6.6 Performance Management

This scenario describes the performance management of the proposed system for two purposes. First, the scenario describes a use-case for monitoring daily operations and improving the day-to-day performance of the proposed system. Second, the scenario also describes a use-case to develop a post-hoc assessments of outcomes and impacts due to the proposed system. In both cases, the scenario describes how data is managed as part of the proposed system.

6.6.1 Performance Management Support

Table 6-15. Use Case #15 – Performance Measurement Dashboard

Use Case Name	Performance Management Support
Short Description	This use-case describes the actors and their interactions to continuously monitor the performance of the system both from measuring the outputs of the system (what is the system supposed to do) as well outcomes (what is the system achieving). The use-case describes how improvements are identified for the proposed system.
Goal	Improve performance of the proposed system over the life of the pilot project.
Constraints	None
Geographic Scope	Corridor-wide
Actors	WYDOT TMC
Illustration	NA
Preconditions	Availability of core system services, specified performance benchmarks.
Main flow (example)	1. The system stores various data elements generated in the CV environment as follows. • Vehicle data – Safety message data, any application-related data, vehicle and road condition data are stored locally and transmitted to the WYDOT data warehouse on a daily basis for all equipped WYDOT Fleets. • Connected trucks – Safety message data, any application-related data, and vehicle and road condition data are stored locally and transmitted to the respective. fleet management centers and then to the WYDOT data warehouse • RSE data – Data collected by RSEs is stored locally and then transferred to the WYDOT data warehouse on a periodic basis. • System data – Alerts, advisories and warnings generated by WYDOT TMC will be timestamped and logged automatically into the data warehouse.

	• Service monitoring data – Service logs for all objects in CV environment will be housed in the data warehouse. 2. Performance dashboards created by analyzing data in the warehouse is used to monitor day-to-day performance of the system.
Alternate flow	None
Post-Conditions	System data are analyzed at different temporal scales to meet operational objectives. Core system service data may be analyzed in real-time, application performance may be analyzed on a weekly or monthly basis.
Information Requirements	Time-stamped system data from vehicles, infrastructure and center systems.
Issues	Establishing ground truth is a challenge to verify accuracy and effectiveness of advisories and alerts generated by the system.

6.6.2 Impact Evaluation Support

Table 6-16. Use Case #16 – Impact Evaluation Support

Use Case Name	Impact Evaluation Support
Short Description	This use-case describes the impact evaluation activities necessary to establish the overall safety and mobility impacts of the proposed system. This use-case describes the actors involved in the impact assessment, provides a framework for data collection (both from the proposed system as well as from external systems), warehousing the data and developing the impact analysis based on an approved plan.
Goal	Assess overall impacts of the proposed system in terms of safety, mobility and productivity for the corridor, as well as potential adverse impacts.
Constraints	Limitations in data collection, especially for elements that are outside the proposed system, combined with exogenous factors may compromise the impact evaluation support.
Geographic Scope	Corridor-wide
Actors	WYDOT TMC, Fleet Management Centers, Impact Assessment Contractor, Others external data systems
Illustration	NA

Preconditions	System requirements will develop adequate data collection capabilities in the proposed system. Approved evaluation plan will also identify supplemental data needs that need to be collected from external DOT and non-DOT systems.
Main flow (example)	1. System data is shared with Impact Evaluators by providing access to the data warehouse. 2. Non-system data collection are collected in Phase II deployment activities including any quantitative and qualitative data collection activities that are needed for establishing the baseline conditions.
Alternate flow	None
Post-Conditions	The impact assessment contractor is responsible for developing a methodology to assess impacts of the proposed system on safety, mobility and productivity, as well as potential adverse impacts.
Information Requirements	The information requirements are defined by the performance measurement and evaluation plan in coordination with the impact assessment contractor.
Issues	None.

7 Summary of Impacts

This section provides information in order to allow all affected users and organizations to prepare for the changes that will be brought about by the new system and to allow for planning of the impacts during the development of, and transition to the new system.

7.1 Operational impacts

The CV Pilot Program will have a direct impact on the operational aspect of the TMC and related WYDOT activities. These impacts include:

- Changes to operator procedures for weather responsive traffic management practices including approaches to set variable speed limits, postings on roadside ITS like DMS signs and HAR and wide area communications like 511 phone, website and apps
- Changes to data management practices within WYDOT to account for the data created by the CV environment from an operational and performance evaluation standpoint
- Changes to asset management and field maintenance practices to support the maintenance of RSEs
- Changes to the role of the weather provider at the TMC to use new data capabilities provided by the system
- Changes to port of entry operations including installation of potential systems such as parking availability, weigh-in-motion and RSEs
- Changes to the WTI to incorporate CV data into 511 phone, web and app platforms
- Impacts to winter maintenance activities during development may include changing snow plows and driver assignments during development and testing phases
- Different partnerships with fleet operators are needed depending on their level of involvement with the pilot.
    - The most involved partnership will be with fleet providers who have their vehicles to be outfitted with the connected vehicle technology.
    - At a slightly lower level of complexity, partnerships for information sharing from center to center between fleet management centers and traffic management centers.
    - Lastly, those who are not officially partners in the project are expected to benefit too. Information in the existing Commercial Vehicle Operator Portal is expected to be improved based on the new information received from commercial vehicles.

From a fleet management perspective, participating fleet providers and freight operators will have operational impacts based on their level of involvement in the proposed system. These include

1. For carriers and fleet operators who are involved primarily through CVOP, their operational impacts due to the proposed system and during its development are minimal. These operators will notice new features being added to the CVOP as the pilot progresses
2. For carriers and fleet operators that are primarily involved by using CV data through their fleet management centers, their operational impacts are expected to primarily focus on interface development between the WYDOT controlling center and the fleet management center. They may have additional operational impacts if they decide to modify their existing in-vehicle interfaces to provide notification to their on-road truckers.
3. For carriers and fleet operators with connected trucks that have DSRC-supported on-board equipment as part of their proposed system, their operational impacts are significant. These carriers will have to make their trucks available for installation of onboard equipment, training for drivers and support data collection services for performance management and evaluation.

External third-party application developers will have access to CV-enabled data as part of the proposed system for integration in to their products.

Additionally, parking management providers along the I-80 corridor are expected to have parking availability technology developed and installed as part of this project.

7.2 Organizational Impacts

The proposed program will also impact the organization and structure of responsibilities across the system. Most of these impacts will be felt by WYDOT. These impacts include:

1. Modification of responsibilities of operators at the TMC, snow-plow drivers and highway patrol staff;
2. No addition or elimination of job positions are expected as part of the system. However certain existing functions can be automated or eliminated by the proposed systems reducing the burden on the operator. As an example, such a change was observed when WYDOT deployed the road condition reporting system which freed up operator time on the radio.
3. Development phase is expected to include significant training for WYDOT TMC operators, WYDOT highway patrol, WYDOT maintenance staff and WYDOT GIS/ITS on CV technology and systems
4. Significant new systems maintenance and development due to the proposed system will fall on the small GIS/ITS staff
5. If new RSE locations are to be deployed, providing wide area network connectivity to them will increase Telecommunications Program workload and costs attributable to these systems
6. GIS/ITS staff and support consultants need to develop capabilities to effectively understand and use DSRC-connectivity as part of the application development.
7. Dedicated staff resources may be needed to support system monitoring, performance measurement and evaluation support during the demonstration phase of the project.

7.3 Impacts during Development

The development phase for the proposed system involves the system design, testing, and verification coupled with training of the drivers who will be involved in the demonstration. Through the activities in Phase I, additional impacts during the development such as human-use, partnership and performance management will be discussed and documented.

8 Analysis of Proposed System

The analysis of the proposed system will focus on measuring the expected benefits and include both quantitative and qualitative assessments. This section summarizes the analysis approach of the proposed system and addresses the expected benefits, disadvantages, limitations, and alternatives and trade-offs considered. The information provided below will form the basis for a more detailed description of quantitative and qualitative assessments that will be documented in the Performance Measurement and Evaluation Support Plan (Task 5) later in Phase 1 project planning activities.

8.1 Summary of Improvements

The following potential improvements are typically consideredfor connected vehicle technologies: improvements in safety, mobility, public agency efficiency; and, reduced negative impacts to the environment. The proposed system focuses heavily on improvements to safety, with some expected improvements in mobility and agency efficiency. Reduction in negative environmental impacts are expected to be minimal, and likely not measureable.

As described in previous sections of this ConOps document, there are three primary systems involved:

- Vehicles – Equipped vehicles (a mixture of commercial, specialty and public fleet vehicles) and personal automobiles. Equipped vehicles such as snowplows and commercial vehicles will participate in the proposed applications for the system. General travelers will benefit from improved broad area traveler information and may benefit from applications developed by third-party use of CV-data but will not be participating in the V2I or V2V capabilities developed by the system during the pilot stage.
- Center – WYDOT's TMC will receive and act on the enhanced level of road and road weather information. Actions include maintenance dispatch, road closures, issuing alerts/advisories, forecasting weather and road weather conditions, activating/managing ITS equipment (VSL signs, DMS, HAR), updating traveler information elements including the general WYDOT travel information website, 511 phone system, Wyoming 511 App, and the commercial vehicle operator portal.
- Roadside infrastructure – ITS equipment (RWIS, speed sensors, closed circuit television cameras (CCTV), VSL, DMS, HAR, etc.), Telecommunications networks, and the new DSRC radio systems and infrastructure deployed for V2I and I2V.

All of these systems will play an important role in achieving the benefits of the proposed system.

Table 8-1 identifies (at a summary level) the proposed system concept elements and the corresponding potential benefits to be measured. The table is organized by major activity areas of enhanced data collection, center actions (based on the existing and enhanced data), V2I, and V2V communications.

Table 8-1. Summary of proposed system concept elements and expected benefit.

Proposed System Concept Elements	Expected Benefits	Category
Enhanced Data Collection (V2I)		
WYDOT Fleets and Connected Trucks: - Road conditions - Incidents - VSL recommendations - Automated location info - Weather atmospherics - Vehicle telematics - Speed - Location - Crash notification	**Improved road condition reporting** - Reduced latency - Increased coverage - Improved forecasts **Improved TMC staff efficiency to record reports and update databases**	Public Agency Efficiency
Center – Broad Area I2V		
Center to perform: - Maintenance dispatch - Weather forecasts - Alert/Advisory notifications - Road closures - VSL speed limit activations - DMS/HAR updates - Traveler Information updates - Comm. Vehicle web portal updates	**Improved TMC staff efficiency** - Dispatching maintenance crews - Generating weather and road weather forecasts - Issuing alerts/advisories and road closures - Posting DMS and HAR messages - Updating VSL signs **Improved broad area traveler information** - Better informed general travelers - Better informed comm. Vehicles - Better informed maintenance crews **Improvements in safety (indirect) through more accurate and timely information and more informed travelers**	Public Agency Efficiency, Mobility, Safety
Roadside to Vehicle – I2V		
Alerts/Advisories provided via RSEs (such as speed	**Improved Commercial Vehicle and snow plow driver awareness**	Safety, mobility

Proposed System Concept Elements	Expected Benefits	Category
limits, incidents, road closures, etc.)	- Speed limits/VSL - Road closures - Crashes - Weather impact warnings - Work zone identification - Emergency vehicles ahead - Parking opportunities - Location - Dynamic travel planning **Improved safety** - Reduced initial crashes - Reduced secondary crashes - Reduced severity/fatalities/injuries - Reduced number of vehicles involved in a crash - Reduced speed variations in the traffic stream - Faster crash notifications	
	Snowplow and Comm. Vehicle – V2V	
Vehicles communicate messages: - Warnings (suchas incidents, work zones, emergency braking, do not pass, etc.) - Speeds (such as posted limits including current VSL values)	**Improved Comm. Vehicle and Snowplow driver awareness** - Speed limits/VSL - Road closures - Crashes - Weather impact warnings - Work zone identification - Emergency vehicles ahead - Parking opportunities - Location - Dynamic travel planning **Improved safety** - Reduced initialcrashes - Reduced secondary crashes - Reduced severity/fatalities/injuries - Reduced number of vehicles involved in a crash - Reduced speed variations in the traffic stream - Faster crash notifications	Safety, mobility

Based on the expected pilot demonstration benefits defined above, the following key performance measures and targets have been preliminarily identified:

- Safety – Improvements in safety is the ultimate goal of the Wyoming CV Pilot Demonstration. Safety improvements can be measured in many ways – the following targets have been identified:
    - Target: 10% reduction in the number of crashes, compared to the most recent 5 year crash average.
    - Target: 20% reduction in the number of serious injuries and fatalities, compared to data for the most recent 5 year average.
    - Target: 50% reduction in the number of vehicles involved in major crashes, compared to the most recent 5 year average.
- Adherence to Speed Limits – Speed and speed variance is often a major contributing factor to both the instance of an initial crash as well as the number of vehicles that are involved in major crashes.
    - Target: Actual vehicle speeds are 15% closer to posted speed limits, on average
    - Target: Speed variance between vehicles is reduced by 15%, on average
- TMC Staff Efficiency – TMC operators are very busy during severe weather events and the improvement in operational efficiency is a key element of the CV Pilot Demonstration.
    - Target: 20% Information to travelers will arrive 20% sooner. Information includes, but not limited to, notifications and alerts, traveler information provided through existing dissemination methods, and activation of ITS systems (VSL, DMS, HAR, etc.).
- Traveler Information, Notifications, and Alerts – A major aspect of this project is to disseminate accurate and timely traveler information. This information could be disseminated through broad area systems to both general travelers as well as commercial vehicle operators (e.g., Wyoming's Traveler Information system and the commercial vehicle portal), targeted notifications and alerts from the roadside to Wyoming state vehicles and commercial vehicles, and vehicle to vehicle notifications and alerts (to and from state and commercial vehicles).
    - Quantitative targets for this key performance measure require additional consideration, but initial thoughts are focused on measuring the increased number of traveler information items, notifications and alerts issued
    - Qualitative targets are also being considered regarding the perceived benefits and impacts due to receipt of traveler information, notifications, and alerts.

The complete evaluation of the Wyoming CV Pilot Demonstration will be accomplished in a two-pronged approach. First, the Wyoming Team will conduct an evaluation of the key performance measures and report those findings in the project final report. This evaluation will focus on the benefits to the Wyoming DOT and the project stakeholders. An independent evaluation will also be conducted focusing on national programmatic aspects of this CV Pilot and how the project outcomes can contribute to the future of the Connected Vehicles Program nationally. Toward this end, the Wyoming Project Team will work collaboratively to ensure a comprehensive and successful evaluation is completed of this CV Pilot Demonstration and documented in such a way to benefit Wyoming, other interested states, and the national CV Program. The Wyoming Team will make available the needed data, where available, identified by the independent evaluator. Additionally, the Wyoming Project Team will support the independent evaluator to assist them in achieving their stated goals.

Additional details regarding the evaluation measures, data needed, analysis techniques, and the overall approach to evaluating the Wyoming Pilot Demonstration will be documented in a subsequent project deliverable: Performance Measurement Evaluation and Support Plan.

8.2 Disadvantages and limitations

The following challenges of the proposed system are being acknowledged and ways to measure them during the pilot demonstration are being considered:

- Crash Prevention –CV technology and the proposed system may not avoid an initial crash, but the system capabilities should be able to limit the extent of the crash (number of vehicles involved), related secondary crashes, and the severity of the crash (injuries/fatalities). These items can be measured and are going to be part of the Performance Measurement Plan.
- Information Overload – System capabilities are limited by how much information can realistically be given to drivers. There is a multitude of possible information that could be provided including speed limits, warnings, incidents ahead, detours, parking opportunities, etc. In the recent stakeholder meeting it was suggested that the information must be simple to understand and easily delivered. It was even stated that the information might only be best viewed in a vehicle if it were a green, amber, or red light or a simple, easily understood graphic. This issue will be a significant design challenge. Measuring the effectiveness of the eventual system will also be a challenge and will be a topic during the development of the Performance Measurement Plan.
- Technology Penetration – The pilot demonstration testing will be challenged by the relatively few number of vehicles that will be capable of receiving direct information from the infrastructure or other vehicles – especially in comparison to the number of total vehicles on I-80. The technology can be shown to work; however measuring the benefits with such a small sample size will be limiting.
- Technology Adoption by Targeted Audiences – New technology involving a change in the way people do things is always challenging. For the proposed system, there are myriad agency personnel that are affected: TMC staff, snowplow drivers, commercial vehicle truck drivers, commercial vehicle company dispatch center personnel, etc. The Performance Measurement Plan will define qualitative data collection methods to assess the level of technology adoption and to what extent the lack of adoption affected the outcomes of the pilot demonstration testing.
- Will the new Information be used? – The proposed system will provide the new information, but we don't know the extent the information will be used by commercial vehicle companies or drivers. This will be a focus of the performance measurement activities.
- Impacts of Improper or Inaccurate Information Disseminated – The project performance measure assessment and evaluation should attempt to measure the impact of improper or inaccurate information provided by the system, management center, or other vehicles. The notifications will be logged and available to those evaluating the pilot demonstration. However, the challenge will be knowing the "truth" to determine if the information disseminated was in appropriate. The evaluation activities may be limited in this regard.

- Short Construction Season – The Wyoming CV Pilot Demonstration will be operated all year, even though much of the focus is on impacts during adverse winter weather events. Notifications of construction work zones may also be included in the project. A limitation in this regard involves the short construction season on I-80 which may constrain the ability to evaluate the effectiveness of these types of notifications.
- Variability of Weather Conditions – The variability of weather events and entire winter weather seasons presents challenges to analyzing pre- and post- system implementation data. Ideally, we would want to compare data during similar weather events – that is not always possible. Before/after analysis will be conducted where appropriate. Another method used in recent Wyoming weather responsive traffic management system evaluations was with/without technology during the same winter weather event. This produced meaningful evaluation data because it compared vehicles with the technology and those without during the same road weather conditions. This method will be proposed during this evaluation.
- Crash Analyses – Typically to analyze crash statics required multiple years of data for statistically valid results because of the variability of crash frequencies from year to year. This will be a challenge during the project evaluation as well. Early trends will be presented, if available. Additionally, surrogate measures will be developed that will be indicators of safety improvements as part of the performance measurement planning.

8.3 Alternatives and trade-offs considered

The proposed system is being developed as part of a pilot project to demonstrate the value of connected vehicle technology. As such, alternatives which didn't involve V2V or V2I connections were not considered as part of the ConOps. Similarly, expansion of traditional ITS devices was discarded as an alternative due to the cost of closing the gaps in coverage. Lastly, higher levels of V2V technology and cooperative systems involving truck platooning were considered but not included due to current levels of capability maturity of the technology. In terms of applications, safety applications were the primary focus of the system and other possible CV applications that involve productivity, intersection-related safety were not included.

9 Notes and Glossary

The following table defines selected project specific terms used throughout this ConOps document.

Table 9-1 – Glossary of Terms

Term	Definition
Advanced Automatic Crash Notification Relay	An application that provides the capability for a vehicle to automatically transmit an emergency message when the vehicle has been involved in a crash or other distress situation.
Advanced Automatic Crash Notification Relay	Provides the capability for a vehicle to automatically transmit an emergency message when the vehicle has been involved in a crash or other distress situation.
Commercial Vehicle Operator Portal	Provides forecasted road condition information on common commercial vehicle routes.
Core Authorization	A CV support application that manages the authorization mechanisms to define roles, responsibilities and permissions for other CV applications.
Data Distribution	A support application that manages the distribution of data from data providers to data consumers and protects those data from unauthorized access.
Freight-Specific Dynamic Travel Planning	An application that provides both pre-trip and enroute travel planning, routing, and commercial vehicle related traveler information, which includes information such as truck parking locations and current status.
GIS/ITS Program	WYDOT's primary division responsible for ITS.
Infrastructure management	A support application that maintains and monitors the performance and configuration of the infrastructure portion of CV.
Location and Time	A support application that shows the external systems and their interfaces to provide accurate location and time to CV devices and systems.
Object Registration and Discovery Service	Application that provides registration and lookup services necessary to allow objects to locate other objects operating within the CVE.
RCR System	An Android-based mobile app that is being used on 10 inch tablets mounted in the plows and allows maintenance personnel to provide

	updates on road conditions. These updates are transferred to WYDOT's public facing traveler information systems directly from the field.
Road Weather Information for Freight Carriers	An application that is a special case of the Road Weather Advisories and Warnings for Motorists application focuses on Freight Carrier users.
Situational Awareness	An application that determines if the road conditions measured by other vehicles represent a potential safety hazard for the vehicle containing the application.
Spot Weather Impact Warning	An application that will alert drivers to unsafe conditions or road closure at specific points on the downstream roadway as a result of weather-related impacts.
Telecom Program	WYDOT's Telecommunications Program is responsible for the statewide WyoLink radio system, most in-vehicle electronics integration, and various wireless networks including backhaul from roadside electronics devices and Wi-Fi hotspots.
Transportation Management Center	Center that collects information and informs the public about changing travel conditions.
Warnings about Upcoming Work Zone	An application that provides information about the conditions that exist in a work zone to vehicles that are approaching the work zone.
WyoLink Radio Network	Statewide digital trunked VHF P-25 compliant public safety land mobile radio communications system, used for voice traffic and secondarily for low-speed mobile data communications.

Table 9-2 – Acronym List

Acronym/Abbreviation	Definition
AACN-Relay	Advanced Automatic Crash Notification Relay
AADT	Annual Average Daily Traffic
ABS	Anti-lock Braking System
App	Mobile application
BSM	Basic Safety Message
CAD	Computer Aided Dispatch
CAN	Controller Area Network
CCMS	Cooperative ITS Credentials Management System
CCTV	Closed Circuit Television Cameras

Concept of Operations	ConOps
CPI	Consumer Price Index
CRL	Certificate Revocation List
CV	Connected Vehicle
CVE	Connected Vehicle Environment
CVOP	Commercial Vehicle Operator Portal
CVRIA	Connected Vehicle Reference Implementation Architecture
DDS	Data Distribution System
DMS	Dynamic Message Sign
DSRC	Dedicated Short Range Communications
ECC	Emergency Communications Center
E-MDSS	Enhanced Maintenance Decision Support System
EMS	Emergency Medical Services
FHWA	Federal Highway Administration
GDP	Gross Domestic Product
GIS	Geographic Information System
HAR	Highway Advisory Radio
HOS	Hours of Service
I/O	Input/Output
I2V	Infrastructureto Vehicle
I-70	Interstate 70
I-80	Interstate 80
I-90	Interstate 90
IRIS	Intelligent Roadway Information System
IT	Information Technology
ITS	Intelligent Transportation System
LIN	Local Interconnect Network
MCV	Maintenance and Construction Vehicle
MOST	Media Oriented Systems Transport
MPH	Miles Per Hour

NWS	National Weather Service
OBE	On-Board Equipment
ORDS	Object Registration and Discovery Service
OSOW	Oversize/Overweight
PID	Personal Information Device
RCR	Road Condition Reporting
ROW	Right of Way
RSE	Roadside Equipment
RSU	Roadside Unit
RWIS	Road Weather Information System
SA	Situational Awareness
SCM	Security and Credentials Management
SCMS	Security Credentials Management System
SET-IT	Systems Engineering Tool for Intelligent Transportation
SLA	Service Level Agreement
SM	System Monitoring
SWIW	Spot Weather Impact Warning
TMC	Transportation Management Center
TRAC	Transportation Reports and Action Console
UTC	Coordinated Universal Time
V2I	Vehicle to Infrastructure
V2V	Vehicle to Vehicle
VSL	Variable Speed Limit
WTI	Wyoming Travel Information
WUWZ	Warnings about Upcoming Work Zone
WYDOT	Wyoming Department of Transportation

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