Connected Vehicle Pilot Deployment Program Phase 1

Concept of Operations (ConOps) – ICF/Wyoming

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Notice

Version History

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1	12/14/2015	ICF-Wyoming	First version of the ConOps technically accepted by USDOT.
2	10/31/2016	WYDOT	Updated version based on final Phase 1 Comprehensive Deployment Plan
3	05/11/2018	WYDOT	Updated version based on the system architecture and design at the end of Phase 2.
4	07/27/2020	WYDOT	Updated version to represent the As Built system.

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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 1 includes the planning for the CV pilot including the concept of operations development. Phase 2 is the design, development, and testing phase. Phase 3 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 1 including security, safety, human-use and performance management plan development. Finally, this 2020 revised version is an update to an earlier version of the report, reflecting the final "As Built" version of the system.

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1 Scope

Wyoming Department of Transportation (WYDOT) is one of the first wave of Connect Vehicle (CV) Pilot sites selected to showcase the value of and spur the adoption of CV Technology in the United States. CV Technology is a broad term to describe the applications and the systems that take advantage of vehicle to vehicle (V2V) and infrastructure to vehicle[1] (I2V) communications to improve safety, mobility and productivity of the users of the nation's transportation system.

As one of the three selected pilots, WYDOT is 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 August 2020) followed by a twelve-month demonstration period in the third phase (ending in August 2021).

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 the Concept of Operations (ConOps) for the **WYDOT Connected Vehicle Pilot System.** This document was updated on July 27, 2020 to reflect the "As Built" 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 twofold:

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

[1] For this pilot, the terminology *Infrastructure to Vehicle* (I2V) already takes into account its complementing direction of communication *Vehicle to Infrastructure* (V2I).

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, USDOT 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 and Glossary) provides definitions for terms, acronyms, and abbreviations used throughout the document.

1.3 System Overview

Wyoming Department of Transportation (WYDOT) is one of the three USDOT-sponsored pilots selected to showcase the value of and spur the adoption of Connected Vehicle Technology in the United States. At a very high level, the pilot scope includes the following implementation elements:

- **Deployment of about 75 roadside units (RSU)** that can receive and broadcast messages using DSRC along various sections on I-80.
- **Equip around 400 vehicles, a combination of fleet vehicles and commercial trucks, with on-board units (OBU).** Of the 400 vehicles, at least 75 would be heavy trucks. All vehicles are expected to be regular users of I-80. Several types of OBU are being procured as part of the pilot and differ based on their communication capabilities, ability to integrate with the in-vehicle network, and connectivity to ancillary devices and sensors. All OBUs will

have the functionality to broadcast Basic Safety Messages (BSM) Part I and will include a human-machine interface (HMI) to share alerts and advisories to drivers of these vehicles.

- **Develop several V2V and I2V applications** that will enable communication with drivers for alerts and advisories regarding various road conditions. These applications include support for in-vehicle dissemination of advisories for collision avoidance, speed management, detours, parking, and presence of work zones and maintenance and emergency vehicles downstream of their current location.
- **Enable overall improvements in WYDOT's traffic management and traveler information practices** by using data collected from connected vehicles. Targeted improvements include better activation of variable speed limits (VSL) and improved road condition dissemination via 511, Dynamic Message Sings (DMS) and other WYDOT sources.

Systems and applications developed in the pilot will enable drivers of connected vehicles to have awareness of hazards and situations they cannot even see. The CV Pilot is considered a System of Systems, with two systems of interest: The *Vehicle System* and the *Wyoming CV System*, see Figure 1-1. The *Vehicle System* includes four Sub-Systems that represent the various vehicle and equipment types to be used in the pilot. These Sub-Systems vary in their data collection and sharing capabilities. The *Wyoming CV System* includes the infrastructure used in the pilot and back-office systems in charge of the various processes that lead to the generation and distribution of advisories and alerts. Together, the Vehicle and *Wyoming CV System*s support a variety of V2V and I2V applications. Both systems interface with external systems, including WYDOT, USDOT and the National Weather Service (NWS).

The CV Pilot Project will, at its core, provide key information to the drivers through five on-board applications: i) Forward Collision Warning (FCW); ii) I2V Situational Awareness (SA); iii) Distress Notification (DN); iv) Work Zone Warning (WZW); and v) Spot Weather Impact Warning (SWIW). In addition, the CV Pilot project will support overall traffic management and traveler information services offered by WYDOT.

Through these applications and functions, WYDOT hopes to improve operations on the corridor especially during periods of adverse weather and when work zones are present. By means of 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, improved and new information outlets.

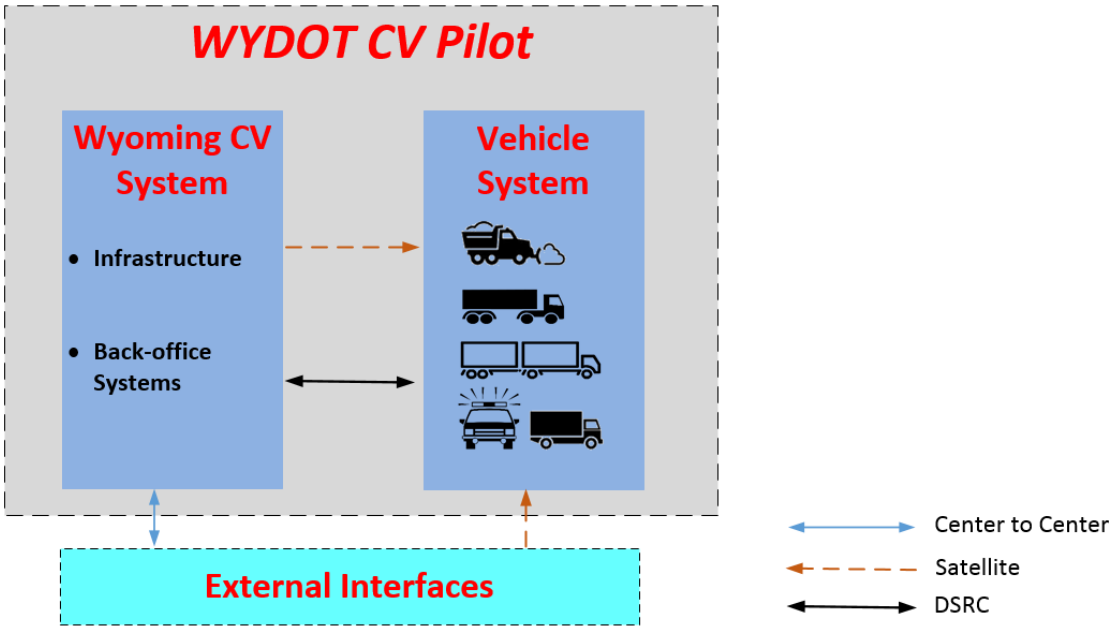

Figure 1-1. Wyoming CV Pilot System of Systems. Source: WYDOT

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
1	Offei, E., & Young, R. (2012). Crash Rates on Interstate Segments with Very Large Truck Percentages. *92nd Annual Meeting of the Transportation Research Board.* Washington, DC: TRB.
2	Office of Freight Management and Operations. (2013). *Freight Facts and Figures 2013.* Washington, DC: US Department of Transportation.
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21	Meenakshy Vasudevan, Karl Wunderlich, Mike McGurrin, William Hyman (Noblis). (2015). *CV Pilots Preliminary Non-Safety Evaluation Needs: ICF/Wyoming.*
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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[2], 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[3] 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.

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.

[2] Wyoming population was estimated at 584,000 in 2014.
[3] 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.

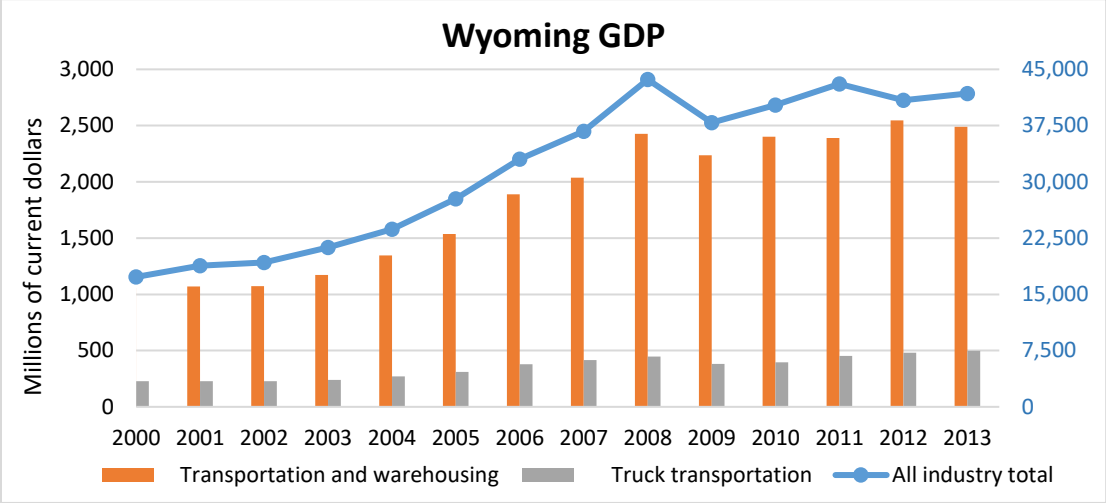


Figure 3-1. Contribution of Truck Transportation to Wyoming's GDP. Source: U.S. Bureau of Economic Analysis (2014).

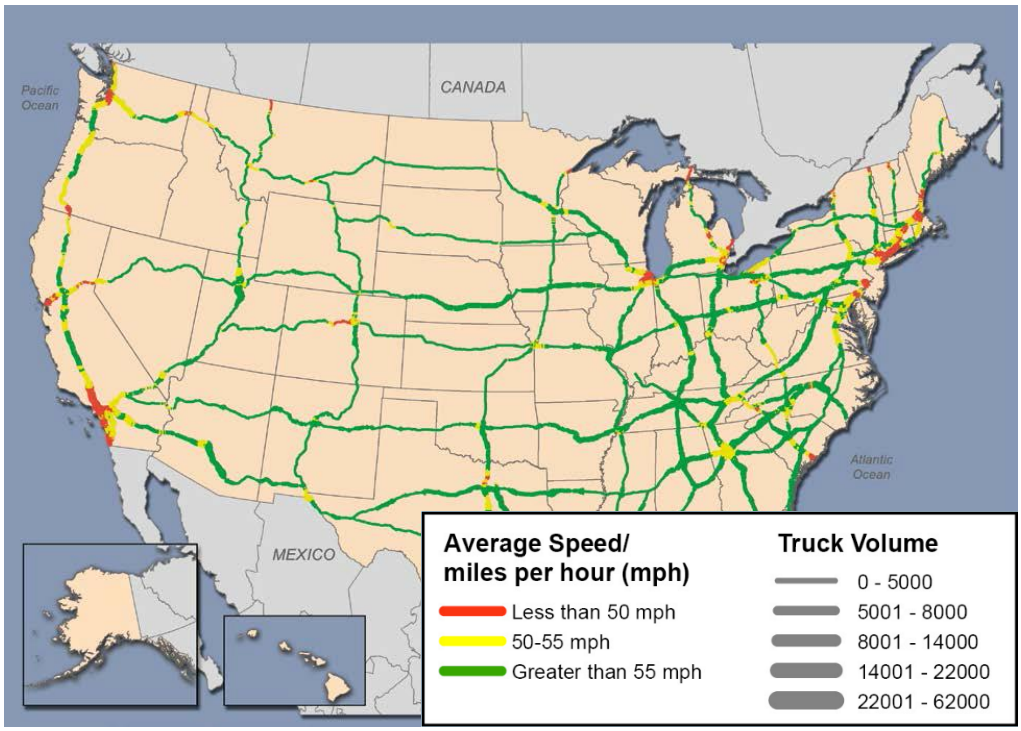


Figure 3-2. Major Freight Corridors in US. Source: Office of Freight Management and Operations (2013).

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). Between September 2015 and August 2016, around 1,500 crashes were reported, involving over 1,900 vehicles. 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[4]. 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.

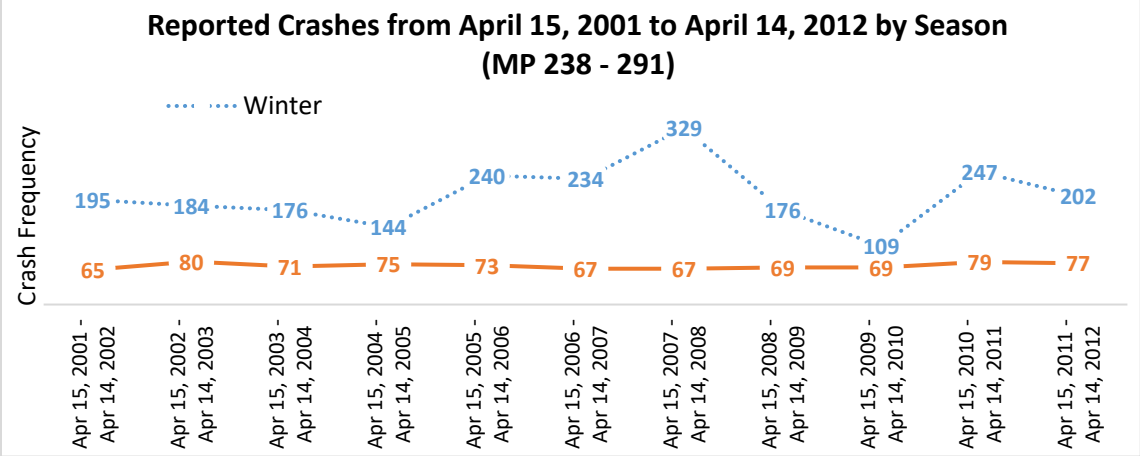


Figure 3-3: Elk Mountain Seasonal Variation of Crash Frequency 2001-2012. Source: Saha and Young (2014a).

3.1.2 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. This event occurs with high frequency in the Wyoming I-80 corridor, with 172 road closures between 2010 and 2012—63% attributed to weather and another 16% were attributed to weather and crashes. Between September 2015 and August 2016, the corridor closed for 250 hours (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.

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

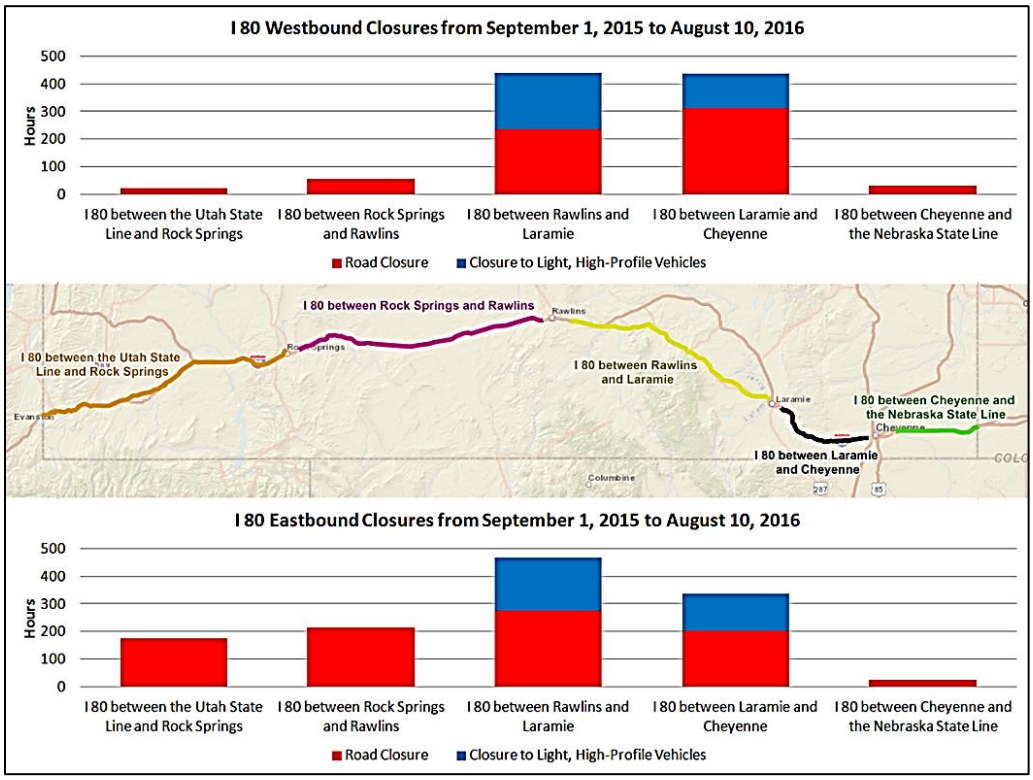


Figure 3-4: Hours and location of road closures between 2015-2016. Source: Wyoming DOT.

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[5]. 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 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

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

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 Crashes, Crash Severity 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.

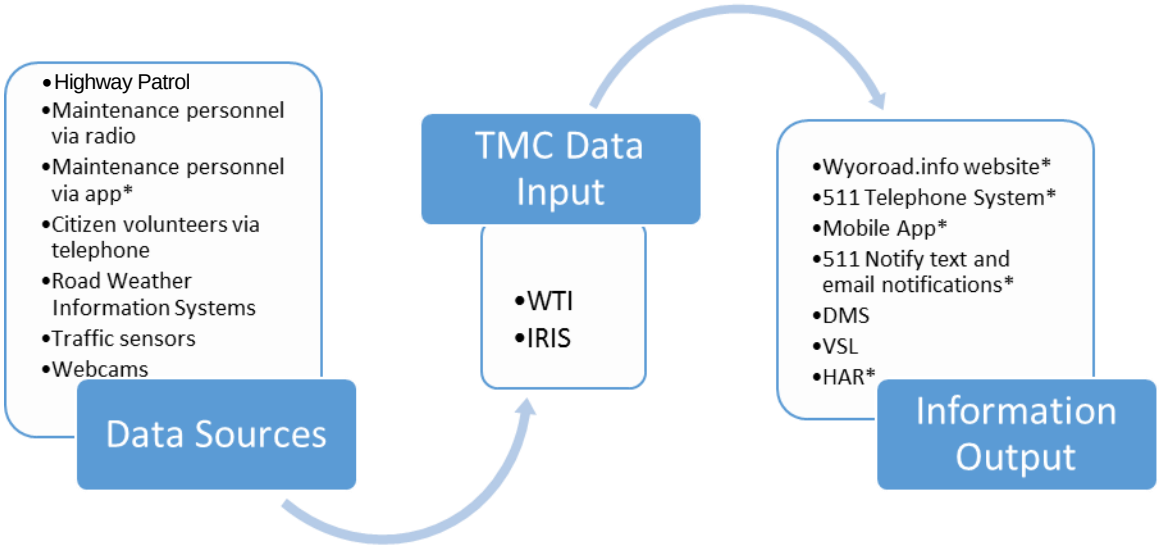


Figure 3-5. TMC's sources of information. Source: Wyoming DOT.

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-based background check 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, WYDOT has 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.

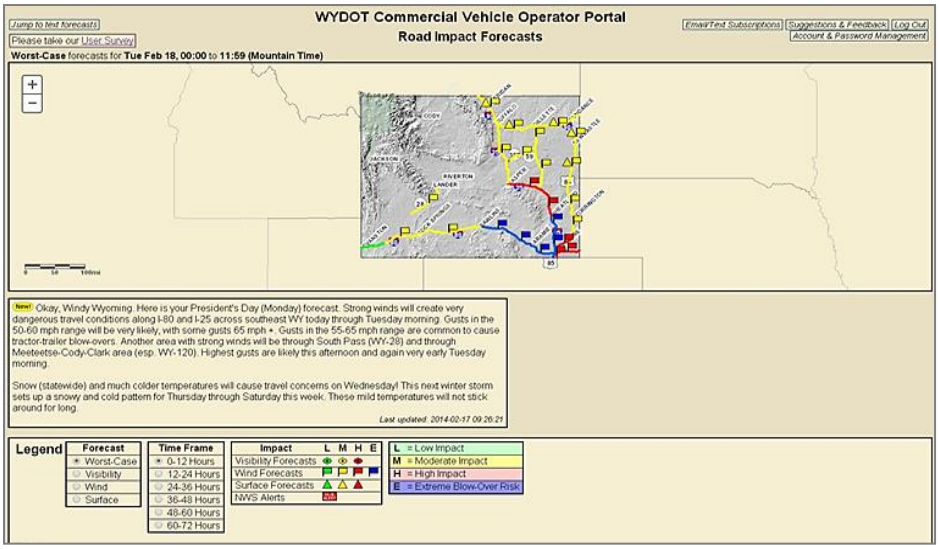


Figure 3-6. CVOP interface. Source: Wyoming DOT.

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 VSL system 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.

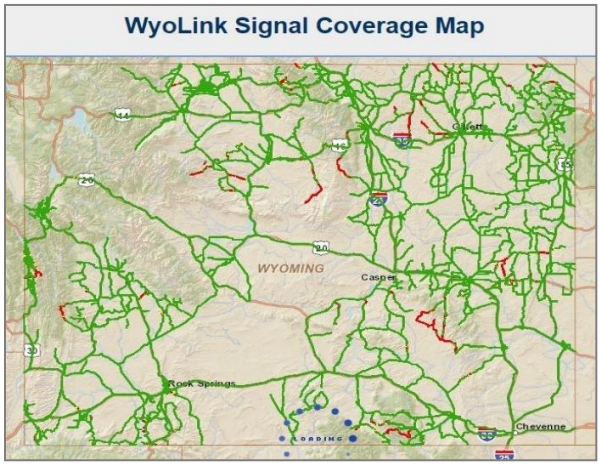


Figure 3-8. WyoLink Coverage Map. Source: Wyoming DOT.

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, WYDOT specified 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, directly or indirectly, 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, snow plow 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.

It should be noted that not all user groups will be affected equally by the proposed system. Significant changes in roles and responsibilities (i.e., directly impacted user classes) are discussed in Section 5.5.

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.
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

User Group	Owner	Short Description
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 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.
9. TMC – Performance Management	WYDOT	Systems and personnel required to support performance management, data archiving, and system evaluation needs during the pilot
10. Wyoming Tele-communications 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.
		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

User Group	Owner	Short Description
		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 OBU 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 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.

In general, 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 (snow plow and highway patrol) and the TMC to support truck advisories and warnings.

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.

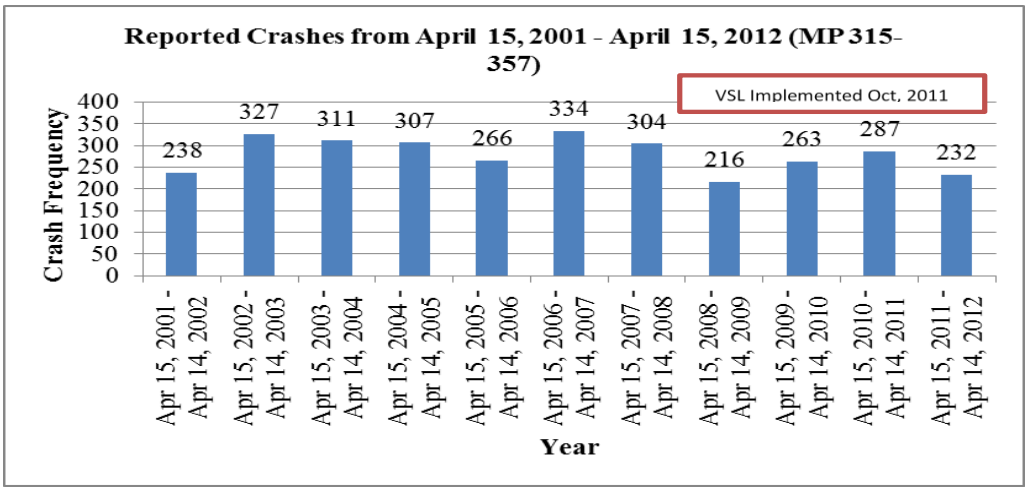


Figure 4-1: Laramie-Cheyenne Corridor Crash Frequency (Source: Wyoming DOT)

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.[6]

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.
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

[6] 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.

the ITS-JPO Standards Training[7] 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[8]:

- 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 different stakeholders of 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 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

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

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 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

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., snow plows 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 WYDOT ITS 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 units (RSUs). 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 from cyber threats	Need capability to safeguard center, field and vehicle systems from cyber 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

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 *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 USDOT. 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 USDOT.

Table 4-10. 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

4.2.1.10 *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 units 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.

WYDOT IT 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 4-11. 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 RSU, 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

4.2.2 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 safest and most efficient manner. The following table provides the user needs for this group.

Table 4-12. 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 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 *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 4-13. 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

4.2.2.3 *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 4-14. 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

4.2.2.4 *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 4-15. 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 Closure and Restriction Management		
WHPF 2.1	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 4-16. 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

4.2.4 Compiled User Needs for the System

Through the process of identifying user needs, the team has identified what the project stakeholders want from the intended system. The stakeholder's needs previously listed in Subsections 4.2.1 through 4.2.3 overlap with each other. As such, they were combined and analyzed to develop the needs for the system itself, and are listed in Table 4-17.

Table 4-17. User Needs for CV Pilot System

UN #	List of User Needs
1	Support warnings of impending forward collision in a host vehicle based on information received from a remote vehicle.
2	Support ability to provide situational awareness of road conditions on the corridor to an equipped vehicle
3	Support notification of distress conditions to and from equipped vehicles
4	Support notification of warnings about work zones to equipped vehicles
5	Support Spot Weather Impact Warnings to equipped vehicles
6	Support WYDOT Corridor Management & Traditional Traveler Information Program Services
7	Need capability to monitor and update CV Pilot field devices system health (up-time, communication strength, device status) remotely during normal and adverse weather conditions
8	Need to develop human machine interface that minimizes the distraction and does not pose a burden on the work load of the driver.
9	Need capability through the pilot of logging time-stamped data for various pilot elements
10	Need a capability to collect, manage, store data collected from equipped fleets as part of the pilot
11	Need to be able to share data to/from vehicles to field, and back-office systems in both real-time and non-real time for various CV applications.
12	Need to ensure that data transfer is secure. Non-reputable, signed, and secured data sent and received by vehicles in this pilot
13	Need to be able to share mobile data at required latency for various pilot applications.

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

f) 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 the summarized stakeholders' needs to requirements will be done in Task 6 of Phase 1.

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 routing and 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 dynamic routing, 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 1 includes the planning for the CV pilot including the development of ConOps. Phase 2 is the design, development, and testing phase. Phase 3 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 2 and Phase 3 are follows:

- Deploy and operate of a set of vehicles that are equipped with on-board unit (OBU) 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 units (RSUs) 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 I2V 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 RSUs, and the number of equipped vehicles (commercial, specialty, and public fleet vehicles) will be finalized through planning activities in Phase 1.

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 units on vehicles and new roadside units to the CV environment along with the back-end systems to support data collection and use.
- Road weather forecasts by segment will likely still 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.
- USDOT-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 all operational policies or identifying all constraints, the following constraints were 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.
- WYDOT and 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 be proprietary with limited data availability due to competitiveness concerns. From a 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, 2016a, IEEE, 2016b; IEEE, 2016c), the SAE J2735 Message Set Dictionary (SAE, 2016b), and the recently released SAE J2945/1 Communication Minimum Performance Requirements standard (SAE, 2016a). As standards change and evolve, system requirements will continue to evolve.

It should be noted that each task in Phase 1 details the challenges and assumptions associated with them. As such, the ICF/Wyoming team refer them for more task-specific information.

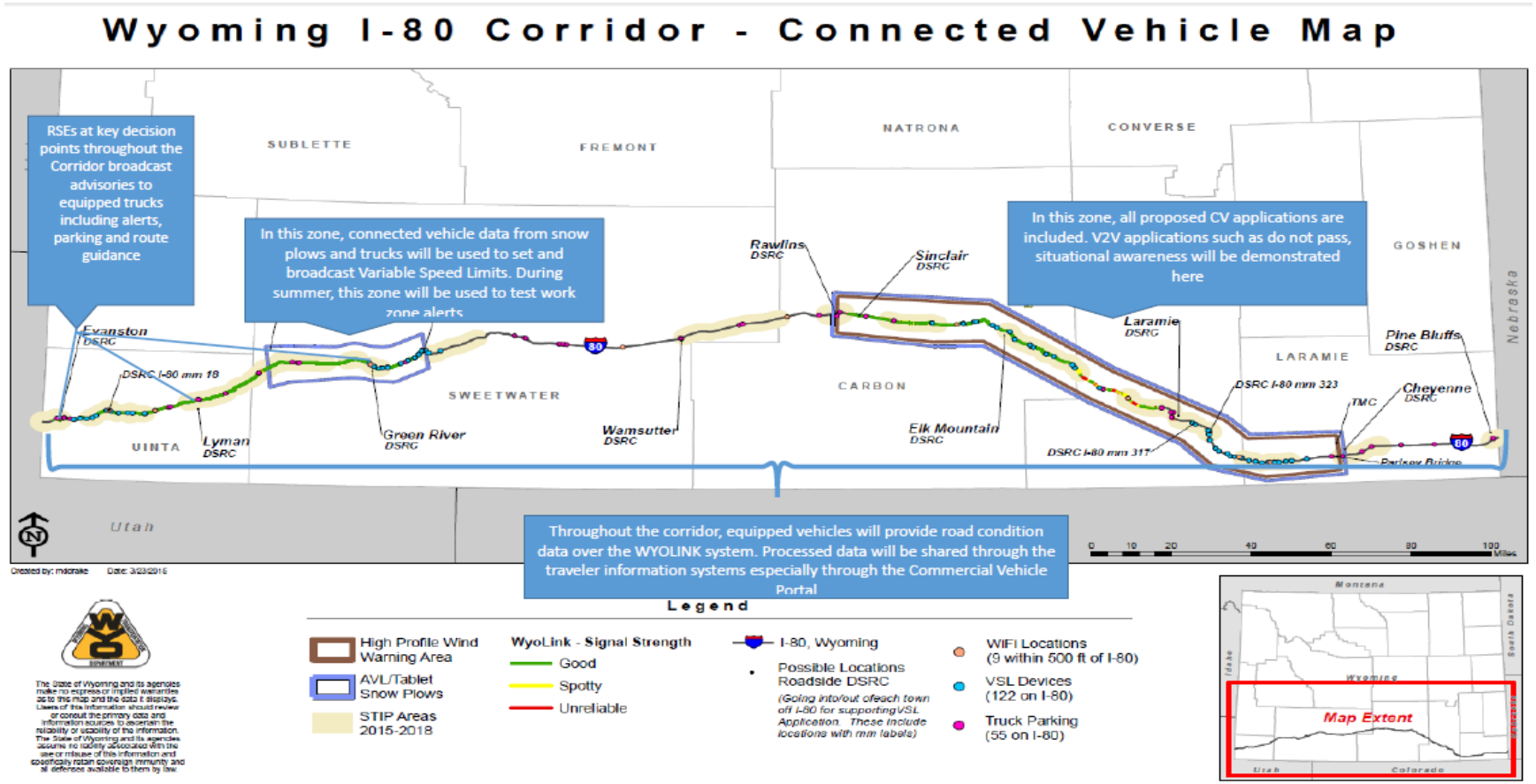


Figure 5-1. CV pilot location and potential zones for deployment (Source: ICF/Wyoming)

5.3 Description of the Proposed System

The CV Pilot is considered a System of Systems, with two systems of interest: The *Vehicle System* and the *Wyoming CV System*, see Figure 5-2. The context diagram highlights the different communication types between the systems of interest, which will be through WYDOT-owned telecom (such as WYDOT's communication backhaul or WYOLINK radio system) or other remote telecommunications (satellite) shown in the figure.

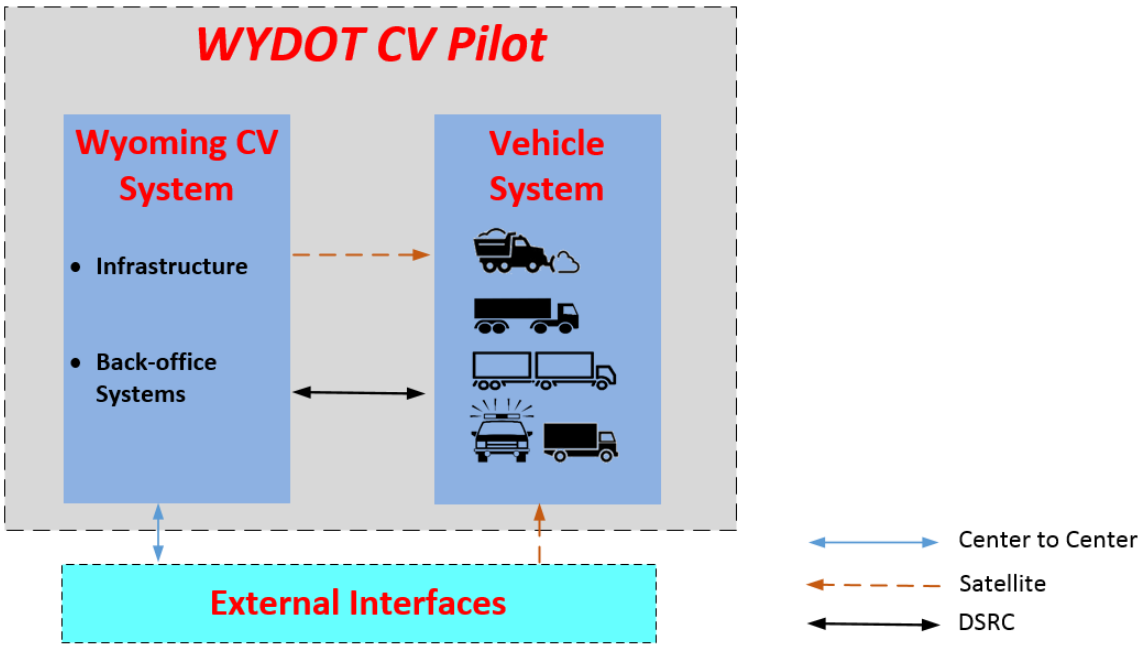


Figure 5-2 Wyoming CV Pilot System of Systems. Source: ICF

The following sections provide more detail on each system and their capabilities, as well as the applications, operational risk factors performance characteristics and safety, security and continuity of operations of the system.

5.3.1 System Capabilities

This section describes functions to be performed by the *Vehicle System* and the *Wyoming CV System*. The *Vehicle System* will perform eight functions:

1. Collect CV Data – Connected vehicles wirelessly receive BSMs from other connected vehicles.
2. Collect TIMs – Wirelessly receives packets containing traveler information from the *Wyoming CV System* and distress information from other connected vehicles.
3. Manage and Process Information for Applications – Manages and processes information for the five on-board applications.
4. Provide In-Vehicle Application Alerts – Provides prioritized alerts and advisories for the Vehicle Operator.
5. Broadcast Vehicle Data – Broadcasts, at a predefined rate, vehicle information (BSMs and DNs) to other connected devices and to the *Wyoming CV System*.

6. Transmit Vehicle Data – Transmits vehicle data to the *Wyoming CV System*. The transmission includes event logs and DNs (including those of other connected vehicles).
7. Store Data – Locally stores selected data collected and generated (both from the field and the applications) until they are transferred to the *Wyoming CV System*.
8. OBU Management – Logs availability and operational capability, including validating and obtaining certificates, time and location accuracy, logging system information, and routine wellness check.

The Wyoming *CV System* performs six functions:

1. Collect CV Information – Collects data from the *Vehicle System*. Data collected includes BSMs Part I and Part II, event logs, other data (e.g., weather sensors), and distress messages.
2. Generate Road Weather Alerts and Advisories – Generates segment-level advisories and alerts of both current and forecast road and weather conditions based on customizable thresholds.
3. Support Information Brokerage – Distributes Road Weather Alerts and Advisories to the WYDOT's interfaces.
4. Distribute TIMs – Distributes the TIM to the *Vehicle System* and the Situation Data Exchange (SDX).
5. Store Data – Data generated are stored by the system.
6. Manage and Maintain System – The WYDOT Maintenance team monitors the system for availability and operational capabilities.

The functional architecture view describes the abstract functional elements or processes and their logical interactions via data flows that satisfy the system requirements. Figure 5-3 depicts the functional diagram of the Systems of Interest along with the external interfaces that interact with the CV Systems. Section 5.3.3 describes in more detail the internal and external interactions of each system.

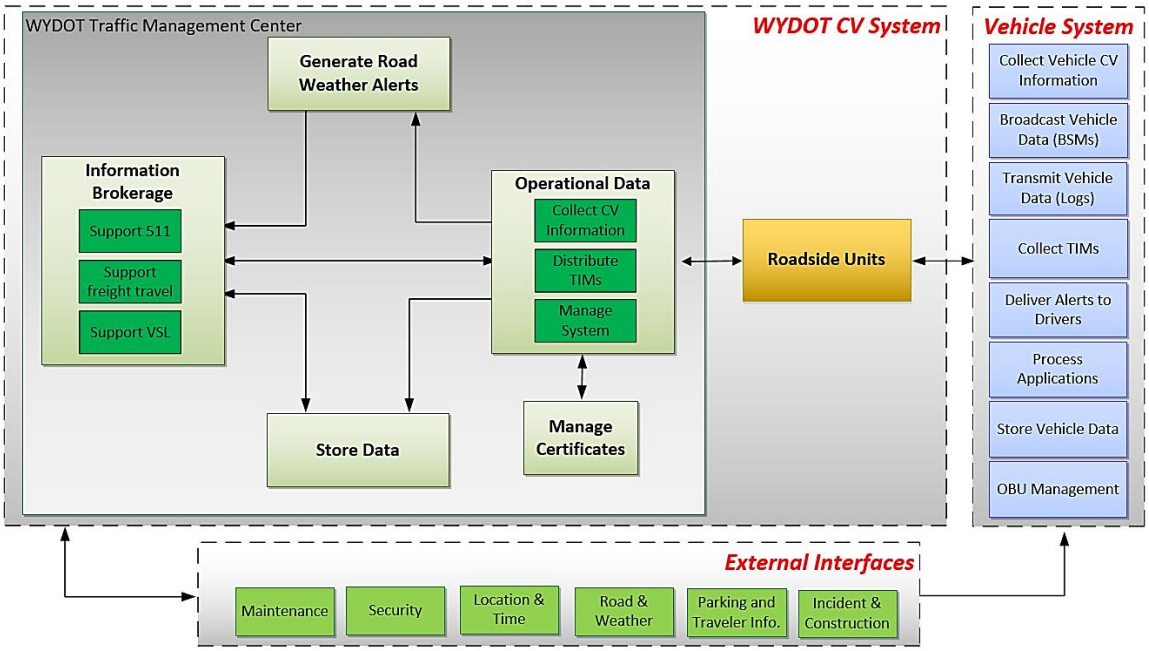


Figure 5-3. Functions of the Wyoming CV System and the Vehicle System. (Source: WYDOT)

5.3.2 Wyoming System

The *Wyoming CV System* includes the infrastructure used in the pilot and the back-office systems in charge of the various processes that lead to the generation and distribution of advisories and alerts for CV Pilot vehicles. The *Wyoming CV System* will be located at the WYDOT TMC. Additionally, this system provides external interfaces to share the advisories and alerts with the public and commercial vehicle operators.

The *Wyoming CV System* is composed of six Sub-Systems:

- Roadside Units (RSU)
- Operational Data Environment (ODE)
- Hardware Secure Module (HSM)
- Pikalert System
- Data Broker (DB)
- Data Warehouse (DW)

5.3.2.1 *Roadside Units*

This Sub-System describes the physical units for deployment as part of the system along I-80. RSUs include DSRC connectivity, application support, data storage, and other support services to enable CV applications, such as necessary certificates. WYDOT RSUs can be either fixed or portable equipment depending on the use. In general, RSUs serve as a two-way communication portal between connected vehicles that provide information through DSRC and the ODE. About 75 RSUs are planned to be deployed in the pilot

5.3.2.2 *Operational Data Environment*

The WYDOT ODE Sub-System receives information collected with connected devices, checks its quality, and then shares it with other Sub-Systems in charge of analyzing and distributing the information. The ODE also exports data to the SDX for USDOT-related activities. The ODE will be hosted at WYDOT TMC and uses the same codebase as the USDOT ODE. High-level requirements for the ODE are contained within the Task 4 ODE ConOps from the Southeast Michigan Test Bed Advanced Data Capture Field Testing. These include requirements for Validation, Integration, Sanitization, and Aggregation (VISA), which are combined in this document with the description of ODE processed data.

5.3.2.3 *Hardware Security Module*

The Wyoming CV Pilot uses the IIS/GHS[9] rented, black box hardware security module (HSM) in the Cheyenne TMC. In essence, the HSM will manage the Wyoming CV System's certifications. It has a Representational State Transfer (RESTful)[10] endpoint that receives an unsigned TIM and outputs a signed TIM. The HSM also has a link to the ISS/GHS Certificate Management System (CMS) to get updated certifications. It should be noted that its internal workings are a black box that is proprietary code, and therefore WYDOT will not have access to it. WYDOT will physically have two 1U rack[11] units that each have dual power supplies and are fail over in capability. The units also have a gig Ethernet connection with IPv4 and IPv6.

5.3.2.4 *Pikalert System*

The Pikalert System supports the integration and fusion of CV and non-CV weather data to develop alerts and advisories regarding adverse weather conditions along I-80. CV data are received from the ODE, while non-CV data derive from weather sources and the WYDOT DB. To generate the alerts and advisories, the Pikalert System assigns CV and non-CV data to 1-mile segments on I-80 every 5 minutes. The CV data is quality checked, then passed to the Road Weather Hazard module (RWH). The RWH uses these data to produce the alerts and advisories for adverse weather and for a 72-hour forecast of road weather conditions and hazards. The generated information is then shared with the DB for further distribution.

5.3.2.5 *WYDOT Data Broker*

WYDOT DB receives information from the ODE, Pikalert and some external systems, analyzes them, and shares them with the corresponding system or service including other sources. The DB supports the information brokerage of road weather alerts and advisories to WYDOT's Third-Party Interface (TPI), TRAC, WTI, Road Condition Reporting System (RCRS), and CVOP. Additionally, this system takes in incident information from the Incident Console (IC), work zone data from the Construction Administrator and parking availability information from the 511 Application. The DB also sends the

[9] IIS/GHS is the company hosting the pilot's certificate management system (i.e., INTEGRITY Software Services/Green Hills Software).
[10] https://en.wikipedia.org/wiki/Representational_state_transfer
[11] Rack height unit 1.75" (https://en.wikipedia.org/wiki/Rack_unit)

information back to the ODE to support the dissemination of TIM to the RSUs and can also access historical data stored at the DW if needed.

5.3.2.6 *WYDOT Data Warehouse*

The WYDOT DW stores various TMC- and CV-related data. The DW includes timestamped and geotagged logs of CV and non-CV data—information collected, generated and shared within the *Wyoming CV System*—that will be used for performance measurement.

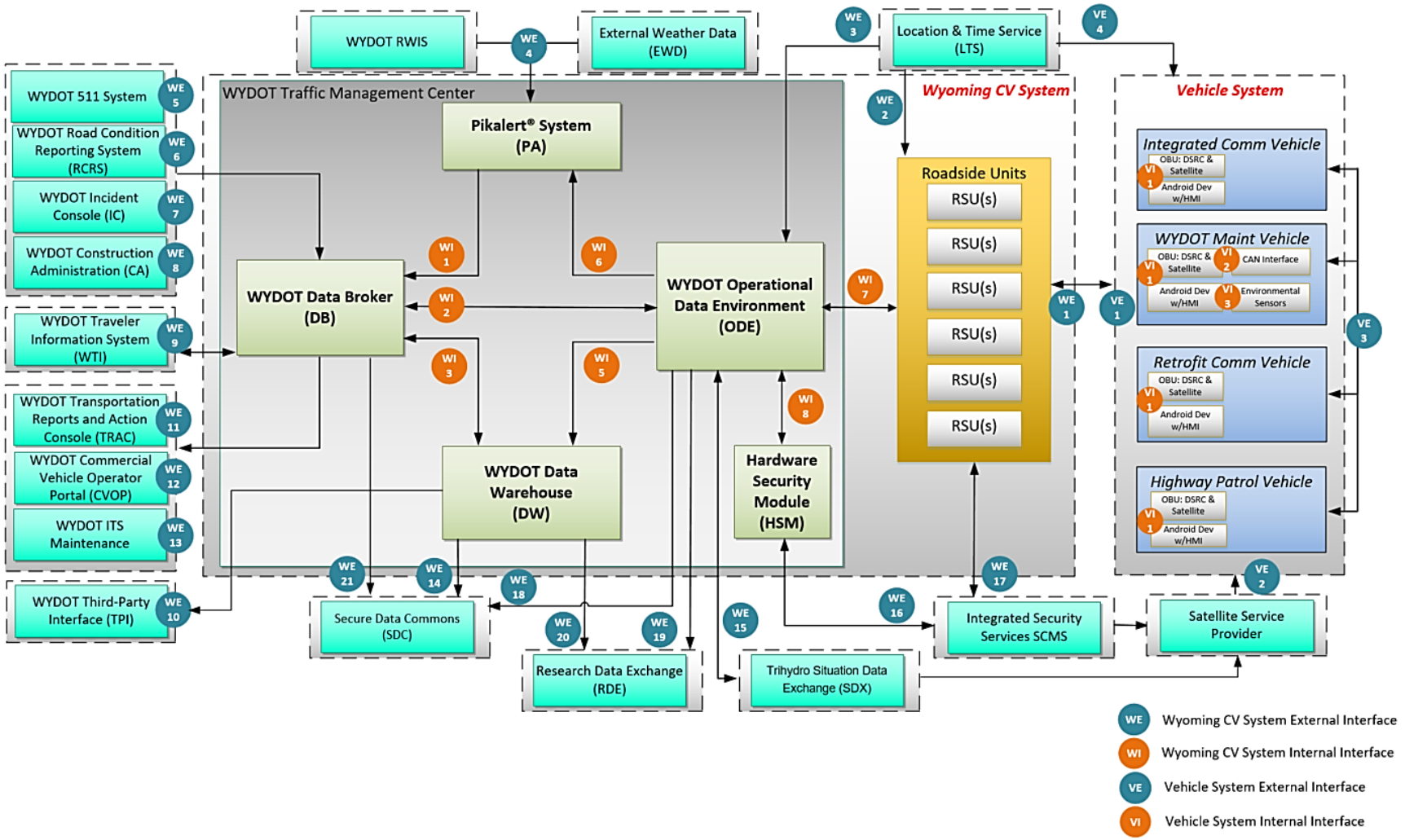
5.3.3 Wyoming CV System External Interfaces

Figure 5-4 shows the physical architecture with interfaces numbered for reference and discussion here and in following sections. The Wyoming CV System includes the following external interfaces for exchanging data and information with external WYDOT and USDOT systems.[12]

- **I2V DSRC Communications Interface** (Interface WE1) Wireless DSRC interface provides communication between Wyoming CV System and Vehicle System through exchange of messages conforming to SAE J2735 and SAE J2945/1.
- **Location and Time Service (LTS)** (Interfaces WE2 and WE 3) – Provides location and time information, which is later used to geotag and timestamp all information produced by the systems of interest.[13]
- **EWD and RWIS** (Interface WE4) – EWD provides regional weather data shared through data sources outside of WYDOT, such as the National Oceanic and Atmospheric Administration's Meteorological Assimilation Data Ingest System and USDOT. **RWIS** provides atmospheric and pavement condition information collected through Environmental Sensor Stations (ESS) deployed as part of the WYDOT RWIS network in the field.
- **WYDOT 511 Application** (Interface WE5) – Provides information to the public regarding I-80's road weather and traffic conditions (e.g., road closure). The application is currently being updated to also share crowdsourced truck parking information with the CV Pilot.
- **WYDOT RCRS** (Interface WE6) – An Android tablet-based application that resides in WYDOT snow plows which enables field personnel (e.g., snow plow operators) to report weather and roadway pavement conditions following WYDOT's 8 Code (roadway condition), 9 Code (atmospheric) and 10 Code (other road condition) system.
- **WYDOT IC** (Interface WE7) – Provides timestamped and geotagged incident information on incidents along I-80 obtained from the WHP and other sources (e.g., maintenance).
- **WYDOT Construction Administration (CA)** (Interface WE8) – Provides timestamped and geotagged information of WYDOT's scheduled and unscheduled work-zone activities along I-80.
- **WTI** (Interface WE9) – Supports traveler information services to the public and to fleet management centers via various means (website, 511, 511 App, text, email, and alerts).

[12] In the figure, WE refers to Wyoming CV System external interfaces, WI refers to Wyoming CV System internal interfaces, VE refers to Vehicle System external interfaces and VI refers to Vehicle System internal interfaces.
[13] The location is obtained from a GPS using WGS-84 coordinates system, and time is provided using UTC from GPS time.

- **WYDOT TPI** (Interface WE10) – A standardized interface based on the TMDD standard that can be used to support delivery of traveler information to external centers and information service providers.
- **WYDOT TRAC** (Interface WE11) – An operator console used in the TMC to monitor and manage planned, ongoing, and forecast events and actions on facilities monitored by the TMC. The TRAC provides a tabular list of currently ongoing events that require operator attention. These events may be entered manually and can be reported based on other systems like RCRS, radio communications with field personnel and citizen reports.
- **WYDOT CVOP** (Interface WE12) – A subscription-based website created by WYDOT for providing advanced notification of forecasted conditions to commercial travelers and fleet managers. Currently there are over 800 companies subscribed to the CVOP. As part of the CV Pilot System, the CVOP will be enhanced to include current weather information for segments on I-80.
- **WYDOT ITS Maintenance** (Interface WE13) – Provides a mechanism to report service outages and resumption of services of WYDOT's ITS equipment.
- **Secure Data Commons (SDC) / Research Data Exchange (RDE)** (Interfaces WE14, WE18, WE19, WE20, and WE21) **–** Provides WYDOT CV Pilot data to the independent evaluators and the RDE for use in independent analysis and impact evaluation across multiple CV pilots.
- **Situation Data Exchange (SDX)** (Interface WE15) – A service operated and hosted by Trihydro that stores near real-time data and shares them with the remote users and developers for further distribution. As shown, this interface also supports communication of messages through **Satellite Service Provider (SSP)** satellites, allowing the system to transmit traveler-related information.
- **USDOT SCMS** (Interfaces WE16 and WE17) – Generates security certificates to manage messages securely from connected devices. As shown, this interface also supports communication of messages through **SSP** satellites, allowing the system to SCMS-related information.



NOTE: The Wyoming CV System Interface WI4 (PA→DW) and VI2 (OBU-CAN Bus) were not implemented in the final system design.

Figure 5-4. Physical View of WYDOT CV Pilot System Architecture with Numbered Interfaces. (Source: WYDOT)

5.3.4 Vehicle System

The *Vehicle System* represents the deployment of on-board equipment, sensors, and an HMI that will support CV applications. All vehicles that are part of the *Vehicle System* will have the following core capabilities:

- Ability to share and receive information via DSRC communication from other connected devices (vehicles and RSUs).
- Ability to share and receive information via Satellite communication.
- Ability to broadcast BSM.
- An HMI that allows alerts and advisories to be communicated with the driver.

Additionally, several vehicles that are part of the *Vehicle System* have further capability. Based on this, the *Vehicle System* is divided into four Sub-Systems, which define the various vehicle types for this pilot based on their data collection, communication capabilities and fleet/vehicle type. Each Sub-System and its rationale are described below.

5.3.4.1 *WYDOT Maintenance Vehicles*

This Sub-System represents the maintenance fleets operated by WYDOT. This includes, but is not limited to, snow plow vehicles assigned to the I-80 corridor. These vehicles represent a set of vehicles over which WYDOT has full control as part of their operations. As such, some of the vehicles will be equipped with the full package of environmental sensors and equipment necessary to support the CV Pilot applications.

Around 60 vehicles are expected to be part of this sub-system, but not all with the same capabilities. Al vehicles will have the ability to:

- Receive TIMs via DSRC and Satellite.
- Broadcast BSM Parts I and II.

Whereas 50 of them are expected to be able to:

- Collect weather sensor data.

All vehicles within this subsystem will have the capability to integrate its network via a Controller Area Network (CAN bus) connection. Although it should be noted that no vehicles within this Pilot are expected to have this connection.

5.3.4.2 *WYDOT Highway Patrol Vehicles*

This Sub-System represents the highway patrol fleet assigned to the I-80 corridor. While also This Sub-system represents the highway patrol fleet assigned to the I-80 corridor. While also operated by WYDOT, these vehicles represent a set over which WYDOT has less flexibility given the nature of their operations. Around 50 highway patrol vehicles are expected to be part of this sub-system, which will have the ability to:

- Receive TIMs via DSRC and Satellite.
- Broadcast BSM Parts I and II.

5.3.4.3 *Integrated Commercial Vehicles*

This connected trucks Sub-System represents a subset of commercial trucks owned and operated by fleet partners involved in the pilot. Similar to Highway Patrol Vehicles, no external weather sensor data will be collected from these systems (i.e., only data from the vehicle) and there is no CAN Bus integration. To summarize, this Sub-system will include the abilities to:

- Receive TIMs via DSRC and Satellite (or other remote communication methods).
- Broadcast BSM Parts I and II.

In essence, these vehicles represent the capability to use vehicle data collected from trucks in the pilot. WYDOT anticipates that about 200 trucks will have these functionalities.

5.3.4.4 *Retrofit Commercial Vehicle*

This Sub-system is intended to simulate a commercial-off-the-shelf system—which is different from the one installed on the integrated commercial vehicles—that enables a vehicle to communicate data through DSRC to other connected devices and receive TIMs through DSRC or satellite. About 50 vehicles are expected in this category and their abilities include:

- Receive TIMs via DSRC and Satellite (or other remote communication methods).
- Broadcast BSM Parts I and II.

5.3.5 Pilot On-Board Applications

The WYDOT CV Pilot will develop five on-board applications that will provide key information to the drivers of equipped vehicles. In addition to on-board applications, information generated by the *Wyoming CV System* is planned to support ongoing WYDOT traffic management and traveler information services. WYDOT expects to use the information from the pilot for:

- Setting and removing VSLs along the I-80 corridor.
- Supporting 511 and other traveler information.
- Supporting road weather advisories and freight-specific travel guidance through WYDOT's CVOP.

The following subsections provide a view of the applications to be developed as for this Pilot.

5.3.5.1 *Forward Collision Warning (FCW)*

FCW is a V2V communication-based safety feature that issues a warning to the driver of the connected host vehicle in case of an impending front-end collision with a connected vehicle ahead in traffic in the same lane and direction of travel on both straight and curved geometry roadways as illustrated in Figure 5-5. FCW will help drivers avoid or mitigate front-to-rear vehicle collisions in the forward path of travel. This application is critically important for safety along I-80 in conditions when snow plows are moving slower than following traffic and/or when visibility may be limited due to adverse weather. The application does not attempt to control the host vehicle to avoid an impending collision. This application will follow the description from standard SAE J2945/1 March 2016 Section 4.2.4.

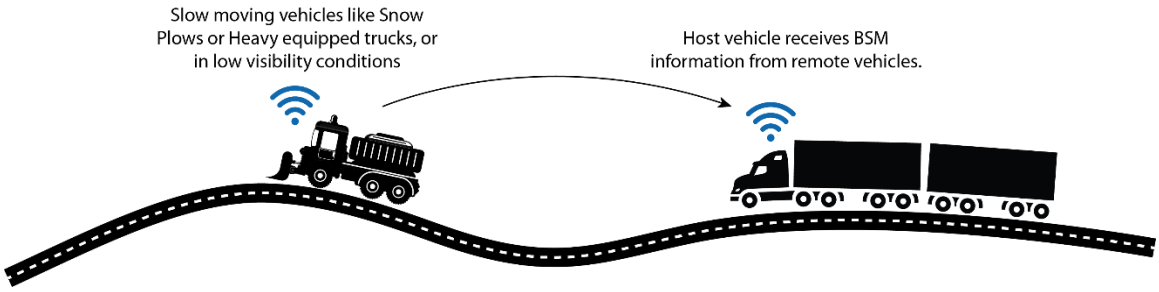


Figure 5-5. Forward Collision Warning Concept Diagram. Source: WYDOT.

5.3.5.2 *Infrastructure-to-Vehicle (I2V) Situational Awareness*

One of the important promises of Connected Vehicle technology is the delivery of up-to-date travel information to drivers that impact their safety and mobility. The WYDOT CV Pilot will implement an I2V Situational Awareness application that assembles important travel information from back-office systems and communications that directly to drivers through both DSRC and satellite communications. This application enables delivery of relevant downstream road condition information to drivers along I-80 in Wyoming, including:

- weather alerts,
- speed restrictions,
- vehicle restrictions,
- road conditions,
- incidents ahead, truck parking[14], and
- road closures.

This information is expected to enhance both safety and traveler mobility along the corridor. The generic application is illustrated in Figure 5-6. It should be noted that the 402 miles of Wyoming I-80 is too long to provide cost effective DSRC communications coverage. Accordingly, the WYDOT CV Pilot will implement satellite-based communications to send situational awareness road condition information directly to satellite enabled connected vehicles along the entire length of Wyoming I-80, when out of range of DSRC communications. This application will follow the description from SAE J3067 August 2014 Section 2.9.3.6.

[14] As part of this project, the WYDOT CV Pilot team will update the WYDOT 511 Application for personal information devices (e.g. smartphones) to capture crowdsourced truck parking information and to share that with commercial vehicle drivers, particularly during inclement road weather conditions

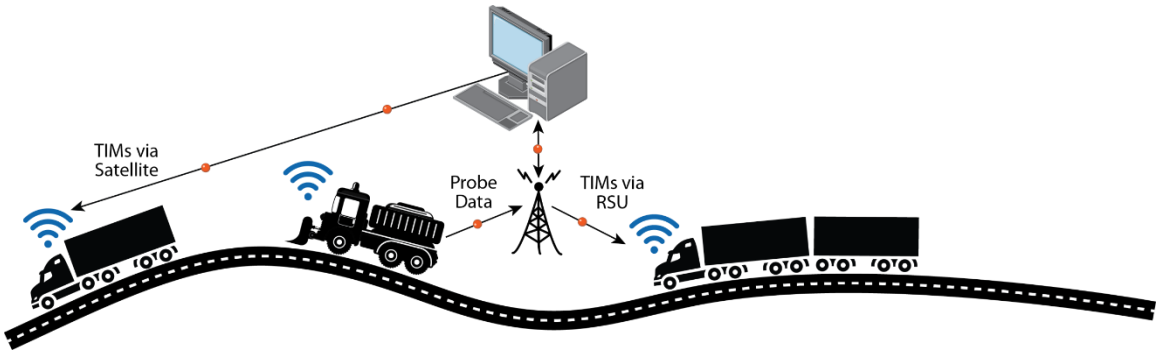


Figure 5-6. I2V Situational Awareness Concept Diagram. Source: WYDOT

5.3.5.3 *Distress Notification (DN)*

This application enables connected vehicles to communicate a distress status back to Wyoming CV System when the vehicle's sensors detect an event that might require assistance from others (e.g., air bag deployed, vehicle disabled) or the vehicle's operator manually initiates a distress status. The vehicle generates and broadcasts a DN (e.g., Mayday) to the nearest RSU. The DN will include the location, time of message, distress message explanation, and vehicle category. The RSU forwards it on to the *Wyoming CV System* for notification of system operators and first responders.

Recognizing that this CV Pilot cannot provide continuous coverage of I-80 by RSUs, this application includes a V2V relay of DNs, illustrated in Figure 5-7. When a distressed vehicle (#1) is not within communication range of an RSU, the message is received by nearby connected vehicles (#2) traveling in the same and/or in opposite directions. These vehicles relay the Notification to the nearest RSU, whether upstream or downstream, which forwards it on to the *Wyoming CV System*. The relay function also enables vehicles traveling the opposite direction (#2), to inform vehicles upstream (#3), traveling in the same direction as the distressed vehicle, of the need for caution ahead.

Although this application is loosely based on the Mayday application description from SAE J3067 Section 3.5.9.2.1, it is built on a higher priority TIM communication using SAE J2735 March 2016, Section 5.16, Part 3, Integrated Transport Information System (ITIS) advisory elements.

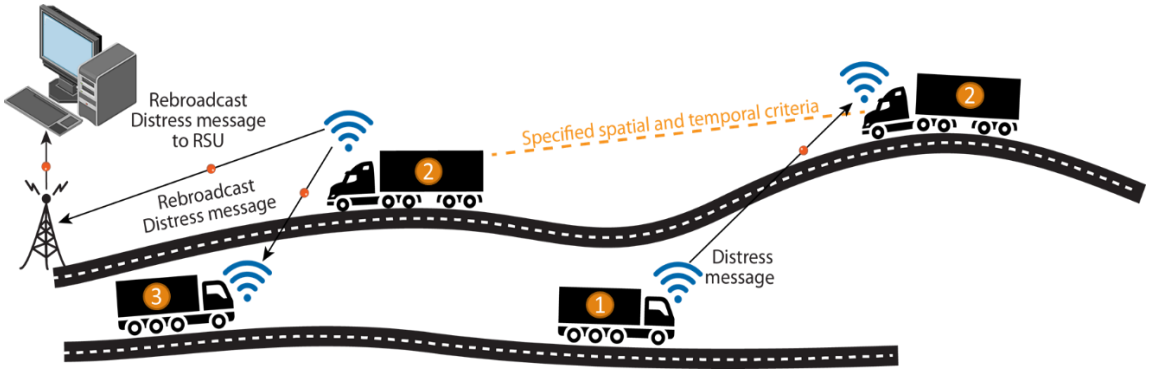


Figure 5-7 Distress Notification concept diagram. Source: WYDOT.

5.3.5.4 *Work Zone Warning (WZW)*

The WZW Application provides information about the conditions that exist in a work zone which the host vehicle is approaching (illustrated in Figure 5-8). This capability provides approaching vehicles with information about work zone activities that could present unsafe conditions for the workers or the host vehicle, such as obstructions in the vehicle's travel lane, lane closures, lane shifts, speed reductions or vehicles entering/exiting the work zone. This application will follow the TIM WZW described in SAE J2735 March 2016 Part 3 in Section 6.142.

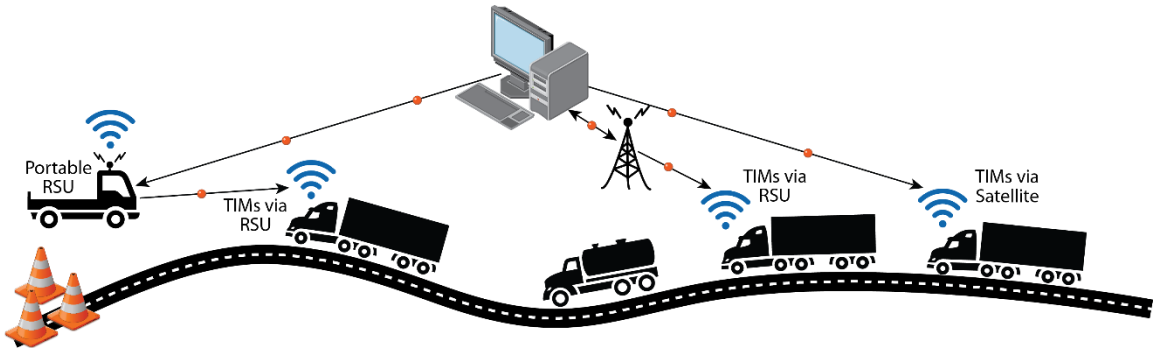


Figure 5-8. Work Zone Warning Concept Diagram. Source: WYDOT

5.3.5.5 *Spot Weather Impact Warning (SWIW)*

SWIW is a special case of I2V Situational Awareness that enables hazardous road condition information due to weather, such as fog or icy roads, to be broadcast from a RSU and received by the connected host vehicles (see Figure 5-9). This application, however, is distinct from other I2V Situational Awareness applications in that it provides more localized information (i.e., at the segment level instead of area wide or region wide). This application will follow the TIM advisory content from part 3 defined in SAE J2735 Section 6.142 for ITIS data elements 6.54 for weather conditions and 6.55 for winds defined in SAE J2540_2.

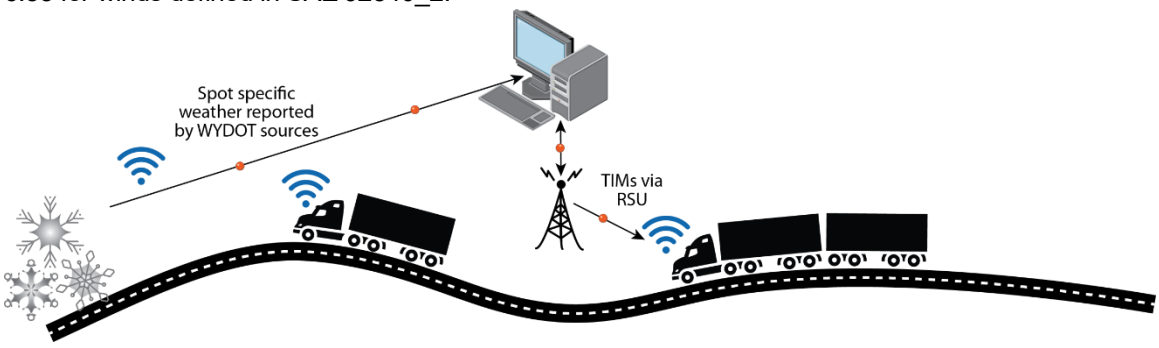


Figure 5-9 Spot Weather Impact Warning concept diagram. Source: WYDOT.

5.3.6 Other Traffic Management and Traveler Information Applications

In addition to on-board vehicle applications, information generated by the Wyoming CV System is expected to be used to support WYDOT traffic management and traveler information. WYDOT expects to use the information from the pilot for the following purposes:

- **Setting and removing VSL along the I-80 corridor –** VSLs will be managed through the Wyoming Traveler Information (WTI) interface. When segment-level alerts and advisories are received from the *Wyoming CV System* in WTI, the TMC operator will have the option to reduce speed according to the normal operation protocols. Similarly, when speed limits are reduced due to information available from the TMC, this information will be communicated with the *Wyoming CV System* and shared as part of the TIM. The VSL zones utilize changeable yet enforceable speed limits in 143 miles along four (4) segments – 23 miles around Evanston, 25 miles around Green River, 57 miles along Elk Mountain and 47 miles between Cheyenne and Laramie.
- **Supporting 511 and other traveler information** – Road weather collected by the Wyoming CV System will be ingested into and processed by the Pikalert system for dissemination to the public. In addition, incident information collected by the CV system will be used to directly update the WTI. The WTI system, upon database saves, has the integrated logic to automatically update the 511 systems (web, phone, email/text messages, app) in near real time.
- **Supporting road weather advisories and freight-specific travel guidance through CVOP** – Information from the *Wyoming CV System* will update the CVOP system to provide freight-specific information to subscribed fleet partners. Currently, more than 800 firms subscribe to CVOP.

5.3.7 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, WYDOT has been able to achieve Wi-Fi signal range of more than a mile in some locations.

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

5.3.8 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 1 of the pilot.

5.3.9 Performance characteristics

Performance of the proposed system will be guided by the Performance Measurement and Evaluation Plan developed in Phase 1. 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 RSUs, OBUs 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 Vehicle Data Translator, alert and advisory generator in terms of data quality and timeliness of alerts. Performance characteristics also include assessment of algorithm performance.

5.3.10 Safety, Security and Continuity of Operations

5.3.10.1 *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 1. 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.

5.3.10.2 *Security*

Security of the CV environment will be supported by use of the USDOT SCMS and be guided by the security and privacy operating concept developed as part of the planning activities in Phase 1. 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.

5.3.10.3 *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 three modes of operation for the proposed system.

- **Normal Operations** – During normal operations, the full suite of CV applications described in Section 5.3.5 is available. Objects in the CV environment are being monitored by the service monitor and are functioning normally.
- **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, OBU 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 RSUs in the proposed system can be managed with redundancy in RSU deployment.
- **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

While some user classes do not change significantly from the description provided in Table 3-1, others do. User groups that are directly impacted by the proposed system are described in Table 5-1, along with their respective change in responsibilities. 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
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. Their primary interface will be through the TRAC system which will include information from the CV environment.
2. 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 protocol. 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 as a result of the notifications from CV Pilot. No direct engagement with *Wyoming CV System*
3. 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
4. Fleet Management Centers	Various	Personnel and systems at participating fleet management centers who will receive information only from the CVOP.	These management centers will see new capabilities realized though improvements in the CVOP.
5. 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 on their human-machine interface. They will also continue their road condition updates
6. 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	Field patrol officers will see additional in-vehicle advisories and alerts. They will also be responsible for setting up portable RSUs around incidents and work zones.

User Group	Owner	Short Description	Changes to responsibilities and interaction with the system
		port-of entries and are responsible for commercial vehicle safety enforcement.	
7. Commercial Truck Drivers	Various	Commercial truck drivers who travel the I-80 corridor as part of their freight movement with OBUs installed in their vehicles	Drivers of Connected trucks will see a significant change to their driving environment including in- vehicle alerts and advisories through a new interface. Drivers may also see an increased amount of communication with their fleet managers and more location-specific information communicated to them.

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:

- USDOT SCMS Operators – Personnel responsible for operating the SCMS.
- USDOT Impact Evaluation Contractor – Personnel involved in USDOT-sponsored impact evaluation that will focus on measures not covered by the Wyoming team's evaluation, impacts of larger scale CV deployments, and national programmatic aspects of this CV Pilot project, combined with other similar projects being conducted.
- 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, USDOT 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 1.

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 five (5) scenarios and twelve (12) 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 (2 use-cases)
4. Travel Planning Support (1 use-cases)
5. 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

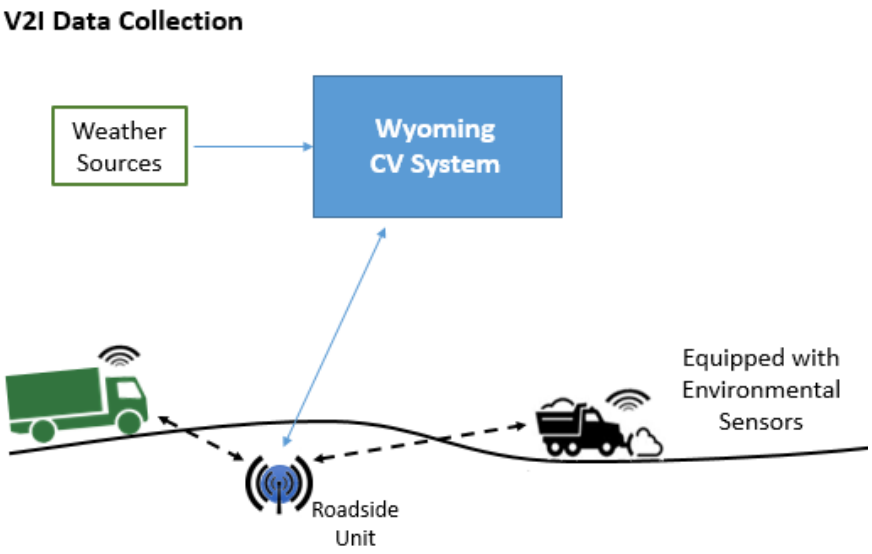
This scenario describes how the new monitoring capabilities from the pilot will be used by WYDOT. Through the pilot, WYDOT will leverage data collected from mobile platforms (WYDOT Fleets and Connected Vehicles), fuse them with existing data sources and develop segment level advisories and warnings. Based on the information received from the field, WYDOT will also initiate several actions that improve the operations of the corridor including delivering 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 V2I 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

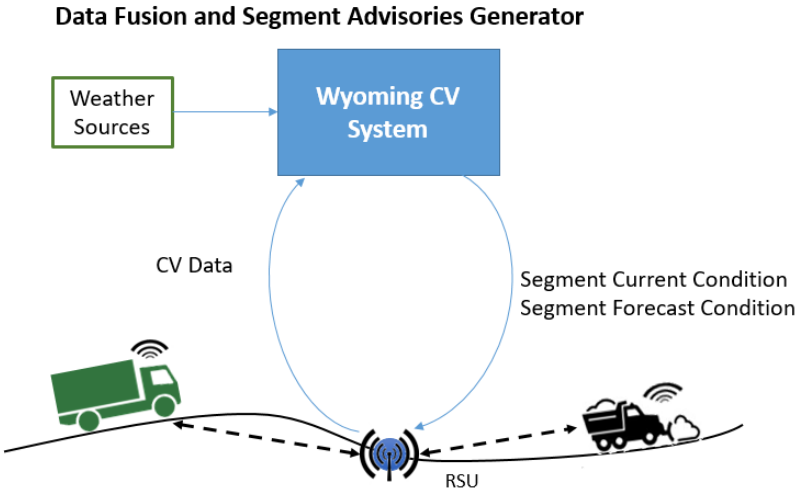
Table 6-1. Use Case #1 – V2I Road Weather Data Collection.

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	RSU spacing requires local on-board storage of data before transmitting to RSUs and WYDOT TMC
Geographic Scope	Corridor-wide
Actors	WYDOT Fleet Vehicles, Connected Trucks, Wyoming CV System
Illustration (Source: WYDOT)	
Preconditions	Equipped vehicles with OBU are necessary for this use-case. Some OBUs are equipped with a sensor package for weather and road condition. Others may also include the ability to collect vehicle operating conditions. All OBUs have the ability to transmit it through DSRC capabilities.
Main flow (example)	1. OBU-equipped vehicle continuously monitors vehicle operating conditions, weather data (if properly equipped) and road condition as it drives along the corridor. 2. When passing by an RSU, the OBU-equipped vehicle transmits the data with a location identifier to the Wyoming CV System over a DSRC communication link.
Alternate flow	None
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 OBU. 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), precipitation, visibility, and surface conditions.
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

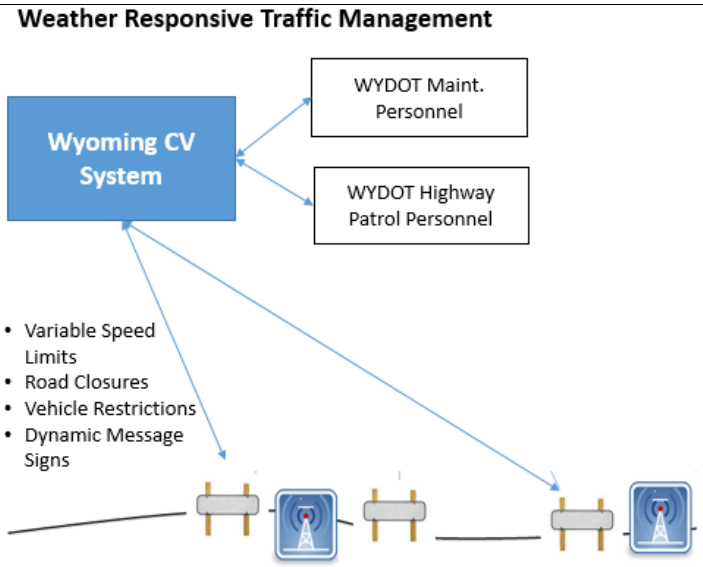
Use Case Name	Data Fusion and Segment Advisories Generator
Short Description	This use-case defines how WYDOT TMC personnel, WYDOT TMC Weather providers, and the Wyoming CV System fuse various sources of atmospheric and road weather data, quality-checks the data, and develops segment-level advisories 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	Wyoming CV System , National Weather Service, WYDOT Weather Provider
Illustration (Source: WYDOT)	
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 received and quality checked by the Operational Data Environment (serving as the Vehicle Data Translator) sub-system at the WYDOT TMC for accuracy, latency and suitability. 2. The Pikalert System fuses quality checked CV data with fixed observations (from RWIS) and other NWS data by segments on I-80. PA serves as the Alerts and Advisory Generator system. 3. "Human in the loop" in form of WYDOT TMC Weather provider may review outputs from Wyoming CV System and combines them with their weather models to produce segment-level forecasts of driving conditions.
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

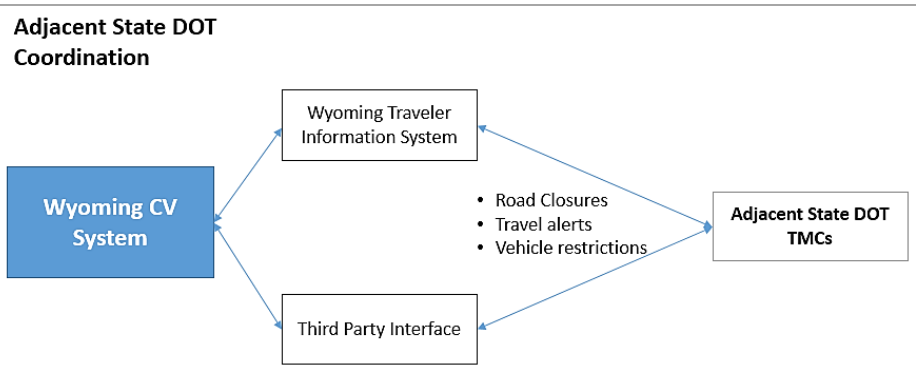
Use Case Name	Weather Responsive Traffic Management
Short Description	This use-case defines the various actors and their interactions to manage the traffic conditions during adverse weather. This use-case defines how the WYDOT TMC, with support of the Wyoming CV System, proactively manages traffic conditions 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, WYDOT ITS Field Equipment, WYDOT Highway Patrol

Illustration (Source: WYDOT)	
Preconditions	Existing policies and field infrastructure to communicate weather responsive traffic information to travelers on I-80.
Main flow (example)	1. The Wyoming CV System alerts WYDOT TMC operators of segment-level alerts and conditions. 2. WYDOT TMC Operators issues 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 WTI, WYDOT TPI, WYDOT TMC Operations Personnel, Adjacent State DOT TMCs
Illustration (Source: WYDOT)	
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 with Adjacent State DOTs through WYDOT's traveler information system. 2. Adjacent State DOTs acknowledge receipt of information and share corresponding response plan with WYDOT TMC operators.
Alternate flow	1a. Adjacent State DOTs request WYDOT TMC to issue road condition alerts based on conditions in their State. 1b. Adjacent State DOT receives road condition alerts generated by WYDOT through WYDOT's third party interface.
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

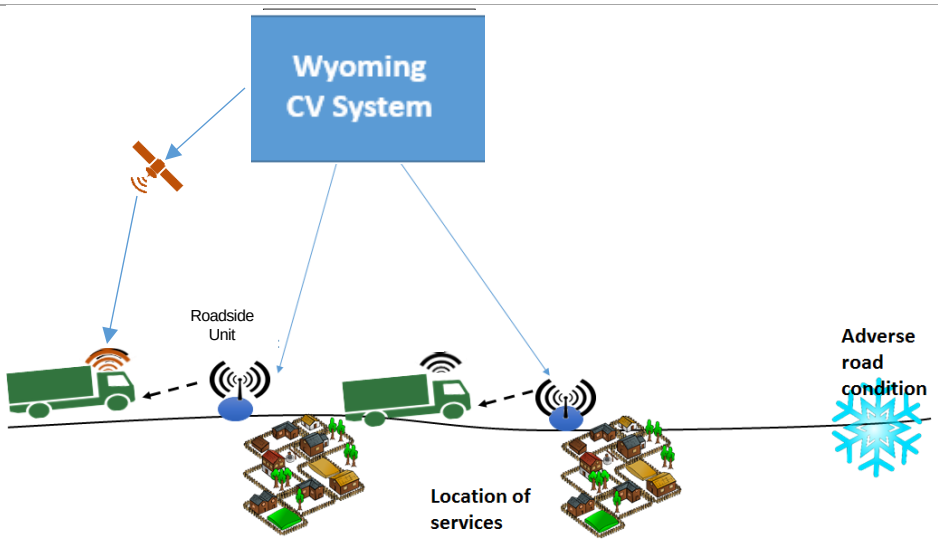
This scenario describes how the proposed system alerts truck drivers on I-80 about affected area or segments of the highway so they can optimize their route selection and overall travel time. It should be noted that the advisories do not demand immediate action from drivers. Advisories in this system 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:

- Infrastructure to Vehicle (I2V) advisory
- Wide-Area Advisory
- V2V Advisory

6.2.1 I2V Advisory

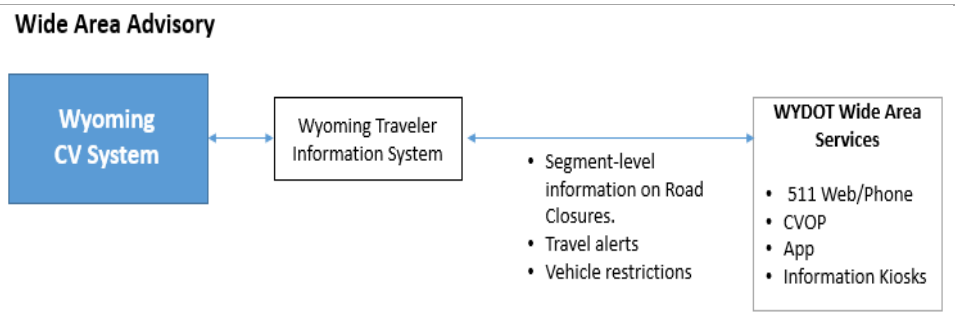
Table 6-5. Use Case #5 – I2V Advisory

Use Case Name	I2V Advisory
Short Description	This use-case represents advisories provided by RSU 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 RSU 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 RSU 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	Wyoming CV System, WYDOT RSU, Connected Trucks OBU
Illustration (Source: WYDOT)	
Preconditions	Availability of parking information and other locations of services such as lodging, restaurants, etc. Location of an RSU upstream of event condition. Available satellite connection.
Main flow (example)	1. The Wyoming CV System sends an advisory to an appropriate set of RSUs upstream of event condition. 2. WYDOT RSUs transmit advisories to passing connected trucks with an OBU.
Alternate flow	1. The Wyoming CV System sends an advisory through satellite to vehicles upstream of event condition. 2. Vehicle equipped with satellite connectivity receive the advisory.

Post-Conditions	RSU advisories are removed once the downstream conditions are no longer in effect.
Information Requirements	Parking locations Location of other services Location of road condition events (including closures, restrictions, speed limit reductions, special events)
Issues	Messaging guidelines to communicate advisories is still uncertain especially for advisories which are more complex in nature for information processing by the driver (e.g., parking guidance).

6.2.2 Wide Area Advisory

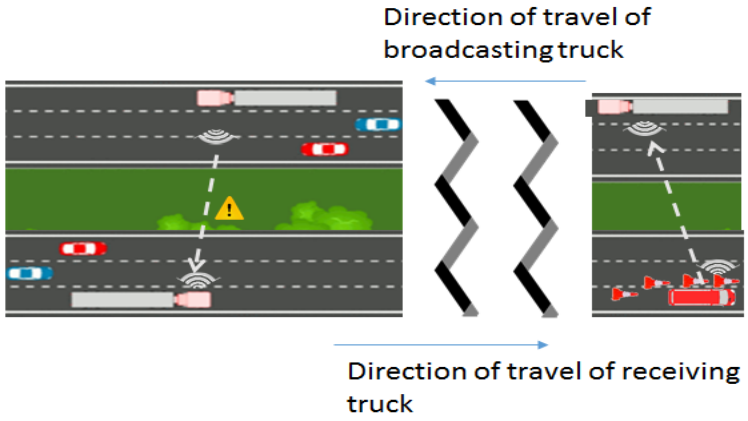
Table 6-6. Use Case #6 – Wide Area Advisory

Use Case Name	**Wide Area Advisories**
Short Description	This use-case defines the wide-area advisories generated by the Wyoming CV System 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, WYDOT Wide Area Services, CVOP
Illustration (Source: WYDOT)	
Preconditions	Existence of a 511 web or phone system that has a road weather element.
Main flow (example)	1. The Wyoming CV System populates the Wyoming Traveler Information (WTI) subsystem with current and forecast conditions. 2. WYDOT WTI populates WYDOT's wide area services such as the 511 web and phone system, WYDOT informational kiosks, WYDOT traffic 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	WYDOT WTI 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 RSUs 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 (Source: WYDOT)	
Preconditions	Equipped vehicles with OBU 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 RSU 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

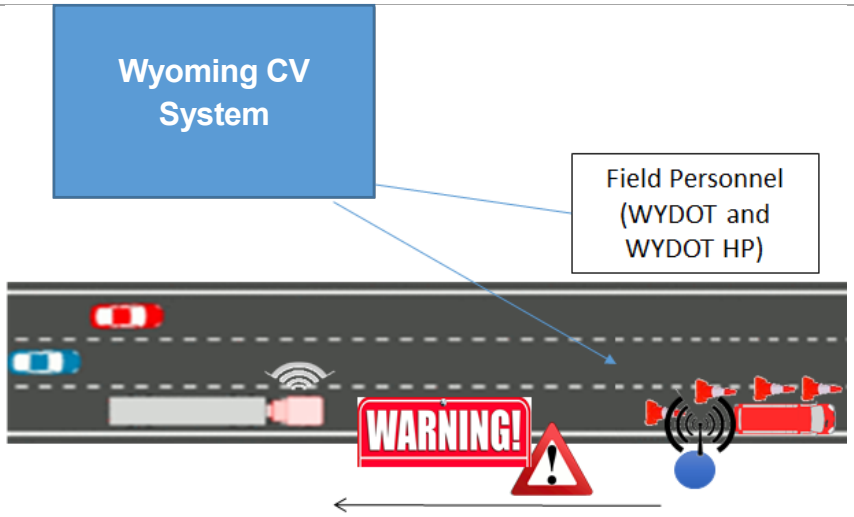
The CV application is intended mitigate the effects of incidents by warning drivers approaching an affected area or segment of the highway so they can take immediate action to optimize their route selection and avoid a potential incident. Compared to advisories, these warnings require an immediate action 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. Warnings can include distress notifications. Two specific use-cases are identified under this scenario:

- Infrastructure to Vehicle (I2V) warning
- Vehicle to Vehicle (V2V) Warning

6.3.1 I2V Warning

Table 6-8. Use Case #8 – I2V Warning

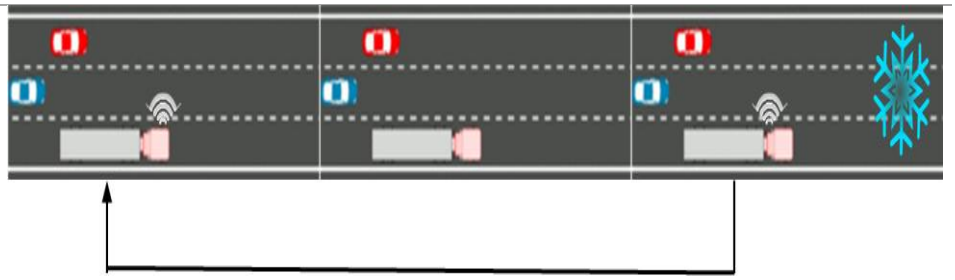
Use Case Name	**I2V Warning – General**
Short Description	This use-case describes how a RSU communicates with equipped vehicles about immediate threats to driving conditions. Warnings may require a driver to take an immediate action (reduce speeds, stop, pull over, or take an exit) in response to conditions downstream of the RSU. 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 RSUs to be conveniently situated to where the warning is required. Since the locations of incidents and events are uncertain, mobile RSU 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	Wyoming CV System, WYDOT Maint. Field Operations Personnel, WYDOT Highway Patrol, WYDOT Fleets and Connected Trucks

Illustration (Source: WYDOT)	
Preconditions	Mobile RSUs with DSRC communications capability. Equipped vehicles with OBU 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 RSUs at prescribed distances from the event to adequately warn drivers upstream. 3. WYDOT activates RSUs to broadcast warnings to equipped vehicles. 4. Equipped vehicles with OBUs receive warnings from mobile RSUs and take evasive action.
Alternate flow	None
Post-Conditions	Field personnel clear the event scene and disassemble the mobile RSUs 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 V2V Warning

Table 6-9. Use Case #9 – 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), changing driving conditions (slowing speed, emergency brake light)—which support the Forward Collision Warning application—and distress notifications—which supports the Distress Notification application.
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 (Source: WYDOT)	
Preconditions	Equipped vehicles with OBU and DSRC communication capabilities.
Main flow (example)	1. Lead vehicle broadcasts safety message as it travels the corridor. 2. Following vehicle OBU 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 OBU. 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.

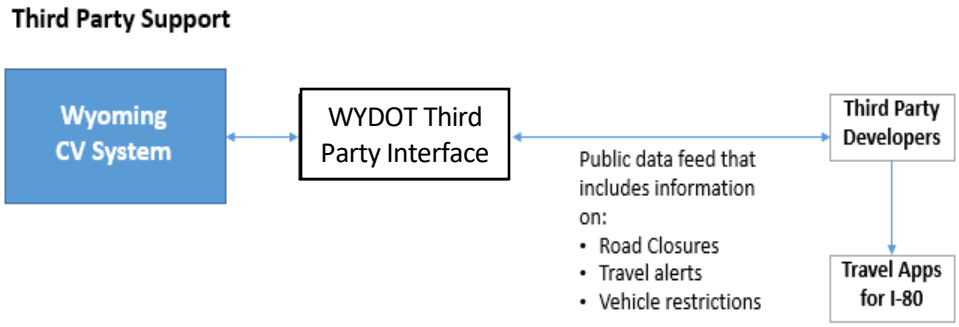
6.4 Travel Planning Support

This scenario illustrates how the proposed system provides travel planning support to application developers. One use-case scenario is defined:

- Third Party Application Developer Support

6.4.1 Third Party Application Developer Support

Table 6-10. Use Case #10 – Third Party Application Developer Support

Use Case Name	Third Party Support
Short Description	This use-case describes how the Wyoming CV System 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 Wyoming CV System 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	Wyoming CV System, WYDOT TPI, Third Party Application Developers, Private Vehicles
Illustration (Source: WYDOT)	
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.

6.5 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.

6.5.1 Performance Management Support

Table 6-11. Use Case #11 – 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 • RSU data – Data collected by RSUs 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.

6.5.2 Impact Evaluation Support

Table 6-12. Use Case #12 – 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, Independent Evaluator, 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 Independent Evaluators by providing access to the data warehouse. 2. Non-system data collection are collected in Phase 2 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 RSUs.
- 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 RSUs.
- 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 units as part of their proposed system, their operational impacts are significant. These carriers will have to make their trucks available for installation of on-board units, 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 RSU 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 1, 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) within the Phase 1 project planning activities.

8.1 Summary of Improvements

The following potential improvements are typically considered for 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.

From the previous sections of this ConOps document, it is possible to define three primary systems involved: the Vehicle System, the Wyoming CV System and External Interfaces. 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 suggestions - Automated location information - 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

Proposed System Concept Elements	Expected Benefits	Category
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 RSUs (such as speed limits, incidents, road closures, etc.)	**Improved Commercial Vehicle and snow plow 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 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	Safety, mobility
Snow plow and Comm. Vehicle – V2V		
Vehicles communicate messages: - Warnings (such as incidents, work zones,	**Improved Comm. Vehicle and Snow plow driver awareness** - Speed limits/VSL - Road closures - Crashes	Safety, mobility

Proposed System Concept Elements	Expected Benefits	Category
emergency braking, etc.) - Speeds (such as posted limits including current VSL values)	- 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	

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: 25% reduction in the number of vehicles involved in a crash, compared to the most recent 5 year crash average.
    - Target: 10% reduction in total and truck crash rate, compared to the most recent 5 year crash average.
    - Target: 10% reduction in total and truck critical crash rates, compared to data for the most recent 5 year average.
    - Target: 10% reduction in total and truck crash rate within work zones, 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: 20% improvement over baseline of total vehicles traveling no more than 5 mph over posted speed during CV Pilot.
    - Target: 20% improvement over baseline of total vehicles traveling within +/- 10 mph of the 85th percentile speed during CV Pilot.
    - Target: Connected vehicles are 20% closer to posted speed.

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. Second, an independent evaluation will 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, snow plow 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
ABS	Anti-lock Braking System
App	Mobile application
BSM	Basic Safety Message
CAD	Computer Aided Dispatch
CAN	Controller Area Network
CCTV	Closed Circuit Television Cameras
Concept of Operations	ConOps
CPI	Consumer Price Index
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
HSM	Hardware Security Module
I2V	Infrastructure to 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
MOST	Media Oriented Systems Transport
MPH	Miles Per Hour
NWS	National Weather Service
OBU	On-Board Unit
ORDS	Object Registration and Discovery Service
PID	Personal Information Device
RCR	Road Condition Reporting
ROW	Right of Way
RSU	Roadside Unit
RWIS	Road Weather Information System
SA	Situational Awareness
SCM	Security and Credentials Management
SCMS	Security Credentials Management System
SDC	Secure Data Commons
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
WYDOT	Wyoming Department of Transportation

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