

Connected Vehicle Pilot Deployment Program

Comprehensive Transition Plan - WYDOT

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16. Abstract <p>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.</p> <p>This document presents a plan to effectively transition from the pilot stage to continuous operation of the system as part of WYDOT's regular operations.</p>			
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1 Introduction

1.1 Project Scope

Wyoming Department of Transportation (WYDOT) is one of the Connected 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 dedicated short-range communications (DSRC) between vehicle to vehicle (V2V) and vehicle to infrastructure (V2I) to improve safety, mobility, and productivity of the users of the nation's transportation system.

As one of the three selected pilots, WYDOT focused 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 worked on a planning phase through September 2016. The deployment process took place in the second phase followed by an 18-month demonstration period in the third phase.

Outreach efforts supported the second and third phases by ensuring that the pilot project was promoted within the transportation community and the media, increasing awareness of the project within the public community, and eliciting buy-in for continued investments from a diverse set of stakeholders including the public and state and local decision makers.

1.2 System Overview

At a very high level, the WYDOT CV Pilot scope includes the following implementation elements:

- **Deployment of about 76 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)**, with all vehicles being regular users of I-80. All OBUs were purchased with the functionality to broadcast Basic Safety Messages (BSM) Part I and included a human-machine interface (HMI) to share alerts and advisories to drivers of these vehicles.
- **Develop several V2V and V2I (and I2V) applications** that enabled 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 included better activation of variable speed limits (VSL) and improved road condition dissemination via 511, Dynamic Message Signs (DMS) and other WYDOT sources.

1. Introduction

Systems and applications developed in the pilot enabled drivers of connected vehicles to have awareness of hazards and situations they could not 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. The *Vehicle System* includes four subsystems that represent the various vehicle and equipment types to be used in the pilot. These subsystems 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 Systems support a variety of V2V and V2I applications. Both systems interface with external systems, including WYDOT, USDOT and the National Weather Service.

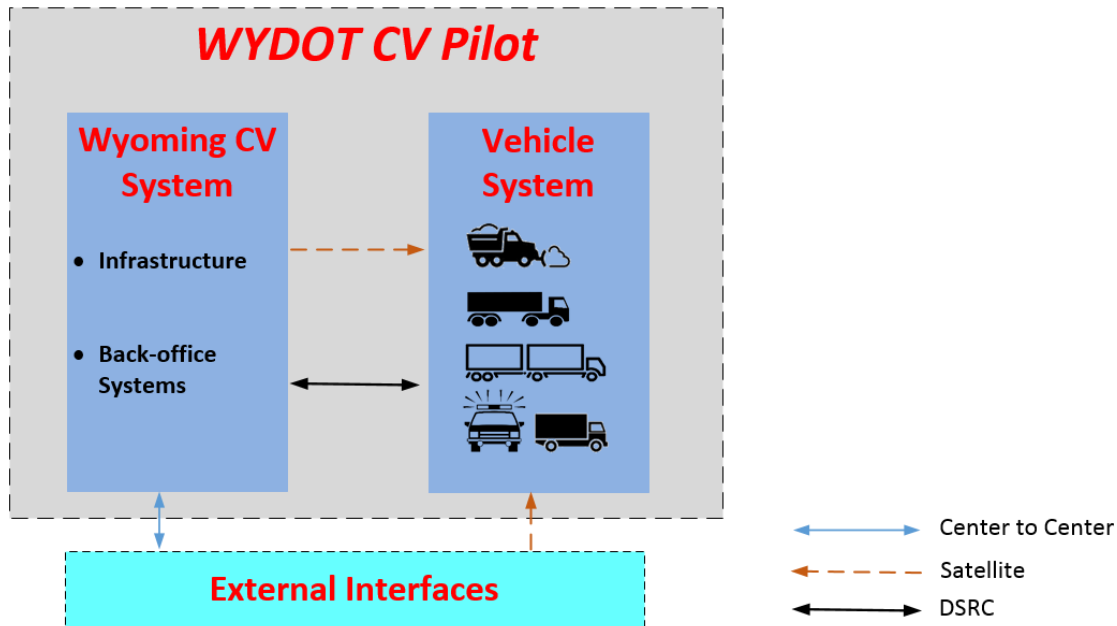


Figure 1. Wyoming CV Pilot System of Systems

Source: WYDOT

The CV Pilot Project, at its core, provides key information to the drivers through five on-board applications: i) Forward Collision Warning (FCW), with Stationary Vehicle Alert as a type of FCW; ii) I2V Situational Awareness; iii) Distress Notification; iv) Work Zone Warning; and v) Spot Weather Impact Warning. In addition, the CV Pilot project supports overall traffic management and traveler information services offered by WYDOT. Through them, WYDOT hopes to improve operations on the corridor especially during periods of adverse weather and when work zones are present. By means of the outcomes of the pilot, fleet managers are able to make better decisions regarding their freight operations on I-80, truckers are made aware of downstream conditions and provided guidance on parking options as they travel the corridor, and automobile travelers receive improved road condition and incident information through various existing, improved, and new information outlets.

A detailed explanation of the Wyoming CV Pilot project can be found in *Connected Vehicle Pilot Deployment Program Phase I, Concept of Operations (ConOps)* (Gopalakrishna, et al., 2015).

1.3 Purpose of the Report

This report details WYDOT's comprehensive plan to transition from Phase 3 of the Pilot to a live, post pilot system that will remain operational for at least 5 years.

1.4 Organization of the Report

The Outreach Plan consists of the following sections:

- Chapter 2 details the transition approach, including the DSRC shut-off approach.
- Chapter 3 provides the expected post pilot operations, listing potential future direction and opportunities for the pilot, as well as ongoing risks.
- Chapter 4 provides reference information of the support documents used.
- Chapter 5 provides a list of the acronyms used in this document.

2 Transition Approach Overview

The following subsection details the overall approach taken as the pilot transitions to WYDOT's regular operations. These sections detail the parts of the pilot that will not continue operating after the pilot.

2.1 Approach Overview

WYDOT plans to continue use of the connected vehicle pilot (CVP) infrastructure in the Transportation Management Center used to create and disseminate traveler information messages (TIMs). With the Federal Communications Commission (FCC) removing the lower 45 MHz and pushing for cellular vehicle to everything (C-V2X) communications, WYDOT will not continue use of DSRC after July 2022. This removes solutions currently in place for log offloads from vehicles, certificate updates, TIMs dissemination from RSUs, forward collision warning, distress notifications, and over the air (OTA) updates for OBUs. Satellite delivery of TIMs will remain in effect for the foreseeable future for the entire state. The Alexa Skill deployed through the situational data exchange (SDX) will also continue and WYDOT will continue to populate the SDX so third-party vendors can use WYDOT data.

2.2 DSRC Shut-off Approach

The following subsections detail the approach to shut of DSRC capabilities in the pilot's deployed devices.

2.2.1 Friendly Fleets

Friendly fleets are composed of WYDOT Highway Patrol and WYDOT snowplows, with the patrols running Sirius XM (SXM) OBUs. The pilot posted an OTA update in the beginning of May 2022 for these SXM devices that turned off BSM broadcasting and removed Security Credential Management System (SCMS) certificate verification for TIMs received via satellite. This also shut off DSRC while retaining the ability to receive satellite TIMs for the foreseeable future. The OTA removed the OBUs ability to offload logs, support FCW, and support future OTA updates.

The snowplows run Lear OBUs; many of these have been removed from the snowplows. Otherwise, they have been powered down to shut-off DSRC. This removes support for OTA updates, log offloads, certificate updates, FCW, and weather cloud log collection and offloading.

2.2.2 Partner Fleets

Partner fleets are composed of mostly heavy freight semis with trailers and all use Sirius XM OBUs.

The partner fleets run SXM OBUs and the CVP posted an OTA update in the beginning of May 2022 for these devices that turned off BSM broadcasting and removed SCMS certificate verification for TIMs received via satellite. This shut off DSRC while retaining the ability to receive satellite TIMs for the foreseeable future. This OTA also removed the OBUs ability to offload logs, support FCW, and support future OTA updates.

2.2.3. RSUs

The 76 Lear RSUs on I-80 had DSRC turned off at the end of June 2022 in support of the FCC requirement. Based on this action, log offloads have stopped, TIM broadcasts via DSRC have stopped, and OTA updates are no longer possible. The team is looking into funding options to switch out the RSUs to C-V2X that could be done by taking down the DSRC units.

The CVP had two websites built to monitor RSUs. One was a public facing website that displayed all RSUs on a map along with the status of the RSUs. The other was a website to allow administrators the ability to remotely update the RSUs and the associated firmware. Both will be taken down for the time being, but WYDOT will keep the source code in case of future deployments of RSUs.

There is currently a reboot script that was built specifically for Lear RSUs to support the automation of rebooting RSUs on the WYDOT network. This script was run nightly and rebooted all RSUs that were deployed for the pilot. As RSUs are no longer operational, the reboot scripts are no longer needed. WYDOT has discontinued the reboot task and removed the reboot scripts from its servers.

2.2.4. Back-Office

The back-office systems will generally keep running after the pilot is over. A few exceptions are annotated below:

- 1) With the RSUs powered down, the RSU reboot script has been removed from the back-office.
- 2) The TIM refresh script for RSUs has been removed.
- 3) The TIM wrapper has been reconfigured to only push to the Situational Data Exchange (SDX) and remove the push to RSUs.
- 4) The existing Transportation Management Center (TMC) Authority consists of dual hardware security modules (HSM) devices installed within the TMC infrastructure that are used to sign CV messages prior to distribution to RSUs or the SDX. After the pilot concludes the TIM messages will no longer be signed with SCMS certificates. This negates the purpose of the TMC authority along with the HMS devices. The rack pair of HSM's will be returned to INTEGRITY Security Services and the Operational Data Environment (ODE) will not be signing TIMs. In the case that WYDOT wishes to incorporate the SCMS for future CV applications, then INTEGRITY Security Services can provide a cloud hosted SCMS service which, again, negates the need for the on-prem HMS devices. It is therefore recommended to remove these from the infrastructure.

2.2.5. Schedule

The schedule for DSRC shut off was as follows:

- 1) At the beginning of May 2022, the team pushed an OTA update to SXM OBUs to disable broadcasting of BSMs and signature validations for satellite delivered TIMs.
- 2) At the beginning of May 2022, the team is unplugging all Lear OBUs. The removal of these devices will happen at their next scheduled maintenance.
- 3) At the end of Jun 2022, the RSUs were remotely turned off, this ended log offloads from OBUs, TIM delivery to RSUs, and over the air updates to OBUs. This was completed before the 2nd of July 2022 deadline from FCC to abandon the lower 45 MHz of the 5.9 GHz spectrum.

2.2.6. Transition Communications

An email was sent on May 11, 2022 to all participants of the pilot detailing the shutdown transmissions on the dedicated short range radio spectrum in the lower 45 MHz and how this will impact certain capabilities of the system. The SXM OBUs will continue to receive and share to driver's traveler information alerts about variable speed limits, closures, and road conditions but certain alerts that depend on the use of the V2V communication will not be available after the installation of the update—for example, forward collision and stationary vehicle alerts.

3 Post Pilot Operations

This section details what aspects of the pilot will continue to operate after its conclusion. After the pilot terminates, maintenance and operations (M&O) will continue for the satellite delivery of TIMs and the Alexa Skill through the SDX. RSU M&O will cease and uploading logs to the secure data commons (SDC) will stop.

3.1 Core Applications, Operations and Resources

WYDOT plans to continue doing TIM validation by driving the roadways with SXM OBUs to ensure TIMs are being received correctly. This includes both the I-80 corridor as well as other roads throughout Wyoming. These operations will include the back-office system to generate the TIMs from Wyoming Travel Information Advanced Traffic Management System.

Table 1 lists the systems and hardware of the CV System and their expected post deployment status, ownership, and level of effort to maintain their operations.

Table 1. Summary of WYDOT's CV System Core Operations.

System /App. / Hardware	Overview	Continuing Operations?	Owner	Expected Level of Effort
SXM OBUs		Yes	WYDOT ITS only	Low (testing TIMs)
Participant Tracker	This application consisted of a website that was meant to be used to track vehicles and participants in the CVP. This website was later abandoned in favor of tracking the information in a spreadsheet. WYDOT will remove the website and all associated databases from its servers.	No	WYDOT	N/A
TIMs		Yes	WYDOT	Medium
TIM Generator	This is the Representational State Transfer (REST) service that interacts with the Data Broker and is responsible for building out and deploying the TIM messages. This also includes the consistency check application and orphaned TIM application that cleans up old / out of date TIMs in the system and, if needed, updates TIMs to stay consistent with what WYDOT is currently reporting.	Yes	WYDOT	Medium
ODE	<p>There are 2 different ODEs deployed in the WYDOT environment now.</p> <ul style="list-style-type: none"> One is used to process incoming CV data and will be useful in cases where an OBU could be used to test scenarios and manually offload and process the log files to a Mongo DB for further analysis. This is still needed to support decoding logs (with manually offloading logs) and for use with follow-on C-V2X project. The second one, responsible for out-going TIMs, is required to encode, build, and send the resulting TIM to the SDX. The other ODE. 	Yes (Both)	WYDOT	Medium
SDX	SDX is a centralized data retention and distribution source for connected and autonomous vehicle (CAV) information. The SDX allows authorized third parties,	Yes	Trihydro	Low

System /App. / Hardware	Overview	Continuing Operations?	Owner	Expected Level of Effort
	like Amazon Alexa and Sirius XM, to use the data. See Section 3.6.2 for more information on planned enhancements.			
Other Backoffice		Yes	WYDOT	Medium
Pikalert	WYDOT will continue to work with the National Center for Atmospheric Research (NCAR) to fine tune and address specific issues associated with Pikalert messages. The team is focusing on adjusting Pikalert messages to align with standard TMC messaging.	Yes	WYDOT & NCAR	Medium
Work Zone System	The application used by the TMC to enter construction information is called ConAdmin, which then shares information with the CV System. See Section 3.6.1 for more information on planned enhancements to the ConAdmin.	Yes	WYDOT	Medium (with updates)
Databases		Yes	WYDOT	Medium
MongoDB	<p>The MongoDB database deployed to the WYDOT servers is used to store all log data for the CV pilot project. This includes all BSMs, TIMs, and weather cloud log files for the pilot. This information that had been collected was most useful for troubleshooting and as a back-up to the data collection required for the SDC.</p> <p>Since this data will be the only data left for the CV Pilot after the SDC is turned off, WYDOT plans to retain and maintain this database going forward. This would also allow the database to remain active in case a next-generation of CV data is available to be integrated. Additionally, the data may be able to be mined for Machine Learning models or other useful transportation insights.</p>	Yes	WYDOT	Medium
SQL Server Database	A Structured Query Language (SQL) Server database was built to manage Traveler Information Messages and maintain a current state for them. WYDOT plans to leave this database in place to support the TIM generation and maintenance going forward. WYDOT will remove references to the RSUs so that the code for pushing TIMs no longer attempts to push TIMs to RSUs.	Yes	WYDOT	Low

3.2 External Dependencies

The continued post pilot operations have external dependences on the Trihydro Situational Data Exchange and Sirius XM satellite delivery of TIMs. Both external groups have agreed to continue operations for the foreseeable future. Neither has any guarantees or contracts for these services. The SCMS is not needed for continued operation of the existing post pilot operations. If C-V2X is used to replace DSRC, then a new SCMS contract will be put into place.

3.3 Governance Framework

WYDOT will maintain sole control and operations of the system with support of contractors who have worked on the CV Pilot (Neaera and Trihydro)

3.4 Financial Resources and Agreements

WYDOT will use Congestion Mitigation/Air Quality funds to maintain the CV infrastructure post-deployment.

3.5 Key Documents

Key documents have been maintained throughout the pilot and updated with USDOT for publishing. No further updates are planned for these documents unless the pilot moves forward with the C-V2X conversion. If this is done, the pilot will provide “light” updates to the key documents for requirements and acquisition.

3.6 Planned / Future Enhancements

With the successful completion of the WYDOT CVP, the team is looking to the future to plan for enhancements. Currently the team is reviewing options for improvements to construction information, continuing to push out more accurate information to the SDX, further integrations with original equipment manufacturers (OEM), updating the DSRC deployment to C-V2X, and new applications. These enhancements are described in the following subsections.

3.6.1. Construction Information

The CV Pilot helped WYDOT identify areas of improvements within its legacy systems. The primary issue with the way WYDOT had been managing work zones was found to be linked to an application that allowed TMC operators to define projects that may be hundreds of miles long or even in some instances just single points along a roadway. The application used by the TMC to enter construction information is called ConAdmin and was previously developed for WYDOT by an outside consultant. Drivers in the CV Pilot began receiving TIM notifications in their vehicles in areas where no road construction was active, magnifying a problem with how work zones were managed. WYDOT recognized the need to improve timeliness and accuracy of construction information since the data was now flowing directly to drivers on the road.

WYDOT's solution here is to work more closely with field crews to improve the accuracy of active work zones and set them as appropriate. As part of this effort WYDOT is also looking to expand its construction information to include a Work Zone Data Exchange (WZDx) feed.

In addition to improving the timeliness and accuracy of reporting construction information previously mentioned, further discussion and cooperation of TIM delivery entered via ConAdmin will be necessary. In order to better understand the timing and sequencing for the desired delivery of construction TIMs, the underlying format of the interface used by ConAdmin to deliver this information to the Connected Vehicle system will need further improvement.

3.6.2 SDX Maintenance and Enhancements

WYDOT plans to continue to use the SDX for distributing Traveler Information Messages to Connected Vehicles via Third Parties. The SDX enhancements that are currently planned include the following:

- **Work Zone Data Exchange (WZDx) Support** – while the SDX currently supports the WZDx message set, WYDOT plans to use the SDX to house and distribute all the WZDx messages for Wyoming work zones. Additionally, the SDX will support advanced querying for WZDx messages.
- **Message Set Conversion** – The SDX is planned to support conversion between the TIM and Road Safety Message (RSM) defined in the forthcoming SAE 2945/4 (RSM) message set as well as the WZDx and TIM message sets. This will allow WYDOT and other agencies to house their data in one location with message set conversion all done in one central location.

With the continued use of the SDX, Wyoming hopes to also promote the SDX as a national solution for disseminating CAV data to third parties.

3.6.3. Potential Integration of WYDOT CV Data with OEMs

The WYDOT team is in contact with OEMs about the use and availability of Connected Vehicle data that may be provided. In particular, discussions with a leading OEM provider have resulted in verifying that they will be supporting the TIM within the next 2-4 years. Specifically, WYDOT has received the current TIM format that they plan to use for messages that they plan to support in the future and plans to support that format for new TIM messages.

WYDOT has also reached out to OEMs and will continue to engage with them on integrating the SDX into their systems so that OEM vehicles may receive TIMs outside of the range for RSUs.

WYDOT will also seek opportunities to incorporate vehicle dynamics from OEMs into TMC operations in an effort to use vehicles and rolling sensors.

3.6.4. Conversion to C-V2X RSUs

WYDOT is watching the FCC rulings to see if C-V2X will become an opportunity to replace DSRC for applications to help with improved mobility and safety. The new infrastructure bill provides for some opportunities to deploy C-V2X in pilot locations that are being considered.

WYDOT is considering a couple of options to deploy C-V2X. The minimal option is to replace the 76 RSUs deployed with only out of the box applications and 10 OBUs for testing in WYDOT Intelligent Transportation Systems (ITS) vehicles. This solution would incorporate SCMS certificates and

broadcasting TIMs. The second option would be far more capable and look more like what is currently running with the CVP. This would include solutions for:

- Wi-Fi to do OTA via RSUs
- Certificate top offs via Wi-Fi with RSUs
- Log offloads via Wi-Fi with RSUs
- Building the Distress Notification application similar to what was done with the DSRC implementation
- Integrating WYDOT CVP standard logging with the OBUs and RSUs, this will match up the log offloading with the ODE decoder
- Satellite distribution of TIMs via SDX
- Dual antennas support for heavy trucks
- Custom TIM display for WYDOT CVP Integrated Taxonomic Information System (ITIS) codes matching current capability with the DSRC implementation for WYDOT
- Smart BSM collections like the ones used for the WYDOT CVP
- TMC Authority (TMCA) signature validation on the RSU strip and re-sign for broadcast with TIMs
- Updates to the RSU monitor
- Outfit 100 WYDOT vehicles

3.6.5 Potential New Applications

Some potential new applications that may result from the pilot include additional functionality for Alexa Skill that may allow users to receive notifications for road closures and road openings. Other applications may be developed for Google and Apple assistants that allow users to integrate with CV messages through their smart devices.

WZDx work zone messaging is another potential new application to further pushout the work zone information that is currently being broadcast with TIMs. The WZDx would be better suited for center-to-center distribution of TIMs. This would also benefit from the efforts to better describe the work zone described in section 3.6.1 above.

3.7 Ongoing Risks

It is difficult to predict what the outcome will be of future FCC and USDOT decisions for spectrum and communication protocol. The WYDOT CVP team would like to see the continued use of the full 75 MHz of the safety spectrum retained for DOT use. It would also be recommended to retain DSRC until C-V2X or other technologies have been thoroughly tested and validated at scale. The current indecision is a risk for all CV deployers.

There is a risk that future funding to support satellite delivery of TIMs does not continue with future administrations.

There is a risk that Sirius XM does not continue to allow the free distribution of TIMs over satellite and WYDOT will need to evaluate the benefit/cost of operating the SDX. It should be noted that General

Motors and other third parties have been in negotiation with the WYDOT CV Pilot to use WYDOT data through the SDX.

No contingency is available to WYDOT at this stage on the previous risks as these are outside of WYDOT's control. Currently, WYDOT is being observant of the field and is looking for alternatives to improve its current system through grant opportunities.

4 References

Table 2 lists the documents, sources and tools used to develop the concepts in this document.

Table 2. References

#	Documents, Sources Referenced
1	Deepak Gopalakrishna, et al. (2015). <i>Connected Vehicle Pilot Deployment Program Phase I, Concept of Operations (ConOps)</i> , ICFWyoming. U.S Department of Transportation.

5 Acronym List

Table 3 provides a list of the acronyms used in this document.

Table 3. Acronym List.

Acronym	Definition
BSM	Basic Safety Messages
C-V2X	Cellular Vehicle to Everything
CAV	Connected and Autonomous Vehicle
CV	Connected Vehicle
CVP	Connected Vehicle Pilot
DSRC	Dedicated short-range communications
FCC	Federal Communications Commission
FCW	Forward Collision Warning
HMI	Human-Machine Interface
HSM	Hardware Security Module
I-80	Interstate 80
ITIS	Integrated Taxonomic Information System
ITS	Intelligent Transportation Systems
M&O	Maintenance and Operations
NCAR	National Center for Atmospheric Research
OBU	Onboard Unit
ODE	Operational Data Environment
OEM	Original Equipment Manufacturers
OTA	Over the Air
RSU	Roadside Unit
SCMS	Security Credential Management System
SDC	Secure Data Commons
SDX	Situational Data Exchange
SQL	Structured Query Language
SXM	Sirius XM
TMC	Transportation Management Center

5. Acronym List

USDOT	U.S. Department of Transportation
V2I	Vehicle to Infrastructure
V2V	Vehicle to Vehicle
WYDOT	Wyoming Department of Transportation
WZDx	Work Zone Data Exchange

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