

Connected Vehicle Pilot Deployment Program Independent Evaluation

Financial and Institutional Assessment— Wyoming

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16. Abstract This report presents the financial and institutional evaluation of the Wyoming Connected Vehicle Pilot Deployment (CVPD) conducted by the Texas A&M Transportation Institute (TTI) CVPD Evaluation Team. The purpose of the financial evaluation was to assess the changes in the financial settings, frameworks, models, elements, and associated impacts from the planned and implemented connected vehicle deployments. The financial evaluation also looked at the likelihood that the Wyoming pilot site would achieve financial sustainability, including identifying the key factors that influence financial sustainability and the key metrics for measuring and evaluating the achievement of financial sustainability, particularly due to changes in the underlying financial and business inputs. The purpose of the institutional evaluation was to assess the organizational changes that stem from the Wyoming CVPD, including the systematic evaluation of the effects of institutional changes in Wyoming to identify potential strategies to minimize institutional risk. The TTI Evaluation Team also worked to identify to what extent the Wyoming CVPD was able to address identified institutional risks.					
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Chapter 1. Introduction

This report provides the results of the financial and institutional evaluations of the Wyoming Connected Vehicle Pilot Deployment (CVPD). The financial evaluation assessed the changes, if any, in the financial settings, frameworks, models, elements, and associated impacts from the planned and implemented CV deployments. The financial evaluation also looked at the likelihood that the Wyoming CVPD achieved financial sustainability, including identifying the key factors that influence financial sustainability and identifying key metrics for assessing the potential for financial sustainability, particularly due to changes in the underlying financial and business inputs. The institutional evaluation assessed the organizational changes that stem from the Wyoming CVPD, including the systematic evaluation of the effects of institutional changes in Wyoming to identify potential strategies to minimize institutional risk.

Summary of the Wyoming Connected Vehicle Pilot Deployment

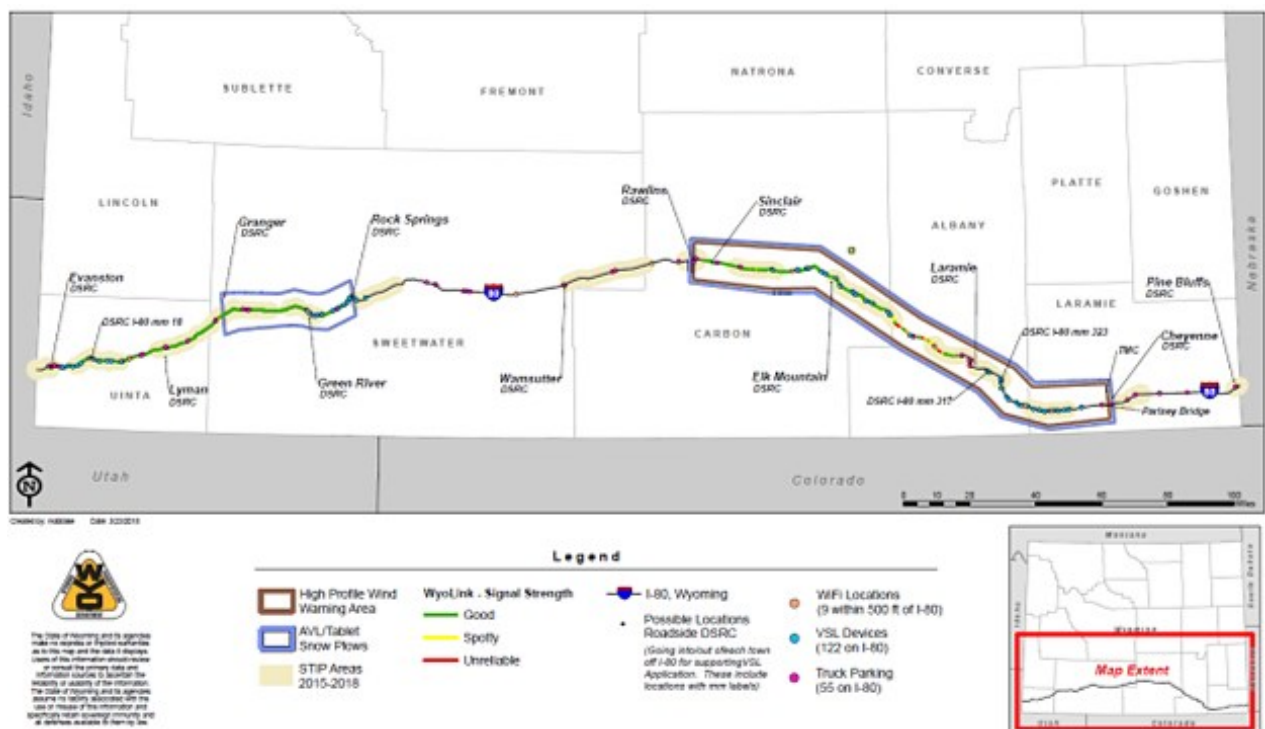
The goal of the Wyoming CVPD was to improve driver safety, particularly for commercial vehicle operators along I-80.⁽¹⁾ I-80, which runs the entire length of the southern edge of the state, is susceptible to multivehicle collisions and roadway closures during winter weather due to icy roads and low visibility from blizzard conditions. These events can result in fatalities, extended closures, and significant economic loss. The Wyoming CVPD included a variety of applications to support a range of existing and new services, including traveler information, roadside alerts, and dynamic travel guidance for freight and passenger travel. These applications included the following:⁽¹⁾

- **Forward Collision Warning (FCW)**—Using vehicle-to-vehicle communications, this application issues warning to drivers if another connected vehicle (CV) ahead is going in the same travel lane and direction. This application helps drivers avoid front-to-rear vehicle collisions by detecting when other vehicles stop or move slowly ahead of the vehicle.
- **Stationary Vehicle Alert (SVA)**—This application is a version of FCW in which the downstream vehicle is parked on the side of the road or an adjacent lane along I-80. SVA notifies the driver of this situation and helps avoid or mitigate a potential collision with this vehicle.
- **Infrastructure-to-Vehicle (I2V) Situational Awareness**—This application allows CVs to receive information about downstream conditions that may affect their travel. This application provides drivers with information about downstream road conditions, weather alerts, speed restrictions, vehicle restrictions, incidents, parking, and road closures.
- **Work Zone Warning (WZW)**—This application extends the I2V Situational Awareness application to provide information to vehicles approaching work zones. The approaching CV receives information about work zone conditions, including obstructions within the travel lane, lane closures, lane shifts, speed reductions, and vehicles entering and exiting work zones.

- **Spot Weather Impact Warning (SWIW)**—This application broadcasts localized road condition information to drivers. The purpose of this application is to alert drivers of fog and icy roads that may exist only at isolated locations along I-80.

Another application— **Distress Notification**—was also operational in the corridor. This application involved the driver activating an alert on their vehicle if it became disabled or involved in a collision in the corridor. The system worked only with the DSRC technology (and not the satellite technology). While the application was active in the corridor, no events involving an equipped vehicle occurred during the deployment period.

To support this pilot, the Wyoming Department of Transportation (WYDOT) deployed 75 roadside units (RSUs) in various sections of I-80 that can receive and broadcast messages using dedicated short-range communication (DSRC). WYDOT installed these RSUs at locations upstream of identified hotspot areas. Through its collaboration partners, WYDOT also equipped 400 vehicles that regularly use I-80 with onboard equipment designed to provide CV information and to receive alerts and advisories issued by WYDOT. A portion of the equipped vehicles have additional capabilities to collect and transmit environmental and road weather conditions through mobile weather sensors.⁽¹⁾ Figure 1 shows the deployment corridor.



Source: Wyoming Department of Transportation, 2018

Figure 1. Map of the Wyoming CVPD Deployment Area ⁽²⁾

Having better quality, quantity, and timeliness of road condition information allows TMCs operators to better manage traffic management assets by:

- Increasing the accuracy and quality of road condition information that TMC operators could use to adjust VSL and other traffic management assets in response to changing weather conditions.
- Expanding the coverage in the network where information is available to make real-time adjustments to traffic management strategies.
- Reducing the time lag between status updates on travel conditions on the roadway network.
- Increasing the frequency of updates to DMS and other traveler information system messaging to reflect evolving travel conditions during significant weather events.
- Sending targeted weather alert messages to vehicle entering specific segments of the deployment corridor.
- Directing maintenance resources to locations requiring attention.
- Enhancing the credibility of WYDOT's weather-related messaging by ensuring that messaging reflects the conditions observed by drivers.

Organization of Report

The Texas A&M Transportation Institute (TTI) CVPD Evaluation Team has organized this report into the following chapters:

- **Chapter 2. Financial Factors**—This chapter identifies the factors that had the potential to influence the financial outcomes of the pilot deployment and documents the assessment of the financial factors for the Wyoming CVPD.
- **Chapter 3. Institutional Factors**—This chapter provides an overview of the information and data provided by the Wyoming Pilot Site to conduct the financial evaluation, as well as how the TTI CVPD Evaluation Team collected them. This chapter also describes the process that the TTI CVPD Evaluation Team used to perform the financial evaluation and reports the overall results of that analysis.
- **Chapter 4. Recommendations on the Sustainability of WYDOT's and Similar Deployments**—This chapter provides summary of some of the recommendations and suggestions for sites may want to consider for sustaining a deployment like that of the Wyoming CVPD.

Chapter 2. Financial Factors

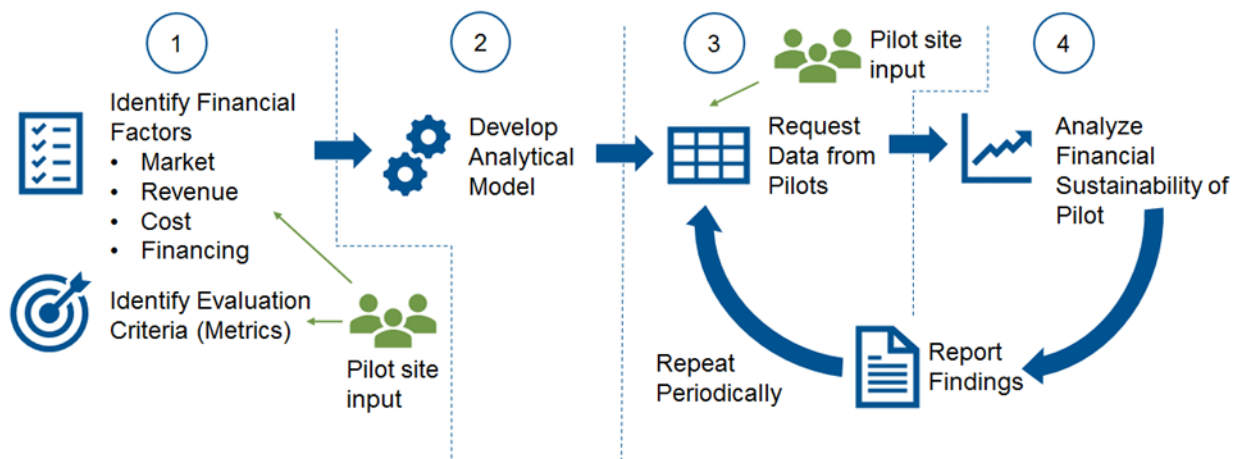
The financial evaluation gathered information to assess whether the Wyoming CVPD achieved financial sustainability based on the planned and implemented deployments. The objectives of this evaluation were to:

- Develop a framework for evaluating the likelihood that the pilot site achieves financial sustainability, including identifying the key factors that impact financial sustainability and identifying key metrics for measuring and evaluating the achievement of financial sustainability.
- Determine the condition at the pilot site for each financial factor identified.
- Evaluate the likelihood of the pilot site achieving financial sustainability based on the site's financial and business projections. Periodically reevaluate the likelihood of the pilot site achieving or maintaining financial sustainability due to changes in the underlying financial and business inputs.

For the purposes of these objectives, the TTI CVPD Evaluation Team defined *financial sustainability* as the deployment agency having resources sufficient to operate and maintain the CV applications over a seven-year period without additional CV Federal grant money after the pilot deployment program ends at the site.

Originally, the TTI CVPD Evaluation Team was tasked with applying quantitative and qualitative evaluation methodologies to conduct before and after performance assessments; conduct cost-benefit assessments of the demonstration; assess user acceptance/citizen satisfaction of the demonstration; document lessons learned, challenges, and approaches for mitigating, addressing, and/or overcoming them; estimate total impacts, costs, and return on investment of the demonstration; and assess how well the initiative in Wyoming managed to bring to the table and use institutional partners.

The TTI CVPD Evaluation Team originally proposed as part of the financial and institutional evaluation plan to use a four-step process to meet the objectives of this task.⁽³⁾ Figure 2 illustrates the four-step process that the TTI CVPD Evaluation Team intended to use to perform the financial analysis. Because of deployment delays and the COVID-19 pandemic, TTI's evaluation transitioned from the intended quantitative analysis to a qualitative analysis supported by financial-related data and qualitative information related to funding and finance as collected by the Wyoming deployment team and the evaluation team. Therefore, other CV systems in the future can apply TTI's qualitative analysis on the financial data along with the lessons learned in deployments and operations of other CV systems in the future.



Source: Texas A&M Transportation Institute, 2018

Figure 2. Diagram. Originally Planned Four-Step Process for Achieving Project Objectives

Because of the limited availability of financial information from the site, the TTI CVPD Evaluation Team was unable to perform any quantitative financial analysis or modeling associated with the Wyoming deployment. However, as part of the interview process, the TTI Evaluation Team asked key stakeholders to provide insight into the financial factors impacting the long-term sustainability of the deployment.⁽⁴⁾ The TTI CVPD Team conducted three sets of interviews:

- Pre-deployment (January–February 2019).
- Near-term post-deployment (November–December 2019).
- Long-term post-deployment (March 2022).

The target stakeholders for the interviews were deployment managers, deployment team members, operating agencies, and policy makers. The stakeholder evaluation plan outlined that TTI would interview the deployment managers at three points in time, deployment team members at two points in time, operating agencies at two points in time, and policy makers at two points in time. TTI accomplished this plan except for policy makers. Table 1 shows the number of stakeholder interviews conducted at each stage of the deployment evaluation. The Wyoming CVPD manager identified the individuals with each stakeholder that TTI interviewed. The selected individuals were from target stakeholder entities that were especially knowledgeable about the CVPD or had history with it.

Table 1. Numbers of Wyoming CVPD Stakeholder Interviews by Type and Timepoint

Stakeholder Type	Pre-deployment	Near-Term Post-deployment	Long-Term Post-deployment
Deployment managers	2	2	2
Deployment teams	6	5	1
Operating agencies	6	Not applicable according to plan	1
Fleet operators	Not applicable according to plan	Not applicable according to plan	1
Policy maker	1	Not applicable according to plan	0
Total interviews	15	7	5

Source: Texas A&M Transportation Institute, 2022

Financial Challenges and Issues

As the deployment progressed, the Wyoming CVPD Team reported encountering several unexpected obstacles that potentially impacted the long-term financial stability of the deployment. TTI asked several critical key stakeholders to highlight some of the greatest factors impacting the financial stability of the deployment. This section summarizes these responses. The customers for the WYDOT deployment were commercial truck fleets. If the pilot demonstrated a benefit for them, then WYDOT would have a case to make a long-term commitment beyond the grant-funded pilot. Even with the technical challenges experienced by users of the system, the Wyoming CVPD Team was able to demonstrate value in terms of improved safety for commercial vehicle drivers on I-80. The consensus among the stakeholders was that the deployment attained all its performance goals. At the end of the deployment, the Wyoming CVPD Team was satisfied with the outcome and felt a sense of accomplishment in being able to get the CV system operational so that better information could be disseminated quicker to the drivers on I-80.

The lack of field-hardened technology overly burdened the pilot and prompted some stakeholders to question its long-term financial sustainability. The Wyoming CVPD Team indicated they required additional financial resources to address the significant amount of time required to deploy, troubleshoot, test, and update prototypes.

Thus, many stakeholders raised the issue of how to attain financial sustainability beyond the grant-funded pilot, particularly with respect to how it would be funded and who would fund it, even though the U.S. Department of Transportation (USDOT) communicated that post-pilot funding would be the responsibility of the site. Stakeholders indicated that much of the potential for future funding relied on the pilot demonstrating benefits. If WYDOT demonstrated the pilot to be successful, WYDOT would commit to future funding to maintain and expand the system. The sentiment of success was not overpowering but did exist. However, a true expansion of the system would depend on private-sector adoption (installation of equipment in vehicles) because that piece of the pilot proved exceedingly challenging for the Wyoming CVPD Team.

Most stakeholders indicated that they were either not aware of a business planning process for the CV pilot or that they were only aware of a business plan for the pilot and nothing beyond that point. One

stakeholder indicated that WYDOT's goal focused on proving the efficacy and value of the system and that pre-deployment WYDOT was not interested in making assumptions regarding long-term business decisions. If the system proved to be beneficial to road users, WYDOT would follow the same process it currently does to add CV technology to its existing intelligent transportation systems program.

With respect to projections for future market participation, costs, and potential revenue associated with the CV pilot, the stakeholders indicated that there had been some "back of the envelope" estimates but that there is no revenue associated with the pilot. The sole focus during the pilot was to determine the long-term benefit and value of the system to commercial vehicle operators, which would determine future market participation. Another stakeholder indicated that the future depends on many external factors and determining market participation also requires major assumptions with respect to revenue and market desires.

When asked about the experience with activation of the CV applications, one stakeholder indicated that the amount of development and testing required to implement the technology required for the pilot has "dulled [WYDOT's] desire" to expand the system through installation of RSUs. Since the technology is not "plug and play enough" and "keeping the technology operational is a lot harder than anticipated," stakeholders need to identify a more robust financial arrangement that considers the significant amount of time required to troubleshoot, test, etc. A stakeholder noted that issues with the vendors responsible for developing the technology caused WYDOT to expend funds beyond what was originally budgeted. The deployment manager suggested that any entity considering implementing something similar "should estimate what they think it's going to take in terms of testing and troubleshooting and then double it."

There was also the concern that WYDOT, as a first deployer of this technology, would be stuck with outdated technology and would not be in a financial position to implement the next generation when the next generation becomes available. The stakeholder explained that the newer generations of CV technology will be easier/less resource intensive for maintenance, deployment, etc., and in their experience, it takes three generations of the technology before you get truly field-hardened technology.

One stakeholder indicated that they have proved that they can deploy and manage vehicle-to-everything (V2X) applications. When transportation agencies are dealing with prototype technology, the resources needed to deploy, test, and update prototypes will be greater than what any agency is capable of affording. However, this stakeholder was clear in their belief that once the technology is field hardened, V2X systems will be financially sustainable for transportation agencies.

Costs to the fleet partner were also higher than anticipated. The fleet mechanic's level of knowledge regarding equipment installation was not sufficient, so a contractor provided support. Additionally, after an initial trial period, the satellite vendor required the fleet partners to pay for in-vehicle satellite services. Some fleet partners believe that this investment was worthwhile because it gives their drivers more information to make better decisions.

Perceived Future Financial Challenges

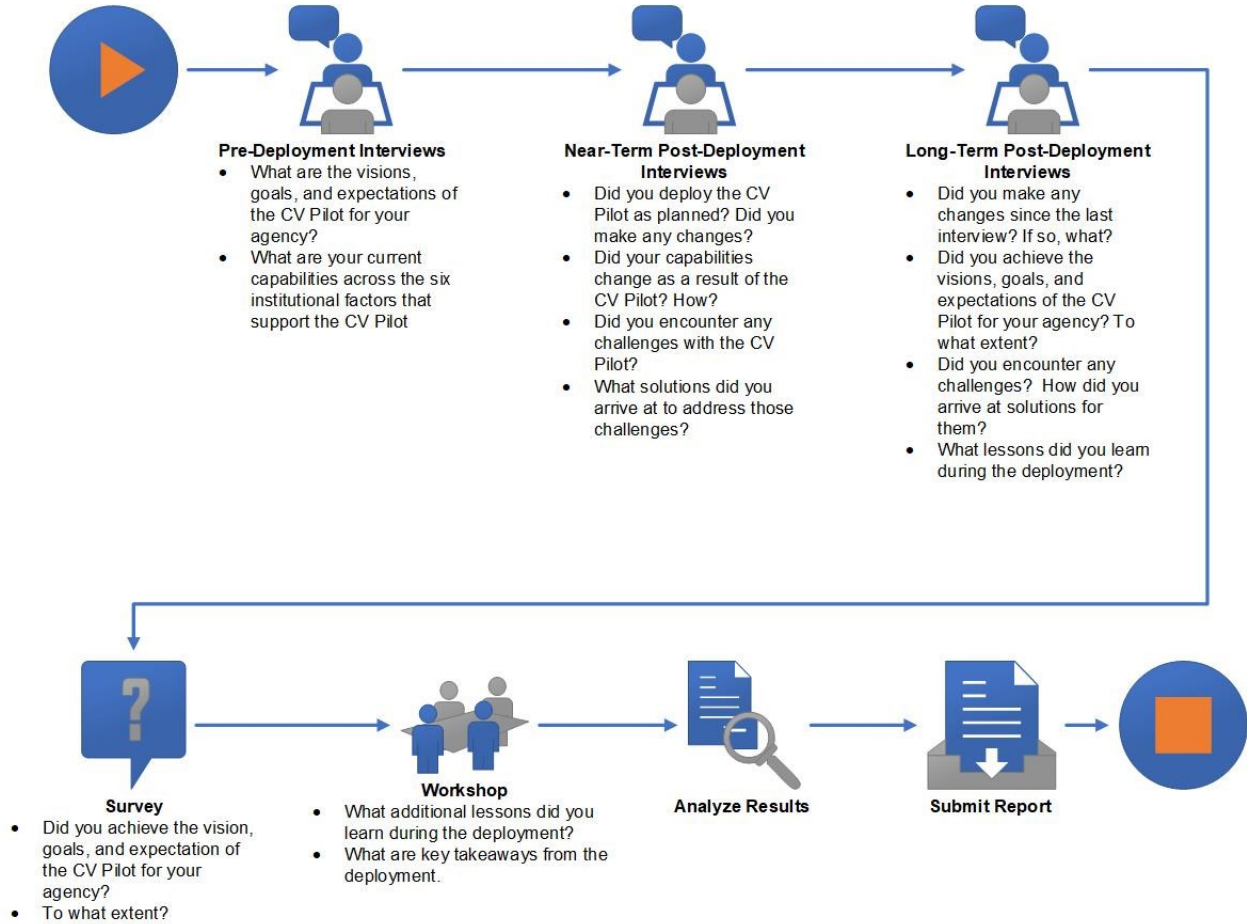
The WYDOT pilot budget increased due to unforeseen challenges, such as RSU maintenance, equipment not being rugged enough for snowplows, and additional time spent on the commercial vehicle antenna system. WYDOT is currently disseminating traveler information statewide. WYDOT plans to incorporate these deployment-related costs into existing budgets to cover these ongoing operational costs.

Because of the FCC's decision to transition to cellular V2X, WYDOT is facing a whole new set of issues to work through and work out. WYDOT is going from a "fairly tried and true" technology in terms of the

pilot to cellular V2X that is a “very new and very unproven technology.” For instance, the Wyoming team successfully tested and demonstrated that over-the-air updates can work in a DSRC environment. The Team is unsure if and how over-the-air updates can be achieved using cellular V2X. The Wyoming CVPD Team felt DSRC was beneficial. They warned others that, moving into cellular V2X, other issues will emerge that will be dramatically different from what this team was able to do with the Wyoming pilot.

Chapter 3. Institutional Factors

As illustrated in Figure 3, the TTI CVPD Evaluation Team broke down the institutional evaluation into a series of activities throughout the deployment period to extract critical information related to the institutional impact the deployments had in each region.⁽⁵⁾ The overall intent was to establish a baseline or starting point for the agency prior to deployment, to identify the vision anticipated by the agency after deployment, to assess the extent to which the agency achieved that vision, to learn how the agency’s capabilities and readiness changed as a result of the deployment, and to document lessons learned throughout the entire deployment.



Source: Texas A&M Transportation Institute, 2022

Figure 3. Diagram. Institutional Assessment Framework

The Wyoming CVPD stakeholders confirmed that projects like this can generate a lot of initial optimism. However, they advised not letting the optimism affect the creation of realistic budgets and schedules. The agency needs to ensure what it is proposing is doable. The agency should have multiple people review the scope, budget, and schedule through the lens of risk assessment.

Additionally, the stakeholders stressed that the focus in these deployments should be on something not offered by the original equipment manufacturers (OEMs). The stakeholders suggested that strong leadership at the Federal level will be necessary to generate the type of confidence needed to attract OEMs, which is vital to the long-term success of similar CV projects.

Institutional Challenges

Stakeholders explained that the companies that produced the CV hardware did not adequately test and quality-check the equipment. One likely reason for this was the fact that the market is not large enough to support the finances that are required to conduct adequate testing of this equipment before it is sold. Interviewees indicated that WYDOT was essentially receiving prototypes, as opposed to road-hardened technology.

WYDOT had to coordinate with the State of Wyoming's centralized information technology department (not part of WYDOT), and this caused issues in being able to quickly work through networking issues because this department was not as responsive as WYDOT would have preferred. The most often-mentioned example was that WYDOT's network was configured for IPv4, and the CV system required IPv6. The existence of incompatible networks led to a time-consuming interagency process to address this issue. Limited staff and limited time to accomplish all tasks were also a challenge because WYDOT did not hire any additional staff for the pilot. Adapting to new business processes (e.g., the priority of maintaining a CV system) was also identified as a challenge.

The lack of road-hardened technology available at the beginning of the pilot exacerbated the project's confined timeline and impacted the project schedule because numerous issues with the technology had to be worked through during the planning stage. WYDOT was not prepared for the level of concept-of-operations documentation detail required by USDOT. Stakeholders reported that the process was onerous and resulted in more staff time spent than anticipated. WYDOT planned the CVPD with its existing traffic management center (TMC) staffing footprint and TMC staff workload in mind.

Additionally, one stakeholder remarked that it was surprising how many WYDOT departments became involved (more than expected), such as geographic information systems, public outreach, telecommunications, fabrication, etc. The various departments worked well together even though there was no official training for people working on the pilot (i.e., they learned as they went). However, there was training for the users of the installed equipment (i.e., training the Institutional Review Board required). With respect to workforce development, the unanimous agreement was that CV responsibilities would be integrated into existing operational units and job descriptions. WYDOT did not hire new personnel specifically for CV-related responsibilities.

Culture

All stakeholders confirmed that their respective organizations supported the pilot and that the pilot benefitted from this support. One significant example of this was that the rollout of the system took significantly longer than planned due to issues with the technology not being ready for actual use.

WYDOT team members worked together to overcome the technical challenges. Because so many distinct parts of WYDOT and the CVPD Team were impacted by this downstream, all organizations had to be flexible to deal with these delays, problems with technology, etc. to see the pilot succeed. All partners had to be supportive and flexible to find troubleshooting solutions.

Collaboration

Most stakeholders agreed that at the end of the day, consensus exists among the various stakeholders, even though some stakeholders had to be reminded of the team's goals. One stakeholder suggested that even though everyone participated for their own reasons (e.g., WYDOT for public good and private companies for potential profit), this did not result in lack of consensus regarding the overarching goal of the pilot.

Stakeholders indicated that the primary mechanisms for collaboration were bi-weekly stakeholder meetings and phone calls to keep all team members informed regarding the progress of the pilot. While trucking partners were an important stakeholder, the Wyoming CVPD Team did not engage them often in the initial planning and programming phase of the deployment to limit the time lag before the technology was installed in their fleet.

Several interviewees mentioned that stakeholders had the opportunity to participate in meetings and provided input on the decisions made during the design of the CV system. One stakeholder indicated that the development, design, and implementation of the CV system was iterative, and input from internal and external partners and stakeholders was considered to make decisions as issues arose. For example, once it was noticed that the antennas on the snowplows vibrated so much that the antennas punched holes in the roofs of the trucks, the CVPD team worked with the snowplow maintenance team to figure out how best to place the antennas.

A stakeholder stated the decision-making process was "top-down," with USDOT making decisions about if or when to move forward, while WYDOT made decisions regarding how to move forward. For example, when it became apparent that a business process change would be needed (e.g., what data should be pushed to the TMC), WYDOT handled the decisions about what should be implemented and when to implement it.

Unforeseen Issues

Unforeseen issues included procurement policies, staff availability, and technology immaturity:

- One stakeholder indicated that a future deployment would need to streamline its procurement of equipment and technology because the procurement process for some of the vendors was challenging and time-consuming.
- Another stakeholder explained that delays led to competing priorities regarding internal staff availability (i.e., staff were not always available when the pilot was finally ready). Stakeholders need to increase communication and make staff availability more flexible to keep the deployment on track.
- Two stakeholders discussed the challenges with the team members who were responsible for developing the onboard units (OBUs). One noted that a lesson learned is that testing of equipment before procurement is critical. One stakeholder dissented from this being an

unforeseen issue, explaining that the technology and especially the OBUs were prototype equipment. But according to this stakeholder, this was not an unforeseen challenge because they were vocal at the beginning of the pilot about the risks presented by the technology manufacturers.

Other Challenges

It was the consensus of the stakeholders that the National Highway Traffic Safety Administration did not provide as strong a leadership role in advance vehicle technology requirements as anticipated. The Wyoming CVPD had expected NHTSA to provide rulemaking requiring the use of DSRC technologies in private automobiles to promote the widespread deployment of safety applications. This did not occur. Furthermore, the Federal Communications Commission ruling on the reallocation of the DSRC bandwidth was extremely impactful on the timing of the deployment and changed the marketplace for CV equipment providers. The departure of an RSU provider due to its perception of market collapse also created challenges. Because the Wyoming CVPD Team elected not to build its deployment using a single OBU provider, it was able to continue with the other vendor without much modification to the architecture.

With respect to roadside infrastructure (RSUs), stakeholders advised that it is important to ensure that coverage of the target highway system is adequate and that the RSUs have adequate connectivity. The RSUs deployed in the Wyoming CVPD required frequent maintenance and this was time intensive because it required a lot of drive time. The RSUs did not have a stable platform, and the RSU provider's code had numerous errors. In the future, agencies should make sure that contracts include software development and ensure there is adequate staff to maintain it.

With respect to the weather sensing technologies, the equipment was not rugged enough for snowplows. Most of the sensors lasted only days. Operators of deployed snowplows ended up with a low opinion of the technology. Once lost, trust and confidence in the system are difficult to regain.

Specific comments about the OBUs included the following:

- Plans were appropriate, but WYDOT assumed the technology was mature, which it was not. WYDOT stated that it should have incorporated more resources for testing of equipment under real-world conditions and not rely only on lab test results.
- Fleet partners (trucking companies) experienced a number of issues with the OBU hardware. Screens would go black if the drivers keyed the microphone on the CB radio. Partners also had issues with system volume and antenna placement.
- Fleet partners were interested in information being entered into the traveler information system more quickly. Some drivers encountered incidents or experienced route closures without notification or with late notification. Such issues decreased the confidence that the drivers had in the system, especially with older drivers.

Chapter 4. Recommendations on the Sustainability of WYDOT's and Similar Deployments

The Wyoming CVPD, as well as future CV deployments, may benefit from additional engagement—from top to bottom—from the experiences and lessons learned from USDOT. The Wyoming CVPD noted that the shortcomings of the OBU manufacturer were (understandably) the responsibility of the pilot deployment team.

The following provides a few recommendations for sustaining the WYDOT's and similar deployments:

- Continue to concentrate on one or two applications that build on successful existing programs, systems, and services already in place. For WYDOT, this includes its entire weather monitoring and reporting systems.
- Work with maintenance section leaders and fleet managers to develop a procurement specification for ruggedized weather reporting systems for use on maintenance vehicles. This would expand a jurisdiction's capabilities to obtain timely information about road weather conditions on other parts of its roadway network outside the deployment area.
- Continue to partner with local and regional fleet operators and other stakeholders that value and have a need for the type of road weather condition reports provided by the deployment. Also look to other market sectors, such as private information service providers, to incorporate alerts and warnings into their systems.
- Considering the FCC's ruling to reallocate the lower portion of the DSRC spectrum to other users, continue to explore the conversion of the deployed RSUs from DSRC to cellular V2X. From a national perspective, this conversion can serve as a demonstration to agencies and can help generate new markets for the technology.
- Approach logistic and truck fleet management software providers about integrating traveler information messages directly in their in-cab software systems.
- Work with the Society of Automotive Engineers to develop best practices documentation based on the findings and lessons learned through the deployment.

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