Connected Vehicle Pilot Deployment Program Independent Evaluation:

Comprehensive Evaluation Plan—Wyoming

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16. Abstract

This report summarizes the analyses plans that the Texas A&M Transportation Institute (TTI), in its role as the Independent Evaluator, will use to assess the mobility, environmental, and public agency efficiency (MEP) impacts of the Wyoming Connected Vehicle Pilot Deployment. This document summarizes the plans for:

- Assessing the MEP benefits associated with the Wyoming CV Pilot Deployment.
- Assessing the stakeholder acceptance and satisfaction with the deployment
- Conducting stakeholder surveys and interviews.
- Managing the data to be used by the TTI CVPD Evaluation Team plans to use to conduct the MEP analysis.
- Using modeling, and simulation evaluation to assess mobility-related.
- Providing outreach plan to disseminate the evaluation results to various stakeholders and audiences.

This report also provides a detailed cost estimate for completing the planned evaluation. Key risks and uncertainties that may impact the evaluation effort are identified.

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Chapter 1. Introduction

Surface transportation travel in the United States is on the verge of unprecedented transformation. As a society, we are searching for new and innovative ways to provide transportation services to traditionally underserved groups, such as our aging population, travelers with disabilities, and veterans. Furthermore, millennials are increasingly shying away from ownership of personal vehicles, which is generating increased demand for safe, efficient, reliable, and cost-effective shared mobility services. Meanwhile, roadway networks are experiencing increasing levels of congestion that in 2014 resulted in 6.9 billion hours of extra time spent in traffic and 3.1 billion gallons of wasted fuel, both of which equate to $160 billion in costs to travelers.

Despite these evolving challenges, advances in electronic and wireless technologies along with automated vehicle and connected vehicle (CV) technologies provide a significant opportunity to realize improved travel safety and mobility nationally. The United States Department of Transportation (USDOT) recognizes the magnitude of these rapidly evolving market trends, emerging technological advances, and their potential to transform the way we travel in the years to come. To facilitate the emergence and adoption of transformative approaches to travel, USDOT is funding a range of deployment activities to demonstrate the significant safety and mobility benefits that can be achieved with their implementation. The Connected Vehicle Pilots Deployment (CVPD) Program seeks to spur innovation among early adopters of CV application concepts. Using best available and emerging technologies, the pilot deployments are integrating CV research concepts into practical and effective elements, enhancing existing operational capabilities. The program includes pilot deployments in southern Wyoming—led by the Wyoming Department of Transportation (WYDOT); New York City—led by the New York City Department of Transportation; and Tampa, Florida—led by the Tampa Hillsborough Expressway Authority.

These deployment activities mark a significant point of transformation in that they encompass a philosophical shift in the way we view transportation improvements. These deployments are intended to enhance the mobility, environmental, and public agency (MEP) impacts of transportation. The improvements expected to emerge from these programs will strive to provide all Americans with safe, reliable, and affordable connections to employment, education, healthcare, and other essential services. As a result, these deployments will undoubtedly impact how public and private entities alike develop, implement, and maintain transportation services.

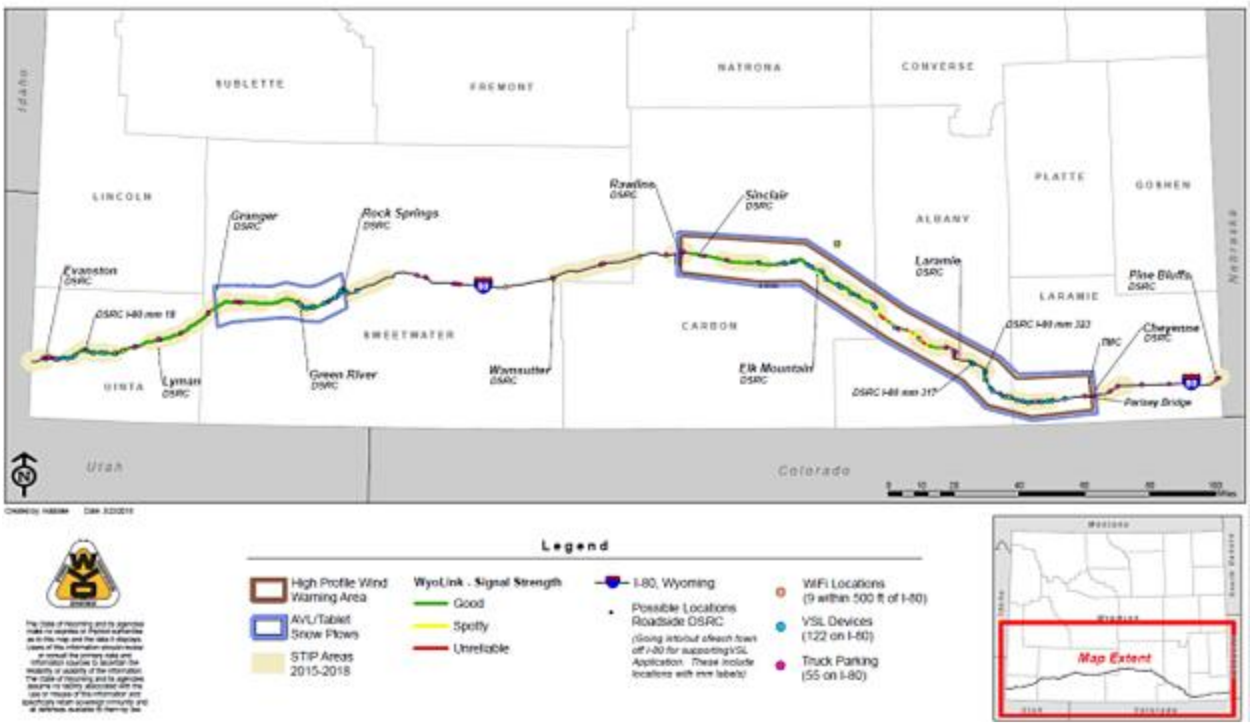
The objectives of the CVPD independent evaluation are to a) perform a comprehensive, independent assessment of the MEP impacts and b) document the stakeholder acceptance and technical, institutional, and financial lessons learned at the three CV Pilot Deployment sites. This evaluation is being performed independently of the sites, each of which is performing its own assessment of its deployment. The Texas A&M Transportation Institute (TTI) CVPD Evaluation Team will use performance data collected by the sites and analysis, modeling, and simulation to provide a quantitative assessment of the mobility and environmental impacts associated with each deployment. The TTI team will also be conducting interviews, surveys, and a workshop to capture the stakeholder acceptance and the financial and institutional implications of the deployments. The stakeholder acceptance and financial and institutional evaluations falls under Task Area C of the CVPD evaluation contract. The Volpe National Transportation Systems Center (Volpe Center) is responsible for conducting the assessment of the safety impacts associated with the deployments. The purpose of this comprehensive evaluation plan is to summarize the overarching plans that the TTI CVPD Evaluation Team will use to complete the assessment of the MEP impacts of the Wyoming CVPD evaluation and to disseminate the findings and lessons learned from the independent evaluation.

Wyoming CV Pilot Deployment Overview

The goal of the Wyoming CVPD is to improve driver safety, particularly for commercial vehicle operators, on 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. The corridor also experiences extreme wind gusts that can cause trucks and other high-profile vehicles to blow over. These events can result in fatalities, extended closures, and significant economic loss. The Wyoming CVPD includes various 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 include the following (*1*):

- Forward Collision Warning—Using vehicle-to-vehicle communications, this application alerts drivers if a rear-end crash is imminent with a CV ahead.
- Infrastructure-to-vehicle (I2V) Situational Awareness—This application allows CVs to receive information about downstream conditions that may impact their travel. This application would provide drivers with information about downstream road conditions, weather alerts, speed restrictions, vehicle restrictions, incidents, parking, and road closures.
- Work Zone Warning—This application extends the I2V Situational Awareness application to provide information to vehicles approaching work zones. The approaching CV will receive information about work zone conditions, including obstructions in the travel lane, lane closures, lane shifts, speed reductions, and vehicles entering and exiting work zones.
- Spot Weather Impact Warning—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 on I-80.
- Distress Notification—This application enables CVs to communicate a distress message if the vehicle's sensors detect an event that might require assistance from others or if the driver initiates a distress request.

To support this pilot, WYDOT is deploying 75 roadside units (RSUs) in various sections of I-80 that can receive and broadcast messages using dedicated short-range communications. WYDOT will install these RSUs at locations upstream of identified hotspot areas. Through its collaboration partners, WYDOT will also equip 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 will have additional capabilities to collect and transmit environmental and road weather condition information through mobile weather sensors (*1*). Figure 1 shows the deployment corridor.



Source: CVPD: WYDOT Pilot. Website (*2*)

Figure 1. Wyoming CVPD Deployment Area.

The overall vision of the Wyoming CVPD is to address the safety needs of commercial vehicle operators in the State of Wyoming, as summarized below from the Wyoming CVPD Concept of Operations document (*3*):

- Reduce the number of truck blow-over incidents and adverse weather-related incidents (including secondary incidents) on the I-80 corridor to improve safety and reduce incident-related delays.
- Improve emergency management on the I-80 corridor through early identification of conditions and improved messaging and communication.
- Improve freight drivers' ability to locate truck parking along the corridor. This objective is safety related since it allows drivers to find safer parking locations in designated areas and to meet hours-of-service regulatory requirements.
- Improve freight traveler information on construction activities in the corridor. This 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.

Organization of Report

This report is divided into the following nine chapters. The titles of each chapter and the major topics covered are highlighted below:

- **Chapter 1. Introduction**. The first chapter provides an overview of the CV Pilot Deployment initiative and a quick guide to the topics covered in the individual chapters.
- **Chapter 2. Refined Mobility, Environmental, and Public Agency Efficiency Evaluation Plan**. This chapter summarizes the approaches and data that the TTI CVPD Evaluation Team plans to use to assess the MEP benefits associated with the Wyoming CVPD. This chapter also describes the process the TTI team plans to use to conduct the benefit-cost analysis.
- **Chapter 3. Stakeholder Acceptance/Satisfaction Evaluation**. The chapter describes the stakeholder evaluation planned to assess whether the CV pilot deployments achieved the vision, goals, and desired MEP impacts.
- **Chapter 4. Survey/Interview Guides**. This chapter highlights the techniques and processes that the TTI CVPD Evaluation Team plans to use to conduct stakeholder surveys and interviews.
- **Chapter 5. Evaluation Data and Data Management.** This chapter summarizes the sources of data that the TTI CVPD Evaluation Team plans to use to conduct the MEP analysis. This chapter also highlights key data management processes that the TTI team plans to implement.
- **Chapter 6. Analysis, Modeling, and Simulation Evaluation**. This chapter describes the analysis, modeling, and simulation evaluation to assess mobility-related performance because of the deployment.
- **Chapter 7. Outreach**. This chapter overviews the evaluation outreach plan designed to disseminate the evaluation results to various stakeholders and audiences.
- **Chapter 8. Detailed Evaluation Cost Estimate**. This chapter overviews the estimated cost to complete the independent evaluation of the Wyoming deployment.
- **Chapter 9**. **Risks and Uncertainties**. This chapter discusses key risks and uncertainties that may impact the evaluation effort.

Chapter 2. Refined Mobility, Environmental, and Public Agency Efficiency Evaluation Plan

This chapter summarizes the approach the TTI CVPD Evaluation Team plans to use to quantify and assess the MEP impacts of the Wyoming CVPD. A comprehensive description of the approaches and methods to be used by the TTI team in conducting the MEP impact assessment can be found in the *Connected Vehicle Pilot Deployment Independent Evaluation: Mobility, Environmental and Public Agency Efficiency (MEP) Refined Evaluation Plan—Wyoming* (*3*).

The goals of the TTI CVPD Evaluation Team are to answer the following evaluation questions:

- To what extent did the CVPD improve mobility, air quality, and public agency efficiency in the study area?
- What are the projected mobility and air quality benefits expected over the next 7 years in the study area for future traffic and different market penetration rates of CVs and RSUs?

While the TTI CVPD Evaluation Team will be estimating the mobility impacts of reducing vehicle crashes, the TTI team is **not** responsible for assessing the extent to which the deployment reduced vehicle crashes. The Volpe Institute is responsible for assessing the safety benefits associated with the Wyoming CVPD. The TTI team will include results of the safety benefit analysis in the benefit-cost assessment.

Table 1 shows the performance measures, data sources, and analysis type that the TTI CVPD Evaluation Team plans to use to assess the evaluation hypotheses.

Table 1. Performance Measures and Data Sources for Independent Evaluation of Wyoming CVPD.

ID	Evaluation Hypothesis	Performance Measure	Data Sources	Analysis Type
1.	The pilot deployment will improve mobility for both equipped and non-equipped vehicles in the deployment corridor during inclement weather events.	• Change in average travel time • Change in average delay • Change in average speed • Change in vehicle throughput • Change in temporal extent of congestion • Change in the spatial extent of congestion	• WYDOT Radar-based Speed Sensors • Basic Safety Message (BSM) Part 1 • National Performance Management Research Data Set (NPMRDS) • WYDOT Road Weather Information System (RWIS) station	• Before/after using observed data
2.	By reducing the number of trucks that are stranded, must backtrack, or otherwise waste time and fuel resulting from road closures or a lack of appropriate parking availability, the pilot deployment will result in improved travel reliability for vehicles equipped with CV technologies in the corridor.	• Change in 95th percentile Travel Time • Change in Buffer Time • Change in proportion of equipped trucks traveling at or above speed limit • Change in number of rapid deceleration of trucks during inclement weather events • Change in proportion of vehicles traveling 5 mph at or above the work zone speed limit	• WYDOT radar-based speed sensors • BSM Part 1 • NPMRDS • WYDOT RWIS station	• Before/after using observed data
3.	The pilot deployment will reduce negative impacts on the environment through reduction in crashes and increases in speed adherence.	• Change in vehicle emissions • Change in fuel consumption	• Simulation of incident/crash situations	• Modeling analysis to assess the impacts of the with vs without cases

ID	Evaluation Hypothesis	Performance Measure	Data Sources	Analysis Type
4.	By increasing situational awareness, the pilot deployment will result in improved public agency efficiency and decision-making by transportation managers.	• Change in perception of agency awareness of conditions in the deployment corridors • Change in perceived accuracy of alerts/warnings/advisories/ traveler information • Change in perceived effectiveness of alerts/ warnings/advisories/traveler information • Change in timeliness of agency responses to changing travel conditions • Number and type of operational changes (such as signal timing adjustments) and business practice changes made by transportation managers • Perceived impact/effectiveness of operational and business practice changes • Change in notification and/or response times to major incidents and crashes • Change in perceived effectiveness of traffic management system responses to changing traffic conditions	• WYDOT crash data • WYDOT road closure Reports • WYDOT dynamic message sign (DMS) Records • WYDOT variable speed limit (VSL) system logs • WYDOT incident console logs • WYDOT Transportation Reports and Console (TRAC) data • Pikalert motorist advisories and warnings • Traffic management center (TMC) generated travel information messages, alerts, and warnings • Mobile Road Weather observations • Interviews and surveys	• Qualitative perception data from surveys • Quantitative data from system logs
5.	As the market penetration of CVs increases, benefits will increase in terms of reduced queues, delays, and emissions, as well as increased vehicle throughput during inclement weather conditions.	• Average trip time per vehicle (vehicle hours traveled per vehicle [VHT/V]) • Average user delay/wait time • Average speeds • Average vehicle miles traveled per vehicle	• Simulation	• Modeling analysis to assess the impacts of the with vs. without cases

ID	Evaluation Hypothesis	Performance Measure	Data Sources	Analysis Type
6.	As the market penetration of CVs increases, non-equipped vehicles traversing the pilot deployment area will see reductions in queues, delays, and emissions.	• VHT/V • Average user delay/wait time • Average speeds • Average vehicle miles traveled per vehicle	• Simulation	• Modeling analysis to assess the impacts of the with vs without cases

7.	The safety, mobility, environmental, and public agency efficiency benefits will exceed the costs associated with deploying the CV technologies in the deployment corridors.	• Total deployment costs
		  ○ Development
		  ○ Procurement
		  ○ Installation
		  ○ Operations
		  ○ Maintenance
		  ○ Salvage
		• Dollar value of benefits
		  ○ Safety
		  ○ Mobility
		  ○ Environmental
		  ○ Public Agency Efficiency
			• Safety analysis
			• Mobility analysis
			• Environmental analysis
			• Public agency efficiency analysis
			• Agency cost records
				• Benefit/cost

8.	Incremental increases in CV deployment will result in higher benefit-cost ratios up to a certain deployment cost threshold.	• Benefit-cost ratio at various market penetrations	• Cost data • Dollar value of benefits	• Simulation

ID	Evaluation Hypothesis	Performance Measure	Data Sources	Analysis Type
9.	End users will be satisfied with the performance of the CV applications and with the impact of the CV deployment on their travel.	• Perception of whether advisories/ alerts/warnings/traveler information were: o Timely o Sufficiently detailed o Easy to understand o Accurate o Useful o Appropriateness • Perceived impact (if any) that alerts/warnings/advisories/ traveler information had on safety and/or mobility. • Attitudes toward the consistency of the alerts (Did they fell they consistently received an alert under similar situations?) • Attitudes toward CV systems (related to trust in information, privacy and security, etc.)	• Surveys/Interviews	• Qualitative perception data from surveys
10.	End users will be satisfied with the performance of the CV devices.	• Overall satisfaction with performance of CV devices • Number and nature of problems with CV devices	• Survey/Interviews	• Qualitative perception data from surveys

ID	Evaluation Hypothesis	Performance Measure	Data Sources	Analysis Type
11.	The Wyoming CVPD agencies have the financial and institutional frameworks in place to provide for the long-term sustainability of the CV pilot deployment.	• Changes needed in business processes • Changes needed in agency systems and technology capabilities • Changes needed in agency culture • Changes needed in organizational structure and workforce requirements • Changes needed in institutional arrangements and collaborations • Changes needed in performance measurement practices • Perceived impact/effectiveness/ acceptance of those changes • Perceived extent to which safety, mobility, environmental, and public agency efficiency goals were met • Lessons learned by agencies	• Stakeholder Surveys/ Interviews	• Qualitative perceptions from interview data

Source: *CVPD Program Independent Evaluation: Refined MEP—Wyoming (3).*

Analysis Approach

Because of the way that the Wyoming CVPD Deployment Team has structured its deployment, the TTI CVPD Evaluation Team will use a before and after approach (non-experimental) to the mobility impacts associated with the deployment. The TTI team will use this evaluation format for the following reasons:

- Because the primary objective of the Wyoming CVPD is to improve safety, mobility is really an ancillary benefit compared to expected safety benefits. It is highly likely that mobility benefits will have to be estimated using simulation.
- The Wyoming CVPD Deployment Team does not plan to equip vehicles to operate either in a shadow mode (i.e., where a vehicle collects all the data and performs all the computations on the deployed vehicle except that is does not provide alerts like a CV) or a control group as part of the deployment. Therefore, direct comparison of vehicle performance with and without the technology active under similar conditions will not be available in the Wyoming deployment.
- The events that the CVPD is trying to address (winter weather, construction, etc.) generally produce significant reductions in capacity (lane closures, slow free-flow speeds, etc.). Any improvement in mobility by the applications are likely to be overpowered by the magnitude of the event. Therefore, direct observation of improvements due to CV applications are likely to be masked by the magnitude of the event itself.

Because operating conditions can vary significantly over the entire length of the I-80 corridor, the TTI CVPD Evaluation Team plans to divide the corridor into shorter analysis sections. Potential analysis sections include the following:

- East State Border to Cheyenne.
- Cheyenne to Laramie.
- Laramie to Rawlins.
- Rawlins to Rock Springs.
- Rock Springs to West State Border.

Identification of Operational Conditions

The TTI CVPD Evaluation Team will identify the key attributes for defining the operational conditions for the Wyoming I-80 corridor using a cluster analysis. These are the underlying conditions at the site, not the measures of system performance. The TTI team anticipates the following to be critical attributes impacting operations in the corridor:

- Daily travel demand.
- Weather conditions (type, duration, severity, precipitation amount, pavement conditions, time-lag of weather effects).
- Incident conditions (type, duration [e.g., total lane-minute closure], and severity).
- Work zone conditions (type, duration, impact severity).

- Special event conditions (type, duration, impact severity).
- Freight (number of trucks).
- Road closure conditions.
- Holidays.
- Day of week.
- Market penetration observed.

The TTI CVPD Evaluation Team will conduct a cluster analysis around key corridor attributes. The purpose of the clustering analysis is to ensure that comparison of observed data is done for similar conditions in the before and after periods. The TTI team will use the data normalization tool from open-source statistical analysis software (such as R or WEKA) in the Secure Data Commons (SDC) to normalize the data or to transform all data to a common scale so that no single attribute dominates. After normalizing the data, the TTI team will use the software tools to down-select attributes. The TTI team will then perform clustering analysis on the data using an open-source statistical and data mining tool in the SDC (such as R or WEKA). The TTI team will develop the clusters based on the post-deployment conditions to define the operational conditions for conducting the analyses. The TTI team will then classify pre-deployment data based on the post-deployment clusters to ensure that data from similar operational conditions are comparable.

Mobility Analysis

Because the primary focus of the Wyoming CVPD is on improving safety and situational awareness, the TTI team expects travel time and speed to be ancillary measures of performance for the Wyoming CVPD. As discussed in chapter 4, the TTI team plans to use a cluster analysis group the operational data into like conditions. The TTI team will use data from the post-deployment period to identify common operating conditions occurring in the deployment corridor. The TTI team will use several different clustering algorithms to group the data and determine a representative day from the conditions. The TTI team will then use group the pre-deployment data similar and to identify a representative scenario from the pre-deployment condition. The TTI team will use standard comparison of means and analysis of variance techniques to determine whether the mean performance of the before and after conditions of the representative scenario differ statistically.

The TTI CVPD Evaluation Team will use travel time and freight delay as the primary measure of performance of mobility. NPMRDS (*4*) will be the primary source of travel time data.

Freight delay is also a performance measure for this pilot because of the nature of the pilot deployment area. For this analysis, the TTI CVPD Evaluation Team plans to compare average (mean) total delay of all trucks (equipped and unequipped) for the same time periods before and after deployment of the CV technologies.

The TTI CVPD Evaluation Team will apply cluster analysis procedures to the data to determine the effects that confounding factors (such as incidents, weather, and special events) have on the travel time data. A separate analysis will be performed for normal conditions (no backups) and congested conditions (when the applications are most likely to be issuing alerts). Other options to explore include the availability of freight data embedded within the NPMRDS.

In addition to travel time and delays, the TTI CVPD Evaluation Team will analyze travel time reliability measures in the deployment area before and after activation of the CV technologies. The TTI team will use two travel time reliability measures in assessing the overall impacts of deploying the CV technologies in the evaluation corridor: the 95th percentile travel time and the buffer time. The 95th percentile travel time is the travel time, reported in minutes and seconds, that 95 percent of vehicles experienced during the analysis period. Buffer time represents the time differential between the average and the 95th percentile travel times for the same analysis period (peak period, peak hour, etc.). Buffer time represents the extra time needed by travelers to ensure a high rate of on-time arrival.

While the TTI CVPD Evaluation Team does not expect throughput to dramatically change because of the Wyoming CVPD, the team will conduct an analysis of throughput during the identified operational conditions. This throughput analysis will consist of comparing traffic volume counts in various corridor segments, pre- and post-deployment. The TTI team will compute throughput using traffic volume data collected by the WYDOT traffic sensors deployed throughout the corridor.

Environmental Evaluation

The TTI CVPD Evaluation Team will construct the environmental model using the U.S. Environmental Protection Agency's Motor Vehicle Emissions Simulator (MOVES2014a) model (*5*). The team will use output data from simulation modeling as input to the MOVES model. MOVES is a project-level simulator that uses a vehicle's operating mode—including idling, acceleration, deceleration, cruise, and hoteling—to measure emissions and petroleum consumption at the national, county, or project scale. MOVES assigns an emission rate for each unique combination of source and operating mode bins and calculates the total emissions and energy use over a specified period.

The TTI CVPD Evaluation Team will report the following model outputs from MOVES in emissions or energy consumption per hour:

- Carbon dioxide (CO_2).
- Particulate matter: PM-2.5.
- Particulate matter: PM-10.
- Nitrogen oxides (NO_x).
- Petroleum energy consumptions.

Public Agency Efficiency Evaluation

The TTI CVPD Evaluation Team expects the deployments of CV technologies to change the level of efficiency of the transportation network. Agency efficiency is measured in terms of how well agencies can respond to changing conditions or unexpected events occurring on their networks. Agency efficiency can be measured in terms of the following:

- Changes in notification and/or response times to major incidents and crashes.
- Improved situational awareness of events occurring on the transportation network.

- Improved timeliness and quality of traveler information messages.
- Improved traffic management system responses to changing traffic conditions.

To assess agency efficiency, the TTI CVPD Evaluation Team will examine operations logs of agencies for events, both before and after the deployment of the CV technologies, to assess how agency responses to these events changed. The TTI team will model the impacts of the changes in performance measures, such as changes in incident clearance times, to quantify their impacts on mobility.

The TTI CVPD Evaluation Team will rely heavily on the data collected by the Wyoming CVPD Deployment Team in assessing the changes in public agency efficiency resulting from the deployment. The specific data elements that the TTI team will be using include the following (*6*):

- Number of messages sent from the TMC that are received by the RSU.
- Number of messages sent and received between the RSU and WYDOT fleet vehicles' onboard unit (OBU) (when vehicles are near an RSU).
- Number of CVs that likely acted following receipt of an alert:
    - Parked.
    - Reduced speed.
    - Came to a stop safely.
    - Exited.
- Number of operational changes made due to information from TMC during CV pilot:
    - Routing.
    - Timing.
    - Parking availability.
    - Canceled trips.
- Number of emergency notifications that are first received in the TMC from CVs (compared to alternate traditional methods, such as 911 caller).

Benefit-Cost Analysis

The TTI CVPD Evaluation Team will also conduct a benefit-cost analysis associated with the I-80 deployment. The purpose of the benefit-cost analysis is to determine whether the safety, mobility, environmental, and public agency benefits exceeded the total costs associated with deploying the CV technologies in the deployment corridors. If the project were to increase the cost of travel, result in other increased user costs, or have any other negative benefits, then those results would also be entered as a benefit, but as a negative benefit.

A challenge with the Wyoming I-80 corridor is the large geographic area and the mostly rural nature of the corridor. The performance data will not be as granular as they might be in an urban corridor or district; however, as a pilot project, this is both a challenge and an opportunity. The analysis will use multiple sources of data to monetize the benefits associated with the deployment.

The benefit-cost analysis will encompass the planning, implementation, and 7 years of post-deployment operations. The TTI CVPD Evaluation Team will use a combination of field data and simulation data to estimate the benefits and costs. The analysis will assume the measured impacts of the projects (such as travel time savings) from the early years will continue at the same level in the later years of the project. The analysis will use a 7 percent discount rate for most items in accordance with Office of Management and Budget guidance. The TTI team will discount all monetary amounts to the start of project operations.

The TTI CVPD Evaluation Team will use travel time as a means of estimating the economic impacts associated with deploying CV technologies in the I-80 corridor. The TTI team will estimate travel times for all travel modes—automobiles, trucks, and buses—based on the current traffic distribution in the corridor. The TTI team will use changes in before and after travel times for each operational condition likely to produce specific benefits from deploying CV technologies. The team will estimate mobility costs associated with each type of operational scenario identified through the cluster analysis. The TTI team will estimate total mobility costs of the deployment by multiplying the costs of individual events by the frequency of occurrence of the event in the evaluation period.

The TTI CVPD Evaluation Team will also include the benefits associated with reduced freight delays in the analysis. Although the availability of this information is limited, the team will investigate sources of information. The Federal Highway Administration (FHWA) Office of Operations has generalized figures for the cost of freight delay (*7*); however, it is hoped that better and more specific information can be obtained. One potential method is to include questions on the survey of the commercial carriers specific to the I-80 corridor asking for the most detailed delay cost information they are willing to provide.

The TTI CVPD Evaluation Team will also include the benefits associated with any reductions in crashes resulting from the deployment. The TTI team will apply the crash reduction predictions for the corridor developed by Volpe to estimate the changes in different types of collisions. (The TTI team will capture the mobility benefits associated with those reductions in crashes in the mobility costs.) The TTI team will use the methodology contained in the *TIGER Benefit-Cost Analysis (BCA) Resource Guide* (*8*) to estimate safety costs.

The TTI CVPD Evaluation Team will also include the benefits associated with any changes in emission due the deploying the CV technology in the corridor. The TTI team will use simulation to estimate the effects of the deployments on emission. The TTI CVPD Evaluation Teams will project changes in emissions between the actual case (with the CV demonstration projects) and a hypothetical base case (with no CV technologies deployed) for a 7-year timeframe. The TTI CVPD Evaluation Team will include the following pollutants in the benefit cost analysis: CO_2, volatile organic compounds, NO_X, PM, sulfur oxide, and carbon monoxide.

The TTI CVPD Evaluation Team will also include the estimated fuel usage costs in the benefit cost analysis. The TTI team will base current and predicted costs for fuel on information from the U.S. Energy Information Administration website (*9*). This website includes current and historical gasoline and diesel fuel prices. Data from these sites will be used to develop average fuel costs during the evaluation period. For the Wyoming deployment, the TTI team will use fuel prices from the Rocky Mountain analysis region, which includes Montana, Wyoming, Colorado, Utah, and Idaho. The portion of the cost of fuel that is taxed will be removed prior to calculations since that is a transfer and not a change in societal benefits.

The TTI CVPD Evaluation Team will also include the vehicle operating costs as part of the benefit-cost analysis. The TTI team will base these costs on data published by the American Automobile Association (AAA) annually (*10*). Any reduction/increase in vehicle miles traveled will result in reduced/increased maintenance, tires, and depreciation based on average per mile vehicle operating costs as calculated by AAA. The costs *will not* include ownership costs, since the TTI team assumes that those costs would be the same regardless of whether the vehicles were equipped with CV technologies. Ownership costs include items such as insurance; license, registration, and taxes; vehicle depreciation; and finance charges.

Because of the number of trucks using the I-80 corridor, the TTI CVPD Evaluation Team will use different cost factors to estimate the costs of the deployment on operations. Unless specific commercial vehicle operating costs are available from the local site, the TTI team will use these values to reflect the operating costs associated with commercial vehicles. The TTI team will adjust these numbers to the baseline analysis year using the methodology described above. The TTI team will use past trends to project future costs.

The implementation costs used for the benefit-cost analysis will include the costs associated with deploying the CVPD. These costs will include the following:

- The costs to plan, implement, operate, and maintain the CV deployment projects.
- The marginal costs that the agencies and users incurred due to the project.

If applicable, the TTI CVPD Evaluation Team will subtract salvage value from the cost of the equipment. The TTI team will not include items such as fees for the travelers to use part of the CV deployment project in the benefit-cost analysis.

In addition to benefits/costs associated with the current deployment, the TTI CVPD Evaluation Team will also use modeling to examine the extent to which different market penetration rates are likely to affect changes in mobility, safety, and the environment in the deployment corridors. The team will estimate the benefits and costs for both the actual CV penetration rate and higher CV penetration rates. The growth scenarios will use only the existing suite of applications being deployed, and no new applications will be added to the vehicles. At a minimum, the study will use the following:

- The cost to increase the penetration rate (additional purchases of CV equipment, labor, maintenance, etc.)
- The estimates of safety, mobility, fuel, and emissions impacts of higher penetration rates.

The study will use simulations based on data collected from the CV deployment project. In addition to examining changes in performance with different penetration rates, the TTI CVPD Evaluation Team will project the effects of changes in background traffic demands on mobility performance in the corridor.

Chapter 3. Stakeholder Acceptance/ Satisfaction Evaluation Plan

As part of the independent evaluation, the TTI CVPD Evaluation Team will collect stakeholder acceptance and satisfaction information to gather stakeholder impressions and experiences related to the Wyoming CVPD. The results will be of benefit to the long-term sustainability of the CV deployed applications and to other entities seeking to deploy CV applications. The *Connected Vehicle Pilot Deployment Program Independent Evaluation: Stakeholder Acceptance Plan* (*11*) describes the approach that the TTI team will use to gather stakeholder acceptation and satisfaction information.

Table 2 shows the stakeholders for the Wyoming CVPD.

The TTI CVPD Evaluation Team will use structured pre-and post-deployment interviews to assess stakeholder perceptions of whether the pilots achieved the intended goals and impacts. Pre-deployment interviews will be used to obtain initial expectations prior to deployment. The TTI team plans to conduct two iterations of the post-deployment interviews: a) the near-term post deployment will be check-in interviews shortly after deployment to get initial feedback, and b) long-term post-deployment interviews will be toward the end of deployment to assess how these perceptions change as the deployment progresses. The TTI team will also document challenges, solutions, and lessons learned at two points in time, shortly after activation, and near the end of the pilot deployment.

The TTI CVPD Evaluation Team plans to conduct a post-deployment survey to gather information from important—but less engaged in day-to-day operations—stakeholders on whether and how the three CV pilot deployments achieved the vision, goals, and desired MEP impacts. The timing of this survey is long-term post-deployment. The survey will also quantify technical challenges, adopted solutions, and lessons learned. The TTI team plans to administer the survey online, accessible through a link in a recruitment email. The TTI team will coordinate with the Wyoming CVPD Team to determine whether TTI can administer the survey directly or if the Wyoming team prefers to administer the survey.

The TTI CVPD Evaluation Team will conduct one post-deployment workshop at the Wyoming site. The purpose of the workshop is to foster additional dialog among the deployment managers, deployment teams, and operating agencies concerning the lessons learned and major takeaways from planning and implementing the deployments. The TTI team will also use the workshop to gather information to conduct the Financial and Institutional Assessments. The TTI CVPD Evaluation Team envisions that these workshops will be one-half to one day in duration. The TTI team will develop open-ended questions designed to facilitate and guide the discussion in the workshop.

Table 2. Wyoming Stakeholder Group Types.

Stakeholder Type	Description	Stakeholder	Respondents
Deployment Managers	Lead deployment agency and decision makers	• WYDOT	• Executive management • Project managers
Deployment Team Members	Individual/agencies responsible for planning, development, and/or implementation of the applications and technologies	• ICF • Trihydro • National Weather Service/ National Center for Atmospheric Research (NCAR) • University of Wyoming • McFarland Mgmt. • Third party application developers • System integrators and vendors	• Project managers • Key technical leads (operations, development, engineering, IT)
Operating Agencies	Agencies involved in pre-deployment planning, development activities, and day-to-day operations of the pilots once started, also, those involved in pass-through of funding	• Wyoming State Highway Patrol • WYDOT—traffic, construction, maintenance, GIS/ITS, IT, Telecom • WYDOT TMC	• Key Technical Leads (operations, development, engineering, IT)
Fleet Operators	Agencies that will be installing and operating CV technologies in multiple vehicles	• WYDOT snowplow operators • Freight operators	• Fleet managers
Supporting Agencies	Agencies that may interact with or whose operations may be impacted by the pilot deployments	• Wyoming Trucking Association • Private truck parking services • City managers, local traffic, and law enforcement officials • County emergency management • Oil and gas industry representatives • Adjacent state DOTs	• Knowledgeable representatives (active in implementation activities/meetings)
Policy Makers	Individuals in a position to have influenced the selection of the pilot site or to decide something about the deployment in the future	• State legislators	• Champion for the pilot within organization

Source: Wyoming CVPD Team

Chapter 4. Survey and Interview Guides

The *Connected Vehicle Pilot Deployment Program Independent Evaluation: Stakeholder Survey/Interview Guide—Wyoming* (*12*) provides details of the questions and approach that will be used to obtain input from the various Wyoming CVPD Team stakeholders. The TTI CVPD Evaluation Team will use a multipronged approach for the data collection that includes qualitative interviews, an online survey, and workshops:

- Interviews will be used to gather in-depth information from those stakeholders most invested and involved in the CV pilot deployments. Interviews will take place at three points in time: pre-deployment, post-deployment near-term, and post-deployment long-term.
- An online survey will be used to gather information from stakeholders less involved in the day-to-day pilot and execution.
- A workshop will be used to obtain additional cross-stakeholder dialog to confirm interview findings and reveal additional insights.

Table 3 shows the distribution of data collection activities across stakeholder types.

Table 3. Data Collection Method by Stakeholder Type.

Stakeholder Type	Pre-Deployment Interviews	Post-Deployment Interviews Near Term[1]	Post-Deployment Interviews Long Term[2]	Survey	Workshop
Deployment Managers	X	X	X	—	X
Deployment Team	X	X	—	—	X
Operating Agencies	X	—	X	—	X
Fleet Operators	—	—	—	X	—
Supporting Agencies	—	—	—	X	—
Policymakers[3]	X	—	X	—	—

— No data

Notes

1 Near-term post-deployment is 2–3 months after activation.
2 Longer-term post-deployment is 9–12 months after activation.
3 If the Champion is no longer in office post-deployment, the TTI CVPD Evaluation Teams will interview the incumbent instead.

Interviews

The TTI CVPD Evaluation Team plans to conduct three types of interviews:

- Pre-deployment interviews —These interviews will elicit vision, goals, and expectations and gather information on financial and institutional preparedness. The TTI team plans to execute these interviews just before activation of the test CV applications.
- Near-term post-deployment interviews — These interviews will capture early deployment experiences, challenges, and solutions. The TTI team plans to conduct these 1–3 months after activation of the deployment.
- Long-term post-deployment interviews — These interviews will gather opinions on whether the deployments achieved the desired vision, goals, and MEP impacts. The TTI team also plans to collect observations and experiences about challenges (e.g., technical, institutional, financial), adopted solutions, and lessons learned. The TTI team will use these interviews to measure stakeholder levels of satisfaction with pilot outputs/outcomes and the long-term sustainability of the CVPD. The team will conduct these interviews about 9–12 months after activation of the applications.

The TTI CVPD Evaluation Team has developed interview protocols that probe the various stakeholder groups on the following topics:

- Policy Challenges.
- Institutional Challenges.
- Collaboration.
- Financial Issues.
- Business Processes.
- Performance Measures.
- Systems and Technology.
- Workforce Development.
- Outreach.

The specific questions to be asked in these interviews can be found in the *Connected Vehicle Pilot Deployment Program Independent Evaluation: Stakeholder Survey/Interview Guide—Wyoming* (*12*).

Online Survey Questionnaires

The TTI CVPD Evaluation Team has developed separate questionnaires to gather perceptions of the outcomes of the pilot deployments from the fleet operators and the supporting agency stakeholders (snow plow operators). These surveys will be administered to these stakeholders 9–12 months after activation. The TTI team anticipates that respondents will require 10–15 minutes to complete the questionnaire. To not overburden fleet operators, the team will coordinate the administration of the fleet online survey with the Wyoming CVPD Team. This coordination will consist of when, where, and how the team will administer the online survey, and could potentially involve combining this survey with other surveys already planned by the Wyoming Team.

For information on the specific questions to be addressed in the questionnaires, see the *Connected Vehicle Pilot Deployment Program Independent Evaluation: Stakeholder Survey/Interview Guide—Wyoming* (*12*).

Post-Deployment Workshop

The TTI CVPD Evaluation Team will conduct a workshop at the conclusions of Wyoming deployment period. The purpose of the workshop is to foster additional dialog among the deployment managers, deployment teams, and operating agencies concerning the lessons learned and major takeaways from planning and implementing the deployment. The common themes identified in the post-deployment interviews will be used to frame the group discussion, which will explore the following topics in more detail:

- Expectations and satisfaction.
- Technical challenges.
- Institutional arrangements.
- Financial arrangements.
- Lesson learned.
- Sustainability.
- Expectation for future operations.

Workshop participants will represent the deployment managers, deployment team members, and operating agencies from Wyoming. It is expected that 15–20 persons will participate in the workshop. Some, but not all, will be individuals who have participated in the interviews. The TTI CVPD Evaluation Team will coordinate with the deployment managers to identify persons to invited to the workshops.

Examples of the specific questions to be asked in the workshop can be found in the *Connected Vehicle Pilot Deployment Program Independent Evaluation: Stakeholder Survey/Interview Guide—Wyoming* (*12*).

Chapter 5. Evaluation Data and Data Management

The *Connected Vehicle Pilot Deployment Program Independent Evaluation: Data Plan—Wyoming* (13) describes the data that the TTI CVPD Evaluation Team plans to use to identify operational scenarios to be examined in the analysis, conduct the MEP evaluation, and calibrate the simulation models for the analysis. The plan also provides the approach that the TTI team plans to use to maintain the privacy and quality of the data it collects. In addition, the plan describes how the TTI team use and upload data to the SDC.

Sources of Evaluation Data

Table 4 summarizes the data that the TTI CVPD Evaluation Team plans to use to conduct the independent evaluation of the MEP benefits of the Wyoming CVPD.

Table 4. Summary of Data Requirements for Independent Analysis of Wyoming CVPD

Data Type	Data Elements	Source	Used in What Analysis
Mobility	• Avg Travel Time (min) • Speed • Buffer Time • Travel Time Index	• TTI access to NPMRDS • WYDOT I-80 individual speed measurements	• Mobility Analysis • Analysis, Modeling, and Simulation (AMS) Model Calibration
Traffic Demand	• Observation Count • Vehicle Classification	• WYDOT I-80 individual speed measurements	• Mobility Analysis • AMS Model Calibration
Weather	• Air Temperature (°F) • Pavement Temp (°F) • Wind Speed (mph) • Maximum Wind Gust (mph) • Precipitation • Visibility (miles)	• WYDOT RWIS logs	• Mobility Analysis • AMS Model Calibration
Incident	• Locations • Type and severity[1] of the incident • Number of lanes impacted	• WYDOT incident console reports • WYDOT TRAC data	• Mobility Analysis • AMS Model Calibration

Data Type	Data Elements	Source	Used in What Analysis
Traffic Management Strategy Data	• Locations • Type (Traveler Alert, Road Closure, Reduced speeds, and others) • Duration • Situation	• WYDOT VSL logs • WYDOT DMS logs • WYDOT road closure logs	• Mobility Analysis • AMS Model Calibration
Public Agency Efficiency Impacts	• Number of messages sent from the TMC received by the RSU • Number of messages sent and received between the RSU and WYDOT fleet vehicles' OBU (when vehicles are near an RSU). • Number of CVs that likely acted following receipt of an alert: o Parked o Reduced speed o Stopped safely o Exited • Number of operational changes made due to information from TMC during CV pilot: o Routing o Timing o Parking availability o Canceled trips • Number of emergency notifications received first in the TMC from CVs (compared to traditional methods, such as 911 caller).	• WYDOT log of the number of messages sent and received between TMC – RSUs – OBUs • WYDOT incident detection and response time log • WYDOT Automated Emergency Notification log • User surveys	• Public Agency Efficiency
Vehicle Emissions	• Link volumes • Average link speeds • Vehicle mix • Operational scenario o Temperature o Humidity	• TTI AMS analysis • TTI cluster analysis	• Emissions Analysis
Safety Benefits	• Probability of crash • Harm reduction	• Volpe safety analysis	• Benefit-Cost Analysis

Data Type	Data Elements	Source	Used in What Analysis
CVO Driver Satisfaction	• Perception of accuracy • Perception of timeliness • Perception of usefulness • Perception of improved mobility • Perception of improved safety	• WYDOT driver user survey	• User Satisfaction
CVO Fleet Satisfaction Survey	• Perception of accuracy • Perception of timeliness • Perception of usefulness • Perception of improved mobility • Perception of improved safety	• WYDOT fleet operator survey	• Stakeholder Acceptance
CVPD Stakeholder Acceptance Survey	• Perception of accuracy • Perception of timeliness • Perception of usefulness • Perception of improved Mobility • Perception of improved public agency efficiency • Perceptions of improved safety • Lessons learned	• TTI stakeholder interviews • TTI post-deployment survey • TTI post-deployment workshop	• Stakeholder Acceptance
Pre-Deployment (Phase I) Costs	• Planning/concept development costs • Evaluation Planning Costs • Other Costs	• TTI stakeholder interviews	• Benefit-Cost Analysis
Deployment (Phase II) Costs	• Development costs/one-time implementation costs • Equipment procurement costs ○ Vehicle ○ Infrastructure • Installation costs ○ Vehicle ○ Infrastructure • Subject recruitment • Evaluation • Other costs	• TTI stakeholder interviews	• Benefit-Cost Analysis

Data Type	Data Elements	Source	Used in What Analysis

Operations & Maintenance
(Phase III) Costs
	• Operations costs
	• Maintenance/repair
	• Equipment replacement costs
	  ○ Vehicle
	  ○ Infrastructure
	• Salvage
	  ○ Vehicle
	  ○ Infrastructure
	• Evaluation
	• Other costs
		• TTI stakeholder interviews	• Benefit-Cost Analysis

[1]The WYDOT TMC does not know the severity of the incident. The TTI CVPD Evaluation Team will attempt to determine severity based on the description and duration of the incident contained in the TMC data logs.

Source: Texas A&M Transportation Institute (*13*)

Data Ownership and Privacy

USDOT and WYDOT are the owners of the data uploaded by WYDOT into the SDC. Any data collected by the TTI CVPD Evaluation Team, including the simulation input file and result files, become the property of USDOT once the project is complete. After removing any personally identifiable information from the data, the TTI team plans to upload any data files generated in the analysis to the SDC. The TTI team will reference and credit appropriately any data obtained from external sources. Both the Wyoming CVPD Team and the TTI team have implemented policies and procedures for protecting and controlling personally identifiable information.

Data Analysis and Management Procedures

The TTI CVPD Evaluation Team plans to conduct all data analyses and statistical comparisons within the structure of the SDC. The SDC is a cloud-based, online analytic portal where data collected by each of the CVPD teams are placed for use in the independent evaluation. The purpose of the SDC is to provide a secure platform that will enable USDOT and others to share large data sets, both structured and unstructured, for evaluation and collaboration. The TTI team will work with the USDOT and the SDC development team to ensure that proper resources and analytical tools are available to the team in the SDC. Other than summary charts, figures, and tables contained in published reports, the TTI team does not plan to disseminate or distribute the data in any form outside of the SDC.

The TTI CVPD Evaluation Team will keep the data gathered from the qualitative interviews, online surveys, and workshops confidential. Survey and interview participants can be identified only by authorized team members of the TTI team. The TTI team will prepare summaries of all interviews, surveys, and the workshop. After preparing the summaries, raw survey responses and interview notes will be kept in a secure file cabinet under lock and key until the final report is prepared. Once the final report is approved by USDOT, the TTI team will destroy any raw notes or materials obtained in the interviews or workshop.

Chapter 6. Analysis, Modeling, and Simulation

Modeling and simulation will play a big part in the TTI CVPD Evaluation Team's approach for assessing the mobility and environmental benefits associated with the Wyoming CVPD. The *Connected Vehicle Pilot Deployment Program Independent Evaluation: Analysis, Simulation, and Modeling Plan* (*14*) contains TTI's plan for how modeling and simulation will be used in the independent evaluation. Specifically, the TTI team will use the AMS analysis to perform the following:

- Estimate the impacts on travel time and delay due to changes in truck-related crashes and incidents by deploying CVs, as well as improved freight traveler information along I-80 during adverse weather and other operating conditions.
- Estimate the impacts on travel reliability due to changes in truck-related crashes and incidents by deploying CVs, as well as improved freight traveler information along I-80 during adverse weather and other operating conditions.
- Estimate the impacts on throughput due to changes in truck-related crashes and incidents by deploying CVs, as well as improved freight traveler information along I-80 during adverse weather and other operating conditions.
- Estimate the impacts on freight mobility due to changes in truck-related crashes and incidents by deploying CVs, as well as improved freight traveler information along I-80 during adverse weather and other operating conditions.
- Estimate the impacts on the environment due to changes in truck-related crashes and incidents by deploying CVs, as well as improved freight traveler information along I-80 during adverse weather and other operating conditions.
- Estimate the cumulative effects of different deployment scenarios (aggressive, slow, moderate) for short-term and long-term periods during different operating conditions (including adverse weather).

The key mobility-related performance measures the TTI CVPD Evaluation Team will compute for each operational scenario include the following:

- Total vehicle miles traveled.
- Total vehicle hours traveled.
- Average travel time.
- Average operating speed.
- Average system vehicle hours of delay.
- Average system speed variance.
- Average system time (i.e., VHT) spent in queue.

The TTI CVPD Evaluation Team will compute these performance measures using data from multiple simulation runs for each operational condition. The TTI team will use these measures to estimate environmental performance measures too.

As part of the Phase II development efforts, the Wyoming CVPD Team is developing a microscopic simulation model for a select portion of the I-80 corridor (15). The Wyoming CVPD Team plans to develop this model using the VISSIM microscopic simulation models. The Wyoming CVPD Team plans to use the simulation model to perform a surrogate safety assessment and to evaluate how the introduction of CV technology influenced corridor performance during adverse weather conditions. The TTI CVPD Evaluation Team plans to use this model as the foundation for conducting its simulation and modeling activities.

Model Development and Calibration

To make estimate these impacts, the TTI CVPD Evaluation Team will use a base model that the Wyoming CVPD Team developed. The TTI team is assuming that the Wyoming team will use a VISSIM model of one of the VSL segments of the deployment corridor—either the Cheyenne-Laramie or the Elk Mountain section . The TTI team is expecting to receive from the Wyoming team a functioning model that is free from errors and calibrated to some level of performance. The TTI team will then calibrate the model for both speed and throughput for the operational conditions identified through the cluster analysis. The TTI team will follow the procedures specified in the *Traffic Analysis Toolbox III Guidelines for Applying Traffic Microsimulation Modeling Software* (*15*) to calibrate the model. The TTI team anticipates that the model will cover both the eastbound and westbound directions of travel in the corridor.

Analysis of Simulation Results

Model scenario identification comes after the clustering analysis of historic data has identified the relevant operating conditions to be included in the model scenarios. Each scenario is then the combination of different CV deployment level alternatives and the operational conditions determined from the clustering analysis. Weather conditions can affect vehicle travel speed (e.g., traveling slower than usual). Not controlling for the effects of changes in weather conditions has the potential to invalidate conclusions about the effectiveness of the CVPD in addressing the needs of the pilot site. Table 5 lists the known confounding factors likely to influence travel behavior in the Wyoming CVPD corridor.

The TTI CVPD Evaluation Team will not model different demand levels independently of the weather, congestion, and crashes. The TTI team will select a set of historical study periods (called historic days for convenience) based on the clustering analysis. The TTI team will input traffic counts, crash data, and weather collected simultaneously for those selected days into the simulation model. The TTI team will calibrate the model's performance results on a day-by-day basis to the speeds observed simultaneously for those same days.

The TTI CVPD Evaluation Team will follow standard statistical analysis procedures to assess differences between system performance between the pre- and post-deployment periods. The TTI team will use analysis of variance of the alternatives to test each mobility-related hypothesis across the range of market penetration levels. Hypothesis testing will deal with the confounding effects of weather, demand, and crashes on mobility by testing only CV application alternatives with identical operational conditions (same levels of demand, weather, and crashes).

Table 5. Treatment of Confounding Factors in Scenario Analysis.

Factors	Wyoming
Weather Changes	The weather types and number of levels of each type that are to be assigned specific model scenarios for each CV deployment alternative will be determined via the clustering analysis.
Changes in Vehicle Demand, due to variety of causes: Economic Conditions (jobs, etc.), Fuel Price, Fare/Toll Changes, Weather, season of year, day of week, etc.	The values of demand and the number of levels of demand that are to be tested in specific model scenarios for each CV deployment alternative will be determined via the clustering analysis.
Changes in Pedestrian Demands	Not a factor for Wyoming site.
Random Variation Crashes	Scenarios involving operating conditions with crashes will model the same specific crash condition (location, timing, lanes closed) for all CV deployment (and non-deployment) levels to control for the influence of random variation in crash rates. Non-random variations due to differing CV deployment levels will be treated in post-processing of model results.
Work Zone Changes	Model runs will use same work zones for evaluating base and different CV deployment levels.
Change in Economic Conditions	Effects included in demand operational conditions.
Fuel Price Changes	Effects included in demand operational conditions.
Changes in Planned Special Events	Not a factor for Wyoming site.

Notes: This table addresses how the confounding effects of these factors will be controlled in the simulation model runs used in the analysis. A later step addresses how the impacts of these factors on CV performance will be determined.

Modeling Higher Levels of Market Penetration

For each of the CV Pilot Deployment sites, the market penetration rates observed are limited by the size of the deployment. The TTI CVPD Evaluation Team will use simulations to estimate potential benefits of higher levels of market penetration, which may be observed in the future, as more vehicles and infrastructure are equipped with communication technology. As alluded to in the previous section, the analysis will test the sensitivity of the conclusions to the following factors: level of market penetration, level of demand, level of poor weather, and presence of and severity level of a crash. Table 6 illustrates the planned framework for the sensitivity analysis.

Table 6. Framework for Presenting Sensitivity Test Results for Each MOE.

Scenario	CV Deployment Level	Operational Conditions Demand	Operational Conditions Weather	Operational Conditions Incident	Hypothesis Test Result Impact on MOE
1a	No Deployment	Low	Snow	None	N/A
1b	No Deployment	Medium	Rain	Minor	N/A
1c	No Deployment	High	Fair	Major	N/A
2a	Actual Deployment	Low	Snow	None	+1%, LTS
2b	Actual Deployment	Medium	Rain	Minor	+2%, LTS
2c	Actual Deployment	High	Fair	Major	+3%, LTS
3a	7-Year Expansion	Low	Snow	None	+2%, LTS
3b	7-Year Expansion	Medium	Rain	Minor	+4%, S
3c	7-Year Expansion	High	Fair	Major	+6%, S
4a	Maximum Expansion	Low	Snow	None	+4%, S
4b	Maximum Expansion	Medium	Rain	Minor	+6%, S
4c	Maximum Expansion	High	Fair	Major	+9%, S

Notes:

1. A separate Sensitivity Analysis Results Table will be prepared for each mobility MOE tested.
2. N/A = not applicable. This is the base case against which the CV deployment alternatives are compared.
3. +1%, LTS = a 1% increase in the mean value of the MOE was observed, but it was less than significant.
4. +6%, S = a 2% increase in the mean value of the MOE was observed, and it was significant.
5. All entries are illustrative.

The number of levels and the specific levels of demand, weather, and incidents to be evaluated in the sensitivity tests will be determined by the clustering analysis. The clustering analysis on the field data may also reveal other factors or additional factors to include in the sensitivity analysis.

For each representative operational condition selected for simulation, the TTI CVPD Evaluation Team will operate the calibrated model to a future scenario in which the market penetration rate is higher for the CV fleet. By increasing the number of CVs in the model, the probability of vehicle-to-vehicle interactions increases, and the number of vehicles that the RSUs detect also increases.

Estimation of Mobility Impacts of Safety Applications

While microsimulation models of mobility are designed to predict the mobility effects of specific demand, weather, and crash conditions, they are not designed to predict the weather, demand, or crashes. Therefore, specific demand levels, weather, and crashes commensurate with each specific operational condition cluster to be modeled will be coded into the analysis scenarios. The TTI CVPD Evaluation Team will estimate the mobility effects of reduced crash frequencies by adjusting the probabilities used to weight the scenarios with crashes to estimate annual performance. Since the clustering is not guaranteed to produce clusters that are composed exclusively of crashes or no crashes, the TTI team must deal with mixed clusters, separating out the days with crashes from those without crashes within each cluster. The average VHT for each cluster is a mix of crash and non-crash periods. The average VHT is computed separately for the crash times and the non-crash times within each scenario cluster. The average VHT for each cluster is then recomputed using the Volpe Center's estimated reductions in crash frequencies for the given CV market level. The new crash and non-crash probabilities are applied to the average VHTs for crash days and non-crash days, and the results are combined into a new estimate of average VHT for each cluster.

Extrapolation of System Results to Whole-Year Results

Once the TTI CVPD Evaluation Team has completed the analysis of each operational scenario, the team will extrapolate the result to estimate the system performance for the whole year. The key is to associate each set of integrated operational conditions with a specific future probability for the whole year. The TTI team will accomplish this by examining the cluster data to determine the number of days that the specific integrated operational condition was observed to occur in that cluster for the before and after deployment periods for the site.

Since the pre- and post-deployment periods will probably not cover a full year, the observed probabilities for these periods will be expanded to full year probabilities. A full year of hourly demands will be gathered from one or more selected permanent count stations representative of the site. A full year of archived crash data will be gathered from agency archives. A full year of weather data will be gathered from a nearby airport. The data by time and day will then be used to construct a full year's worth of daily operational conditions for the site. The team will aggregate weather and traffic data to 15-minute intervals. The full year's probability for each cluster will then be computed by dividing the total number of days in each cluster by the total number of days in the year (may be less than 365 days if the analysis focuses only on non-holiday weekdays and may be less than 24-hour days if the analysis focuses only on the peak periods).

Once the annual probabilities are obtained for the clusters used in the simulation runs, the model performance results will be translated into estimates of annual performance by multiplying the average performance observed in the repeated model runs by the estimated annual probability for the integrated operational conditions represented in that scenario.

Chapter 7. Outreach

Throughout the outreach effort, the TTI CVPD Evaluation Team will undertake a comprehensive outreach process that ensures that each target audience group is exposed to the research results in various formats. The *Connected Vehicle Pilot Deployment Program Independent Evaluation: Outreach Plan* (*17*) describes the process that TTI plans to follow to provide outreach on the analysis status and results. This process, displayed in Figure 2, begins with the development of a technical report, follows with public media outreach, and expands to include the variety of outreach products listed Table 7.

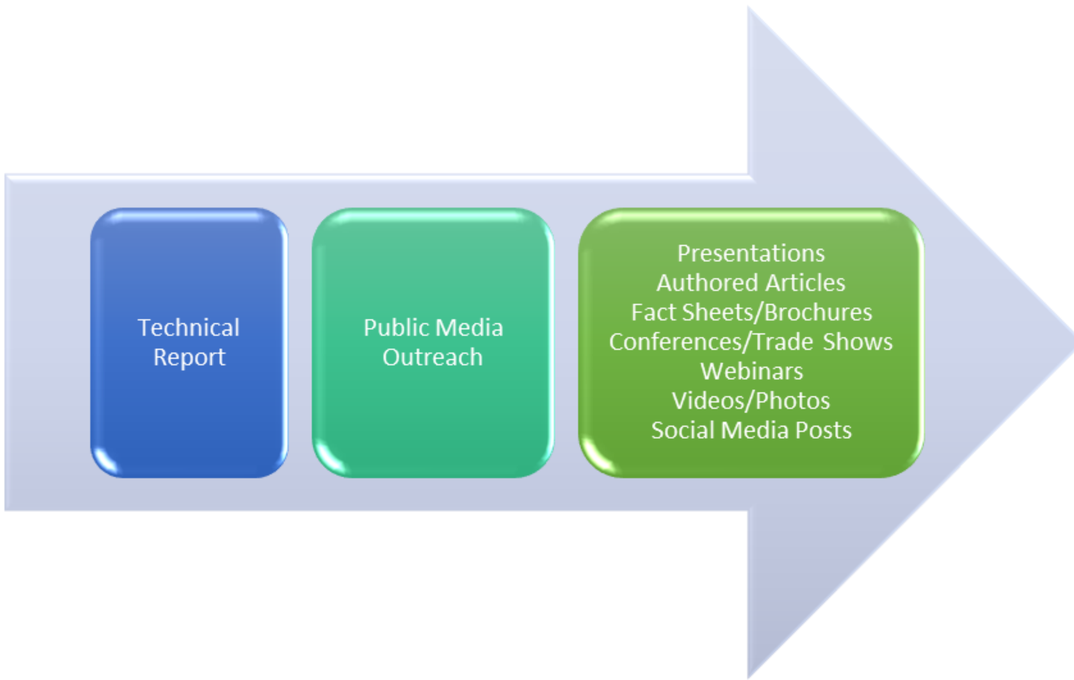


Figure 2. Proposed Outreach Process.

The TTI CVPD Evaluation Team will work closely with the CVPD Outreach Roundtable Team to coordinate efforts on an ongoing basis to ensure specific activities are complementary and not duplicative in nature. The TTI team will develop a master outreach calendar, inventory of resources available and under development, and list of specific outreach activities underway or planned by the team, sharing these documents with the Outreach Roundtable Team and providing updates during the regularly scheduled meetings.

Table 7. Outreach Methods

Method	Frequency	Primary Purpose	Dissemination
Technical Reports	Throughout project	Promote project results Share information	Post on website Press releases
Authored Articles	Throughout project	Promote project results Share information	Post on website Press releases
Presentations	Throughout project	Provide inputs to other outreach deliverables such as brochures, website, social media posts, etc.	Post on website Webinars Conferences Trade shows
Conferences	As available	Promote project visibility Share information	Post on website after event
Trade Shows	As available	Promote project visibility Share information	Post on website after event
Webinars	Timed with key evaluation reports	Determined by USDOT	Attendees will be dependent on webinar focus
Videos	Throughout project	Provide project explanation and benefits	Post on website Press conferences Conferences Trade shows
Photos	Throughout project	Use for all other outreach efforts	May need approval prior to use
Fact Sheets	Timed with key evaluation reports	Help ensure consistent message through all outreach	Conferences Trade shows Handouts at meetings, events, etc.
Brochures	Timed with key evaluation reports	Help ensure consistent message through all outreach	Conferences Trade shows Handouts at meetings, events, etc.
Articles	Throughout project	Share consistent message	Website Handouts at meetings, events, etc.
Press Releases	Timed with key evaluation reports	Provide public education on CVPD purpose and outcomes	All press releases will be shared with USDOT prior to release
Local Press	Timed with key evaluation reports	Provide public education on CVPD purpose and outcomes	Will use the local media channels to handle all information requests from Local Press

Method	Frequency	Primary Purpose	Dissemination
National Press	Timed with key evaluation reports	Provide public education on CVPD purpose and outcomes	Will use the local media channels to handle all information requests from National Press
Social Media Posts	Post progress Post scheduled events	Increase project presence and visibility with Facebook, Twitter, YouTube, etc.	Produce spontaneous, unplanned content as needed
Website	Content update at each project milestone Frequent updates for project news, upcoming events, and status	Serve as main point for project information dissemination Inform all stakeholders and interested parties	—

No data.
Source: Texas A&M Transportation Institute (*17*).

The TTI CVPD Evaluation Team will work with FHWA to organize a series of webinars throughout the course of the evaluation project to disseminate research results to a broad stakeholder audience. The TTI team anticipates that FHWA will host the webinars through either internal means or external collaborative relationships with ITS America per its contract with Intelligent Transportation Systems Joint Program Office (ITS JPO) to host webinars. The TTI CVPD Evaluation Team will be responsible for delivering the webinars. The webinars will be recorded and posted on the evaluation project website for those who may have missed the live version. Webinars will be publicized through the website, e-newsletter, conferences, trade shows, and other products and distribution methods described in this outreach plan.

Chapter 8. Detailed Evaluation Cost Estimate

Table 8 provides a cost breakdown for each of the major work activities. For this assessment, the TTI CVPD Evaluation Team divided the entire planned independent evaluation into a series of precursor and analysis activities. The precursor activities involve work effort that must be completed before the analysis activities begin. Precursor tasks include activities such as preparing data sets, conducting a cluster analysis, and preparing the models for execution. Analysis activities include work efforts such as analyzing the field data, performing a modeling analysis of identified operational scenarios, performing benefit-cost analyses, and so forth. The TTI team then estimated the cost associated with completing each activity and analysis

Table 9 provides the value/risk cost assessment for the analysis tasks of the independent evaluation of the Wyoming CVPD. The Appendix provides the justifications associated with the value and risk scores associated with each work activity.

The TTI CVPD Evaluation Team assigned a value and risk score to each analysis activity. Scores ranged from 1 to 5, with 5 being the highest value/risk, to each risk and value. The TTI team assigned a value score considering how critical the activity is expected to be to the independent evaluation, based on the nature of the analysis, the potential observability of the results, and the scope and extensibility of the analysis. High-value scores indicate that the analyses are essential to the overall assessment of the deployment. The TTI team also assigned a risk score for each analysis activities. Risk scores represents the TTI team's opinions about level of uncertainty associated with an analysis activity. Risk scores reflect the overall level of difficulty, availability of data, and potential issues associated with performing the analysis. High risk values represent activities that have a high risk associated with them.

The TTI CVPD Evaluation Team then computed a weighted score for each analysis activity by dividing the values score by the risk score. The TTI team plans to use the weighted value/risk score to prioritize and manage the work activities throughout the analysis period, with activities receiving high value/risk scores being completed first and activities receiving lower value/risk scores being performed based on the availability of funds.

Table 8. Estimated Cost Breakdown of Work Activities for the Independent Evaluation of the Wyoming CVPD.

ID	Task	Task Type	Precursor Task(s)	Cost
10	**Project Management**	**Precursor**	**None**	**$118,901**
11	Project Administration	Precursor	None	$71,034
12	Coordination with FHWA	Precursor	None	$9,471
13	Internal Coordination	Precursor	None	$14,207
14	Site Visit	Precursor	None	$24,189
20	**Data Preparation**	**Precursor**	**None**	**$13,501**
30	**Support Safety Analysis**	**Precursor**	**None**	**$ 57,612**
31	Data Analysis	Precursor	20	$26,406
32	Safety Data Collection	Precursor	None	$ 31,206
50	**Perform cluster analysis—Wyoming CVPD**	**Precursor**	**20**	**$148,999**
51	Cluster Analysis—Pre-Deployment	Precursor	20	$ 64,549
52	Cluster Analysis—Post-Deployment	Precursor	20	$ 84,450
60	**AMS Model Prep**	**Precursor**	**50**	**$48,687**
61	Model Prep—Coordination	Precursor	50	$19,935
62	Model Prep—Baseline Prep	Precursor	61	$28,752
			Total (Precursor Tasks)	**$387,700**
100	**Mobility—Travel Reliability—Adverse Weather**	**Analytical— Observed**	**50**	**$65,700**
110	Mobility—Travel Times	Analytical—Observed	50	$21,900
120	Mobility—Travel Time Reliability	Analytical—Observed	50	$21,900
130	Mobility— Throughput	Analytical—Observed	50	$21,900
200	**Mobility—Accident Reduction**	**Analytical—Observed**	**31, 50**	**$9,386**
210	Mobility—Analysis of weather accidents	Analytical—Observed	31 ,50	$ 9,386
300	**Mobility—Freight Reliability**	**Analytical—Observed**	**50**	**$18,772**
400	**AMS—Modeling**	**Analytical—Modeled**	**50, 61**	**$ 369,620**
410	AMS—Modeling-Op Condition 1	Analytical—Modeled	50, 61	$61,603
420	AMS—Modeling-Op Condition 2	Analytical—Modeled	50, 61	$61,603

ID	Task	Task Type	Precursor Task(s)	Cost
430	AMS—Modeling-Op Condition 3	Analytical—Modeled	50, 61	$61,603
440	AMS—Modeling-Op Condition 4	Analytical—Modeled	50, 62	$61,603
450	AMS—Modeling-Op Condition 5	Analytical—Modeled	50, 62	$ 61,603
460	AMS—Modeling-Op Condition 6	Analytical—Modeled	50, 62	$ 61,603
500	**AMS—Market Penetration Analysis**	**Analytical—Modeled**	**50, 62**	**$98,958**
510	AMS—Market Penetration—Low	Analytical—Modeled	50, 62	$32,986
520	AMS—Market Penetration—Medium	Analytical—Modeled	50, 62	$ 32,986
530	AMS—Market Penetration—High	Analytical—Modeled	50, 62	$32,986
600	**Environment Assessment**	**Analytical—Modeled**	**300-400**	**$31,616**
610	Environment—Mobility Improvements	Analytical—Modeled	300	$20,551
620	Environment—Market Penetration	Analytical—Modeled	400	$11,066
700	**Public Agency Efficiency (PAE) Assessment**	**Analytical—Survey**	**20**	**$45,063**
710	PAE— Logs	Analytical—Survey	20	$45,063
720	PAE—Stakeholder Perspectives*	Analytical—Survey	20	$—
800	**Benefit-Cost Analysis (BCA)**	**Analytical—Computed**	100—600	**$33,382**
810	BCA—Deployment	Analytical—Computed	100—600	$22,032
820	BCA— Market Penetration	Analytical—Computed	500	$11,350
1000	**End User Survey***	**Analytical—Survey**	20	**$—**
1010	End User Survey—Mobility*	Analytical—Survey	20	$—
1020	End User Survey—Technology*	Analytical—Survey	20	$—
1200	**Lesson Learned**	**Analytical—Survey**	**20**	**$45,325**
1210	Lesson Learned	Analytical—Survey	20	$45,325
1300	**Outreach/Report Preparation**	**Outreach**	**100—1200**	**$33,211**
			Total (Analysis Tasks)	**$751,032**
			TOTAL	**$1,138,732**

*This analysis task will be funded through a separate work order.

Table 9. Value/Risk Assessment of Analysis Activities Associated with Independent Evaluation of Wyoming CVPD.

ID	Task	Value	Risk	Value/ Risk	Cost	Hypothesis Map
1300	Outreach/Report Preparation	5	1	5	$33,211	Outreach
1210	Lesson Learned	5	1	5	$45,325	Stakeholder Goals Met
720	PAE—Stakeholder Perspectives*	3	1	3	$—	6. Improved Public Agency Decision-making
130	Mobility—Throughput	5	2	2.5	$21,900	1. Travel Impacts of Adverse Weather
120	Mobility—Travel Time Reliability	5	2	2.5	$21,900	1. Travel Impacts of Adverse Weather
110	Mobility—Travel Times	5	2	2.5	$21,900	1. Travel Impacts of Adverse Weather
810	BCA-Deployment	4	2	2	$22,032	9. Benefits exceed Costs
210	Mobility—Anal. of accid. reduction	4	2	2	$ 9,386	2. Impacts of Accident Reduction
1010	End User Survey—Mobility*	3	2	1.5	$—	3. End User Acceptance of Impacts
460	AMS—Modeling-Op Condition 6	4	3	1.3	$61,603	1—3. Mobility Impacts of Adverse Weather
450	AMS—Modeling-Op Condition 5	4	3	1.3	$61,603	1—3. Mobility Impacts of Adverse Weather
440	AMS—Modeling-Op Condition 4	4	3	1.3	$61,603	1—3. Mobility Impacts of Adverse Weather
430	AMS—Modeling-Op Condition 3	4	3	1.3	$61,603	1—3. Mobility Impacts of Adverse Weather
420	AMS—Modeling-Op Condition 2	4	3	1.3	$61,603	1—3. Mobility Impacts of Adverse Weather
410	AMS—Modeling-Op Condition 1	4	3	1.3	$61,603	1—3. Mobility Impacts of Adverse Weather
310	Mobility—Freight Reliability	5	4	1.25	$18,772	3. Improve Freight Reliability
620	Environment—Market Penetration	3	3	1	$11,066	7. & 8. Reduce negative environmental impacts
610	Environment—Mobility Improvements	2	2	1	$20,551	7. Reduce negative environmental impacts
1020	End User Survey—Technology*	2	4	0.5	$—	5. End User Acceptance of Technology
820	BCA— Market Penetration	2	4	0.5	$11,350	9. B/C Changes with Market Penetration
710	PAE—Logs	2	4	0.5	$45,063	4. Improved Emergency Management
530	AMS-Market Penetration—High	2	4	0.5	$32,986	8. Market Penetration
520	AMS-Market Penetration—Medium	2	4	0.5	$32,986	8. Market Penetration
510	AMS-Market Penetration—Low	2	4	0.5	$ 32,986	8. Market Penetration
	Total (Analysis Tasks)				**$751,032**	

*Analysis activity funded through a different task order.

Chapter 9. Risks and Uncertainties

This chapter discusses key risks and uncertainties that may impact the evaluation effort.

Inconclusive Safety Benefits

Volpe is conducting an analysis of the potential safety benefits using the data provided by the sites (*15*). Like TTI, Volpe's approach is to extract as much value as possible from site-generated data sources, including vehicle performance data and infrastructure data. The specific performance metrics that Volpe plans to use to assess potential safety benefits associated with the Wyoming CVPD include the following:

- Change in driving speeds (both absolute vehicle speeds and speed differential between vehicles).
- Change in total crash rates and number of equipped vehicles involved in a crash.

Volpe identified the following challenges associated with conducting the safety evaluation of the Wyoming deployment:

- Because the deployment does not include a control group (i.e., vehicle operating in a silent mode), no data will exist to permit a direct comparison of driver behavior with and without safety application warnings.
- Since most of the alerts produced by the applications are advisory in nature, an analysis of conflicts, a surrogate measure for crashes, will be possible. Volpe will need to rely on analyses of actual observed crashes to determine safety impacts. With relatively low market penetration rates and a short post-deployment period, it is possible that changes in actual crashes may not be observed.
- Some of the scenarios being addressed by the safety applications (e.g., adverse weather conditions) are already being addressed via other communication modalities (e.g., variable message signs and speed limits, cellular-based applications). The presence of these applications will make it difficult for the Volpe team to determine the incremental benefits achieved through the deployment of the CV technologies.
- Because the evaluation period spans multiple years, year-to-year differences in conditions could potentially mask the safety impacts of the applications.

Lack of Continuous Data along I-80

Radar speed sensors are spaced approximately 6–7 miles apart in the VSL sections of the I-80 corridor. These speed sensors are located along with the VSL signs and RWIS sensors to take advantage of the power and communication infrastructure available at these sites. Vehicle speeds between VSL signs are unknown. To accurately capture speed variations within the corridor and enhance the efficacy of the VSL application, alternative speed data collection techniques should be investigated to supplement the data, such as NPMRDS, especially since the market penetration of connected trucks will be limited during the pilot deployment period.

Additional equipment and devices may be needed to supplement the data available from the site. Some options for data collection equipment and devices include:

- Procuring portable speed sensing trailers and installing them at various locations within the VSL corridor to obtain additional sensing data, such as vehicle speed or weather data.
- Procuring and installing Bluetooth® readers to estimate travel times and speeds.
- Purchasing global positioning system or after-market safety devices and outfitting vehicles with these devices to collect vehicle speed data.

Incident detection time (i.e., the time when a distress message sent by a truck is received by the center) is not currently available from the deployer. The Wyoming CVPD Team should explore acquisition of this information if possible. In the absence of this information, an alternative is to interview connected truck drivers, fleet managers, TMC operators, and highway patrol personnel to determine if there is a perceived reduction in the incident response time. In this case, of course, the accuracy of this measurement will be reduced.

Institutional Issues

While good cooperation and buy-in from partners can bolster the success of this type of project, institutional challenges can hamper the success. Institutional challenges can occur both within the primary agency and with the partner agencies. Often, institutional issues stem from a lack of buy-in or opposition to the project by participants for various reasons. Institutional issues can also present themselves in the form of agency processes or policies that inhibit the project implementation. There is no single solution to institutional issues; they can be complex. As with any technology project, the Wyoming CVPD Team should take steps to address institutional challenges when they become evident. Future project tasks will address institutional issues in more detail.

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Appendix. Initial Value/Risk Assessment Scores

This appendix provides the justifications for the scores that the TTI CVPD Evaluation team assigned to assess the value and risks for each major work activity proposed in the independent evaluation. The scores are intended to provide an initial weighting to the analysis and may change as work progresses in Phase II of the independent evaluation.

110—Mobility—Travel Reliability—Travel Times

Directly related to hypothesis #1: Assess the extent to which deploying CV technologies improved mobility, travel reliability, and throughput in the I-80 corridor during adverse weather conditions.

Value	*Score: 5*
Nature:	Quantitative assessment.
Observability:	Assessments based on observed data for the most part.
Scope:	Comprehensive assessment—covers most of the entire project.
Extensibility:	Goal is to be generalized to determine if these applications should be broadly applied.

Risk	*Score: 2*
Traffic Data	Low risk since agencies are likely to have good traffic data (speed, travel time, throughput, queue, delay).

120—Mobility—Travel Reliability—Travel Time Reliability

Directly related to hypothesis #1: Assess the extent to which deploying CV technologies improved mobility, travel reliability, and throughput in the I-80 corridor during adverse weather conditions.

Value	*Score: 5*
Nature:	Quantitative assessment.
Observability:	Assessments based on observed data for the most part.
Scope:	Comprehensive assessment - covers most of the entire project.
Extensibility:	Goal is to be generalized to determine if these applications should be broadly applied.

Risk	*Score: 2*
Traffic Data	Low risk since agencies are likely to have good traffic data (speed, travel time, throughput, queue, delay).

130—Mobility—Travel Reliability—Throughput

Directly related to hypothesis #1: Assess the extent to which deploying CV technologies improved mobility, travel reliability, and throughput in the I-80 corridor during adverse weather conditions.

Value	*Score: 5*
Nature:	Quantitative assessment.

Observability: Assessments based on observed data for the most part.
Scope: Comprehensive assessment—covers most of the entire project.
Extensibility: Goal is to be generalized to determine if these applications should be broadly applied.

Risk *Score: 2*
Traffic Data Low risk since agencies are likely to have good traffic data (speed, travel time, throughput, queue, delay).

210—Observed Analysis—Weather Crash Data

Directly related to hypothesis: #2: Estimate the extent to which reductions in crash frequency and severities contributed to improvements in mobility and travel reliability along the I-80 corridor as a result of equipping commercial fleet vehicles and WYDOT maintenance vehicles with CV technologies.

Value *Score: 4*
Nature: Quantitative assessment.
Observability: Assessments based on observed data for the most part.
Scope: Comprehensive assessment - covers most of the entire project.
Extensibility: Goal is to be generalized to determine if these applications should be broadly applied.

Risk *Score: 2*
Traffic Data Limited data, but data should be good if sufficient CV present throughout duration of weather event.

310—Observed Analysis—Freight Reliability

Directly related to hypothesis: #3: Estimate the extent to which deploying CV technologies improved travel and freight reliability for commercial fleet vehicles equipped with CV technologies.

Value *Score: 5*
Nature: Quantitative assessment.
Observability: Assessments based on observed data for the most part.
Scope: Comprehensive assessment—covers most of the entire project.
Extensibility: Goal is to be generalized to determine if these applications should be broadly applied.

Risk *Score: 4*
Traffic Data Moderately high-risk data will not be available for site.

400—AMS of Mobility Improvements

Directly related to hypothesis: #1: Assess the extent to which deploying CV technologies improved mobility, travel reliability, and throughput in the I-80 corridor during adverse weather conditions., hypothesis #2: Estimate the extent to which reductions in crash frequency and severities contributed to improvements in mobility and travel reliability along the I-80 corridor as a result of equipping commercial fleet vehicles and WYDOT maintenance vehicles with CV technologies; and hypothesis #3: Estimate the extent to which deploying CV technologies improved travel and freight reliability for commercial fleet vehicles equipped with CV technologies.

Value *Score: 4*

Nature:	Quantitative assessment but based on simulation.
Observability:	Assessments based on simulated and predicted data.
Scope:	Comprehensive assessment - covers most of the entire project.
Extensibility:	Goal is to be generalized to determine if these applications should be broadly applied.

Risk *Score: 3*

Traffic Data:	Low risk since agencies should have excellent current traffic data (speed, travel time, throughput, queue, delay)
Location Data:	Medium risk since simulation calibration is needed, which would rely on knowing the location of the CVs.
Calibration Data:	Medium risk since CV location data may not be correlated to traffic data locations due to obfuscation.

500—AMS of Different Market Penetration Rates

Directly related to hypothesis #8: Estimate the extent to which the life-cycle mobility, environmental, and public agency efficiencies benefit as market penetration and background traffic changes over the seven years after deployment.

Value *Score: 2*

Nature:	Quantitative assessment but based on simulation.
Observability:	Assessments based on simulated and predicted data.
Scope:	Comprehensive assessment.
Extensibility:	Unknown.

Risk *Score: 4*

Traffic Data	Low risk since agencies should have excellent current traffic data (speed, travel time, throughput, queue, delay).
Location Data	Medium risk since simulation calibration is needed, which would rely on knowing the location of the CVs.
Calibration Data	Medium risk since CV location data may not be correlated to traffic data locations due to obfuscation.

610—Environmental Analysis of Project as Delivered

Directly related to hypothesis #7: Estimate the extent to which improved mobility for connected trucks and for all traffic will reduce negative environmental impacts along I-80 during adverse weather.

Value *Score: 2*

Nature:	Quantitative assessment.
Observability:	Assessments based on combination of observed and simulated data for the most part; significant congestion already exists.
Scope:	Likely to be small percentage of vehicles.
Extensibility:	Because of where applications are to be deployed, may not be representative of other locations.

Risk *Score: 2*

Fleet Data	Medium risk since agencies should have reasonable fleet data (vehicle type distribution, vehicle age, etc.)
Mobility Data	Will be the same as the risk associated with each input (travel time, crashes, emissions, etc.)

620—Environmental Analysis at Different Market Penetration Rates

Directly related to hypothesis #7: Estimate the extent to which improved mobility for connected trucks and for all traffic will reduce negative environmental impacts along I-80 during adverse weather.

Value *Score: 3*

Nature:	Quantitative assessment.
Observability:	Assessments based on simulated and predicted data.
Scope:	Comprehensive assessment.
Extensibility:	Only applicable to Wyoming deployment.

Risk *Score: 3*

Fleet Data	Medium risk since agencies should have reasonable fleet data (vehicle type distribution, vehicle age, etc.).
Mobility Data	Will be the same as the risk associated with each input (travel time, crashes, emissions, etc.).

710—Public Agency Efficiency Analysis of Project as Delivered

Directly related to hypothesis #4: Quantify the extent to which CV technologies helped improve emergency management on the I-80 corridor through early identification of conditions and improved messaging and communication.

Value *Score: 2*

Nature:	Qualitative assessment.
Observability:	Assessments based on observed data such as response times; quality of data suspect, though.
Scope:	Comprehensive assessment - unknown coverage area, coverage area may not be representative
Extensibility:	Only applicable to Wyoming deployment.

Risk *Score: 4*

Observed Data	Sites may not have level of data needed to support assessment
Observed Data	High likelihood the data not collected by sites; agency responses and associated event conditions not collection.

720—Public Agency Efficiency Analysis of Project as Delivered (Stakeholder Perspective

Directly related to hypothesis #6: Assess the extent to which deploying CV technologies in the I-80 corridor helps public agency officials to better manage operations and deploy traffic management strategies.

Value *Score: 3*

Nature:	Qualitative assessment based on logs data (reductions in detection times, changes in response times, etc.).
Observability:	Assessments based on survey data for the most par.t
Scope:	Comprehensive assessment—covers most of the entire project.
Extensibility:	Goal is to be generalized to determine if these applications should be broadly applied.

Risk *Score: 1*

Survey Data	Low risk since survey data should be easily collected from site agency participants.

810—Benefit Cost Analysis of Project as Delivered

Directly related to hypothesis #9: Conduct a benefit-cost assessment associated with equipping commercial fleet vehicles with CV technologies in the I-80 corridor.

Value		*Score: 4*
Nature:	Quantitative assessment.	
Observability:	Assessments based on combination of observed data for the most part, augmented by simulation data.	
Scope:	Comprehensive assessment—covers most of the entire project.	
Extensibility:	Goal is to be generalized to determine if these applications should be broadly applied.	

Risk		*Score: 2*
Cost Data	Low risk since agencies should have excellent current costs and reasonable predictions of future costs.	
Benefit Data	Will be the same as the risk associated with each input (travel time, crashes, emissions, etc.)	

820—Benefit Cost Analysis at Different Market Penetration Rates

Directly related to hypothesis #9: Conduct a benefit-cost assessment associated with equipping commercial fleet vehicles with CV technologies in the I-80 corridor.

Value		*Score: 2*
Nature:	Quantitative assessment	
Observability:	Assessments based on simulated and predicted data	
Scope:	Comprehensive assessment - covers most of the entire project	
Extensibility:	Goal is to be generalized to determine if these applications should be broadly applied	

Risk		*Score: 4*
Cost Data	Medium risk as agencies should have excellent current costs and reasonable predictions of future costs and costs for more/less penetration	
Benefit Data	Will be similar as the risk associated with each input (travel time, crashes, emissions, etc.) but even higher since these are predictions for CV penetration rates that do not exist	

1010—End User Satisfaction Analysis (Mobility)

Directly related to hypothesis #3: Estimate the extent to which deploying CV technologies improved travel and freight reliability for commercial fleet vehicles equipped with CV technologies.

Value		*Score: 3*
Nature:	Qualitative assessment.	
Observability:	Assessments based on survey data for the most part.	
Scope:	Comprehensive assessment—covers most of the entire project.	
Extensibility:	Goal is to be generalized to determine if these applications should be broadly applied.	

Risk		*Score: 2*
Survey Data	Medium risk since survey data may not be easily collected from all public participants or may be reported by fleet managers rather than individual drivers.	

Observed Data	Medium risk associated with the reliability and thoroughness of reported agency responses and associated event conditions

1020—End User Satisfaction Analysis (Technology)

Directly related to hypothesis #5: Assess the extent to which improved traveler information on road weather conditions and construction activities in the corridor improved freight drivers' ability to better plan and adjust their trips (e.g., locate truck parking along the corridor).

Value *Score: 2*

Nature:	Qualitative assessment.
Observability:	Assessments based on survey data for the most part. Deployment limited to audible alerts only.
Scope:	Comprehensive assessment—covers most of the entire project.
Extensibility:	Goal is to be generalized to determine if these applications should be broadly applied. Deployment limited to audible alerts only.

Risk *Score: 4*

Survey Data	Medium risk since survey data may not be easily collected from all public participants or may be reported by fleet managers rather than individual drivers
Observed Data	Medium risk associated with the reliability and thoroughness of reported agency responses and associated event conditions

1210—Lesson Learned

Value is assessed based on task relationship to hypotheses—important to capture for other deployments.

Value *Score: 5*

Nature:	Qualitative assessment.
Observability:	Assessments based on survey data for the most part.
Scope:	Comprehensive assessment—covers most of the entire project.
Extensibility:	Goal is to be generalized to determine if these applications should be broadly applied.

Risk *Score: 1*

Survey Data	Low risk since survey data easily collected from all public participants.
Observed Data	Not applicable

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