Connected Vehicle Pilot Deployment Program Independent Evaluation:

Data Plan—Wyoming

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16. Abstract

This report describes the data management plan that the TTI Connected Vehicle Pilot Deployment (CVPD) Evaluation Team, as the Independent Evaluator, plans to follow in conducting its evaluation of the Wyoming CVPD. This plan describes the data that the TTI CVPD Evaluation Team plans to use to identify operational scenarios to be examined in the analysis, conduct the mobility, environmental, and public agency efficiency (MEP) evaluation, and calibrate the simulation models used in the analysis. The plan also provides the approach that the TTI CVPD Evaluation Team plans to use to maintain privacy in the data it collects. The plan also highlights the step that the TTI CVPD Evaluation Team is using to maintain the quality of the data it collects. This plan also describes how the TTI CVPD Evaluation Team use and upload data to the Security Data Commons.

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Chapter 1. Introduction

Wyoming Department of Transportation (WYDOT) is one of the first waves of connected vehicle (CV) pilot sites selected to showcase the value of and spur the adoption of CV technology in the United States. As one of the three selected pilots, WYDOT is focusing on improving safety and mobility by creating new ways to communicate road and travel information to commercial truck drivers and fleet managers along the 402 miles of Interstate 80 (I-80) in the state. For the pilot project, WYDOT worked on the planning phase through September 2017. The deployment process followed in the second phase (ending in September 2018) followed by an 18-month demonstration period in the third phase (starting in October 2018).

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

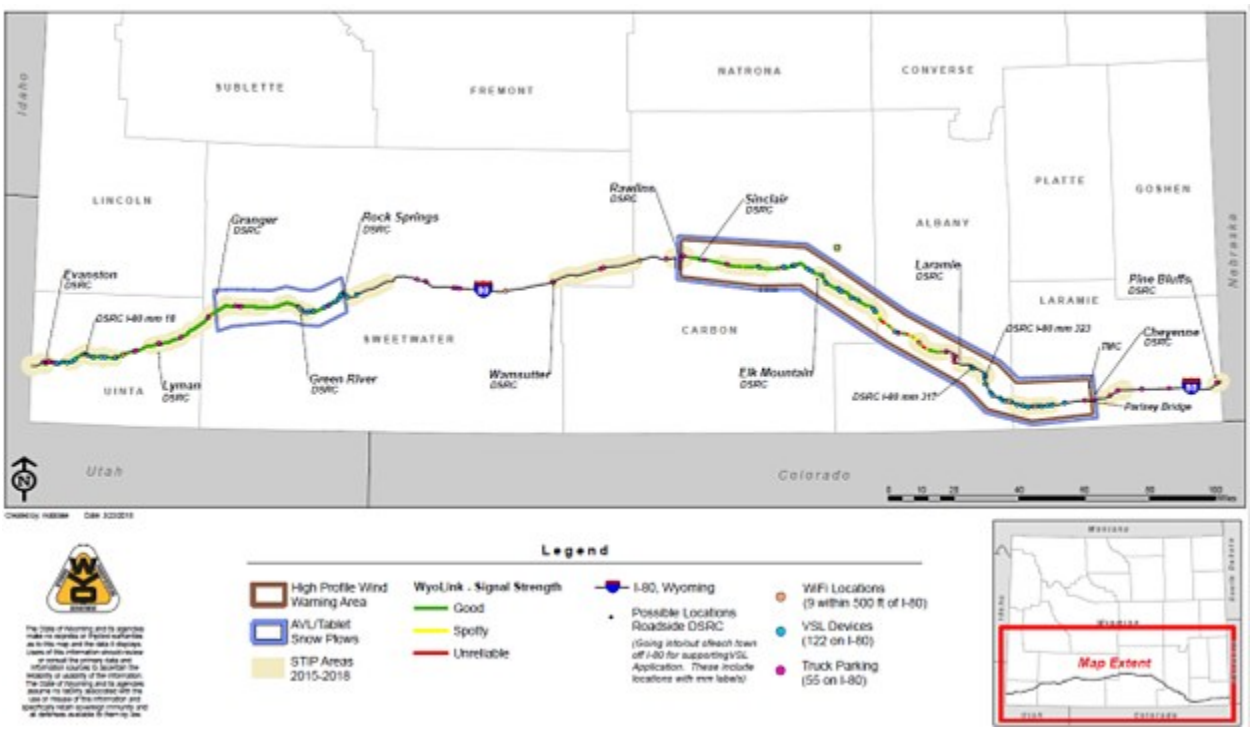
Wyoming Connected Vehicle Pilot Deployment

The goal of the Wyoming Connected Vehicle Pilot Deployment (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 (V2V) communications, this application alerts drivers if a rear end crash is imminent with a CV ahead.
- **Infrastructure-to-Vehicle 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 infrastructure-to-vehicle Situational Awareness application to provide information to vehicles approaching work zones. The approaching CVs 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 other 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 (DSRC). WYDOT is installing these RSUs at locations upstream of identified hotspot areas. Through their collaboration partners, WYDOT is also equipping 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 has additional capabilities to collect and transmit environmental and road weather conditions information through mobile weather sensors (*1*). Figure 1 shows the deployment corridor.



Source: CV Pilot Deployment Program: Wyoming Website

Figure 1. Wyoming CVPD Deployment Area.

The overall vision of the WYDOT 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 locations of 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.

Objectives of Independent Evaluation of Wyoming CVPD

The goals of the Texas A&M Transportation Institute (TTI) Connected Vehicle Pilot Deployment (CVPD) Evaluation Team are to answer the following evaluations questions:

- To what extent did the CVPD improve **mobility** in the study area?
- To what extent did the CVPD improve **air quality** along the deployment corridors?
- What are the **projected** mobility and air quality **benefits** expected over the next seven years in the study area for future traffic and different market penetration rates of CVs and RSUs?

While the TTI CVPD Evaluation Team is estimating the mobility impacts of reducing vehicle crashes, the TTI CVPD 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 CVPD Evaluation Team is using the results of the safety benefits analysis in the benefit-cost assessment.

As defined in the *Connected Vehicle Pilot Deployment Program Independent Evaluation: Mobility, Environmental, and Public Agency Efficiency Refined Evaluation Plan: Wyoming* (*4*), the specific objectives of the independent evaluation for the Wyoming CVPD evaluation are as follows:

1. Assess the extent to which deploying CV technologies improved mobility, travel reliability, and throughput in the I-80 corridor during adverse weather conditions.
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 because of equipping commercial fleet vehicles and WYDOT maintenance vehicles with CV technologies.
3. Estimate the extent to which deploying CV technologies improved travel and freight reliability for commercial fleet vehicles equipped with CV technologies.
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.
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 locations along the corridor).

6. Assess the extent to which deploying CV technologies in the I-80 corridor helps public agencies officials to manage operations better and deploy traffic management strategies.
7. Estimate the extent to which improved mobility for connected trucks and all traffic reduces negative environmental impacts along I-80 during adverse weather.
8. Estimate that extent to which the life-cycle mobility, environmental, and public agency efficiencies benefits as market penetration and background traffic changes over the seven years after deployment.
9. Conduct a benefit-cost assessment associated with equipping commercial fleet vehicles with CV technologies in the I-80 corridor.

Organization of Report

The remainder of this report contains the following four chapters. The titles of each chapter and the major topics contained therein are highlighted below:

- **Chapter 2. Data Collection Plan**—this chapter outlines the data collection plan to conduct the mobility and environmental assessments of the CVPD for the Wyoming site.
- **Chapter 3. Data Privacy Plan**—the chapter outlines the steps and procedures that the TTI CVPD Evaluation Team plans to implement to ensure and protect the privacy of the information used in the independent evaluation of the Wyoming CVPD.
- **Chapter 4. Data Quality Assurance/Quality Control Plan**—this chapter describes the manual and automated processes (including thresholds and criteria) for verifying data quality, cleaning data, and approach for addressing missing or unavailable data.
- **Chapter 5. Data Management Approach**—this chapter describes the processes and procedure that the TTI CVPD Evaluation Team plans to use to manage the data for the Wyoming CVPD evaluation.

Chapter 2. Data Collection Plan

This chapter identifies the primary data sources the TTI CVPD Evaluation Team plans on using for conducting an independent evaluation of the Wyoming CVPD. Through either their existing systems or system installed as part of this deployment, the site is collecting most of the data that the TTI CVPD Evaluation Team plans to use in the assessment. This includes both CV data logs and traditional traffic management system logic (such as Traffic Management Center Operator logs, variable speed limit operations logs). The section also describes the proposed methods of collection for these data and any supplementary data required to perform its analysis.

Table 1 summarizes the data that the TTI CVPD Team plans to use to conduct the independent evaluation of the mobility, environment, and public agency efficiency benefits of the Wyoming CVPD. The plans for conducting this analysis can be found in the following documents:

- *Connected Vehicle Pilot Deployment Program Independent Evaluation: Mobility, Environment, and Public Agency Efficiency Refined Evaluation Plan—Wyoming* (*4*).
- *Connected Vehicle Pilot Deployment Program Independent Evaluation: Analysis, Modeling, and Simulation Plan–Wyoming* (*12*).
- *Connected Vehicle Pilot Deployment Program Independent Evaluation: Stakeholder Acceptance Plan* (*13*).
- *Connected Vehicle Pilot Deployment Program Independent Evaluation: Wyoming Stakeholder Survey/Interview Guide* (*14*).

Data for Identifying Operational Scenarios

As specified in the *Traffic Analysis Toolbox, Volume III* (*9*), several key attributes that define the operational and travel conditions experienced impact traffic performance in a corridor. These attributes include the following:

- Traffic Demand.
- Weather.
- Incident.
- Traffic Operations and Management.

The following describes the sources of data that the TTI CVPD Evaluation Team plans to use to identify operational scenarios.

Table 1. Summary of Data Requirements for Independent Analysis of Wyoming CVPD

Data Type	Data Elements	Frequency	Aggregation	Source	Used in What Analysis	Gap
Mobility	• Date • Time • Segment ID • Avg Travel Time (min) • Speed • Buffer Time • Travel Time Index	5 min for the duration of the event	• 15 min • Variable Speed Limit (VSL) Segment • Vehicle Class	• TTI Access to National Performance Measures Research Data Sets (NPMRDS) • WYDOT I-80 Individual Speed Measurements	• Mobility Analysis • Analysis, Modeling, and Simulation (AMS) Model Calibration	No
Traffic Demand	• Date • Time • Station ID • Observation Count • Vehicle Classification	5 min for the duration of the event	• 15 min • VSL Segment • Vehicle Class	• WYDOT I-80 Individual Speed Measurements	• Mobility Analysis • AMS Model Calibration	No
Weather	• Date • Time • Air Temperature (°F) • Pavement Temp (°F) • Wind Speed (mph) • Maximum Wind Gust (mph) • Precipitation • Visibility (miles)	5 min	• 15 min • WYDOT VSL segments	• WYDOT Road Weather Information System (RWIS) Logs	• Mobility Analysis • AMS Model Calibration	No
Incident	• Date • Start and end time • Locations • Type and severity of the incident • Number of lanes impacted	Per Event	• WYDOT VSL segments	• WYDOT Incident Console Reports • WYDOT TRAC Data	• Mobility Analysis • AMS Model Calibration	No

Data Type	Data Elements	Frequency	Aggregation	Source	Used in What Analysis	Gap
Traffic Management Strategy Data	• Date • Start and end time • Locations • Type (Traveler Alert, Road Closure, Reduced speeds, and others) • Duration • Situation	Per Event	• WYDOT VSL segments	• WYDOT Variable Speed Limit Logs • WYDOT Dynamic Message Sign Logs • WYDOT Road Closure Logs	• Mobility Analysis • AMS Model Calibration	No
Public Agency Efficiency Impacts	• The number of messages sent from the Transportation Management Center (TMC) received by the RSU • The number of messages sent and received between the RSU and WYDOT fleet vehicles' OBU (when vehicles are near an RSU) • Connected vehicles that likely acted following receipt of an alert: o Parked o Reduced speed o Stopped safely o Exited • The number of operational changes made due to information from TMC during CV pilot: o Routing o Timing	• Pre-Deployment • Post-Deployment	• By Event Type	• WYDOT Pikalert alert and advisory log • 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	• Public Agency Efficiency	Maybe

Data Type	Data Elements	Frequency	Aggregation	Source	Used in What Analysis	Gap
	○ Parking availability ○ Canceled trips • The number of emergency notifications received first in the TMC from connected vehicles (compared to traditional methods, such as 911 caller)					
Vehicle Emissions	• Link volumes • Average link speeds • Vehicle mix • Operational scenario ○ Temperature ○ Humidity	• NA	• Per Operational Scenario	• TTI AMS Analysis • TTI Cluster Analysis	• Emissions Analysis	No
Safety Benefits	• Probability of Crash • Harm Reduction	• Pre-Deployment • Post-Deployment	• By Crash Type	• Volpe Safety Analysis	• Benefit/Cost Analysis	Maybe
CVO Driver Satisfaction	• Perception of Accuracy • Perception of Timeliness • Perception of Usefulness • Perception of Improved Mobility • Perception of Improved Safety	• Pre-Deployment • Post-Deployment	• NA	• WYDOT Driver User Survey	• User Satisfaction	No

Data Type	Data Elements	Frequency	Aggregation	Source	Used in What Analysis	Gap
CVO Fleet Satisfaction Survey	• Perception of Accuracy • Perception of Timeliness • Perception of Usefulness • Perception of Improved Mobility • Perception of Improved Safety	• Pre-Deployment • Post-Deployment	• NA	• WYDOT Fleet Operator Survey	• Stakeholder Acceptance	No
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	• Pre-Deployment • Post-Deployment	• NA	• TTI Stakeholder Interviews • TTI Post-Deployment Survey • TTI Post-Deployment Workshop	• Stakeholder Acceptance	No
Pre-Deployment (Phase I) Costs	• Planning/Concept Development Costs • Evaluation Planning Costs • Other Costs	• Pre-Deployment	• NA	• TTI Stakeholder Interviews	• Benefit/Costs Analysis	No

Deployment (Phase II) Costs	• Development Costs/One-Time Implementation Costs
	• Equipment Procurement Costs
	  ○ Vehicle
	  ○ Infrastructure
	• Installation Costs
	  ○ Vehicle
	  ○ Infrastructure
		• Post-Deployment	• NA	• TTI Stakeholder Interviews	• Benefit/Costs Analysis	No

Data Type	Data Elements	Frequency	Aggregation	Source	Used in What Analysis	Gap
	• Subject Recruitment • Evaluation • Other Costs					

O&M (Phase III) Costs	• Operations Costs
	• Maintenance/Repair
	• Equipment Replacement Costs
	  ○ Vehicle
	  ○ Infrastructure
	• Salvage
	  ○ Vehicle
	  ○ Infrastructure
	• Evaluation
	• Other Costs
		• Post - Deployment	• 1-year post-deployment
			• Estimated 6 years
				• TTI Stakeholder Interviews	• Benefit/Costs Analysis	Maybe

Traffic Demand

The impact of a traffic event or situation on mobility is highly dependent on the traffic demand. Typically, traffic demand data are available from sensors installed on the roadways to specifically to collect traffic volumes.

The WYDOT CVPD Team is not collecting traffic demand data. To estimate traffic demands for identifying operational scenarios, the TTI CVPD Evaluation Team plans to use data collected by the I-80 traffic sensors. WYDOT has installed radar-based sensors in specific sections of I-80 to support their variable speed limit system. According to WYDOT's Phase II Data Management plan, WYDOT is modifying the data stream from these sensors to provide speeds of individual vehicles. The new data stream provides the following data elements:

- Date.
- Time.
- Speed.
- Lane.
- Vehicle length.
- Vehicle classification.

The TTI CVPD Evaluation Team plans to aggregate these individual speed data in 15-minute bins. The TTI CVPD Evaluation Team plans to estimate traffic demands by counting the number of observations per bin for each vehicle classification for each interval. The TTI CVPD Evaluation Team plans to average demand estimates from multiple sensors to determine typical time-of-day traffic demand for each segment of I-80.

Weather Conditions

According to the Wyoming Phase II Data Management Plan (*6*), weather data from 41 WYDOT Road Weather Information Station (RWIS) are available in the Secure Data Commons (SDC). Weather information stored in the SDC include the following:

- Air temperature (°F).
- Pavement temperature (°F).
- Wind speed (mph).
- Maximum wind gust (mph).
- Precipitation.

- Visibility (miles).
- Road Surface Condition (Code).[1]

The Wyoming Phase II Data Management Plan (*6*) indicates that these data are uploaded to the SDC every 5 minutes. Table B-7 in *Final System Performance Report, Baseline Conditions – WYDOT CV Pilot* (*10*) lists the name and milepoint location of these stations. Table 2 shows the RWIS data available at each site.

The TTI CVPD Evaluation Team plans to assign data from each weather stations to an analysis segment based on their location. The TTI CVPD Evaluation Team plans to average data from multiple weather stations in the same roadway segment to obtain a representative condition for the evaluation interval. The TTI CVPD Evaluation Team plans to aggregate weather data into the 15-minute interval.

Table 2. Sample Process RWIS Data from Wyoming CVPD

Station_ ID	Date_Time_ Mountain	Relative_ Humidity_ set_1	Wind_ speed_set _1	road_ temp_set_1	Road_su rface_co ndition_ set_1	Visibility_ set_1
KCMS	11 30 2016 16:02	79	12.44	33.08	1	—
KCMS	11 30 2016 16:07	79	13.04	32.9	1	—
KCMS	11 30 2016 16:12	79	12.44	32.54	1	—
KCMS	11 30 2016 16:17	80	14.29	32.36	1	—
KCMS	11 30 2016 16:22	80	13.04	31.82	1	—
KCMS	11 30 2016 16:27	80	10.56	31.82	1	—
KCMS	11 30 2016 16:32	80	10.56	31.46	1	—
KCMS	11 30 2016 16:37	81	9.33	31.1	1	—
KCMS	11 30 2016 16:42	81	11.81	31.1	1	—
KCMS	11 30 2016 16:47	81	10.56	30.74	1	—
KCMS	11 30 2016 16:52	81	11.81	30.56	1	—
KCMS	11 30 2016 16:57	82	10.56	30.2	1	—
KCMS	11 30 2016 17:02	83	8.7	29.48	1	—

— = Not available

Source: *CVPD Program Phase 2, Final System Performance Report, Baseline Conditions —WYDOT CV Pilot*.

[1] Road Surface Condition is given on a scale of 0–10. Code 1 is ideal, dry conditions. Code 0, 9, and 10 are defaults for ideal conditions. Code 2 through Code 8 range from Damp to Black Ice conditions.

Incident Data

The Wyoming Phase II Data Management Plan (*6*) indicated that several sources of incident data are available to assist the TTI CVPD Evaluation Team in identifying operational scenarios. These sources include the following:

- Alerts and messages generated by WYDOT's Traveler Information Message system (secondary source).
- WYDOT's TRAC system, which includes reports for the highway patrol, operator action logs, and citizen reports (primary source).
- WYDOT incident console event information (primary source).

The TTI CVPD Evaluation Team plans to use these data sources to identify potential operational scenarios for evaluating the Wyoming CVPD. The TTI CVPD Evaluation Team plans to use the following information, if available, to help identify situations and circumstances that impact traffic operations on the I-80 corridor:

- Start and end time.
- Locations.
- Type and severity of the incident.
- Number of lanes impacted.

Traffic Operations and Management Data

According to the *Traffic Analysis Toolbox Volume III* (*9*), the types of traffic management strategies deployed during different operating conditions has the potential to change the operating characteristics of the roadway. Categories of traffic operations and management data include driver warning data, regulatory data, information (guidance) data, and surveillance detectors.

Variable Speed Limit Data

WYDOT operates 59 variable speed limit (VSL) signs in the following four sections of the I-80 corridor:

- Between Evanston and Three Sisters.
- Between Rock Springs and Green River.
- Along Elk Mountain.
- From Cheyenne to Laramie.

WYDOT uses these systems to reduce the speed limit on I-80 during different weather events, such as snowstorms, high wind events, and others. WYDOT collects and records the time when a VSL display is changed. These are uploaded daily to the SDC. Table 3 shows the structure of this data file.

Table 3. Content of the WYDOT Variable Speed Limit Data File

Data Field	Description	Units	Notes
DEVICEID	The individual ID of the sign	Unique three- or four-digit number	—
ROUTE	The road on which the signs are installed	N/A	All signs are located on I-80 corridor
FROM_RM	Starting milepost	Miles	—
TO_RM	Ending milepost	Miles	—
DISPLAY_NAME	Describes placement of signs based on geography	N/A	—
LAT_DECIMAL	Latitude location of the sign	N/A	Some sensors are not located precisely at these coordinates but are approximately within a quarter mile of the coordinates.
LONG_DECIMAL	Longitude locations of sign	N/A	Some sensors are not located precisely at these coordinates but are approximately within a quarter mile of the coordinates.
DIRECTION	The direction the sign is facing	N/A	D: decreasing milepost I: increasing milepost
DEFAULT_SPEED	Unadjusted speed limit	MPH	—
BLANK	—	—	—
VSL_MPH	Current speed limit	MPH	—
UPDATED	Time and date of data reading	MDY with military time	Data are collected every 5 minutes.
MILEPOST	Location of the sensor	Miles	—

— indicates no data

Source: *CVPD Program Phase 2, Final System Performance Report, Baseline Conditions —WYDOT CV Pilot*.

Dynamic Message Sign Data

WYDOT operates 40 dynamic message signs (DMS) along the I-80 corridor. WYDOT uses these signs to provide warnings and alerts about travel conditions in the corridor. WYDOT logs the time and content of the information displayed on each sign. The TTI CVPD Evaluation Team can use the DMS logs as a secondary source of information to confirm condition information broadcast to the drivers. The system produces a new log entry each time WYDOT updates a message on the DMS. Like the VSL speed logs, the DMS logs are output monthly. Table 4 shows the content of this data file.

Table 4. Content of WYDOT's Dynamic Message Sign Logs

Data Field	Description	Units	Notes
DEVICEID	The individual ID of the sign	A unique two- to four-digit number	—
ROUTE	Road the signs are installed on	N/A	All signs are located on I-80 corridor
DISPLAY_NAME	Describes placement of signs based on geography	N/A	—
LAT_DECIMAL	The latitude of the sign	N/A	—
LONG_DECIMAL	The longitude of the sign	N/A	—
DIRECTION	The direction the sign is facing	N/A	D: decreasing milepost I: increasing milepost
BLANK	—	—	Field not used
SIGN_TEXT	The text of the sign message	N/A	—
UPDATED	Time and date of data reading	MDY with military time	—
MILEPOST	Location of the Sign	Miles	—

— indicates no data.

Source: *CVPD Program Phase 2, Final System Performance Report, Baseline Conditions —WYDOT CV Pilot*.

Road Closure Data

WYDOT uses a series of gates to closure the segments of I-80 during severe weather events. WYDOT has located these gates generally at the edges for urban areas so when I-80 is closed, it generally affects a range of mileposts for a given direction of travel. Appendix A lists the segments between road closure gates.

According to the Wyoming Phase II Data Management Plan (*6*), the WYDOT CVPD team is providing road closure data. WYDOT describes a closure event by the date and time the closure was added, removed, or updated, the direction of the closure, and the reason for the closure. Table 5 provides a sample of the data contained in this database. NOTE: WYDOT records road closure data by road segment, reporting section, and milepoint. The data shown in Table 5 are from I-80 between the Utah State Line and Rock Springs, between Evanston and Exit 18/US 189, mileposts 6.26–18.29.

Table 5. Sample of Unprocessed WYDOT Road Closure Data

Date/Time	Closure Status	Closure Direction	Closure Reason
10/17/16 06:18	Added	Eastbound	Winter conditions
10/17/16 09:26	Removed	—	—
11/23/2016 19:20	Added	Eastbound	Winter conditions
11/23/2016 19:52	Updated	Both	Winter conditions
11/24/2016 19:52	Updated	Eastbound	Winter conditions
112/05/2016 05:07	Added	Both	Winter conditions
12/05/2016 07:49	Removed	—	—
12/10/2016 19:34	Added	Eastbound	Crash
12/10/2016 19:38	Updated	Both	Crash
12/11/2016 03:46	Removed	—	—

— indicates no data.

Source: *CVPD Program Phase 2, Final System Performance Report, Baseline Conditions —WYDOT CV Pilot*.

Work Zone/Construction Data

WYDOT maintains a database of the active construction projects on I-80. The database contains two tables: one that contains project information and another containing specific lane closures. These files can be used to identify lane closure events likely to impact traffic operations on I-80 (*10*). As specified in the *Wyoming Phase II Data Management Plan (6)*, these data include the following:

- Start time.
- End time.
- Location.
- Type of construction.

Data are uploaded to the SDC on a continuous basis and should be available for both pre- and post-deployment analysis periods.

Data for MEP Performance Measurement and Evaluation

This section identifies the type, quantity, and quality of data that needs to be collected to estimate the MEP-related performance measures.

Mobility

The TTI CVPD Evaluation Team plans to use data from the National Performance Management Research Data Set (NPMRDS) (*11*) as the primary source of mobility data. The NPMRDS is a data portal procured by FHWA to assist state and local governments with performance measures. The NPMRDS has 5-minute

speed and travel time data sets for over 400,000 road segments, including I-80 in Wyoming. The data are stored in three separate databases: one for passenger cars only, one for trucks only, and one for a combination of trucks and passenger cars. These data sets contain the following data elements:

- Speed — Speed is recorded in mph as an integer. The harmonic average speed for all reporting vehicles on the segment.
- Average speed — the historical average speed. Historical average speeds are calculated by the Center for Advanced Transportation Technology Laboratory (CATT LAB) by taking the harmonic average of speeds on each segment for each hour of the day and each day of the week. For data from beyond February 1, 2017, the average speed is calculated from February 1, 2017, to June 30, 2017. For data before February 1, 2017, the average is calculated using the 12-month period preceding November 2014.
- Reference speed — an approximation of free-flow speed for the segment. This value is calculated by the CATT Lab using the 95th percentile of the speeds between 10 PM and 5 AM. The reference speed is calculated over a 6-month period starting April 1, 2017–September 30, 2017.
- Travel Time — travel time recorded in minutes or seconds. It is the ratio between the segment length and the harmonic average speed for all reporting vehicles on the segment.
- Data Density — refers to one of three values:
  - A: Fewer than five values.
  - B: Five to nine values.
  - C: More than nine values.

Using the raw speed measurement data, the NPMRDS calculates the following metrics as defined from the *Travel Time Reliability* publication provided by the Federal Highway Administration and produced by the TTI with Cambridge Systematics, Inc.:

- Comparative Speed — measured speed as a percentage of the historical average speed for this time of day and day of the week.
- Congestion — measured speed as a percentage of the free flow speed.
- Historic Average Congestion — historic average speed as a percentage of the free flow speed for this time of day and day of the week.
- Buffer Time — the extra time (or time cushion) that travelers must add to their average travel time when planning trips to ensure on-time arrival (95 percent Travel Time − Average Travel Time).
- Buffer Index — the Buffer Time's percentage value of the Average Travel Time ((95 percentile Travel Time − Average Travel Time) / Average Travel Time). Its value increase as reliability worsens. For example, a buffer index of 0.4 (40 percent) means that a traveler should budget an additional 8 minutes in a 20-minute trip (20 minutes × 40 percent = 8 minutes) to ensure on-time arrival most of the time.
- Planning Time — the total time a traveler should plan to ensure on-time arrival (95 percent Travel Time).

- Planning Time Index — the total travel time that should be planned when an adequate buffer time is included (95 percent Travel Time / Free-flow Travel Time). The planning time index differs from the buffer index because it includes typical delay and unexpected delay. Thus, the planning time index compares near-worst case travel time to the travel time in light or free-flow traffic. For example, a planning time index of 1.60 means that, for a 15-minute trip in light traffic, the total time that should be planned for the trip is 24 minutes (15 minutes × 1.60 = 24 minutes).
- Travel Time Index — Travel time represented as a percentage of the ideal travel time (Travel Time / Free-flow Travel Time).

The NPMDS use the traffic message channels (TMC) standard to identify each road segment uniquely. Under this standard, a unique 9-digit code identifies each road segment. As shown in Figure 2, TMCs span a stretch of road from one exit or entrance ramp to the next. The fourth character in the code signifies whether the segment is an internal or external segment. Internal segments represent stretches of roadways within an interchange, while external segments represent stretches of roadways between interchanges. The typical convention for identifying the direction of travel for the TMC and whether the segment is an internal or external segment is as follows:

- "P" is used to indicate a northbound or eastbound internal link.
- "N" is used to indicate a southbound or westbound internal link.
- "+" is used to indicate a northbound or eastbound external link.
- "−" is used to indicate a southbound or westbound external link.

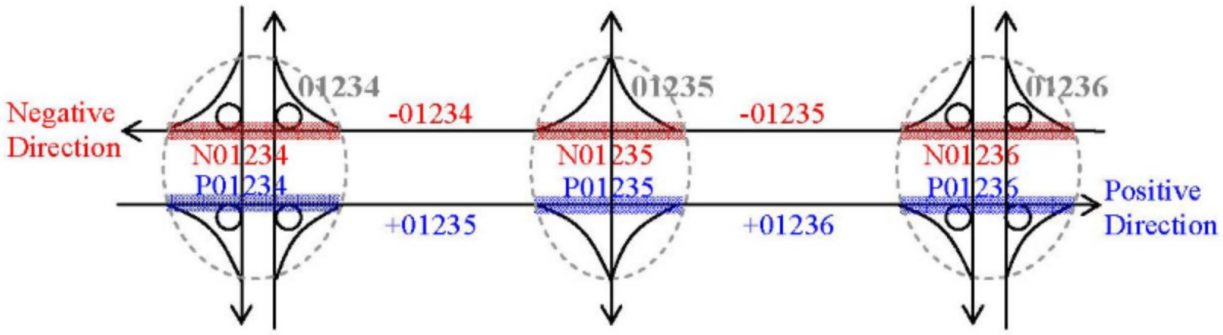


Figure 2. Nomenclature for Identifying Roadways Segments in NPMDS

The TTI CVPD Evaluation Team plans to assign a TMC link to a VSL segment. The TTI CVPD Evaluation Team is extracting the 15-minute average travel times in both directions for the time periods of specific weather events in the corridor by TMC. The TTI CVPD Evaluation Team plans to produce segment travel times by summing the link travel times from all the TMCs associated with a VSL segment.

Vehicle Emissions

The evaluation of the environmental impacts of the CV applications requires the following data in addition to the data cited above for developing and calibrating the traffic simulation model. These data serve as input to the MOtor Vehicle Emissions Simulator (MOVES) model:

- The number, location, and length of the links (obtained from the simulation model(s)).
- Link road types: urban versus rural; restricted versus unrestricted; running versus hoteling obtained by the TTI CVPD Evaluation Team from an examination of the site).
- Link volumes: the total number of vehicles per hour on each link (obtained from the output of the simulation model).
- Link average speed: speeds of vehicles on links (obtained from the output of the simulation model).
- Average grade of each link (obtained by the TTI CVPD Evaluation Team from an examination of the site).
- Vehicle mix in the study area by buses, motorcycles, light-duty vehicles, single-axle trucks, combination trucks. The TTI CVPD Evaluation Team is requesting the site provide these data. Failing that, the TTI CVPD Evaluation Team plans to select appropriate default values that would be representative of the site conditions.
- Age distribution of vehicles in the study area by vehicle type. The TTI CVPD Evaluation Team will request these data from the sites. Failing that, the TTI CVPD Evaluation Team plans to select appropriate default values that would be representative of the site conditions.
- Meteorological data on humidity and temperature (obtained from online historical records).

The TTI CVPD Evaluation Team is planning to 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.

To create customized scenarios for the Wyoming CVPD site, the TTI CVPD Evaluation Team plans to enter input parameters in the MOVES graphic user interface (GUI). The smallest unit of analysis in the MOVES model is a “link.” A link is an off-network location where a similar type of vehicle activity occurs. MOVES can model four separate conditions of hoteling loads:

- Extended idle.
- Auxiliary Power Units (APU).
- Battery power.
- Engine off.

Additionally, MOVES can model the number of engine starts (the more starts, the higher emissions all else equal) and the soak time with the engine off. The TTI CVPD Evaluation Team plans to work with the site to obtain the best values for the following input variables:

- Operating Mode Distribution (%)— the fraction of time long-haul trucks spends in each operating mode (e.g., APU, grid-supported).
- Vehicle population (#)—number of trucks in hoteling (i.e., stationary) mode.
- Start fraction (%)— the average fraction of the population that started during the hour.
- Road type of link (restricted/unrestricted rural/urban).
- The length of the link (miles).
- The volume of the link (vehicles/hour)—Output from the microsimulation model.
- The grade of the link (optional) (%)—grade of the link. Obtained from the site.
- Vehicle mix on the link (%)— the fraction of vehicle hours traveled for each vehicle/fuel combination. Fractions must sum to 1 for each link.

Public Agency Efficiency

Evaluating the effects on public agency efficiency will require logs from the TMC (pre- and post-deployment) to determine if the information is quickly disseminated to the connected vehicles or if the TMC can disseminate more accurate information to the public through existing systems based on data provided by CVs. The Wyoming Phase II Data Management Plan (*6*) lists the following as potential sources of public agency efficiency data sources:

- Pikalert alert and advisory log (including acceptance rate and time to operator acceptance).
- Log of the number of messages sent and received between TMC – RSUs – OBUs.
- Incident detection and response time log.
- Automated Emergency Notification log including number and time received and response time.

The TTI CVPD Evaluation Team is relying heavily on the data collected by the Wyoming CVPD Team in assessing the change in public agency efficiency due resulting from the deployment. The following lists some of the specific data elements that the TTI CVPD Evaluation Team plan to use:

- The number of messages sent from the TMC that are received by the RSU.
- The number of messages sent and received between the RSU and WYDOT fleet vehicles' OBU (when vehicles are near an RSU).
- CVs that likely acted following receipt of an alert:
  - Parked.
  - Reduced speed.
  - Stopped safely.
  - Exited.
- The number of operational changes made due to information from the TMC during the CV pilot:
  - Routing.
  - Timing.

  - Parking availability.
  - Canceled trips.
- The number of emergency notifications first received in the TMC from CVs (compared to traditional methods, such as 911 caller).

Safety Performance Estimates

The TTI CVPD Evaluation Team is not responsible for assessing, through either direct observations or simulation and modeling, the safety benefits associated with the different CV applications deployed by WYDOT. The Volpe Institute is responsible for conducting the safety assessment. However, the reduction in potential crashes and improved safety plays a critical part in the benefit-cost analysis (BCA). The TTI Evaluation Team is looking to Volpe to provide information related to the reduction of the probability of crashes or harm reduction factors. The TTI Evaluation Team plans to work with Volpe to estimate potential estimates of crash reductions that it can use in the BCA. The TTI CVPD Evaluation Team will coordinate this activity with the Volpe Team.

Data for Simulation Model Development and Calibration

The TTI CVPD Evaluation Team expects simulation and modeling to play a significant role in the Independent Evaluation. The following section describes that data that the TTI CVPD Evaluation Team require to verify the model development and to calibrate the model for the specific operational conditions.

Base Model Development

As discussed in the *Analysis, Modeling, and Simulation (AMS) Plan for Wyoming* (*12*), the TTI CVPD Evaluation expects the Wyoming CVPD Team to deliver a baseline model. The base model development encompasses all the data required to portray the existing roadway conditions accurately. The base model shall include the following:

- Model Network Geometry—the TTI CVPD Evaluation Team is assuming the Wyoming Deployment Team is coding the network geometry as part of their model development effort. The TTI CVPD Evaluation Team plans to verify the network geometry by comparing the representation of the network geometry in the model to online data sources, such as Google Earth or Google Maps. The TTI Evaluation Team will discuss any discrepancies with the Wyoming CVPD Team.
- Variable Speed Limit Control Algorithms— These are the control logic WYDOT uses to activate the weather-responsive variable speed limit system on I-80. The TTI CVPD Evaluation Team is assuming the model provided by the deployment already contains these algorithms. TTI plans to verify their operation while evaluating the model.
- Traffic Demands—the TTI CVPD Evaluation Team is assuming the Deployment Team is collecting traffic data at 15-minute intervals for use in their base model. To be able to verify the accuracy of the microsimulation model, the TTI CVPD Evaluation Team needs the basic traffic demand data that WYDOT have used the traffic volume counts obtained from WYDOT.
- Vehicle stock—the TTI CVPD Evaluation Team is assuming the Deployment Team is including the distribution of age and vehicle types, for both the CVs and non-CVs.

Calibration

Calibration refers to adjusting model parameters to represent the field conditions accurately compared to the operational conditions developed previously. This step encompasses both the local and system-wide performance. Data associated with calibration often include all operational condition data for a sample of historical events. As specified in the AMS Plan for Wyoming (*12*), the TTI CVPD Evaluation Team plans to use the following data to calibrate the simulation model to the operational scenarios:

- Traffic demands—15-minute turning movement counts for freeway segments.
- Road weather conditions—Hourly rate of rainfall and snowfall, hourly miles of visibility for fog conditions, and hourly pavement temperature to indicate icy road surface conditions.
- Crashes and work zones—Milepost location and direction, start time, end time, number of lanes blocked each 15-minute period over the duration of the incident.
- Special events (if applicable)—Venue, attendance, start time, end time, hourly arrival, and departure volumes over the duration of the event, any special lane and signal controls before, during, or after the event. In this corridor, special events also include construction events and incidents.
- Travel Times—15-minute travel times through for the modeled section of I-80.

The TTI CVPD Evaluation Team would like to use 365 days of data. At a minimum, we can work with 100 days of data to be able to predict to the nearest 1 percent the probability of a combination of demand, weather, and crash events occurring for the site in the future. For Wyoming, 100 days minimum is essential, because the winter weather may last only about 100 days, not 365 days. The TTI CVPD Evaluation Team plans to aggregate the data to 15-minute intervals. The TTI CVPD Evaluation Team plans to use data from both pre- and post-deployment conditions.

Stakeholder Evaluation and Survey Data

Stakeholder acceptance and survey data are significant data elements that the TTI CVPD Evaluation Team is responsible for collecting and digitizing. These data are qualitative and need to be coded with numerical values to provide a foundation for objective analysis.

As referenced in the CVPD Stakeholder Evaluation Plan (*13*), the TTI CVPD Evaluation Team plans to use different data collection methods to collect acceptance/satisfaction information from the stakeholder types due to varying roles in the CV pilots:

- The TTI CVPD Evaluation Team plans to conduct qualitative interviews in the form of one-on-one, dyads, or triads with deployment managers, deployment team members, operating agencies, and policymakers. TTI plans to interview deployment managers, deployment team members, and operating agencies because these stakeholders are the most invested and involved in the pilots and will be able to provide productive feedback. TTI also plans to interview policymakers as well, given their status and potential influence on long-term sustainability. TTI plans to conduct these interviews at three points in time: 1) immediately after the planning/design stage (i.e., pre-deployment), 2) shortly after activation (i.e., near-term post-deployment), and 3) toward the end of the deployments (i.e., long-term post-deployment). TTI plans to use the pre-deployment

interviews view and opinions on the vision, goals, and expectations of the deployment. Post-deployment interviews serve to capture information about deployment experiences, outcomes, and satisfaction.

- The TTI CVPD Evaluation Team plans to administer the post-deployment online survey (rather than in-depth interviews) to fleet operators and supporting agencies because they are less involved in day-to-day pilot planning and execution. The survey is intended to gather information on how well the pilot deployment program fulfilled these stakeholders' goals and objectives.
- TTI plans to hold site-specific post-deployment workshops after the interviews have been completed to foster additional dialog among deployment managers, deployment team members, and operating agencies. Workshops are intended to capture distinct information and foster cross-stakeholder dialog and discussion about challenges, solutions, and lessons learned. TTI also plans to use the workshops to confirm and clarify critical findings.

The specific questions that the TTI CVPD Evaluation Team plans to use in each of these can be found in the *Stakeholder and Interview Guide for Wyoming* (*14*).

Cost Data

To complete a BCA, the TTI CVPD Evaluation Team is asking the Wyoming CVPD Team to provide cost data related planning, implementation, and operation of the pilot. To the extent possible, the Wyoming CVPD Team is asked to provide cost information that is as comprehensive and disaggregate as possible. The types of cost data needed by the TTI CVPD Evaluation Team include the following:

- **Planning and design costs** — These costs include any costs associated with the planning and design of the CVPD deployment. These costs represent primarily Phase I costs. Examples of the types of costs included in the planning cost include the following:
  - The costs associated with doing the system engineering for the deployment. These costs include the cost of developing the concept of operations, detailed system requirements, and test plan development.
  - The costs associated with any proof-of-concept testing performed by the deployment team before procuring the equipment.
  - The costs associated with developing outreach and participant recruitment and training materials.
  - The preparation of the performance and evaluation test plan support.
  - Any other costs that the Wyoming CVPD Team might have incurred as part their Phase I activities not included above. The TTI CVPD Evaluation Team asks that the Wyoming CVPD Deployment Team list.

- **Deployment and Implementation Costs** — These costs include any costs associated with the physical deployment and integration of system needed to support the pilot deployment. These costs are primarily Phase II costs. Example of the types of costs include the following:
  - The costs associated with the development, testing, and integration of applications. If possible, the TTI CVPD Evaluation Team asks that the site disaggregate the costs by each

application. If that is not possible, then the TTI CVPD Evaluation Team requests that the Wyoming CVPD Team note all the applications included in each cost figure provided.

- The costs associated with procuring and installing the connected technology in the vehicles.
- The costs associated with procuring and installing the infrastructure devices and technologies (e.g., RSU stations, communications).
- The costs of recruiting and training of both private- and public-sector participants (including any incentives for maintaining participation in the pilot deployment).
- The costs associated with collecting and developing the baseline (pre-deployment) evaluation of the corridor.
- Any other one-time costs incurred by the deployment team. These costs may represent any costs incurred by the Wyoming CVPD Team as this is the first time for deploying the application. An example of this one-time costs might be the costs associated with development, testing, and evaluation of a first-time application where if another entity were to deploy the application, they would not incur these costs.

- **Actual Annual Operations and Maintenance Costs (Year 1 after Activation)** — These costs include any costs associated with operating and maintaining the deployment once it becomes live. These costs would include anything required to keep the system operational and in a good state of repair, including planned equipment replacement (both vehicle and infrastructure equipment), emergency repairs, recurring communications costs (i.e., cellular modems), and others. The site may combine operations and maintenance into one row. These would represent the costs incurred by the WYDOT and the other stakeholders during Phase III.
- **Estimated Annual Operations and Maintenance Cost (Years 2 through 7 after Activation)** — These would include the estimated costs associated with operating and maintaining the deployment in a state of good repair for Years 2 through 7. WYDOT should base these costs estimates on their Year 1 experiences.
- **Salvage Value** — This represents the estimated value of any equipment at the end of the Year 7 after activation of the CVPD. As the deployment is expected to become part of WYDOT's normal operations, the TTI CVPD Evaluation Teams does not expect salvage value; however, the Wyoming CVPD Team plans to remove or deactivate any application after the deployment period, it should provide salvage values, if any, for the removed technologies. If WYDOT envisions keeping the deployment active beyond Year 7, then no salvage value should be reported.

Table 6 provides a template that the Wyoming CVPD Team can use to collect and report cost information to the TTI CVPD Team. Table 7 shows a similar template that the Wyoming CVPD Team can use to report costs after the pilot has become operational. Note that the Wyoming CVPD Team needs to estimate operating and maintenance costs annually for 6 years behold the first year of operations.

Table 6. Template for Providing Planning and Deployment Costs Associated with Wyoming CVPD

Costs Category	Year 1 (Actual)	Year 2 (Actual)	Year 3 (Actual)
PHASE I – Planning and Design	**PHASE I – Planning and Design**	**PHASE I – Planning and Design**	**PHASE I – Planning and Design**
Planning/Concept Development Costs	—	—	—
Evaluation Planning Costs	—	—	—
Other Costs*	—	—	—
PHASE II – Deployment	**PHASE II – Deployment**	**PHASE II – Deployment**	**PHASE II – Deployment**
Vehicle Technology • Procurement • Installation	—	—	—
Infrastructure Technology • Procurement • Installation	—	—	—
Participant Recruitment and Training	—	—	—
Evaluation (Baseline)	—	—	—
Other Costs*	—	—	—

*Please specify. Please list multiple costs separately. — indicates empty cell to be filled in by user.

Table 7. Template for Providing Projecting Costs Associated with Wyoming CVPD

Costs Category	Year 1 (Actual)	Year 2 (Est.)	Year 3 (Est.)	Year 4 (Est.)	Year 5 (Est.)	Year 6 (Est.)	Year 7 (Est.)
PHASE III – Operations	**PHASE III – Operations**	**PHASE III – Operations**	**PHASE III – Operations**	**PHASE III – Operations**	**PHASE III – Operations**	**PHASE III – Operations**	**PHASE III – Operations**
Operations Costs*	—	—	—	—	—	—	—
Maintenance Costs	—	—	—	—	—	—	—
Equipment Replacement • Vehicle • Infrastructure	—	—	—	—	—	—	—
Evaluation (Post-Deployment)	—	—	—	—	—	—	—
Other Costs**	—	—	—	—	—	—	—
Decommissioning	**Decommissioning**	**Decommissioning**	**Decommissioning**	**Decommissioning**	**Decommissioning**	**Decommissioning**	**Decommissioning**
Salvage Value*** • Vehicle • Infrastructure	—	—	—	—	—	—	—

*WyDOT may combine operations and maintenance on one row.

**Please list multiple costs separately.

***Shown as a negative cost

Chapter 3. Data Privacy Plan

The chapter outlines the steps and procedures that the TTI CVPD Evaluation Team plans to implement to ensure and protect the privacy of the information used in the independent evaluation of the Wyoming CVPD.

Data Ownership

The TTI CVPD Evaluation Team has deemed that the United States Department of Transportation (USDOT) and WYDOT are the owners of that data uploaded by WYDOT into the SDC. The TTI CVPD Evaluation Team agrees to use the data provided by the Wyoming CVPD Team only for the purposes outlined in the *Connected Vehicle Pilot Deployment Program Independent Evaluation: Mobility, Environment and Public Agency Efficiency Refined Evaluation Plan—Wyoming* (*4*). The TTI CVPD Evaluation Team also agrees not to use or share the data in any manner that exceeds the parameters of the informed consent document. The TTI CVPD Evaluation Team plans to limit the access to the data only to authorized Team members.

Any data collected by the TTI CVPD Evaluation Team, including the simulation input file and result files, becomes the property of the USDOT once the project is complete. After removing any personally identifiable information (PII) from the data, the TTI CVPD Evaluation plans to upload any data files generated in the analysis to the SDC. The TTI CVPD Evaluation Team will reference and credit appropriately any data obtained from the NPMRDS.

The TTI CVPD Evaluation Team adhere to the policies and procedures of the Texas A&M University Institutional Review Board (IRB) for any data containing PII. The TTI CVPD Evaluation plans to prepare summaries of the interview and survey information. TTI plans to remove any identifiable information to any individual when preparing these summaries. TTI plans to secure any raw notes from the findings in a locked filing cabinet in the TTI offices. The TTI CVPD Evaluation Team plans to destroy any raw notes from the stakeholder interviews, surveys, and workshops after they have been summarized and uploaded to the SDC.

University of Wyoming also has an IRB that with whom the Wyoming CVPD team works. Coordination, and maybe approval, could be needed by the University of Wyoming IRB if sensitive or secure data are needed. The TTI CVPD Evaluation Team will work with the Wyoming CVPD team to ensure that sensitive data are not compromised.

Personally Identifiable Information

The PII and sensitive personally identifiable information (SPII) is paramount for the USDOT, the Wyoming CVPD Deployment Team, and the TTI CVPD Evaluation Team. PII refers to any information that can be used to distinguish or trace an individual's identity, such as their name, Social Security number, biometric

records, alone, or when combined with other personal or identifying information can be linked or linkable to a specific individual. SPII is a subset of PII and is sensitive in that, if lost, compromised, or disclosed without authorization, could result in substantial harm, embarrassment, inconvenience, or unfairness to an individual. Both the Wyoming CVPD Team and the TTI CVPD Evaluation Team have implemented policies and procedures for protecting and controlling PII and SPII information.

Removing PII from Collected by TTI Evaluation Team

The TTI CVPD Evaluation Team does not envision needing access to any PII or SPII obtained from the sites. The Wyoming CVPD Team plans to remove any PII and SPII before posting the data in the SDC.

The TTI CVPD Evaluation Team is responsible for accessing stakeholder acceptance and satisfaction information. The TTI CVPD Evaluation Team plans to collect this information through a series of interviews and surveys performed at different times during the operational phase (Phase III). The TTI CVPD Evaluation Team is required to post this information into the SDC. Before posting this information, the TTI CVPD Evaluation Team plans to remove any PII from the data. The information that TTI plans to remove includes the following:

- The name of the individual being interviewed or surveyed.
- The name of the agency that employs the interviewee.
- The address of the individual and agency completing the interview or survey.
- The email address and phone number of the individual.
- Any other information is linkable to any specific individual.

Chapter 4. Data Quality Assurance/ Quality Control Plan

This chapter describes the manual and automated processes (including thresholds and criteria) for verifying data quality, cleaning data, and approach for addressing missing or unavailable data.

Data Quality Checks

The Wyoming CVPD Team is responsible for verifying the quality of their data before uploading data to the SDC. Therefore, the TTI CVPD Evaluation Team is assuming all data going into the SDC to be clean. The TTI CVPD Evaluation Team plans to spot-check the data to ensure the quality of the data is satisfactory for the analysis. The TTI CVPD Evaluation Team plans to follow the data quality verification process specified in NCHRP's *Guide to Effective Freeway Performance Measures* (*18*). This section describes the additional steps that the TTI CVPD Evaluation Team will take to verify the quality of the data.

Data Fusion Spot Checks

The TTI CVPD Evaluation Team will spot-check some of the CV Pilot generated data against data from external sources. The TTI CVPD Evaluation Team will look for event data (such as speeds, delays, travel time variance, and weather events) and will compare the variances between the CV data and the external data sources (which will capture CV and non-CV data). Based on the variance between the different sources, the TTI CVPD Evaluation Team will identify if there are any quality concerns with the data fusion conducted by the Wyoming CVPD Team. The TTI CVPD Evaluation Team plans to notify the WYDOT CVPD Team if any discrepancies or issues are identified during spot-checks.

Verify Data Quality

The TTI CVPD Evaluation Team will not conduct site visits to verify the data through field inspection or survey, as commonly done in traffic analysis studies. Instead, the TTI CVPD Evaluation Team will compare data from multiple sources to verify the accuracy of the data. The TTI CVPD Evaluation Team will screen the Wyoming CVPD Team-provided data by comparing data from the same sensor over time or by comparing data from neighboring sensors. The TTI CVPD Evaluation Team will abide by the following data screening procedures (*18*):

- Traffic data screening categories.
  - Known errors recorded in the field.
  - Thresholds on a single variable (e.g., speed usually ranges from 5 to 70 mph in urban areas).
  - The relationship between the variables (i.e., that volume, speed, and occupancy conform to the fundamental traffic diagrams).

  - The relationship among records at the same sensor over time (e.g., time series data could be mathematically fitted by a time series model with specific errors under control).
  - The relationship among records reported by neighboring sensors over time.
- Explore and understand the data.
  - Understand the aggregation level and methods used for aggregations.
  - Understand data type included.
  - Understand spatial and temporal resolution of data (e.g., lane-by-lane data or aggregated lane data; 10 records per seconds or an aggregated record every 5 minutes).
- Evaluate the applicability of screening.
  - Speed below 5 mph (human walking speed usually ranges from 3–4 mph).
  - Average effective vehicle length.
  - Volume–speed relationship.
  - Volume–occupancy relationship.
- Select thresholds for the data screening.
  - Law enforcement policy may provide potential thresholds for traffic movement (e.g., speed limit and HOV lane).
  - The thresholds can be selected based on either statistical estimators using field observation or prior knowledge of traffic studies.
- Identify additional tests from data exploration. Various data sources may have unique features. Additional data screening tests are required if traffic data are not ubiquitous.
- Validate selected screening tests.

The TTI CVPD Evaluation will flag data that appear to be suspect and report the anomaly to WYDOT. If the WYDOT cannot resolve the anomaly, TTI may consider removing the faulty data from the analyses.

Traffic Simulation Model Data Quality Check

The TTI CVPD Evaluation Team will follow the error checking process outlined in the FHWA *Traffic Analysis Toolbox Volume III* (*9*) to validate the site-provided simulation model input files:

- Review software errors.
- Review input coding errors, including geometry, control, demand, and driver behavior and vehicle characteristics.
- View animation.

The TTI CVPD Evaluation Team will review the model input files for the following data quality:

- Geometric data—spot-check the geometric and traffic control type data using Google Earth; look for apparent violations of design standards and practices.
- Traffic control data—spot-check the traffic signal phase and timing data using site-provided signal timing plans.

- Traffic counts—spot-check traffic counts for internal consistency (balancing within 10 percent).
- Traffic operations and management data— spot-check travel time and speed data from CV data or control vehicle probe data if available.

The TTI CVPD Evaluation Team plans to follow the *Highway Capacity Manual* (HCM) (*17*) methodology for measuring travel time distributions and reliability performance measures.

Driver Behavior Model Verification

If the sites do not share these detailed data required for model validation, then it will not be possible for the TTI CVPD Evaluation Team to validate the driver behavior model. If that is the case, then the sites must develop their process to demonstrate that the driver behavior model they developed is calibrated accurately to the existing conditions. The TTI CVPD Evaluation Team will ask the Wyoming CVPD Team to provide the data that they used to develop the CV driver behavior model developed. The TTI CVPD Evaluation Team will also conduct a visual check of the simulation to see if unusual vehicle behaviors appear in the animation. The TTI CVPD Evaluation Team will work with the Wyoming CVPD Team to resolve issues associated with unusual vehicle behaviors in the simulation model. If the WYDOT and TTI cannot resolve the anomaly, TTI may consider removing the faulty data from the analyses.

Data Availability

Based on a review of the draft *Connected Vehicle Pilot Deployment Program Phase 2: Data Management Plan* (*6*) and the *Connected Vehicle Pilot Deployment Program Phase 2. Final System Performance Report, Baseline Condition – WYDOT CV Pilot* (*10*), it appears that the Wyoming CVPD Team is providing the data necessary to conduct the planned independent evaluation. The TTI CVPD Evaluation Team will supplement these data from data from other sources (e.g., NPMRDS).

Table 8. Availability of Wyoming CVPD Data Sources

Data Type	Data Needed for Independent Evaluation	Pre-Deployment (Baseline)	Post Deployment
BSM Part 1	No	–	✓
BSM Part 2	No	–	✓
Mobile Road Weather Observations	Maybe	–	✓
Vehicle Interaction Events – V2V and V2I	Yes	–	✓
Pikalert Road Conditions	Maybe	–	✓
Pikalert Motorist Advisories and Warning	Maybe	–	✓
TMC Generated TIMS, alerts, and warning	Yes	–	✓
WYDOT TRAC data (Highway patrol incident reports, operator action logs, citizen reports)	Yes	✓	✓
WYDOT Construction Console Events	Yes	✓	✓
WYDOT Incident Console Events	Yes	✓	✓
Individual vehicle speed data	Yes	✓	✓
WYDOT RWIS data	Yes	✓	✓
WYDOT VSL System Events	Yes	✓	✓
WYDOT DMS Records	Yes	✓	✓
WYDOT Road Closures	Yes	✓	✓
Crash Data Records	Yes	✓	✓
CVO Fleet Manager Survey Responses	Yes	✓	✓
CVO Driver Survey Responses	Yes	–	✓
WYDOT Staff Surveys and Interviews	No	✓	✓

– indicates no data

Source: Adapted from *CVPD Program Phase 2, Data Management Plan.*

Chapter 5. Data Management Procedures

This chapter describes the processes and procedure that the TTI CVPD Evaluation Team will use to manage the data for the Wyoming CVPD evaluation. Specifically, this chapter presents the plans for sharing data and disseminating data to others. The data sharing section discusses how the TTI CVPD Evaluation Team plans to share data internally within the Team, while the Data Dissemination section discusses how the TTI CVPD Evaluation Team plans to share data with individuals external to the Evaluation Team.

Data Sharing

The USDOT requires the TTI CVPD Evaluation Team 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 from each of the CVPD Teams are placing the data collected by their systems 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 (*16*). Except for charts, figures, and tables generated to support the preparation of evaluation reports, the TTI CVPD Evaluation Team will not be able to download any raw or processed data from the SDC. The TTI CVPD Evaluation Team will work with the USDOT and the SDC development team to ensure that proper resources and analytical tools are available to the TTI CVPD Evaluation Team in the SDC.

The only exception to USDOT's requirement may be the simulation and modeling effort. While the TTI CVPD Evaluation Team will attempt to conduct the simulation modeling directly in the SDC platform, licensing and software requirements may require the TTI CVPD Evaluation Team to perform the planned simulation modeling outside of the SDC environment. NOTE: The TTI Evaluation Team already has the simulation software installed and functioning on standalone machines outside of the environment. If the TTI CVPD Evaluation Team must perform simulations outside the SDC environment, the TTI CVPD Evaluation Team will devise a process for uploading and downloading input and data files to the SDC. TTI will explore the possibly of embedding a version control software tool (such as GitHub or other version control tools) into the SDC to store and manage the data files. Initial data files will be developed and stored on local machines. Prior to running each model, the TTI CVPD Evaluation Team will upload all the data files to the version control tool. After the simulation is complete, the TTI CVPD Evaluation will upload the output for the simulation models into the same version control tool. That way, input files can be correlated with output files. The SDC will be responsible for providing backups of the data files. Once the modeling is complete, TTI CVPD Evaluation Team will upload final copies of the input and output files into the SDC for storage and future use by other researchers and all copies of the files will be removed from the local machines.

As the WYDOT CVPD Team are the original owners of the simulation models, the TTI CVPD Evaluation Team will not share original versions of the simulation and emission models outside of the SDC and the ITS Public Data Hub.

Data Dissemination

Other than summary charts, figures, and tables contained in published reports, the TTI CVPD Evaluation Team does not plan to disseminate or distribute the data in any form. The SDC should prohibit the TTI CVPD Evaluation Team from downloading any data, in full or in part. The TTI CVPD Evaluation Team will upload any data that it collects (such as survey data or ancillary data to support the evaluation) to the SDC, once the TTI CVPD Evaluation Team has removed all the PII and SPII data. While the TTI CVPD Evaluation does not expect to collect or need any sensitive data, the TTI CVPD Evaluation Team will place any sensitive data in a secured location.

Managing Survey and Interview Data

As specified in the *Connected Vehicle Pilot Deployment Program Independent Evaluation: Stakeholder Acceptance Plan* (*13*), the TTI CVPD Evaluation Team will keep the data gathered from the qualitative interviews, online survey, and workshops confidential. Survey and interview participants can be identified by only authorized team members of the TTI CVPD Evaluation Team. TTI will not list any individual responses to questions posed in the qualitative interviews, online survey, or workshops. TTI plans to keep all PII separate from data for analysis in a locked file cabinet.

Informed consent procedures approved by the Texas A&M University IRB will be followed in conducting the interviews, online survey, and workshops. TTI plans to send each participant a consent form via email before scheduling an interview appointment, starting the online survey, or participating in the workshops. Each prospective participant will have an opportunity to ask questions about the study and will have ample time to decide whether to participate.

The TTI CVPD Evaluation Team will prepare summaries of all interviews, surveys, and workshops. Even though the PII will be separated from the information gathered, there is the risk that an individual could be identified through his/her responses to questions. To minimize this risk, the TTI CVPD Evaluation Team will scrub any publicly released reports or technical memoranda to ensure that a specific individual cannot be deciphered through his/her responses. 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 CVPD Evaluation Team will destroy any raw notes or materials obtained in interviews or workshops.

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