Connected Vehicle Pilot Deployment Program Independent Evaluation:

Comprehensive Evaluation Plan—Tampa

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16. Abstract

This report summarizes the analysis 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 Tampa Connected Vehicle Pilot Deployment (CVPD). This document summarizes the plans for:

- Assessing the MEP benefits associated with the Tampa CVPD.
- Estimating the benefit/costs associated with the Tampa CVPD.
- Assessing stakeholder acceptance and satisfaction with the deployment.
- Conducting stakeholder surveys and interviews.
- Managing the data that the TTI CVPD Evaluation Team plans to use to conduct the MEP analysis.
- Using modeling and simulation evaluation to assess mobility-related performance.
- Disseminating 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 Pilot 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; 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 (AMS) 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 fall 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 plans to use to complete the comprehensive assessment of the MEP impacts of the Tampa CVPD and to disseminate the findings and lessons learned from the independent evaluation.

Overview of Tampa CVPD

The goal of the Tampa CVPD is to transform the experience of automobile travelers, transit riders, and pedestrians by preventing crashes, enhancing traffic flow, improving transit trip times, and reducing emissions of greenhouse gases in the downtown Tampa area (*1*). The Tampa Hillsborough Expressway Authority (THEA) and its partner entities will be equipping buses, streetcars, and privately owned vehicles with CV technologies that will allow them to exchange safety and travel condition information with each other and with the infrastructure. Pedestrians will also be equipped with mobile devices to receive alerts and warnings to improve their safety and mobility. The objectives of the Tampa CVPD are as follows:

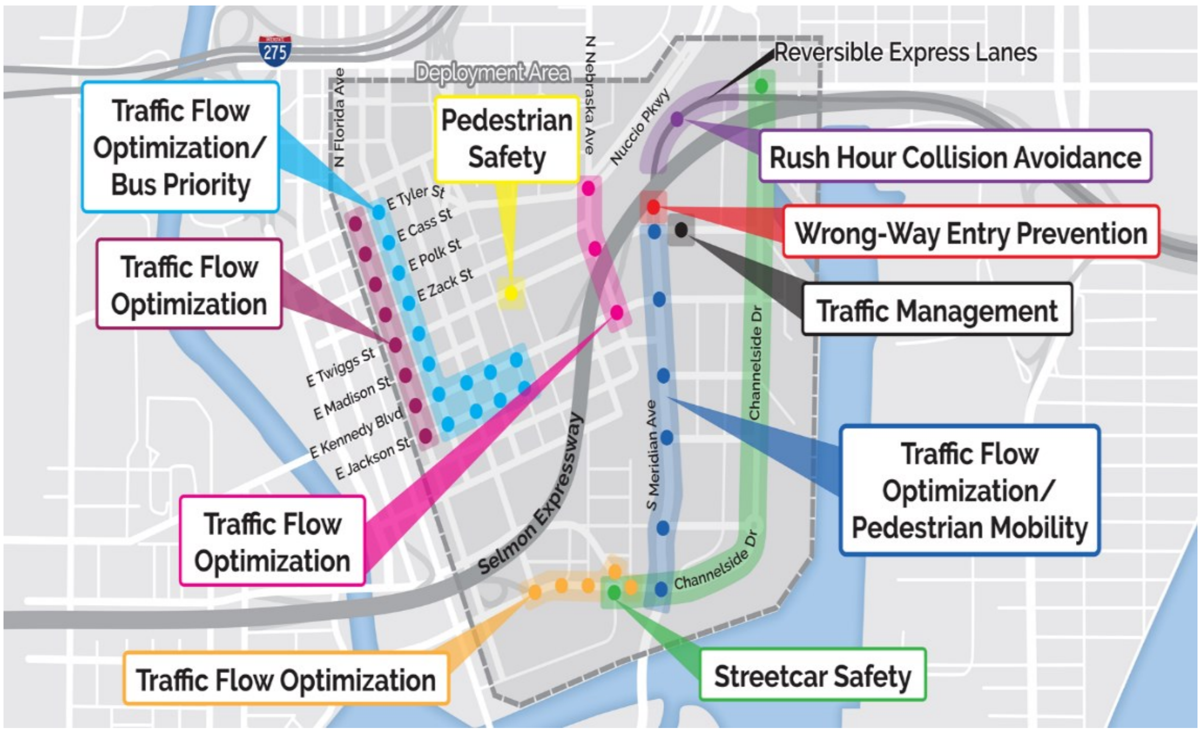
- Reduce morning peak-hour delays and rear-end crashes on the Lee Roy Selmon Expressway's Reversible Express Lane (REL) exit to downtown Tampa.
- Reduce vehicle/pedestrian conflicts at a busy mid-block crosswalk near the Hillsborough County Courthouse.
- Improve traffic flow by supporting traffic signal optimization on commuting corridors in downtown Tampa.
- Improve transit trip times by enhancing transit signal priority in the Marion Street Transitway.
- Reduce vehicle and pedestrian conflicts with the TECO Streetcar Line in downtown Tampa.

Figure 1 shows the corridors where THEA plans to deploy CV technologies in the downtown areas.

To support these objectives, THEA will be deploying the following applications as part of its CVPD (*1*):

- Emergency Electronic Brake Light Warning—This application alerts drivers when connected vehicles ahead are braking hard.
- End of Ramp Deceleration Warning—This application warns drivers to slow down to a recommended speed as the vehicle approaches the end of a queue.
- Forward Collision Warning (FCW)—This application warns drivers if a rear-end crash is imminent with a connected vehicle ahead using vehicle-to-vehicle (V2V) communications.
- Intelligent Signal System (I-SIG)—This application optimizes traffic signal timing based on real-time connected vehicle data.
- Intersection Movement Assist—This V2V application warns drivers when it is not safe to enter an intersection.
- Mobile Accessible Pedestrian Signal System—This application allows pedestrians equipped with a smartphone application approaching a crosswalk at a signalized intersection to request service from the traffic signal.
- Pedestrian in a Signalized Crosswalk Vehicle Warning—This application identifies conflicts between pedestrians in a crosswalk and approaching vehicles.

- Probe Data Enabled Traffic Monitoring—This application gathers traffic data from collected vehicles in real time and provides the data to traffic managers to assist in optimizing traffic flow.
- Transit Signal Priority (TSP)—This application gives buses priority at traffic signals to keep them running on schedule.
- Vehicle Turing Right in Front of Transit Vehicle—This application alerts a streetcar operator when a vehicle is turning right at an intersection as the streetcar is approaching.
- Wrong-Way Entry—This application warns drivers that enter the REL from the wrong direction. The application will also broadcast a warning to other equipped vehicles on the REL to be alert for wrong-way vehicles.



Source: Tampa Connected Vehicle Pilot Website (2)

Figure 1. The Tampa (THEA) CVPD Deployment Corridors.

In the Tampa CVPD, THEA plans to deploy CV technologies in 1600 privately owned vehicles, 10 buses, and 10 streetcars. THEA plans to equip up to 500 pedestrians with mobile devices as well. THEA also plans to install 40 roadside units (RSUs) at strategic locations in the downtown area to support the CV applications (*1*).

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 Tampa 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 presents the estimated cost to complete the independent evaluation of the Tampa CVPD.
- **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 Tampa 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 Program Independent Evaluation: Mobility, Environment, and Public Agency Efficiency (MEP) Refined Evaluation Plan—Tampa* (*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 Tampa 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 Tampa CVPD.

ID	Hypothesis	Performance Measure	Suggested Data Source	Type
1	The pilot deployment will reduce V2V and vehicle-to-streetcar crashes and incidents (or other safety surrogate measures if crashes are rare) in the pilot deployment area.	• Change in the number of vehicle-to-streetcar collisions in the deployment corridors • Change in the number of severe (KSI*) vehicle-streetcar collisions in the deployment corridor • Reduction in conflict exposures** • Change in probability of crash	• Collision Records System • Conflicts per V2V interaction • Harm Reduction Effectiveness***	• Volpe Safety Analysis
2	The pilot deployment will reduce crashes and incidents (or other safety surrogate measures if crashes are rare) due to wrong-way entries into the REL.	• Change in the number of collisions attributed to wrong-way entries at the REL exit ramp • Change in the number of KSI collisions attributed to wrong-way entries at the REL exit ramp • Reduction in conflict exposures • Change in probability of crash • Number of alerts/warnings issued at the signal due to potential wrong-way entries	• Collision Records System • Conflicts per V2V Interaction • Harm Reduction Effectiveness • RSU Data Logs	• Volpe Safety Analysis
3	The pilot deployment will reduce crashes and incidents (or other safety surrogate measures if crashes are rare) by giving drivers speed warning advice at the REL exit.	• Change in the number of collisions attributed to wrong-way entries at the REL exit ramp • Change in the number of KSI collisions attributed to wrong-way entries at the REL exit ramp • Reduction in conflict exposures • Change in probability of crash • Number of FCWs issued when entering the REL exit curve	• Collision Records System • Conflicts per V2V Interaction • Harm Reduction Effectiveness • RSU Data Logs	• Volpe Safety Analysis

ID				
4	The pilot deployment will reduce pedestrian-to-vehicle conflicts in the pilot deployment area by warning vehicles.	• Change in the number of pedestrian-related conflicts with vehicles and streetcars • Number of pedestrian conflict warnings issued to vehicles	• Conflicts per Pedestrian-to-Vehicle Interaction • Harm Reduction Effectiveness • Onboard Unit (OBU) Data Logs from Streetcars	• Volpe Safety Analysis
5	The pilot deployment will increase transit schedule reliability through TSP.	• Change in on-time performance in TSP corridor	• Hillsborough Area Regional Transit (HART) On-Time Performance Logs • Transit Basic Safety Messages	• Before/After Analysis
6	The pilot deployment will improve transit ridership through TSP.	• Change in average weekday boarding passengers	• HART Ridership Reports	• Before/After Analysis
7	The pilot deployment will improve traffic signal progression through use of CV data.	• Change in average through trip travel time for each coordinated street	• Probe Vehicle Data • I-SIG Applications Logs • City of Tampa's ATSPMS**** • City of Tampa's Traffic Signal System (traffic count)	• Before/After Analysis
8	The pilot deployment will reduce negative environment impacts through reductions in crashes, improvements in signal progression, and resulting reductions in vehicle and bus idle times.	• See performance measures for hypotheses 1–7 above • Reduction in fuel consumption	• Emission Estimates from Motor Vehicle Emissions Simulator (MOVES)	• Modeling Analysis
9	As the market penetration of CVs increases, benefits will increase in terms of reduced	• Average trip time per vehicle (in vehicle hours traveled per vehicle [VHT/V])	• Total Vehicle Hours Traveled/Total Vehicle Count	• Modeling Analysis

ID	Hypothesis	Performance Measure	Suggested Data Source	Type
	stops, queues, delays, and emissions, and increased vehicle throughput, transit schedule reliability, and travel time reliability.	• Average vehicle hours traveled per mile (VHT/M) • Average user delay/wait time • Average speeds • Average vehicle miles traveled per vehicle	• Difference in VHT//M at Speed Limit and VHT/M • Vehicle Miles Traveled/ Vehicle Hours Traveled • Vehicle Miles Traveled/ Total Vehicle Count	
10	As the market penetration of CVs increases, non-equipped vehicles traversing the pilot deployment area will see reductions in stops, queues, delays, and emissions.	• Average VHT/V • Average user delay/wait time • Average speeds • Average throughput—see hypothesis 9	• Same as Above but for Non-Equipped Vehicles Only	• Modeling Analysis
11	Incremental increases in CV deployment will result in higher benefit-cost ratios up to a certain deployment cost threshold, after which benefit-cost ratios will reduce.	• Benefit-cost ratio at various market penetrations of CVs and technology	• Cost Data • Dollar Values of Benefits	• Modeling Analysis • Benefit-Cost Analysis
12	The pilot deployment will result in improved public agency efficiency and decision-making by transportation managers.	• Change in the quality of the information • Perceived usefulness of alerts/warnings/advisories • Change in staff time to take appropriate action and disseminate information • Number of operational and business practice changes made by transportation managers • Nature of operational and business practice changes made by transportation managers • Perceived impacts of operational and business practice changes • Perceived improvements to decision-making abilities due to alerts/warnings/advisories	• Interview Responses	• Stakeholder Interviews

ID	Hypothesis	Performance Measure	Suggested Data Source	Type
13	Pilot deployers and transportation managers will find that their safety and MEP (SMEP) goals were met.	• Qualitative assessment of the extent to which SMEP goals were met • If SMEP goals were not met, factors or reasons why	• Interview Responses	• Stakeholder Interviews
14	End users will be satisfied with the performance of CV applications and with the impact of the CV deployment on their travel.	• Perception of whether advisories/alerts/warnings were: ○ Timely ○ Sufficiently detailed ○ Easy to understand ○ Accurate ○ Useful • Perceived impact (if any) that alerts/warnings/advisories had on safety and/or mobility • Perception of whether trip expectations (e.g., red light violation, stopped vehicles on exit curve, pedestrian-vehicle conflicts) matched trip experiences	• Interview Responses	• Stakeholder Interviews

ID	Hypothesis	Performance Measure	Suggested Data Source	Type
15	The pilot deployment will result in end users taking appropriate action based on alerts/warnings/advisories.	• Number and type of actions in response to alerts/warnings/advisories • Reasons why no action was taken when alerts/warnings/advisories were received	• Data analysis of Action Logs • Interview Responses (may require surveying drivers immediately following a trip in which they received alerts/warnings/advisories/ traveler information)	• With/Without Comparison • Qualitative
16	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	• Interview Responses	• Qualitative

*KSI = Killed and severely injured
**Conflict Exposure is the rate at which a vehicle is exposed to a potential conflict.
***Harm Reduction Effectiveness refers to the effectiveness of the application to reduce the adverse risks and harms associated with driving the deployment corridors.
****ATSPMS = Automated Traffic Signal Performance Measurement System. It is the understanding of the TTI CVPD Evaluation Team that the City of Tamp will be installing a module in their traffic signal management system that will perform this function.

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

Analysis Approach

The TTI CVPD Evaluation Team plans to use an interrupted time series with no control group to analyze the impacts of the deployment (*3*). In the TSP application, all transit vehicles using the corridor will be equipped with the CV technologies, so the potential to have a control group does not exist.

For the I-SIG application analysis, the TTI CVPD Evaluation Team plans to use data from traditional sources to assess the impacts of deployment. The I-SIG application will combine information from equipped vehicles and traditional detection devices to adjust the signal timings in the deployment corridors. These signal timings will impact equipped and unequipped vehicles equally. The CVs—whether they are in the treatment group or the control group—will not receive any special information beyond what the non-equipped vehicles receive. Because both non-equipped and equipped vehicles will receive the same benefit from the application in the after activation of the I-SIG, only a before-and-after assessment is planned.

Identification of Operational Conditions

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

- 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], severity).
- Work zone conditions (type, duration, impact severity).
- Special event conditions (type, duration, impact severity).
- 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 cluster 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 the cluster 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

The approach that the TTI CVPD Evaluation Team plans to use to assess the mobility impacts of the Tampa CVPD is described in the *Connected Vehicle Pilot Deployment Program Independent Evaluation: Mobility, Environment, and Public Agency Efficiency (MEP) Refined Evaluation Plan—Tampa* (*3*). The specific performance measures that the TTI team plans to use to assess the impacts of the CVPD on mobility in the Tampa deployment area include the following:

- Travel times on specific links in the downtown deployment area.
- Delays and average queue length estimates as measured by the City of Tampa's Traffic Signal System.
- Throughput/traffic volumes.

The TTI CVPD Evaluation Team also plans to use reliability measures to assess the consistency or variability in travel in the deployment area. The specific measures of reliability that the TTI team plans to use include the following:

- Travel time reliability, including both the 95th percentile travel time and the buffer time.
- On-time performance by transit vehicles.
- Changes in arrival on green patterns at specific signalized intersections.

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 (*4*). 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 oxide (NO_x).
- Petroleum energy consumptions.

Public Agency Efficiency Evaluation

The TTI CVPD Evaluation Team plans to measure public agency efficiency in terms of how well agencies can respond to changing conditions or unexpected events occurring on their networks (*3*). Public 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 impacts of the changes in performance measures such as changes in incident clearance times will be modeled to quantify their impacts on mobility.

Benefit-Cost Analysis

The TTI CVPD Evaluation Team will also conduct a benefit-cost analysis associated with the Tampa 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.

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 that 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 changes in before and after travel times for each operational condition likely to produce specific benefits from deploying CV technologies. The TTI 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 any reductions in crashes resulting from the deployment. The TTI team will apply the crash reduction predictions for the corridors 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* (*5*) to estimate safety costs.

The TTI CVPD Evaluation Team will also include the benefits associated with any changes in emissions due to deploying the CV technology in the corridors. The TTI team will use simulation to estimate the effects of the deployment on emissions. The TTI team 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 time frame. The TTI 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 (*6*). This website includes current and historical gasoline and diesel fuel prices. Data from this site will be used to develop average fuel costs during the evaluation period. The portion of the cost of fuel that is taxed will be removed prior to calculations since that portion 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 (*7*). 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 because the TTI team assumes that those costs would be the same whether or not the vehicle were equipped with CV technologies. Ownership costs include items such as insurance; license, registration, and taxes; vehicle depreciation; and finance charges.

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 project.
- 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 corridors.

Chapter 3. Stakeholder Acceptance/ Satisfaction Evaluation Plan

As part of the independent evaluation, the TTI CVPD Evaluation Team will also be collecting stakeholder acceptance and satisfaction information to gather stakeholder impressions and experiences related to the Tampa 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* (*8*) describes the approach that the TTI team will use to gather stakeholder acceptation and satisfaction information.

Table 2 shows the stakeholders for the Tampa 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 interviews will be check-in interviews shortly after deployment to get initial feedback, and (b) the 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 Tampa CVPD Deployment Team to determine whether TTI can administer the survey directly or if the Tampa team prefers to administer the survey.

The TTI CVPD Evaluation Team will conduct one post-deployment workshop at the Tampa 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 deployment. The TTI team will also use the workshop to gather information needed to conduct the financial and institutional assessments. The TTI team envisions that the workshop 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. Tampa Stakeholder Group Types.

Stakeholder Category	Agency/Entity
Deployment Manager	• THEA
Deployment Team Members	• BrandMotion • University of South Florida Center of Urban Transportation • Global 5 Communications • Siemens Industry Inc., Mobility Division • HNTB
Operating Agencies	• City of Tampa Traffic Engineering/Traffic Management Center • Florida Department of Transportation, District 7
Fleet Operators	• HART • TECO Streetcar Line
Supporting Agencies	• Hillsborough Metropolitan Planning Organization • Hillsborough County • City of Tampa Police • Florida Highway Patrol (Tampa) • Hillsborough County Sheriff's Office • Tampa Bay Port Authority (Cargo and Cruise)
Policy Makers	• THEA Board of Directors • Mayor's Office

Source: Tampa CVPD Team.

Chapter 4. Survey and Interview Guides

The *Connected Vehicle Pilot Deployment Program Independent Evaluation: Stakeholder Survey/Interview Guide—Tampa* (*9*) provides details on the questions and approach that will be used to obtain input from the various Tampa CVPD Deployment Team stakeholders. The TTI CVPD Evaluation Team will use a multipronged approach for the data collection that includes qualitative interviews, an online survey, and a workshop:

- Interviews will be used to gather in-depth information from those stakeholders most invested and involved in the CV pilot deployment. 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	—
Policy Makers[3]	X	—	X	—	—

— No data.
[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 Team 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 deployment 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—Tampa* (*9*).

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. 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. In order to not overburden fleet operators, the TTI team will coordinate the administration of the fleet online survey with the Tampa CVPD Deployment 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 Tampa 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—Tampa* (*9*).

Post-Deployment Workshop

The TTI CVPD Evaluation Team will conduct a workshop at the conclusion of the Tampa 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 Tampa. 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 invite to the workshop.

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—Tampa* (*9*).

Chapter 5. Evaluation Data and Data Management

The *Connected Vehicle Pilot Deployment Program Independent Evaluation: Data Plan—Tampa* (*10*) 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 will 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 Tampa CVPD.

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

Data Type	Data Elements	Potential Source	Used in What Analysis
Mobility	• Date • Time • Roadway • Segment Speed/Travel Time	• Florida 511 • I-SIG Data Logs • City of Tampa Centracs System • WAZE Travel Time Data Set	• Mobility Analysis • AMS Model Calibration • Avg Travel Time • Buffer Time • Travel Time Index
Delay	• Date • Time/Period • Roadway • Intersection Delay	• I-SIG Application	• Mobility Analysis • AMS Model Calibration
Queue Lengths	• Date • Time/Period • Roadway • Average Queue Length • Maximum Queue Length	• I-SIG Application • OBU Equipped Vehicles • Traffic System Detectors	• Mobility Analysis • AMS Model Calibration
Traffic Demand	• Date • Time • Station ID • Observation Count • Vehicle Classification	• Vehicle Counts Associated with City of Tampa Traffic Signal System Detectors or Count Stations	• Mobility Analysis • AMS Model Calibration

Data Type	Data Elements	Potential Source	Used in What Analysis
Turning Movement Counts	• Date • Time • Right Turn on Red Vehicle Observation Counts • Turning Movement Counts	• Traffic Volume Counts • Traffic Turning Movement Counts at Courthouse-Area Intersections and Other Pedestrian Application Intersections	• Mobility Analysis • AMS Model Calibration
Pedestrian Counts	• Date • Time • Pedestrian Observation Counts • Pedestrian Call Requests • Pedestrian Call Granted	• Pedestrian Counts • RSU PED-SIG Application Logs	• Mobility Analysis • AMS Model Calibration
TSP Requests	• Date • Time • Priority Requests to Transit Server • Signal Status Message (SSM) • Priority Granted/Denied	• RSU TSP Application for Priority Requests • RSU for SSM • Transit Server for Priority Decision	• Mobility Analysis • AMS Model Calibration
Transit Performance	• Routes • On-Time Performance • Average Ridership Counts	• HART Performance Logs	• Mobility Analysis • AMS Model Calibration
Weather	• Date • Time • Air Temperature (°F) • Pavement Temp (°F) • Wind Speed (mph) • Maximum Wind Gust (mph) • Precipitation • Visibility (miles)	• National Oceanic and Atmospheric Administration Weather Station (Tampa International Airport)	• Mobility Analysis • AMS Model Calibration
Incident/Work Zones	• Date • Start and End Time • Locations • Type and Severity of Incident • Number of Lanes Impacted	• City of Tampa Active Traffic Management (ATM) Report	• Mobility Analysis • AMS Model Calibration
Special Event Logs	• Date • Start and End Time • Locations • Event Type • Duration • Situation	• City of Tampa ATM Report	• Mobility Analysis • AMS Model Calibration

Data Type	Data Elements	Potential Source	Used in What Analysis
Public Agency Efficiency	• Changes in the Quality of the Information • Perceived Usefulness of Alerts/Warnings/Advisories • Changes in Staff Time to Take Appropriate Action and Disseminate Information • Number of Operational and Business Practice Changes Made by Transportation Managers • Nature of Operational and Business Practice Changes Made by Transportation Managers • Perceived Impacts of Operational and Business Practice Changes • Perceived Improvements to Decision-Making Abilities Due to Alerts/Warnings/ Advisories	• TTI Stakeholder Interviews	• 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
Driver Satisfaction	• Perception of Accuracy • Perception of Timeliness • Perception of Usefulness • Perception of Improved Mobility • Perception of Improved Safety	• Tampa Driver User Survey	• User Satisfaction
Transit Vehicle Operator Fleet Satisfaction Survey	• Perception of Accuracy • Perception of Timeliness • Perception of Usefulness • Perception of Improved Mobility • Perception of Improved Safety	• Tampa Bus Fleet Operator Survey	• Stakeholder Acceptance

Data Type	Data Elements	Potential Source	Used in What Analysis
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
	  o Vehicle
	  o Infrastructure
	• Installation Costs
	  o Vehicle
	  o Infrastructure
	• Subject Recruitment
	• Evaluation
	• Other Costs
		• TTI Stakeholder Interviews	• Benefit-Cost Analysis

Operations & Management (Phase III) Costs	• Operations Costs
	• Maintenance/Repair
	• Equipment Replacement Costs
	  o Vehicle
	  o Infrastructure
	• Salvage
	  o Vehicle
	  o Infrastructure
	• Evaluation
	• Other Costs
		• TTI Stakeholder Interviews	• Benefit-Cost Analysis

Source: Texas A&M Transportation Institute (*10*).

Data Ownership and Privacy

USDOT and THEA are the owners of the data uploaded by THEA 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 Tampa CVPD

Deployment Team and the TTI CVPD Evaluation 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 (*10*). The TTI team will work with USDOT and the SDC development team to ensure that proper resources and analytical tools are available to the TTI 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 workshop 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 Tampa CVPD. The *Connected Vehicle Pilot Deployment Program Independent Evaluation: Analysis, Simulation, and Modeling Plan—Tampa* (*11*) 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 of deploying I-SIG on travel time, travel time reliability, and corridor throughput under the different operating conditions and time of day that prevail in the corridors (Tampa Deployment Goal #2).
- Estimate the impacts of TSP and other connected bus rapid transit applications on transit and vehicular mobility, travel time reliability, and corridor throughput under the different operating conditions and times of day that prevail in the corridors (Tampa Deployment Goal #2).
- Estimate the impacts of reducing crash frequency and severity on the REL on mobility, travel time reliability, and corridor throughput under the different operating conditions and times of day that prevail in the corridors (Tampa Deployment Goal #3).
- Estimate the impacts on the environment due to changes in mobility under different operating conditions that prevail in the corridors (Tampa Deployment Goal #4).
- Estimate the cumulative effects of different market penetration levels of connected vehicles and changes in background traffic levels on system performance on the deployment corridors in Tampa.

To estimate these impacts, the TTI CVPD Evaluation Team will use the base model that the Tampa CVPD Deployment Team will develop.

The TTI CVPD Evaluation Team will first verify that the model is functioning properly and will then calibrate the model to the operational scenarios identified through the cluster analysis. The TTI team will be responsible for any model enhancements, calibration, and measurement estimations that diverge from what the Tampa CVPD Deployment Team plans to do.

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 team will use these measures to estimate environmental performance measures too.

Model Development and Calibration

To estimate these impacts, the TTI CVPD Evaluation Team will use a base model that the Tampa CVPD Deployment Team developed. The TTI team will receive from the Tampa team a functioning model that is free from errors and calibrated to some level of performance. The TTI team will then refine the model and calibrate it 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* (*12*) to calibrate the model. The TTI team anticipates that the model will cover both the eastbound and westbound directions of travel in the corridors.

Analysis of Simulation Results

Model scenario identification comes after the cluster 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 cluster 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 CV pilot deployment in addressing the needs of the pilot site. Table 5 lists the known confounding factors likely to influence travel behavior in the Tampa CVPD corridors.

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 cluster 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 in 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	Tampa
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 cluster analysis.
Vehicle demand changes 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 cluster analysis.
Pedestrian demand changes	Depending on the pedestrian data available for each site, one or more levels of pedestrian demand will be identified for testing in each scenario. This will be done only where CV applications are expected to be influenced by pedestrian demands.
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 the same work zones for evaluating base and different CV deployment levels.
Economic condition changes	Effects will be included in demand operational conditions.
Fuel price changes	Effects will be included in demand operational conditions.
Planned special event changes	All model scenarios will assume the same planned events.
Planned waterfront construction	All model scenarios will assume the same level of construction.

Note: 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 Measure of Effectiveness (MOE).

Scenario	CV Deployment Level	Operational Conditions Demand	Operational Conditions Weather	Operational Conditions Incident	Hypothesis Test Results 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 cluster analysis. The cluster 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

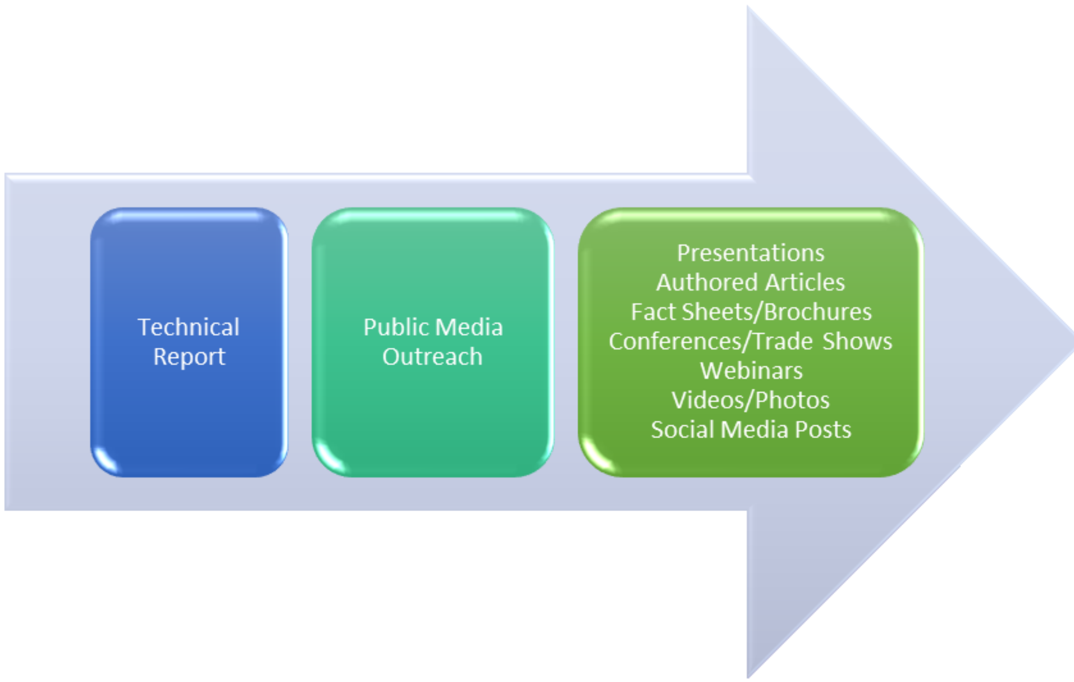
Once the TTI CVPD Evaluation Team has completed the analysis of each operational scenario, the team will extrapolate the result to estimate the system performance for the whole year. The key is to associate each set of integrated operational conditions with a specific future probability for the whole year. The 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 TTI 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* (*13*) 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 in table 7.



Source: Texas A&M Transportation Institute

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	Serve as main point for project information dissemination	—
	Frequent updates for project news, upcoming events, and status	Inform all stakeholders and interested parties	

— No data.
Source: Texas A&M Transportation Institute (*13*).

The TTI CVPD Evaluation Team will work with the Federal Highway Administration (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 the Intelligent Transportation Systems Joint Program Office (ITS JPO) to host webinars. The TTI 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 activities include tasks 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 costs 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 Tampa 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, for each risk and value. The TTI team assigned a value score based on how critical the activity is expected to be to the independent evaluation, considering 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 activity. Risk scores represent 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 value 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 Tampa CVPD.

ID	Task	Task Type	Precursor Task(s)	Cost
10	**Project Management**	**Precursor**	**None**	**$43,491**
11	Project Administration[1]	Precursor	None	$90,108
12	Coordination with FHWA	Precursor	None	$12,014
13	Internal Coordination	Precursor	None	$18,022
14	Site Visit[2]	Precursor	None	$23,346
20	**Data Preparation[3]**	**Precursor**	**None**	**$13,501**
30	**Support Safety Analysis**	**Precursor**	**None**	**$59,931**
31	Data Analysis	Precursor	20	$26,679
32	Safety Data Collection	Precursor	None	$33,252
50	**Perform Cluster Analysis—Tampa CVPD**	**Precursor**	**20**	**$203,756**
51	Cluster Analysis—Pre-Deployment	Precursor	20	$96,701
52	Cluster Analysis—Post-Deployment	Precursor	20	$107,064
60	**AMS Model Prep**	**Precursor**	**50**	**$137,568**
61	Software Site License	Precursor	50	$77,288
62	Model Prep—Coordination	Precursor	61	$19,935
63	Model Prep—Baseline Prep	Precursor	61	$28,752
64	Software Annual Renewal (1 yr)	Precursor	61	$11,593
100	**Mobility—Accident Reduction**	**Analytical—Observed**	**31, 50**	**$11,122**
110	Mobility—Analysis of Streetcar Crash Data	Analytical—Observed	31, 50	$1,668
120	Mobility—Analysis of Wrong-Way Crash Data	Analytical—Observed	31, 50	$3,336
130	Mobility—Analysis of REL Crash Data	Analytical—Observed	31, 50	$1,668
140	Mobility—Analysis of Ped Crash Data	Analytical—Observed	31, 50	$4,449
200	**Mobility—Transit Reliability**	**Analytical—Observed**	**50**	**$44,487**
210	Mobility—Schedule Reliability	Analytical—Observed	50	$22,243
220	Mobility—Transit Ridership	Analytical—Observed	50	$22,243
300	**Mobility—Signal Timing**	**Analytical—Observed**	**50**	**$55,608**

ID	Task	Task Type	Precursor Task(s)	Cost
310	Mobility—Travel Times	Analytical—Observed	50	$18,536
320	Mobility—Travel Time Reliability	Analytical—Observed	50	$18,536
330	Mobility—Throughput	Analytical—Observed	50	$18,536
400	**AMS-Modeling** Mobility—Throughput[4]	**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
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**[5]	**Analytical—Survey**	**20**	**$45,421**
1210	Lesson Learned	Analytical—Survey	20	$45,421

ID	Task	Task Type	Precursor Task(s)	Cost
1300	**Outreach/Report Preparation[6]**	**Outreach**	**100–1200**	**$33,211**

Total (Precursor Tasks) **$558,255**
Total (Analysis Tasks) **$768,487**
TOTAL **$1,326,742**

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

[1]This cost includes activities by the whole project team such as participating in Sprint meetings and other activities associated specific to the Wyoming deployment. Task order A supports the PM in performing overall project management activities associated with all the task orders.

[2]The costs assumes one site visit for 5 members of the evaluation team, one from each of the major analysis leads for the evaluation. This cost includes both travel costs and salary costs associated with the site visit.

[3]This cost includes the time required to resolve issues associated with the SDC, such as uploading the modeling software in the SDC, working with Volpe to install the appropriate software, etc.

[4]The following costs have been estimated for each scenario: Calibration $25735; baseline model execution = $17934, scenario execution = $17934. This includes multiple iterations (5 random seeds), error checking, and analysis of the results.

[5]This cost assumes that there may be a needed in preparing the final report to bring in lesson learned while doing the evaluation. Examples might include lesson learned about the SDC, data preparation, analysis techniques, etc.

[6]The cost includes the time for preparing, editing, and generating 508-compliant reports for the evaluation. All other outreach efforts in included in Task Order A.

Source: Texas A&M Transportation Institute

Table 9. Value/Risk Assessment of Analysis Activities Associated with Independent Evaluation of Tampa 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	$45,421	13. Stakeholder Goals Met
330	Mobility—Throughput	5	2	2.5	$18,536	7. Improve Travel Reliability via Signal Timing
720	PAE—Stakeholder Perspectives*	2	1	2	$—	12. Improved Public Agency Decision-Making
810	BCA—Deployment	4	2	2	$22,032	11. Benefits Exceed Costs
210	Mobility—Schedule Reliability	5	3	1.67	$22,243	5. Improve Schedule Reliability
220	Mobility—Transit Ridership	5	3	1.67	$22,243	6. Improve Transit Ridership
310	Mobility—Travel Times	5	3	1.67	$18,536	7. Improve Travel Reliability via Signal Timing
320	Mobility—Travel Time Reliability	5	3	1.67	$18,536	7. Improve Travel Reliability via Signal Timing
140	Mobility—Analysis of Ped Crash Data	3	2	1.5	$4,449	4. Reduce Pedestrian Crashes
410	AMS-Mobility-Op Condition 1	4	3	1.33	$61,603	7. Improve Travel Reliability via Signal Timing
420	AMS-Mobility-Op Condition 2	4	3	1.33	$61,603	7. Improve Travel Reliability via Signal Timing
430	AMS-Mobility-Op Condition 3	4	3	1.33	$61,603	7. Improve Travel Reliability via Signal Timing
440	AMS-Mobility-Op Condition 4	4	3	1.33	$61,603	7. Improve Travel Reliability via Signal Timing
450	AMS-Mobility-Op Condition 5	4	3	1.33	$61,603	7. Improve Travel Reliability via Signal Timing
460	AMS-Mobility-Op Condition 6	4	3	1.33	$61,60	7. Improve Travel Reliability via Signal Timing
610	Environment—Mobility Improvements	2	2	1	$20,551	8. Reduce Negative Environmental Impacts
620	Environment—Market Penetration	2	2	1	$11,066	8. Reduce Negative Environmental Impacts
1010	End User Survey—Mobility*	3	3	1	$—	14. End User Acceptance of Impacts
110	Mobility—Anal. Streetcar Crash Data	3	4	0.75	$1,668	1. Reduce Collisions with Streetcars
1020	End User Survey—Technology*	3	4	0.75	$—	16. End User Acceptance of Technology
130	Mobility—Analysis of REL Crash Data	2	4	0.5	$1,668	3. Reduce Collisions at REL Exit
510	AMS-Market Penetration—Low	2	4	0.5	$32,986	9 & 10. Market Penetration (equipped, uneq)
520	AMS-Market Penetration—Medium	2	4	0.5	$32,986	9 & 10. Market Penetration (equipped, uneq)
530	AMS-Market Penetration—High	2	4	0.5	$32,986	9 & 10. Market Penetration (equipped, uneq)
710	PAE—Logs	2	4	0.5	$45,063	12. Improved Public Agency Decision-Making
820	BCA—Market Penetration	2	4	0.5	$11,350	11. B/C Changes with Market Penetration

ID	Task	Value	Risk	Value/ Risk	Cost	Hypothesis Map
120	Mobility—Anal. Wrong-Way Crash Data	2	5	0.4	$3,336	2. Reduce Wrong-Way Driving Collision
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) $768,487

* Analysis activity funded through a different task order.

Chapter 9. Risks and Uncertainties

The TTI CVPD Evaluation Team has identified the potential confounding factors and risks that may affect the Tampa pilot deployment evaluation. This section discusses key risks and uncertainties that may impact the evaluation effort.

Potential confounding factors include the following:

- Variations in travel demands.
- Potential major weather events (such as hurricanes) occurring during the evaluation period.
- Major special events occurring in the downtown area.
- Planned development along the Tampa downtown waterfront.
- Unusually high or low frequencies of crashes or incidents.
- Changes in economic conditions, either locally or nationally.
- Changes in fuel prices.

Major risks to the independent evaluation include the following:

- Lack of quality data to perform valid evaluation of some or all deployments.
- Data limitation for safety analysis.
- Insufficient CV traveling in the downtown area to influence mobility.
- Participant attrition.

The *Connected Vehicle Pilot Deployment Program Independent Evaluation Team: Mobility, Environment, and Public Agency Efficiency Refined Evaluation Plan—Tampa* (*3*) identifies actions that the TTI CVPD Evaluation Team can implement, in concert with the Tampa CVPD Deployment Team, to avoid, control, or mitigate these risks. These are the minimum confounding factors and risks; additional ones may arise at later stages of the evaluation. Thus, confounding factors and risks should be identified and assessed at the outset of the evaluation effort and tracked throughout the project.

References

1. Connected Vehicle Pilot Deployment Program: Tampa, Florida. Factsheet. US Department of Transportation, ITS Joint Program Office. Available at https://www.its.dot.gov/factsheets/pdf/TampaCVPIlot_Factsheet.pdf. Accessed August 13, 2017.

2. Tampa Connected Vehicle Pilot. Website. Available at https://www.tampacvpilot.com. Accessed August 13, 2017.

3. Balke, K., M. Lukuc, B. Kuhn, M. Burris, J. Zmud, A. Morgan, K. Passetti, R. Dowling, G. Morrison, R. Marsters, and T. Szymkowski. *Connected Vehicle Pilot Deployment Program Independent Evaluation: Mobility, Environment, and Public Agency Efficiency Refined Evaluation Plan—Tampa*. FHWA-JPO-18-655. US Department of Transportation, ITS Joint Program Office. Revised May 2018.

4. MOVES and Other Mobile Source Emissions Models. United States Environmental Protection Agency. Available at https://www.epa.gov/moves. Accessed March 18, 2019.

5. *TIGER Benefit-Cost Analysis (BCA) Resource Guide*. US Department of Transportation, Federal Highway Administration, Washington, DC. Updated 3/27/15. Available at https://www.transportation.gov/sites/dot.gov/files/docs/Tiger_Benefit-Cost_Analysis_%28BCA%29_Resource_Guide_1.pdf. Accessed August 13, 2017.

6. Gasoline and Diesel Fuel Update. Petroleum and Other Liquids. US Energy Information Administration. Available at https://www.eia.gov/petroleum/gasdiesel/. Accessed February 15, 2018.

7. American Automobile Association. AAA's Your Driving Costs. Available at https://exchange.aaa.com/automotive/driving-costs/. Accessed February 15, 2018.

8. Zmud, J., K. Balke, and M. Lukuc. *Connected Vehicle Pilot Deployment Program Independent Evaluation: Stakeholder Acceptance Plan*. FHWA-JPO-18-656. US Department of Transportation, ITS Joint Program Office. September 18, 2017.

9. Zmud, J., K. Balke, and M. Lukuc. *Connected Vehicle Pilot Deployment Program Independent Evaluation: Stakeholder Survey/Interview Guide—Tampa (THEA).* FHWA-JPO-18-659. US Department of Transportation, ITS Joint Program Office. March 2019.

10. Balke, K., A. Morgan, and M. Lukuc. *Connected Vehicle Pilot Deployment Program Independent Evaluation: Data Plan—Tampa.* FHWA-JPO-18-662. US Department of Transportation, ITS Joint Program Office. December 2018.

11. Morgan, A., R. Dowling, G. Morrison, M. Burris, and K. Balke. *Connected Vehicle Pilot Deployment Program Independent Evaluation: Analysis, Modeling, and Simulation Plan—Tampa*. FHWA-JPO-18-665. US Department of Transportation, ITS Joint Program Office. August 2018.

12. Wunderlich, K., M. Vasudevan, and P. Wang. *Traffic Analysis Toolbox Volume III: Guidelines for Applying Traffic Microsimulation Modeling Software*. FHWA-HOP-16-070. US Department of Transportation, Washington, DC. November 2017 (Draft).

13. Kuhn, B., B. Storey, K. Balke, and M. Lukuc*. Connected Vehicle Pilot Deployment Program Independent Evaluation: Outreach Plan.* US Department of Transportation, ITS Joint Program Office. December 2017.

Appendix. Initial Value/Risk Assessment Scores

This appendix provides the justifications for the scores that the TTI CVPD Evaluation Team assigned to assess the values 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—Analysis of Streetcar Crash Data

Directly related to hypothesis #1: The pilot deployment will reduce vehicle-to-vehicle and vehicle-to-streetcar crashes and incidents (or other safety surrogate measures if crashes are rare) in the pilot deployment area.

Value *Score: 3*

Nature:	Quantitative assessment.
Observability:	Assessments based on observed data for the most part.
Scope:	Limited to specific locations.
Extensibility:	Results could be extensible to other locations.

Risk *Score: 4*

Traffic Data:	Limited data, but data should be good if interactions between equipped vehicles occur.

120—Mobility—Analysis of Wrong-Way Crash Data

Directly related to hypothesis #2: The pilot deployment will reduce crashes and incidents (or other safety surrogate measures if crashes are rare) due to wrong-way entries into the REL.

Value *Score: 2*

Nature:	Quantitative assessment.
Observability:	Assessments based on observed data for the most part.
Scope:	Limited to specific locations.
Extensibility:	Not likely to be extensible to other areas.

Risk *Score: 5*

Traffic Data:	High risk that data are not likely available to support analysis.

130— Mobility—Analysis of REL Crash Data

Directly related to hypothesis #3: The pilot deployment will reduce crashes and incidents (or other safety surrogate measures if crashes are rare) by giving drivers speed warning advice at the REL exit.

Value *Score: 2*

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: Limited data, but data should be good if interactions between equipped vehicles occurs.

140—Mobility—Analysis of Pedestrian Crash Data

Directly related to hypothesis #4: The pilot deployment will reduce pedestrian to vehicle conflicts in the pilot deployment area by warning vehicles.

Value *Score: 3*
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 interactions between equipped vehicles occurs.

210—Mobility—On-Time Schedule Reliability

Directly related to hypothesis #5: The pilot deployment will improve transit schedule reliability through TSP.

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: 3*
Traffic Data: Moderate risk since agencies are likely to have good traffic data (speed, travel time, throughput, queue, delay).

220—Mobility—Transit Ridership

Directly related to hypothesis #6: The pilot deployment will improve transit ridership through TSP.

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: 3*

Traffic Data: Moderate risk since agencies are likely to have good traffic data (speed, travel time, throughput, queue, delay).

310—Mobility—Travel Time

Directly related to hypothesis #7: The pilot deployment will improve traffic signal progression through use of CV data.

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: 3*

Traffic Data: Low risk since agencies are likely to have good traffic data (speed, travel time, throughput, queue, delay). Data may be incomplete.

320—Mobility—Travel Time Reliability

Directly related to hypothesis #7: The pilot deployment will improve traffic signal progression through use of CV data.

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: 3*

Traffic Data: Low risk since agencies are likely to have good traffic data (speed, travel time, throughput, queue, delay). Data may be incomplete.

330—Mobility—Throughput

Directly related to hypothesis #7: The pilot deployment will improve traffic signal progression through use of CV data.

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). Data may be incomplete.
Work Zone Data: The extent of work zones in the evaluation corridors is unknown.

400—AMS of Mobility Improvements

Directly related to hypothesis #9: As the market penetration of CVs increases, benefits will increase in terms of reduced stops, queues, delays, emissions, and increased vehicle throughput, transit schedule reliability, and travel time reliability; and hypothesis #10: As the market penetration of CVs increases, non-equipped vehicles traversing the pilot deployment area will see reductions in stops, queues, delays, and emissions.

<u>Value</u> *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.

<u>Risk</u> *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 #9: As the market penetration of CVs increases, benefits will increase in terms of reduced stops, queues, delays, and emissions, and increased vehicle throughput, transit schedule reliability, and travel time reliability; and hypothesis #10: As the market penetration of CVs increases, non-equipped vehicles traversing the pilot deployment area will see reductions in stops, queues, delays, and emissions.

<u>Value</u> *Score: 2*

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

<u>Risk</u> *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 #9: As the market penetration of CVs increases, benefits will increase in terms of reduced stops, queues, delays, and emissions, and increased vehicle throughput, transit schedule reliability, and travel time reliability; and hypothesis #10: As the market penetration of CVs increases, non-equipped vehicles traversing the pilot deployment area will see reductions in stops, queues, delays, and emissions.

<u>Value</u> *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 vehicles where applications are to be deployed, may not be representative of other locations.

<u>Risk</u> *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 #9: As the market penetration of CVs increases, benefits will increase in terms of reduced stops, queues, delays, and emissions, and increased vehicle throughput, transit schedule reliability, and travel time reliability; and hypothesis #10: As the market penetration of CVs increases, non-equipped vehicles traversing the pilot deployment area will see reductions in stops, queues, delays, and emissions.

<u>Value</u> *Score: 2*

Nature:	Quantitative assessment.
Observability:	Assessments based on simulated and predicted data.
Scope:	Comprehensive assessment—covers most of the midtown area where significant volumes exist.
Extensibility:	Midtown is already heavily congested during most periods in the day.

<u>Risk</u> *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.).

710—Public Agency Efficiency Analysis of Project as Delivered

Directly related to hypotheses #12: Agencies find their SMEP goals were met.

<u>Value</u> 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 NYC deployment.

Risk *Score: 4*
Observed Data: Sites may not have level of data needed to support assessment.
Survey Data: High likelihood that 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 #13: Agencies find their SMEP goals were met.

Value *Score: 2*
Nature: Qualitative assessment based on log data (reductions in detection times, changes in response times, etc.).
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 should be easily collected from site agency participants.
Observed Data: Medium risk associated with the reliability and thoroughness of reported agency responses and associated event conditions.

810—Benefit-Cost Analysis of Project as Delivered

Directly related to hypothesis #11: Benefits exceed costs.

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 #11: B/C changes with market penetration.

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 since 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 #11: End users are satisfied with performance of CV devices.

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.

<u>Value</u>		*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.	

<u>Risk</u>		*Score: 1*
Survey Data:	Low risk since survey data easily collected from all public participants.	
Observed Data:	Not applicable.	

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