Connected Vehicle Pilot Deployment Program Independent Evaluation

Program Assessment

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16. Abstract

The U.S. Department of Transportation's Intelligent Transportation Systems Joint Program Office awarded three Connected Vehicle Pilot Deployment Program projects to three sites in 2015: Wyoming, New York City, NY, and Tampa, FL. The program's vision was to spur innovation among early adopters of connected vehicle application concepts using the best available and emerging intelligent transportation systems and communications technologies. The program used innovative management concepts including (a) a new project solicitation approach, (b) a structural emphasis on cooperation among sites as opposed to competition, (c) a focus on technologies that were key to the program, and (d) an emphasis on sustainability to encourage continued operation of systems. This report assesses the program's structure, its benefits, and lessons learned.

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Executive Summary

Background

To paraphrase Albert Einstein, if we want different results, we need to do things differently. That perspective was a core tenet of the U.S. Department of Transportation approach to the Connected Vehicle Pilot Deployment (CVPD) Program—use a different, innovative set of program strategies to enable public-sector deployment of new technologies in a new, emerging marketplace of connected vehicles.

Those new program strategies brought forward in the CVPD Program were meant to help achieve the vision of enabling "innovation among early adopters of connected vehicle application concepts using the best available and emerging ITS [intelligent transportation systems] and communications technologies" to deploy applications that support improved transportation system performance and enhanced performance-based management (*1*). The goals of that vision were to spur early connected vehicle technology deployment, to target improvements in safety and mobility, and to identify and resolve deployment issues of new technologies.

For this program, three sites were selected through a competitive process in September 2015. The Intelligent Transportation Systems Joint Program Office (ITS JPO) selected these three sites to proceed toward implementation: Wyoming, New York City, NY, and Tampa, FL. The Wyoming Department of Transportation was the lead agency for the Wyoming deployment. The New York City Department of Transportation led the deployment efforts in New York City, and the Tampa Hillsborough Expressway Authority led the deployment in Tampa. The ITS JPO CVPD Program website (https://www.its.dot.gov/pilots/) contains extensive documentations about the planning, design, and implementation of each deployment.

New Strategies

The new program strategies that ITS JPO used for this connected vehicle program included:

- A new project solicitation approach.
- A structural emphasis on cooperation among sites as opposed to competition.
- A focus on technologies that were key to the program.
- An emphasis on financial sustainability to encourage continued operation of systems.

New Project Solicitation Approach

The new project solicitation and management strategy included extensive pre-solicitation outreach, an emphasis on real-world problem solving, a two-phase program structure that encouraged a diversity of proposals, and a phased structure using the systems engineering process that required significant capability to progress through to award.

Stakeholder interviews indicated that the number of proposals was much more than anticipated, and interviewees attributed the response to the extensive outreach that ITS JPO did leading up to the request for proposals. The consensus among the interviewees was that because of the extensive outreach effort through multiple channels, ITS JPO was able to reach a lot of potential proposers with relevant information. Interviewees also agreed that having the proposers provide a “problem to solve” in the proposal process was effective. Interviewees generally noted that the process increased the diversity of the proposals. Finally, interviewees thought the phased structure that used the systems engineering process to describe the deployment process worked well and mitigated the risk of getting untenable deployments.

Structural Emphasis on Cooperation among Sites

The structural emphasis on cooperation among sites as opposed to competition was effective at identifying issues and providing opportunities for informed actions. As an example, conversations initiated at the roundtables sometimes generated further conversations to address issues especially for the technical roundtable. This process was new, but with experience it provided a good opportunity for updates and sharing challenges and lessons learned. The roundtables (technical, performance measurement, and outreach) acted as peer exchanges. There was some feedback that the number of roundtable meetings may have created a workload challenge for the sites at times.

Connected Vehicle Technology Focus

Most respondents acknowledged that there were issues with the lack of maturity of some of the technologies (e.g., dedicated short-range communications issues, onboard unit issues, and application issues) and the deployment challenges of those technologies (such as urban canyon communications). While some thought that these issues were dealt with innovatively, others believe that this lack of maturity was a real problem that caused significant delay. More testing of the technology prior to the deployment could have helped resolve these issues.

Emphasis on Financial Sustainability

Public operating agencies have many competing uses for their limited funding. Demonstration of positive outcomes for their investments is key to achieving sustained financial funding for those services at the local level. For the sites on-road penetration of instrumented vehicles was very low, and that hindered data availability. With limited data and with so few vehicles in the traffic stream, it was too big a challenge to accurately assess the impacts of the deployed technologies and services. The number of instrumented vehicles was too small in comparison to the total volume of traffic to observe an impact at the aggregate level. The lack of that information could be a significant impediment to gathering financial support for sustained operations for public operating agencies.

Benefits and Lessons Learned

The assessment of benefits for this program evaluation is a qualitative description that draws from the CVPD Team interviews and the CVPD published documents. These descriptions identify the impacts of the program work that was done while helping the sites overcome deployment challenges. The benefits and lessons learned can be institutionalized for future programs and stakeholders. The benefits and lessons learned are as follows.

Benefits

- There was operational and deployment value in the interoperability testing that occurred at the Turner-Fairbank Highway Research Center. The CVPD Program was able to show that if standards were followed, then multiple vendors could produce devices that were interoperable. The CVPD Program also learned the scope, stakeholders, procedures, and costs associated with this type of interoperability testing.
- Another benefit was that the CVPD Program was able to demonstrate three different deployment models for in-vehicle devices. These devices were in private autos, in government fleet vehicles, and with commercial fleet operators. This success and the details about those deployment models are assets for future initiatives and for advancing the marketplace.
- An important planning benefit for future programs is a more informed understanding of the maturity of the involved technologies and the level of support that the government can provide to support the transition from research to deployment. Future programs might develop a definition of technology deployment readiness and risk that informs all the stakeholders about the challenges of technologies in the context of the program and projects deployed by agencies.
- There were also anecdotal observations that the publicity, outreach, and engagement with the CVPD Program encouraged "spinoff deployments" of CV technologies and services, including by the Colorado Department of Transportation and others who used funding sources such as the Advanced Transportation and Congestion Management Technologies Deployment Program.

Lessons Learned

- From a programmatic perspective, there is an increased understanding about the deployment value of collaboration, the impact of the gated phased program approach, and the difficulties of assessing the performance of pilot deployments. For those topics, some of the comments about future endeavors were that:
  - Collaboration roundtables were effective. However, throughout the project they could have been adjusted for topic, length, and meeting frequency so that they used agency, contractor, and US DOT resources effectively in a busy deployment setting.
  - The gated process using systems engineering was effective but took too "long" in an environment where the technology was rapidly changing.
  - More reliance on site self-evaluations and less on independent evaluations could be appropriate especially when the ability to gather data from new systems is not yet proven and when each site might have unique data gathering capabilities and constraints such as differing perspectives on personally identifiable data.

- Large, complex programs take time to procure, design, deploy, operate, and evaluate. In a rapidly changing environment, they run the risk of facing new challenges that are outside the scope of the project, outside the control of the stakeholders, and that can add delays and expenses. Future programs could consider projects that have a combination of vehicles, technologies and field sites that can be accomplished in a shorter time frame. These smaller scopes would have less exposure to external uncertainties, could have less risk, and could more rapidly yield outcomes that influence the transportation marketplace.
- The definition and concept of technological maturity might be broadened for these kinds of projects in the future. The dimensions of the definition could include device and process maturity, pilot and demonstration experiences, commercial availability, marketplace penetration, maintenance capabilities, and other aspects helpful to the US DOT and performing agencies. This broad definition could aid stakeholder knowledge and enable better risk management.

Conclusion

The CVPD Program was ambitious in an environment of emerging technology and uncertainty about key elements such as spectrum allocation and commercial availability of systems and components. The program required an impressive level of effort and dedication by all involved—USDOT, public infrastructure operating agencies, stakeholder organizations, and commercial suppliers. Program innovation and flexibility coupled with nimble site adaptations helped to address these marketplace challenges.

The CVPD Program was designed and planned in 2014 with Phase 1 awards in September 2015. This timeline aligns with the 2014 National Highway Traffic Safety Administration Advanced Notice of Proposed Rulemaking (ANPRM) that would require automakers to include vehicle-to-vehicle communications technologies in all new light-duty vehicles. In addition, a key previous vehicle communications project, the Safety Pilot Model Deployment Connected Vehicle Program in Michigan, was concluding in late 2013 and independent evaluations of the project were finalizing in 2014. (*5*) In this environment there was reason to anticipate the resolution of major technology challenges such as use of the 5.9 GHz spectrum for DSRC use with supporting implementations from vehicle manufacturers.

As the program progressed some events reinforced the expectation that these challenges could be successfully addressed. For instance, in December 2016 the U.S. Department of Transportation's (DOT) National Highway Traffic Safety Administration (NHTSA) unveiled its long-awaited proposal for requiring vehicle-to-vehicle (V2V) communications technology in all new vehicles. With that announcement there was added hope the marketplace would adopt the DSRC 5.9 GHz communications approach that had been used in Michigan for the Safety Pilot Model Deployment.

However, a year into the project the telecommunications industry was asking to share the 5.9 GHz spectrum with unlicensed Wi-Fi, NHTSA rulemaking for vehicle-to-vehicle communications had not completed, some companies were proposing a cellular communications approach for vehicle safety instead of the DSRC approach used in Michigan, and the Federal Communications Commission was aware of these viewpoints. This uncertainty contributed to the reluctance of broad industry investment in the DSRC approach. The CVPD sites, their stakeholders, and the US DOT were addressing technology issues with less than full industry engagement. If this program had been on the forefront of a massive industrywide adoption of DSRC technology the results would have been trendsetting. The benefits produced by the new program strategies of extensive pre-solicitation outreach, real-world problem solving, phased selection, collaboration, roundtables, local performance measurement, and financial sustainability were key in achieving the resulting outcomes despite the uncertainties.

Additional factors contributed toward making the deployment build particularly challenging for the sites and the US DOT. Technical issues of DSRC communications in the canyons caused by the buildings in New York had never been experienced and solved before this program. Sharing of detailed vehicle location data outside of immediate use for safety applications was an impediment for evaluation in New York because of concerns about personally identifiable information – but it did not impact the ability of the technology to function. In Wyoming one of the project's two DSRC vendors dropped support for their equipment including vehicle and roadside units in December 2020, forcing WYDOT to scramble to find a new supplier late in the project. Tampa transitioned its deployment into a testing site to bring financial sustainability to their build. In addition, the US DOT faced significant challenges with the security credential management system and the move to a secure data commons approach for datasets.

Despite all these challenges the CVPD Program structure and approach was a success. CV technologies and services were deployed. The deployers and providers were engaged and expanded their knowledge and capabilities. The innovative program was instrumental in bringing a qualified set of deployers to the table who were able to collaboratively face the challenges of the ecosystem.

These types of programs that pilot innovative technologies and techniques to risk-averse, budget-constrained, public-sector agencies are likely to remain challenging. The lessons learned and documentation published by the CVPD Program will be useful in continuing the advancement of transportation capabilities. Wirelessly connected vehicles are already here, even if they all do not broadcast the messages used in the CVPD Program. So even with the end of DSRC there will still be a move to a future where vehicles are increasingly connected. The results of the pilots will be useful to anyone considering "CV" deployments, using DSRC or any other approach.

Chapter 1. Introduction

The U.S. Department of Transportation (USDOT) connected vehicle (CV) research program is a multimodal initiative that strives to enable safe, interoperable networked wireless communications among vehicles, the infrastructure, and travelers' personal communication devices. Together, USDOT and other agencies and entities are sponsoring CV research to leverage the potentially transformative capabilities of wireless technology to make surface transportation safer, smarter, greener, and sustainable for the long run. This program is funded through the Intelligent Transportation Systems Joint Program Office (ITS JPO).

Throughout the life cycle of the Connected Vehicle Pilot Deployment (CVPD) Program, the initiative was planned and shaped by a set of fundamental hypotheses that were structured to achieve program goals. Some decisions related to program structure and process were made early, while other choices came later during the conduct of the CVPD. USDOT provided the Texas A&M Transportation Institute (TTI) with the program structure and process foundational hypotheses that served as the basis for the Evaluation Plan for the CVPD Program Independent Evaluation (*2*). The evaluation investigates whether USDOT's CVPD Program structure and processes were effective in meeting the program's vision, goals, schedule, and roadmap structure.

The Connected Vehicle Pilot Deployment Program

Through the CVPD Program, USDOT initiated pilot deployments in three locations—Wyoming, New York City, NY, and Tampa, FL—to showcase the benefits of CVs, mobile devices, and smart infrastructure data to improve safety, mobility, environment, and public-agency efficiency. The following captures the program vision, program goals, program schedule, and program roadmap of USDOT's CVPD, as specified on the ITS JPO CVPD Program website, as of April 30, 2019 (*1*).

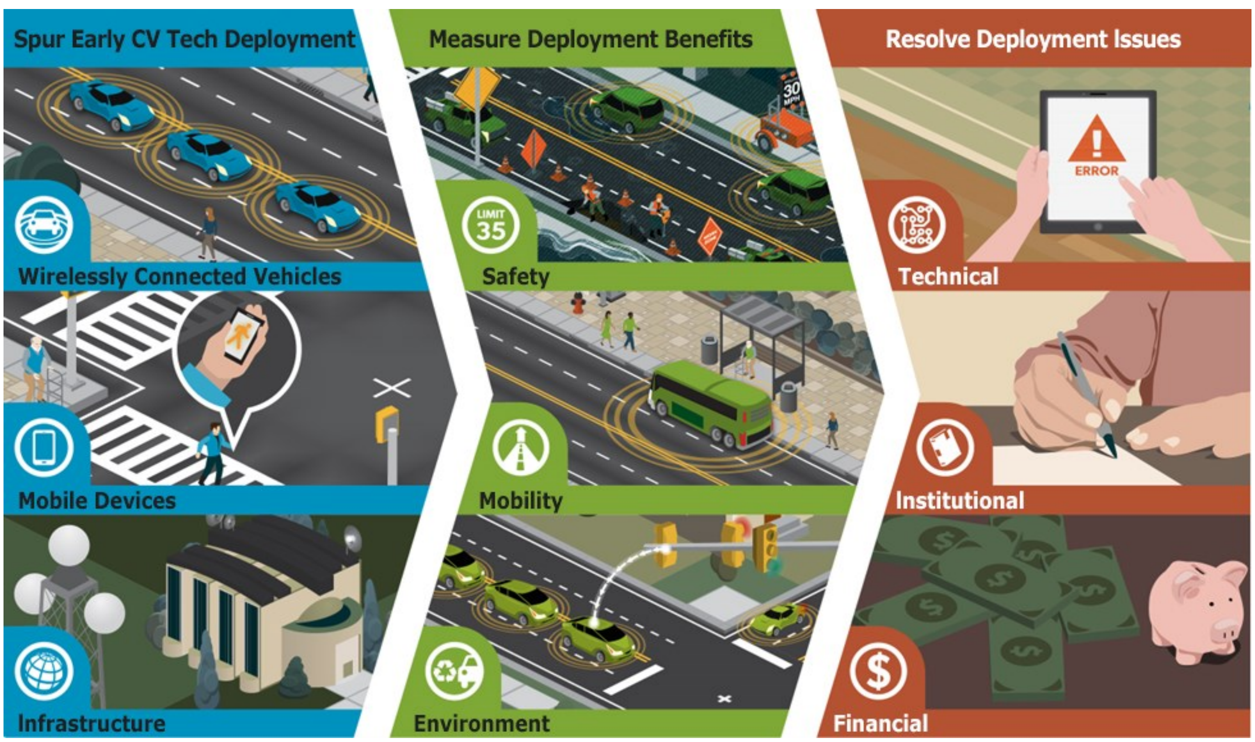
CVPD Program Vision

The program seeks to spur innovation among early adopters of CV application concepts using the best available and emerging intelligent transportation systems (ITS) and communications technologies. The pilot deployments are expected to integrate CV research concepts into practical and effective elements, enhancing existing operational capabilities. The intent of these pilot deployments is to encourage partnerships of multiple stakeholders (e.g., private companies, States, transit agencies, commercial vehicle operators, and freight shippers) to deploy applications using data captured from multiple sources (e.g., vehicles, mobile devices, and infrastructure) across all elements of the surface transportation system (e.g., transit, freeways, arterials, parking facilities, and tollways) to support improved system performance and enhanced performance-based management. The pilot deployments are also expected to support an impact assessment and evaluation effort that will inform a broader cost-benefit assessment of CV concepts and technologies.

CVPD Program Goals

As illustrated in Figure 1, USDOT identified the following as the goals for the CVPD Program:

- To spur early CV technology deployment, not just through wirelessly connected vehicles but also through other elements that are major players in this connected environment, such as mobile devices, infrastructure, traffic management systems, and other elements. Data can be integrated from these multiple sources to help make key decisions.
- To target improving safety, mobility, and environmental impacts, and to commit to measuring those benefits. Measurement of the impacts and benefits will be gathered from real-world deployments, rather than an isolated test bed or a computer-based simulation test bed. Differentiating and finding these benefits and identifying what can be attributed to these CV applications and technologies are important components of the activity.
- To resolve issues of various deployments. People often first jump to technical areas and focus on getting applications to work together, but that is only part of the concern. Institutional arrangements must be put in place to ensure installation of the technology and to manage and govern the sharing of information. Also, financial arrangements must be made that may integrate the technologies into a financially sustainable model that can be sustained following the initial funding from the initial pilots.

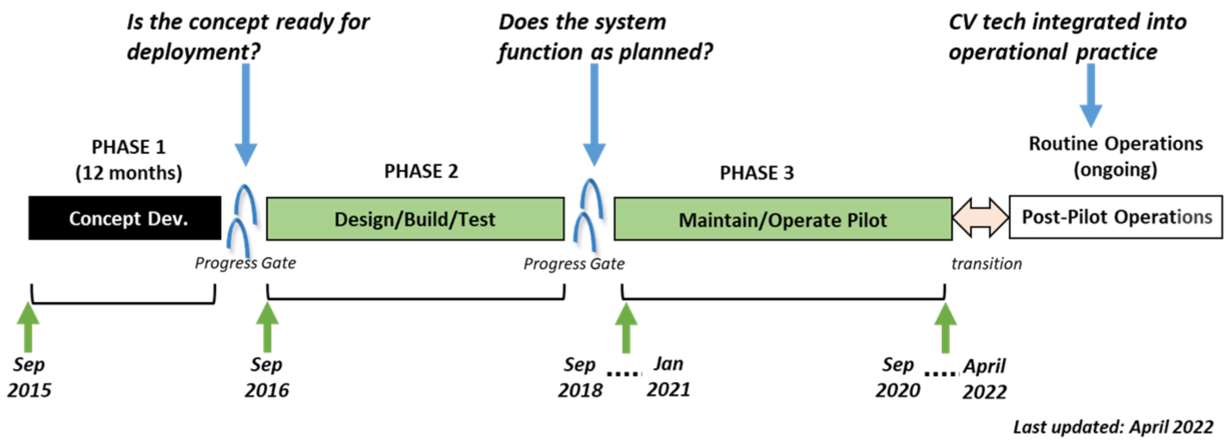


Source: USDOT ITS JPO Connected Vehicle Pilot Deployment Program website, 2019

Figure 1. Graphic. USDOT CVPD Program Goals

CVPD Deployment Timeline

Each pilot deployment site developed its deployment in three distinct phases. In Phase 1, the sites spent 12 months preparing a comprehensive deployment concept to ensure a rapid and efficient CV capability rollout. The sites transitioned to Phase 2 for designing, building, and testing these deployments of integrated wireless in-vehicle, mobile device, and roadside technologies. Tampa spent 2.5 years in Phase 2 while New York City and Wyoming each spent 4-5 years in Phase 2. In Phase 3, the tested CV systems were operationalized, and the systems' impact was monitored on a set of key performance measures. Figure 2 illustrates the timeline for the deployment.



Source: USDOT ITS JPO Connected Vehicle Pilot Deployment Program

Figure 2. Timeline. CVPD Program Schedule

Program Assessment Objectives and Scope

The objective of this assessment was to evaluate the extent to which the CVPD Program achieved the desired USDOT goals. The overall program evaluation includes three thrust areas:

- Assessing the effectiveness of the performance-based approach used by USDOT to identify, select, and manage the CVPDs.
- Identifying the benefits achieved by USDOT through the CVPD Program.
- Assessing if the CVPD Program achieved its overall vision effectively.

The intent of this overall evaluation was to determine whether ITS JPO's approach for the CVPD Program was effective at encouraging widespread deployment of CV technologies. The widespread deployment of CV technologies requires a significant investment to move from model pilot deployment to full-scale deployments, particularly from the standpoint of State and local governments. The CVPDs are intended to be a keystone effort in the USDOT ITS JPO program. These pilot deployments play a key role in accelerating deployment across the country, promoting interoperability, and generating enterprise data. The CVPDs are likely to serve as models for widespread deployment and offer insight into how other regions can advance the deployment of CV technologies in their jurisdictions.

TTI collected stakeholder feedback on the overall effectiveness of the program to spur wide-scale acceptance of the technology. Following appropriate Institutional Review Board procedures, TTI used an interview format to solicit feedback and lessons-learned information from the following CVPD Program stakeholders:

- USDOT CVPD program manager and deployment teams.
- Site deployers.
- Safety evaluator (Volpe National Transportation Systems Center).
- Deployment site leads and evaluation team.
- Other critical stakeholders.

The program evaluation looked at near-term outcomes/impacts with respect to encouraging deployment of CVs across the United States only. Because of the time frame for the evaluation, the COVID-19 pandemic, and the delays associated with the sites deploying some of their systems, TTI was unable to assess the potential longer-term impacts of the program.

Methodology

The methodology used to examine the connected CVPD Program was to develop a set of relevant program hypotheses and to assess those hypotheses by conducting a series of interviews with USDOT-designated team members. The observations about the hypotheses were further augmented by relevant information from published USDOT CVPD reports.

The hypotheses and the evaluation approach were developed and approved in a previous CVPD plan evaluation document, *Connected Vehicle Pilot Deployment Program Independent Evaluation: Program Evaluation Plan*, published in 2019 (*2*). That plan was further refined in another 2019 report that describes the interview survey process, titled *Connected Vehicle Pilot Deployment Program Independent Evaluation: Program Evaluation Survey Plan* (*3*).

The 16 hypotheses from the 2019 documents are the foundation for the work described in this report. The interviews and associated data are organized around those proposed hypotheses.

Organization of Report

This report is divided into the following six chapters:

- Chapter 1. Introduction. This first chapter contains an overview of the CVPD initiative, a perspective of the program evaluation, and a quick guide to the topics covered in the individual chapters.
- Chapter 2. Program Assessment Hypotheses and Research Questions. This chapter lists the hypotheses and research questions that were addressed as part of the program evaluation.
- Chapter 3. Methodologies and Analysis Tools. This chapter summarizes the approaches and data that TTI used to assess the quality, impacts, and outcomes of the CVPD Program structure and processes.

- Chapter 4. Program Assessment. This chapter describes the findings for each of the 16 hypotheses.
- Chapter 5. Conclusions, Benefits, and Lessons Learned. This chapter highlights the conclusions and lessons learned.
- Chapter 6. References. This chapter includes the references cited in the document.

Chapter 2. Program Assessment Hypotheses and Research Questions

Background

The USDOT Team provided 14 foundational hypotheses spanning 10 topic areas to TTI (*1*). Each hypothesis addressed a specific program structure or process activity that was related to the CVPD Program goals. In addition to these hypotheses, TTI added two other hypotheses based on discussions with and questions from USDOT. These two hypotheses address the overall program structure, vision, and goals.

The list of 16 hypotheses, a description of data needs (many from USDOT), candidate questions for interviews, and other assumptions were submitted to USDOT. The USDOT agreed on the hypotheses, noting that the survey questions should be tailored to what the normal behaviors for deployment programs are, where possible, because there is no set template for deployment activity.

Hypotheses

Table 1 lists the 14 foundational hypotheses that USDOT established in developing the CVPD Program (noted with an asterisk behind the hypothesis number). The table also defines the rationale, the program structure, and the process activities they support. These 14 foundational hypotheses plus two additional hypotheses developed by TTI comprise the full set of evaluation hypotheses that TTI used to assess the effectiveness of the USDOT CVPD Program.

Table 1. Evaluation Hypotheses for Assessing USDOT CVPD Program Effectiveness

No.	Program Overview Link	Topic Category	Topic	Evaluation Hypotheses	Background
1*	Stakeholder engagement roadmap activity area	Solicitation planning	Pre-solicitation outreach	Extensive pre-solicitation outreach would increase the number and enhance the quality of submitted proposals.	The CVPD Program committed to a nine-month period prior to the initial solicitation that included a workshop, multiple webinars, and outreach efforts articulating the program vision.
2*	Pilot deployment roadmap activity area	Solicitation planning	Emphasize real-world problem solving	Focusing on real-world problem solving would lead to proposals/projects where a definitive impact could be realized, even if only a limited total number of devices, vehicles, and technology might be deployed.	Pre-solicitation outreach and solicitation criteria emphasized that there must be a problem to be solved (rather than a technology to be deployed). Hypothetical deployment concepts illustrating a problem-focused approach were developed and used extensively in workshops, webinars, and other outreach. The goal was to avoid proposals for technology showcases or temporary field tests that would be dismantled at the end of the deployment period.

No.	Program Overview Link	Topic Category	Topic	Evaluation Hypotheses	Background
3*	Pilot deployment roadmap activity area	Solicitation planning	Two-phase solicitation structure	The two-phase solicitation structure of broad agency announcement for private- and public-sector leads in Phase 1 and cooperative agreements for public-sector leads in Phase 2 would allow agencies that are too small or with cumbersome contracting methods to respond to the procurement.	Phase 1—Broad Agency Announcement (BAA)/contracts with private- or public-sector leads, 12 months. Phase 2/3—Cooperative agreements with public-sector agencies (only), 38 months. The solicitation structure would allow agencies without the ability to contract/ subcontract quickly to respond to the BAA as a sub to a private-sector entity (with presumably more nimble contracting capabilities). Once the deployment concept was fully vetted in Phase 1, then a cooperative agreement (with a longer lead time) could be put in place with a public agency.
4*	Pilot deployment roadmap activity area	Solicitation planning	Phases with consequential gates	The two consequential phase gates (one technical and the other operational) would provide USDOT with needed leverage to encourage sites to adhere to schedule, cost, and scope.	Teams that could not show progress toward a unified deployment concept or with fundamental flaws in institutional or technical planning could be dropped from the deployment program after Phase 1. Phase 1 costs were estimated to be roughly 12–20% of total deployment costs prior to the original solicitation, with the low-end figure for large deployments ($15–$20 million) and high-end figure for smaller deployments ($3–$7 million). The Phase 3 gate was not technical but rather on a two-trigger decision (site and Federal) to proceed to operations based on a risk assessment—will the deployments operate safely, securely, and as designed?

No.	Program Overview Link	Topic Category	Topic	Evaluation Hypotheses	Background
5*	Application and open-source roadmap activity	Program structure	Post-award collaboration among deployment sites, not competition	Collaboration among sites would provide more value than creating a competitive "funnel" program with roughly twice as many Phase 1 participants as Phase 2–3 awardees.	Cooperation/collaboration among site cohort, using positive peer pressure rather than competitive structure, ensures schedule/scope adherence and drive innovation.
6*	Stakeholder engagement roadmap activity area	Program structure	High rate of interaction post-award: meeting cadence and topics/roundtables	A set of regular structured topical roundtables plus monthly check-ins would ensure sites knew of each other's challenges, resolutions, and progress.	Related to Hypothesis 5, this decision was to engage the sites in a steady set of meetings and roundtables to encourage the sites to compare notes/progress.
7*	Application roadmap activity	Technological maturity	CV tech mature enough to mount a successful deployment program	The level of CV readiness was high enough to mount a deployment program and the deployment program would help the industrial base to make these technologies more robust and deployable.	The maturity of CV technologies and applications were known to be in a mixed state—some developed at a research level, and others available commercially but not yet deployed at scale or in combination.
8*	Pilot deployment roadmap activity area	Dedicated short-range communications (DSRC) focus	DSRC an element of each deployment but not a comprehensive requirement	Requiring sites to use DSRC in some way as part of the deployment, but not requiring use for all applications, would allow a more realistic, practical, and effective deployment concept.	The program wanted to encourage deployers to consider logical use of DSRC technologies, both to determine their level of readiness and to test using the 5.9-GHz spectrum at a deployment-level scale.

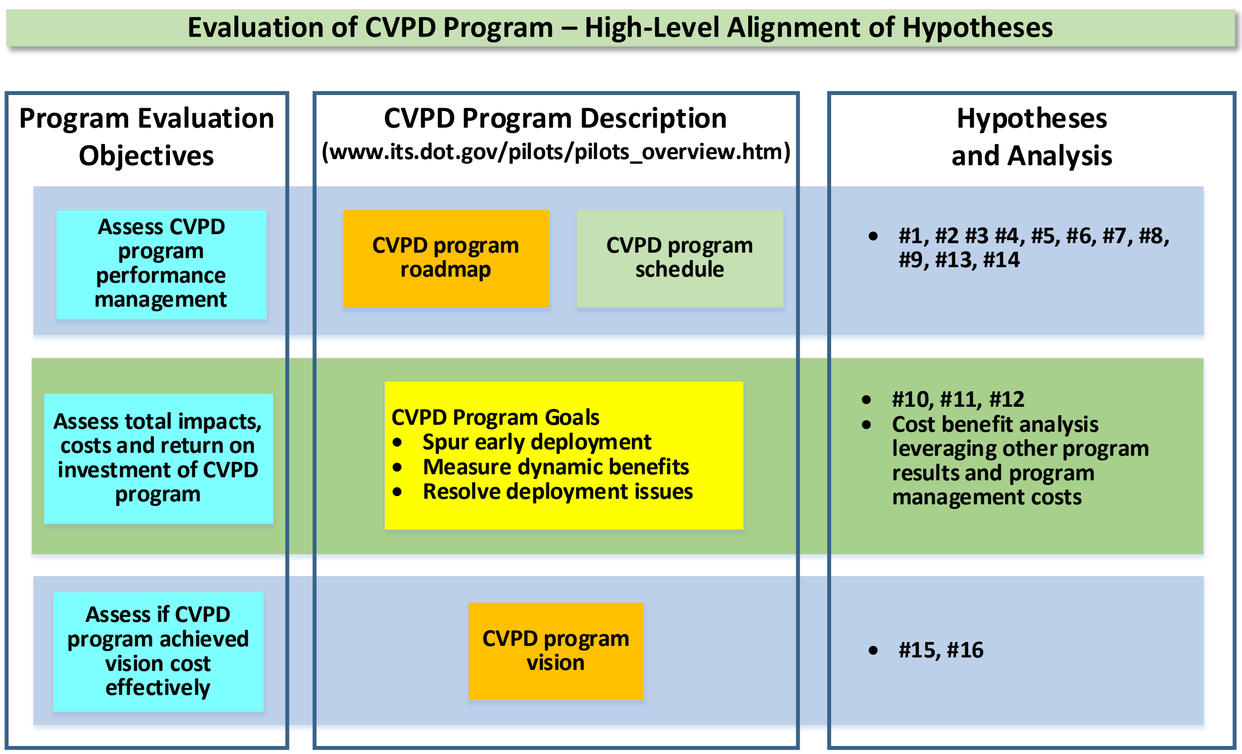
No.	Program Overview Link	Topic Category	Topic	Evaluation Hypotheses	Background
9*	Application and open-source roadmap activity	Open data/open source	Open data and open source a required element of all deployments	The open source/data requirement would not put off serious deployers, would not prove too onerous, and would assist in technology transfer to deployments outside the CVPD program.	The sharing of deployment-related data and code was required as a deployment element from pre-solicitation and through all three phases.
10*	Pilot deployment roadmap activity area	Security/ privacy	Deployment of cybersecurity and privacy protection emphasized early	An early emphasis on cybersecurity and privacy would reduce the risk of cyber- or privacy-related issues in the operational phase of the deployments.	Phase 1 deliverables on security and privacy ensured that sites considered these topics early in the project, not afterward.
11*	Pilot deployment roadmap activity area	Security Credential Management System (SCMS)/ certification	Certified devices connected with a credential management system required	Similar to the technical maturity hypothesis (#7), the dependence of the program on external certification and credential management would speed the maturation of these needed capabilities without the program itself having to directly finance/manage their creation.	The CVPD Program recognized the need for device certification and centralized credential management and made these requirements for the sites although neither a proven certification process nor a large-scale SCMS existed.
12*	Pilot deployment roadmap activity area	Financial/ institutional sustainability	Financial sustainability after Federal funding ceased emphasized	By reiterating the need for long-term financial sustainability of the deployments, the program would reduce the risk of the deployed technologies being removed at the end of the funding period (as in field tests) or the risk of the sites developing a long-term need for Federal funding to continue.	Phase 1 deployment concepts were evaluated for financial sustainability before Phase 2 funding. Independent evaluation of financial sustainability was performed.

No.	Program Overview Link	Topic Category	Topic	Evaluation Hypotheses	Background
13*	Impact assessment roadmap activity	Performance measurement/ evaluation	Sites required to implement a performance measurement capability	A performance measurement capability would reinforce a performance-driven management of the system, allowing impacts to be more easily observed and quantified through an independent evaluation of near-term impacts.	Integrated performance measurement for sites was required, in addition to supporting a supplementary independent evaluation.
14*	Stakeholder engagement roadmap activity area	Outreach/other early deployers	Sites required to participate in a range of structured, coordinated outreach activities	Getting the word out in a variety of forms, but within a structured and coordinated construct provided by the program, would assist USDOT and the sites transfer knowledge to other early deployers more efficiently.	Sites were required to participate in outreach events, conduct webinars/ showcases, and document plans and findings in some detail so other early deployers would benefit.
15	Program vision	Program structure	Overall program structure and process assessment	The overall effect of the program's innovative approaches and roadmap of activities resulted in outcomes that were positive to the USDOT Team.	The CVPD Program structure and vision are at https://www.its.dot.gov/pilots/pilots_overview.htm.
16	Program vision	Program vision and goals	Overall program vision	The CVPD Program met the vision laid out at the onset of the program.	The CVPD Program vision and goals are at https://www.its.dot.gov/pilots/pilots_overview.htm.

Note: An asterisk behind the hypothesis number indicates it was a foundational hypothesis provided by USDOT.

Alignment of Hypotheses with Vision and Goals

Figure 3 provides a high-level depiction of how the hypotheses and financial analysis relate to key elements of the program and to the program evaluation objectives. The figure shows the primary alignments. Some objectives may be informed by multiple hypotheses. However, only primary relationships are shown in the table for ease of conceptual understanding. Many of the hypotheses respond to the objective of determining if the CVPD Program's performance management focus was beneficial. These hypotheses include processes in the pre-procurement planning phase, and considerations about the program structure, technology maturity, DSRC, data, performance measurement, and outreach. Other hypotheses relate to the goals of the program including those associated with credential management and financial stability. Two hypotheses pertain to the CVPD Program's vision.



Source: Texas A&M Transportation Institute

Figure 3. Graphic. Program Evaluation and Hypothesis Relationships

Chapter 3. Methodologies and Analysis Tools

This chapter summarizes the approaches and data that TTI used to assess the quality, impacts, and outcomes of the CVPD Program structure and processes. Table 2 shows the performance measures, data sources, and analyses TTI used to assess the effectiveness of the USDOT CVPD Program.

Assessment of Performance-Management Focus of Pilot Deployments

Performance-based management involves using a systematic approach to improve performance through an ongoing process of establishing strategic performance objectives; measuring performance; collecting, analyzing, reviewing, and reporting performance data; and using those data to drive improvement. The performance-based management process involves providing answers to the following questions:

1. What are the needed capabilities?
2. What are the technical and operational requirements?
3. What are the cost and schedule?
4. What are the periodic measures of performance?
5. What are the impediments to progress?

TTI documented and assessed how the CV Pilots Program use of performance-based management processes helped facilitate the spread and use of CV technologies. TTI assessed how effective the program was at spurring growth of the CV applications and technologies, and identifying and overcoming technical, institutional, and financial constraints to deployment of this new technology. TTI assessed the extent to which the pilot deployment integrated CV research concepts into practice and enhanced existing operational capabilities. Also, TTI assessed how these pilot deployments encouraged partnerships of multiple stakeholders (e.g., private companies, States, transit agencies, commercial vehicle operators, and freight shippers) to deploy applications using data captured from multiple sources (e.g., vehicles, mobile devices, and infrastructure). TTI examined how the pilot deployments helped inform the state of the practice about the broader cost-benefits associated with deploying CV concepts and technologies in a region or metropolitan area.

Table 2. Performance Measures, Data Sources, and Analysis Types to Assess USDOT Program Effectiveness

No.	Hypothesis	Performance Measures	Data Sources	Analysis Type
1	Extensive pre-solicitation outreach would increase the number and enhance the quality of submitted proposals.	• Perceived impact/ effectiveness of pre-solicitation outreach activities	• Interviews conducted as part of program evaluation work • Documentation of pre-solicitation outreach activities in USDOT CVPD Program documents	• Qualitative perception data from interviews • Qualitative information from USDOT CVPD Program documentation
2	Focus on real-world problem solving would lead to proposals/projects where a definitive impact could be realized, even if only a limited total number of devices, vehicles, and technology might be deployed.	• Perceived impact/ effectiveness of problem-solving focus	• Interviews conducted as part of program evaluation work • Documentation of pre-proposal instances where focus of outreach material and conversations were addressed to problem solving	• Qualitative perception data from interviews • Qualitative information from USDOT CVPD Program documentation
3	The two-phase solicitation structure of broad agency announcement for private- and public-sector leads in Phase 1 and cooperative agreements for public-sector leads in Phase 2 would allow agencies that are too small or with cumbersome contracting methods to respond to the procurement.	• Perceived change in smaller and contract-challenged proposers	• Interviews conducted as part of program evaluation work • Documentation of pre-solicitation outreach activities in USDOT CVPD Program documents	• Qualitative perception data from interviews • Qualitative information from USDOT CVPD Program documentation

No.	Hypothesis	Performance Measures	Data Sources	Analysis Type
4	The two consequential phase gates (one technical and the other operational) would provide USDOT with needed leverage to encourage sites to adhere to schedule, cost, and scope.	• Perceived impact/ effectiveness of two-phase program structure	• Interviews conducted as part of program evaluation work • Program schedule impacts	• Qualitative perception data from interviews • Qualitative information from USDOT CVPD Program documentation
5	Collaboration among sites would provide more value than creating a competitive "funnel" program with roughly twice as many Phase 1 participants as Phase 2–3 awardees.	• Perceived impact/ effectiveness of post-award work collaboration	• Interviews conducted as part of program evaluation work • Examples of sites cooperating that add deployment value to the program	• Qualitative perception data from interviews • Qualitative information from USDOT CVPD Program documentation
6	A set of regular structured topical roundtables plus monthly check-ins would ensure sites knew of each other's challenges, resolutions, and progress.	• Perceived impact/ effectiveness of topical roundtables	• Interviews conducted as part of program evaluation work	• Qualitative perception data from interviews • Qualitative information from USDOT CVPD Program documentation
7	The level of CV readiness was high enough to mount a deployment program and the deployment program would help the industrial base to make these technologies more robust and deployable.	• Perceived impact/ effectiveness of CV readiness and technical value to the industrial base • Perceived changes to CV industry during the deployment period as a result of the program	• Interviews conducted as part of program evaluation work	• Qualitative perception data from interviews • Qualitative information from USDOT CVPD Program documentation

No.	Hypothesis	Performance Measures	Data Sources	Analysis Type
8	Requiring sites to use DSRC in some way as part of the deployment, but not requiring use for all applications, would allow a more realistic, practical, and effective deployment concept.	• Perceived impact of having a DSRC requirement for only a limited number of apps, instead of having it stipulated for the full range of apps	• Interviews conducted as part of program evaluation work	• Qualitative perception data from interviews • Qualitative information from USDOT CVPD Program documentation
9	The open source/data requirement would not put off serious deployers, would not prove too onerous, and would assist in technology transfer to deployments outside the CVPD Program.	• Perceived impact/ effectiveness of open-source data requirement and usefulness in technology transfer	• Interviews conducted as part of program evaluation work	• Qualitative perception data from interviews • Qualitative information from USDOT CVPD Program documentation mentation
10	An early emphasis on cybersecurity and privacy would reduce the risk of cyber- or privacy-related issues in the operational phase of the deployments.	• Perceived impact/ effectiveness of cyber risk and privacy reduction attributed to cybersecurity requirement	• Interviews conducted as part of program evaluation work	• Qualitative perception data from interviews • Qualitative information from USDOT CVPD Program documentation
11	Similar to the technical maturity hypothesis (#7), the dependence of the program on external certification and credential management would speed the maturation of these needed capabilities without the program itself having to directly finance/manage their creation.	• Perceived impact/ effectiveness of external certification and credential management on program delivery	• Interviews conducted as part of program evaluation work	• Qualitative perception data from interviews • Qualitative information from USDOT CVPD Program documentation

No.	Hypothesis	Performance Measures	Data Sources	Analysis Type
12	By reiterating the need for long-term financial sustainability of the deployments, the program would reduce the risk of the deployed technologies being removed at the end of the funding period (as in a field test) or the risk of the sites developing a long-term need for Federal funding to continue.	• Perceived impact/ effectiveness of emphasis on long-term financial stability with regard to continued operation after program completion without Federal funding	• Interviews conducted as part of program evaluation work	• Qualitative perception data from interviews • Qualitative information from USDOT CVPD Program documentation
13	A performance measurement capability would reinforce a performance-driven management of the system, allowing impacts to be more easily observed and quantified through an independent evaluation of near-term impacts.	• Perceived impact/ effectiveness of performance requirements on sustained performance-driven management of the systems	• Interviews conducted as part of program evaluation work	• Qualitative perception data from interviews • Qualitative information from USDOT CVPD Program documentation
14	Getting the word out in a variety of forms, but within a structured and coordinated construct provided by the program, would assist USDOT and the sites transfer knowledge to other early deployers more efficiently.	• Perceived impact/ effectiveness of USDOT program outreach activities as a means for sites to manage their outreach actions more effectively	• Interviews conducted as part of program evaluation work	• Qualitative perception data from interviews • Qualitative information from USDOT CVPD Program documentation
15	The overall effect of the program's innovative approaches and roadmap of activities resulted in outcomes that were positive to the USDOT Team.	• Perceived impact/ effectiveness of overall program's innovative approaches to structure	• Interviews conducted as part of program evaluation work	• Qualitative perception data from interviews

No.	Hypothesis	Performance Measures	Data Sources	Analysis Type
16	The CVPD Program met the vision laid out at the onset of the program.	• Perceived impact/ effectiveness of program-achieved vision laid out at the onset of the program	• Interviews conducted as part of program evaluation work	• Qualitative perception data from interviews

The TTI team used the following process to collect the data for this evaluation. The team checked whether the data needed were available through information posted on the ITS JPO CVPD website, including the site's documents (e.g., Phases 1–3 deliverables and presentations). After this initial review, the team constructed interview questions tailored to address specific needs. If there were still needs that could not be answered rapidly through surveys/interviews, the team forwarded those needs to USDOT/Noblis for processing.

Review of Documentation

The first step in the analyses was to review the existing literature and documentation produced by USDOT ITS JPO related to the project. This review included the information and reports published on USDOT's CVPD Program website (https://www.its.dot.gov/pilots/). This website includes reports and articles on the following:

- Success stories and lessons learned by USDOT and sites throughout the planning and deployment process.
- Responses to the CVPD Program's Request for Information.
- Reports, webinars, and presentation material on the site experiences during the preliminary planning phase of the pilot deployments.
- USDOT guidance documents related to the planning and design for the CVPD sites.

The purpose of this review was to obtain necessary information related to how USDOT structured the project and to gain insight into the processes and procedures that USDOT used to develop, promote, and managed the site selection, planning, and deployment process. A review of lessons-learned documentation also allowed TTI to obtain insight into the issues and solutions that USDOT faced throughout the pilot deployment process.

Surveys and Interviews

The data used to conduct this assessment came from surveys and interviews. This section highlights the techniques and processes that TTI used to conduct stakeholder surveys and interviews.

Stakeholder Data Collection Plan

The purpose of the stakeholder evaluation was to gather information to assess the benefits and challenges of the CVPD Program structure and process. The types of information gathered were guided by a predetermined set of hypotheses and data needs as noted in the *Program Evaluation Plan* (*2*).

The stakeholder data collection consisted of qualitative interviews and a workshop at the end of the evaluation. Qualitative interviews were structured to examine and explore contextual issues for the solicitation planning, program structure, technology issues, security and privacy, financial and institutional sustainability, and outreach as well as overall perspectives on the vision, goals, and desired impacts of the program.

TTI used a workshop with key stakeholders at USDOT to review and discuss the findings of the interviews and to provide strategic and operational recommendations (and lessons learned) for subsequent activities.

Target Stakeholders

For the purposes of this program evaluation plan, a *stakeholder* is a person at USDOT or one of the three pilot sites who is directly responsible for planning, managing, and guiding the CVPD. USDOT stakeholders were staff of ITS JPO, FHWA, and Volpe, as well as CV pilot USDOT team contractors from Noblis. Stakeholders also included the CV Pilot Site Deployment Managers and team members; however, their inputs on the program structure and process was gathered as part of the stakeholder satisfaction and acceptance surveys/interviews (Task C).

Data Collection Design

The TTI Team conducted qualitative interviews with USDOT stakeholders in two phases. Phase 1 interviews took place in fall 2019 and covered topics mainly related to solicitation planning and other pre-deployment topics. Phase 2 interviews covered all other topics and occurred after the deployments were completed. Table 3 shows the topics and associated hypotheses covered in each phase.

Table 3. Interview Topics and Hypotheses Covered in Each Phase of USDOT Stakeholder Interviews

Interview Phase	Topic	Structure and Process Activities	Foundational Hypothesis
1	Solicitation planning	Pre-solicitation outreach	#1 Extensive pre-solicitation outreach would increase the number and enhance the quality of submitted proposals.
1	Solicitation planning	Emphasize real-world problem solving	#2 Focusing on real-world problem solving would lead to proposals/projects where a definitive impact could be realized, even if only a limited total number of devices, vehicles, and technology might be deployed.
1	Solicitation planning	Two-phase solicitation structure	#3 The two-phase program structure of broad agency announcement for private- and public-sector leads in Phase 1 and cooperative agreements for public-sector leads in Phase 2 would allow agencies that are too small or with cumbersome contracting methods to respond to the procurement.
1	Solicitation planning	Phases with “go, no-go” gates	#4 Two consequential phase gates (one financial and the other operational) would provide USDOT with needed leverage to encourage sites to adhere to schedule, cost, and scope.

Interview Phase	Topic	Structure and Process Activities	Foundational Hypothesis
2	Program structure	Post-award collaboration among deployment sites, not competition	#5 Collaboration among sites would provide more value than creating a competitive "funnel" program with roughly twice as many Phase 1 participants as Phase 2–3 awardees.
2	Program structure	High rate of interaction post-award: meeting cadence and topics/roundtables	#6 A set of regular structured topical roundtables plus monthly check-ins would ensure sites knew of each other's challenges, resolutions, and progress.
2	Technological maturity	CV tech mature enough to mount a successful deployment program Changes to CV technology caused by deployment program	#7 The level of CV readiness was high enough to mount a deployment program and the deployment program would help the industrial base to make these technologies more robust and deployable.
2	DSRC focus	DSRC an element of each deployment but not a requirement	#8 Requiring sites to use DSRC in some way as a part of the deployment, but not requiring use for all applications, would allow a more realistic, practical, and effective deployment concept.
2	Open data/ open source	Open data and open source required of all deployments	#9 The open-source data requirement would not put off serious deployers, would not prove too onerous, and would assist in technology transfer to deployments outside the CVPD Program.
2	Security/ privacy	Cybersecurity and privacy protection emphasized	#10 An early emphasis on cybersecurity and privacy would reduce the risk of cyber- or privacy-related issues in the operational phase of the deployments.
2	SCMS/ certification	Certified devices connected with a credential management system required	#11 Similar to the technical maturity hypothesis (#7), the dependence of the program on external certification and credential management would speed technology maturation without the program itself having to directly finance/manage SCMS creation.

Interview Phase	Topic	Structure and Process Activities	Foundational Hypothesis
2	Financial/ institutional sustainability	Financial sustainability after Federal funding emphasized	#12 By reiterating the need for long-term financial sustainability of the deployments, the program would reduce the risk of the deployed technologies being removed at the end of the funding period (as in a field test) and the risk of the sites developing a long-term need for Federal funding to continue.
2	Performance measurement/ evaluation	Sites required to implement a performance measurement capability	#13 A performance measurement capability would reinforce performance-driven management of the system, allowing impacts to be more easily observed and quantified—even after a transient, complementary independent evaluation was completed.
2	Outreach/ other early deployers	Sites required to participate in a range of structured, coordinated outreach activities	#14 Outreach in a variety of forms, but structured and coordinated by the program, would help early deployers and shield the sites from numerous repetitive information requests.
2	Program vision and goals	Overall program structure and process assessment	#15 The overall effect of the program's innovative approaches and roadmap of activities resulted in outcomes that were positive to the USDOT Team.
2	Program vision and goals	Overall program vision	#16 The CVPD Program met the vision laid out at the onset of the program.

Source of Hypotheses 1 to 14: Karl Wunderlich, Noblis

Qualitative interviews with the pilot site deployment managers and team members took place in conjunction with the Task C data collection. The interview guides contain some questions that inform the program evaluation; any new questions were added to the long-term post-deployment interview guide. Questions already in the guide informed Hypotheses #7, #11, #12, and #13. New questions were added to the long-term post-deployment interview guide to address Hypotheses #3, #5, #6, #7, #8, #9, #10, and #14. These interviews occurred when the deployment at each site was completed.

TTI conducted interviews by telephone and by web conferencing. TTI used a semi-structured interview format for the USDOT stakeholder interviews (as used with the sites for the Task C data collection). In semi-structured interviewing, a guide is followed, with questions and topics that must be covered. An interviewer has some discretion about the order in which questions are asked, but the questions are standardized, and probes may be provided to ensure that the researcher covers the correct material. This kind of interview collects detailed information, which is needed for the program evaluation but in a way that is somewhat conversational. The interview guide for the Phase 1 interviews were developed to include 10–15 questions, resulting in an interview length of about 30 minutes. The interview guide for the Phase 2 interviews was longer, with an interview length of 60 minutes.

The TTI Team conducted a workshop (or focus group) after all of the post-completion interviews were completed. The purpose of the workshop was to foster additional dialog concerning the lessons learned and major takeaways from planning and managing the deployments. The common themes identified in the post-deployment interviews were used to frame the group discussion, which explored these and other topics in more detail.

Benefits and Lessons Learned

As the sites transitioned through the CVPD Program's phased gates shown in Figure 2, their workspace environment was changing. These changes impacted the CVPD Team's and the sites' work plans. In April 2019, USDOT noted this circumstance and confirmed with the TTI Evaluation Team that the benefit-cost analysis might be difficult to assess and might need to be a soft goal. The benefits metrics have transitioned to a qualitative assessment much like Task B of the CVPD Program. References to data sources for quantitative analysis have been removed from this document so that its content now reflects the benefits that were captured in the program evaluation and described in Chapter 5 of this document.

Achieving the CVPD Program Vision

The last level of analysis involves assessing the extent to which FHWA achieved its overall vision for the CVPD Program. According to the ITS JPO, the overall objectives of the CVPD Program were as follows (*1*):

- To spur early CV technology deployment not just through wirelessly connected vehicles but also through other elements that are major players in this connected environment, such as mobile devices, infrastructure, TMCs, and other elements. Data can be integrated from these multiple sources to help make key decisions.
- To target improving safety, mobility, and environmental impacts, and to commit to measuring those benefits. Measurement of the impacts and benefits were gathered from real-world deployments, rather than an isolated test bed or a computer-based simulation test bed. Differentiating and finding these benefits and identifying what can be attributed to these CV applications and technologies are important components of the activity.
- To resolve issues of various deployments. People often first jump to technical areas and focus on getting applications to work together, but that is only part of the concern. Institutional arrangements must be put in place to ensure installation of the technology as well as to manage and govern the sharing of information. Also, financial arrangements must be made that may integrate the technologies into a financially sustainable model that can be sustained following the initial funding from the initial pilots.

The interviews provided a perspective on these topics.

Chapter 4. Program Assessment

This chapter describes the assessment of the CVPD Program's structure in its pre-solicitation phase and the subsequent three-phase, gated deployment structure. This chapter includes summary comments developed from the interviews; direct comments made by interviewees that are included in quotes without attribution to the individual's identity; and references to documents developed throughout the CVPD Program's work efforts and posted on its website, https://www.its.dot.gov/pilots/index.htm.

The 16 hypotheses are organized into the following five categories:

- Solicitation planning.
- Cooperation and collaboration.
- Technology.
- Sustainability and performance measurement.
- Attainment of program vision and goals.

Solicitation Planning

#1 Pre-solicitation Outreach

The hypothesis was that extensive pre-solicitation outreach would increase the number and enhance the quality of submitted proposals. The interviews for this hypothesis were conducted in December 2019. Some additional comments were received during the 2022 interviews and workshop.

Table 4. #1 Number and Quality of Proposals

Outreach Would Increase the Number and Quality of Submitted Proposals
The interview responses supported the hypothesis that outreach was effective in encouraging many high-quality proposals. The interviewees believed the solicitation process filtered out proposers that had low technological competency, low organizational maturity, or both.

The interview responses and the references from the CVPD Program's publications supported the hypothesis that outreach was effective in encouraging many high-quality proposals.

The interviewees stated that the number of proposals was much greater than anticipated, and interviewees attributed the response to the extensive outreach that ITS JPO did leading up to the request for proposals. The consensus among the interviewees was that because of the extensive outreach effort through multiple channels, ITS JPO was able to reach many potential proposers with relevant information.

Most interviewees agreed that the quality of the proposals was high, as evidenced by the fact that they could have picked as many as nine different proposed sites, and they received only a few inadequate proposals. The interviewees believed the solicitation process filtered out proposers that had low technological competency, low organizational maturity, or both.

In addition, the USDOT Team had taken proactive actions to prepare the team for outreach. Typical responses included:

- "We held collaborative meetings among program staff before the solicitation."
- "We developed various talking points, formulated answers to likely questions, came to consensus on likely responses."
- "We received questions from stakeholders; then, we would tailor talking points to address those questions."
- "We were very organized in that at least 12 staff were able to talk about the solicitation without violating procurement rules."

The interest in the CVPD Program and the impact of the outreach were highlighted when one of the interview respondents said, "After the solicitation was live—the number of potential responders was enormous. People asked hundreds of questions. For example, we had a webinar using the normal contract office capability—over 1,200 people tried to get on it. The system crashed, and the webinar needed to be rescheduled."

Another interviewee also said, "We followed the protocol. If we couldn't answer a question at that time, we'd typically go through the process of sending updates through the Contracts office to all proposers."

Also, the "Contracts staff did post a response to all the questions that were asked." The interviewees thought that this outreach yielded "proposal quality that was high," and that they "could have picked as many as eight or nine good sites."

One comment mentioned an unintended consequence of the process: "The downside was this process was long. By the time planning finished, the technology changed."

USDOT published a lessons-learned document in 2017 that provided a perspective on this topic (*4*). Lessons learned 2.1.1 from that report notes that the USDOT Team conducted biweekly meetings for over a year to discuss program needs and requirements while conducting focused outreach to the ITS community. The outreach included news releases, social media posts, website postings, and webinars. The outreach included a February 2015 series of webinars on dynamic mobility application projects that increased awareness of mobility-related prototype applications available to potential deployment proposers.

#2 Real-World Problem Solving

The hypothesis was that focusing on real-world problem solving would lead to proposals/projects where a definitive impact could be realized, even if only a limited total number of devices, vehicles, and technology might be deployed. The interviews for this hypothesis were conducted in December 2019. Some additional comments were received during the 2022 interviews and workshop.

Table 5. #2 Real-World Problem-Solving Proposals

Problem-Solving Focus Would Lead to Proposals with Real-World Impact
The interview responses supported the hypothesis that proposals were received addressing problems where a real-world impact could be realized. This focus on solving real-world problems followed through into the implementation.

The interview responses supported the hypothesis that proposals were received addressing problems where a real-world impact could be realized.

The interviewees thought that having the proposers provide a “problem to solve” in the proposal process was effective. ITS JPO required each proposer to submit a proposal that identified problems that needed solving and then to find applications to solve the problems. This focus on solving real-world problems followed through into the implementation. In Phase 1, ITS JPO required each CV pilot site to complete a concept-of-operations documentation before installing any application. Following a system engineering process, each site spent approximately a year documenting what it was going to do. ITS JPO also then required each site to conduct webinars on its concepts to solicit input from the public. The entire process made the pilot sites focus on problem solving and not technology showcasing.

The interviewees stated:

- “All three sites tackled fundamental real-world problems.”
- “Part of the outreach was communicating that if a bidder had not identified a problem worth solving, then don’t bother submitting.”
- “It had local agencies think through the problem they were going to solve.”
- “They had to submit proposals that would meet their needs—to solve their problems.”

USDOT published a lessons-learned document in 2017 that provides a perspective on this topic (*4*). Lessons learned 2.1.1 from that report notes that the program did provide six hypothetical examples that assisted sites in defining their real-world local issues.

#3 Two-Phase Program Structure to Increase the Diversity of Proposals

The hypothesis was that the two-phase solicitation structure of BAA for private- and public-sector leads in Phase 1 and cooperative agreements for public-sector leads in Phase 2 would allow agencies that are too small or with cumbersome contracting methods to respond to the procurement. The interviews for this hypothesis were conducted in December 2019. Some additional comments were received during the 2022 interviews.

Table 6. #3 Phased Solicitation Increased Proposal Diversity

Phased Solicitation Increased Proposal Diversity
The interview responses supported the hypothesis that the process increased the diversity of proposals with respect to organizations and technologies. They also stated that the phased deployment process "did not seem to deter any proposers.

The interviewees agreed that the phased approach led to better deployments and increased the diversity of proposal agencies and technologies. The interviewees attributed this to the extensive outreach and education that ITS JPO did to make sure that proposers understood the requirements regarding the pilot deployments. The interviewees also stated that the phased deployment process "did not seem to deter any proposers."

According to one interviewee the use of a Broad Agency Announcement (BAA)/ Fixed Firm Price (FFP) contract followed by a Cooperative/ Agreement Cost Plus Fixed Fee (CPFF) contract with match in Phases 2 and 3 provided flexibility that enabled a site to continue its participation with a change in leadership in at least one site: Wyoming.

That interviewee further noted that while at least one selected team utilized the flexibility afforded by the contract/cooperative agreement structure, it's not clear how many teams proposed such a plan, nor is it clear how many additional proposals were received because of the solicitation structure. They also noted that the strategy was also applied to the ITS4US program, and that there, 3 of 5 deployer teams proposed to change lead agency/organizations between Phase 1 and Phase 2: ARC to GDOT, CALACT to VVTA, and ICF to NFTA. U-Washington and HIRTA retained the prime position in both Phase 1 and proposed the same arrangement in Phase 2/3.

The interviewees agreed that the collaboration process produced stronger Phase 2 designs from each of the sites.

Interviewees provided the following comments related to this hypothesis:

- "[This was] a good process."
- "Filtered out low-tech competence and low organizational maturity folks."
- "The phased process was a way to weed out proposers who didn't have the capabilities to implement a pilot."
- "The best example [of the two consequential gate program structure] is Wyoming. ICF was the lead for Phase 1 (Concept Development), but then WYDOT [the Wyoming Department of Transportation] was the lead in Phase 2 (Design, Build, Test) because it was determined [locally] that the road operator needed to be in the lead."

#4 Three Phase Deployment Process with Consequential Gates between Phases

The hypothesis was that the two consequential phase gates (one technical and the other operational) would provide USDOT with needed leverage to encourage sites to adhere to schedule, cost, and scope. The interviews for this hypothesis were conducted in December 2019. Some additional comments were received during the 2022 interviews.

Table 7. #4 Gated Deployment Process Would Encourage Schedule, Cost, and Scope Adherence

Gated Deployment Process Would Encourage Schedule, Cost, and Scope Adherence
The interview responses supported the hypothesis that the gated process allowed the sites to better understand their projects and thereby increase their ability to adhere to schedule, cost, and scope.

Interviewees thought the three-phased deployment process worked well and mitigated the risk of pursuing deployment choices that are not constructable. There was a continuum of development across phases. In the first phase, the sites took a year to produce a deployment concept of operations (i.e., blueprint) before designing their deployments. ITS JPO needed to accept the blueprint before it would obligate funds for the actual deployment in Phase 2. This process allowed ITS JPO to retain some control over the design process to ensure the constructability of the deployments.

Comments from the interviews included:

- "We made two gateways. First, selected sites developed a concept of operations that the government believed would be worthy of development. We needed to establish that proposers had a good understanding of the technology they were proposing to deploy."
- "The CVPD involved multiple people with multiple specializations (e.g., software, hardware vendors, consultants, . . . , suppliers, after-market safety device manufacturers) and had them come together to solve a real-world problem. It promoted innovative thinking. It couldn't have been in a traditional project."
- "We had dozens [actual number redacted] of CV applications. The CV pilot sites thought the applications were already developed. We had to show them in the solicitation that it was the sites' responsibility to develop the applications. We advised them to put the burden on vendors to develop applications to maturity in their own solicitations with vendors. We had the con ops done; we had to walk them to the website where requirements were listed. 'You can give these to your vendors to develop apps.'"
- "The 'gates' at the end of each phase allowed the flexibility to drop a site if it was underperforming. $40 million or so is a huge amount of investment. We didn't want money to be tied up with a site that was not performing well, but it turned out all three sites performed well."
- "Three pilot sites all tackle fundamental real-world problems. Excellent platform to map out and explore the technology challenges."

Cooperation and Collaboration

#5 Post-award Collaboration

The hypothesis was that collaboration among sites would provide more value than creating a competitive "funnel" program with roughly twice as many Phase 1 participants as Phase 2–3 awardees. The interviews for this hypothesis were conducted in early 2022.

Table 8. #5 Post-award Collaboration Provides More Value than Competition

Collaboration Provides More Value than Competition
The interview responses supported the hypothesis that cooperation provided added value and is a process that could be repeated in the future.

The interview remarks supported the hypothesis that effective collaboration occurred among the teams. A representative comment was that "having multiple sites with a wide variety of challenges will set a good example to future deployment teams." The sites had differing geographies, differing applications, and unique local institutional and financial considerations. Whether that uniqueness contributed to goodwill and cooperation or whether it may have constrained cooperation was explored during the workshop.

One participant said that the collaboration was an eight on a scale of one to ten. Also, "things got very cordial," and it "was almost like everyone was on the same team."

Comments from the interviewees included:

- "The collaboration facilitated an environment where participants willingly shared both their successes and failures. Had it been competitive, I can see where participants would have been less likely to share."
- "At the onset there was a risk that there would not be any collaboration, but it worked out better than we expected. It was not an accident. There were individuals that were driving the teamwork concept. On a scale of one (least collaborative) to ten (most collaborative), I'd give it an eight. Having multiple sites with a wide variety of challenges will set a good example to future deployment teams. I think it may perhaps encourage other sites to pursue similar initiatives. I think the CVPD really created some positive marketing, which wasn't really part of the plan."
- "Overall, I think it was both effective and good. I appreciate the USDOT trying something different. There is a lot of interest in this pilot. Each site is unique, and that brings a lot of complexity to the table."
- "All the sites worked together. I think there was a bit of peer pressure, but it was not a full-blown competition. And because of that, I think they all benefited and were able to make progress and move from one phase to the next."
- "I think it really worked. There were multiple touchpoints (meetings focused on various topics). These meetings were like peer exchanges. It was a good way to convey lessons learned. After the [2020] election, any competition that existed went away. It was almost like everyone was on the same team.

Things got very cordial. I feel like it was a function of how long everyone had been working together on a common goal. I think the interoperability tests were also good for enhancing collaboration."

One interviewee did comment that "higher levels of collaboration can be achieved in the future if the sites are more similar to one another" while still noting that "On a scale of one to five, I'd give it a five."

#6 Meetings and Roundtables

The hypothesis was that a set of regular structured topical roundtables plus monthly check-ins would ensure sites knew of each other's challenges, resolutions, and progress. The interviews for this hypothesis were conducted in early 2022.

Table 9. #6 Meetings and Roundtables

Roundtables Would Ensure Exchange of Project Issues
The interview responses supported the hypothesis that the roundtables enabled communications so that sites gained deployment value from learning about challenges, resolutions, and progress results.

Most interviewees agreed that the roundtables worked well and accomplished the goal of providing an environment where ideas could be exchanged. However, some noted that there were too many meetings and that it was hard to attend all of them. Only one individual reported that the meetings were not successful in accomplishing the goals.

Comments from the interviewees included:

- "The roundtable attendance and participation were good, and it provided a good opportunity for providing updates and sharing challenges and lessons learned in an open environment."
- "The whole process was new, so there was a bit of a learning curve, particularly with how information was transferred. I think we got better as things went on. There were some instances where things got a bit too far into the weeds. When this happened, we saw some folks forming their own groups to try alternative solutions. This was unanticipated and good. I think it was the right number of roundtables."
- "The outreach roundtable helped resolve messaging without having to prescribe a top-down directed hierarchical approach. The roundtables worked but were not the most important element that encouraged collaboration. There was a lot of communication between teams outside the roundtables directed at resolving issues."
- "I think the sites really liked the roundtables (technical, performance measurement, and outreach), which acted like peer exchanges. Personally, I feel like the technical roundtable was the most beneficial because I saw a lot of issues resolution happening in this meeting."
- "I think the roundtables were designed well, but there were just too many meetings. I could not keep track of them all. Initially, there was an idea to have 'shadow deployers' involved. These were agencies that were interested in deploying but were not part of the official CVPD. They could just listen in the background. I don't think that really ever took off."

- "Even though there were many meetings, I did not find them to be that useful. If they were meant to be for coordination efforts, I didn't see it."

Technology

#7 Technological Maturity

The program was built on the hypothesis that the level of CV readiness was high enough to mount a deployment program and that the deployment program would help the industrial base to make these technologies more robust and deployable. The interviews for this hypothesis were conducted in early 2022.

Table 10. #7 Technological Maturity

CV Technology Maturity Would Enable a Deployment Program
The interviewees had mixed comments about technology maturity. Some thought that these issues were dealt with innovatively; others believed that the lack of maturity was a real problem that caused significant delay. The state of technology maturity was a key factor in causing the period of performance to be adjusted several times.

Most respondents acknowledged that there were issues with the lack of maturity of some of the technologies (e.g., dedicated short-range communications issues, onboard unit issues, and application issues) and the deployment challenges of those technologies (such as urban canyon communications). While some thought that these issues were dealt with innovatively, others believed that this lack of maturity was a real problem that caused significant delay. More testing of the technology prior to the deployment could have helped resolve these issues.

During the December 2019 interviews while discussing the pre-solicitation topic, one of the respondents said that "USDOT was still trying to develop the SCMS with the Crash Voidance Metrics Partnership [at the beginning of the project]. CV pilot was like a guinea pig for this system." During that same interview, another comment was that "we were tap dancing to some degree because the SCMS and applications were still being developed. Potential bidders didn't really understand what the risks were as they had never responded to this type of solicitation before."

Comments from the interviewees included:

- "There were some issues regarding unexpected technology 'discoveries' such as urban canyon communications issues in New York. Technology choices were influenced by stakeholder participation, COVID-19, and contractual agreements. It's also important to note that the period of performance was edited multiple times to reflect technology maturity and availability. In the long run I don't think we need to change the structure because of technology maturity. We were aware that the technology would not be 100 percent, and we were able to adapt."
- "It seems like there were examples of technology that worked better than expected. An example was the over the air updating. That technology was more mature than expected. So, the emphasis on

maintainability wasn't as big an issue as expected. In spite of the lack of maturity of some technology, if the program had more money, it could have had more deployments. There was substantial interest."

- "The V2V [vehicle-to-vehicle] applications deployed in the CVPD were immature and not an improvement over what had been deployed 10 years ago. Tampa had some unique V2I [vehicle-to-infrastructure] applications, but they were not mature. New York's red-light-running application was not really mature. Both Tampa and New York had pedestrian detection systems that warned drivers that they're about to cross the road. Neither worked in the Ann Arbor safety pilot model deployment; you had OEM involvement. OEMs help integrate the systems really well into the vehicle. The end result is a better performing application, especially for V2V applications. There should have been more rigorous testing of the apps. There should have been a decision gate regarding whether or not to deploy. We end up wasting money that we spend on unproven technology. We also waste time on collecting data on apps that don't work."
- "I would say the technology was not really ready for a full deployment, despite 15 or so years of research on CV technology. There were issues with the New York City and Tampa pedestrian application. There needs to be more testing before launching into these massive deployments. Perhaps there should have been more small-scale demonstrations, prior to such a big deployment. These small-scale deployments could test the devices and establish standards."
- "There were issues with the RSUs [roadside units] and the OBUs and the security component SCMS, which was supposed to be in place by the time the pilots got started. We spent a lot of time trying to find a solution for the SCMS issue. There was also an issue of vendors going out of business mid-race. That was a big challenge. There was a lack of maturity of multiple facets. When technology starts failing, team members start losing confidence. It's hard to get that back. The project would have benefited from more testing. Maybe a mini pilot would have been beneficial. You need technology to work at least 90 percent of the time. Also, if you want interoperability, you have to have good standards, which we did not."

#8 DSRC Focus

The hypothesis was that requiring sites to use DSRC in some way as part of the deployment, but not requiring use for all applications, would allow a more realistic, practical, and effective deployment concept. The interviews for this hypothesis were conducted in early 2022.

Table 11. #8 DSRC Focus

DSRC in at Least One Application Allows for Realistic Deployment
The interview responses suggest that although deployment sites were aware of potential DSRC issues, the magnitude of the issues was not fully known. There was some agreement that DSRC issues should have been reiterated to the sites at the onset of the deployment

Several interviewees stated that most (if not all) deployments were aware of the potential issues with DSRC at the onset of the deployment. Yet there was some agreement that these potential issues should have been reiterated to the sites at the onset of the deployment. This may have resulted in the sites taking a more conservative approach in their technology budgets. Multiple respondents mentioned that DSRC issues were most prevalent in the Wyoming deployment, and that the DSRC issue acted like a roadblock, preventing risk-averse localities from going after CV deployments and similar projects. At least one interviewee suggested that time be spent on identifying how cellular vehicle-to-everything (CV2X) technology might be incorporated into the next deployment in lieu of DSRC.

Comments from the interviewees included:

- “The sites had to use at least one application [and were not required to use more than one] that involved DSRC because the [US DOT] program recognized the spectrum uncertainty. The sites already knew that the regulation of the spectrum could have some effect. Even so, they should have been reminded more strongly that there was a lot of uncertainty, and they should budget accordingly.”
- “When the pilot started, we felt like DSRC was the best available technology. Shortly after this, we started hearing about the capabilities of CV2X. After the pilot, we’ll need to figure out how to operationalize the devices. This issue continues to be a roadblock that prevents risk-averse localities from going after these types of projects.”
- “There were some issues regarding unexpected technology ‘discoveries’ such as urban canyon communications issues in New York. Technology choices were influenced by stakeholder participation, COVID-19, and contractual agreements. It’s also important to note that the period of performance was edited multiple times to reflect technology maturity and availability. In the long run I don’t think we need to change the structure because of technology maturity. We were aware that the technology would not be 100 percent, and we were able to adapt.”
- “Wyoming had to make some adjustments about their broadcast in the 5.9-GHz band after receiving a letter from the FCC [Federal Communications Commission]. However, they were able to adjust.”

One workshop participant stated that many technology-specific lessons learned were picked up throughout the course of the deployments. To this end, the sites were asked to conduct technology readiness assessments. Most workshop participants agreed that there was a significant amount of technology testing that occurred prior to the deployment. However, this testing largely took place outside real-world conditions. The deployments uncovered new challenges that were previously unknown. At least one individual commented that not only is the level of maturity associated with specific technology important, but equally important is the level of maturity associated with the infrastructure needed to support a specific technology.

USDOT published a lessons-learned document in 2017 that provides a perspective on this topic (*4*). Lessons learned 5.2 from that report notes that “the pilot sites initially spent more time on filing for DSRC licensing than originally expected. This speaks to one of the many challenges faced with DSRC.”

#9 Open Data/Open Source

The hypothesis was that the open-source/data requirement would not put off serious deployers, would not prove too onerous, and would assist in technology transfer to deployments outside the CVPD Program. The interviews for this hypothesis were conducted in early 2022.

Table 12. #9 Open Data/Open Source

Open Source Would Not Put Off Serious Deployers
While the program did have serious deployers, the platform for data sharing was new and there were issues. The near real-time data availability offered by the data hub was groundbreaking and yet the amount of shared code from the sites was less than anticipated.

The actual platform for sharing the data was new, and there were issues. If the data tools would have been tested more rigorously beforehand, this issue might have been avoided.

Open data resulted in some frustrations from the sites. Multiple respondents stated that the removal of personally identifiable information (PII) was a significant issue in New York. To avoid transmitting PII and to comply with open data sharing in New York, GPS data was removed. This removal limited the analysis. One respondent stated that in the future there should be a requirement from USDOT stating that participants must share CV GPS coordinates.

Workshop participants pointed out that the open-data requirements were discussed at the onset of the project and that data management plans were required from each site. Participants also felt the near real-time data availability offered by the data hub was groundbreaking, pointing out that the data generated from this deployment had been downloaded more than many other available datasets. One workshop participant questioned if perhaps more emphasis should be placed on providing more tools that would facilitate analysis of the publicly available data, as opposed to providing the data itself. Another workshop participant suggested that in the future, perhaps a uniform data structure prescribed to the sites might be beneficial. Additionally, interviewees confirmed the significance of the PII issues (particularly with New York) and stated that PII will need to be managed better in future deployments.

USDOT published a lessons-learned document in 2017 that provides a perspective on this topic (*4*). Lessons learned 10.1 from that report notes that "the Open-Source Data Applications Portal (OSADP) enables stakeholders to collaborate and share insights, methods, and source code related to connected vehicle applications. By utilizing resources available on the OSADP, the sites could reduce costs through the prevention of uncoordinated, proprietary and duplicative mobility applications research and testing." One interviewee noted that the amount of shared code from the sites was less than anticipated. They thought this might have been due to the amount of code developed by vendors as opposed to deployment agencies. They noted that the Wyoming team was a counterexample to this and developed several open-source capabilities tied to the Operational Data Environment development effort. At the completion of the program, it would be informative to verify the extent to which applications are uploaded to the OSADP.

#10 Security/Privacy

The hypothesis was that an early emphasis on cybersecurity and privacy would reduce the risk of cyber- or privacy-related issues in the operational phase of the deployments. The interviews for this hypothesis were conducted in early 2022.

Table 13. #10 Security/Privacy

Security Emphasis Would Reduce Risk of Cyber Issues
The interview responses support the hypothesis that the emphasis on privacy and security did reduce risk of cyber- or privacy-related issues. Most interviewees agreed that while there were no significant security issues, moving forward there could be better security standards put in place.

Most interviewees agreed that while there were no significant security issues, moving forward there could be better security standards put in place. Some comments that support the general level of satisfaction with cybersecurity and data privacy are as follows:

- "The sites were in a pretty good place with security with respect to the functioning of certificates."
- "Overall, there were not any issues that could not be overcome."
- "A big concern was that a cybersecurity attack could poison the well. The program got lucky in not having these types of issues. Even if there were malicious attacks, they were handled expeditiously."

Multiple respondents mentioned an issue in Tampa, where a HAM radio broadcast on a project frequency interfered with the project. Only one individual noted data truncation due to privacy concerns.

USDOT published a lessons-learned document in 2017 that provides a perspective on this topic (*4*). Lessons learned 4.1 from that report notes that "the sites were encouraged to follow NIST [National Institute of Standards and Technology] guidance for determining the specific security approaches (controls) needed in their CV Pilot systems. However, it was noted that the current Federal guidelines on security are focused on IT [information technology] systems and not cyber-physical systems, so that the sites needed to be accommodating." Lessons learned 4.2 from that report notes that "maintaining user privacy was far more complex than the sites and USDOT first realized. There was concern over what data was appropriate to collect and how to put forth the data collection design. The pilot sites had to consider ALL users' priorities and concerns relating to privacy and liability and factor them early into the security and privacy concept and ultimately the system requirements."

#11 SCMS/Certification

The hypothesis was that the dependence of the CVPD Program on external certification and credential management would speed the maturation of these needed capabilities without the program itself having to directly finance/manage their creation. The interviews for this hypothesis were conducted in early 2022.

Table 14. #11 SCMS/Certification

Dependence on External SCMS Would Speed Maturation of Capabilities
The interview responses were limited and suggested that the SCMS processes and procedures characteristic of the deployment needed refinement. There was also mention of needing multiple vendors for a critical function like SCMS.

Most interviewees did not comment on this hypothesis. One respondent felt that initially there was a lot of risk and lauded the USDOT for coming up with a solution. One commentor stated, “This was a big risk, and it was good that DOT came up with a commercial alternative. It wouldn’t have felt like a real deployment without SCMS. Even though we finally got it done, it was such a miserable experience that others probably won’t be encouraged to follow this path. The lesson learned here is to not put all your eggs in one basket. Always make sure there are multiple vendors in a critical function, not just one.”

USDOT published a lessons-learned document in 2017 that provides a perspective on this topic (*4*). Lessons learned 4.1 from that report notes that “the role of the SCMS and what it would or would not do was a complicated issue throughout Phase 1 that did not have a simple answer. The USDOT provided the pilot sites with draft and final versions of the SCMS Proof of Concept [POC] document that featured detailed requirements and specifications for the SCMS POC system (i.e., interfacing via RSUs/OBUs/ASDs [aftermarket safety devices]). In addition, the USDOT conducted a webinar for the CV Pilot sites that provided an overview of the document.”

Sustainability and Performance Measurement

#12 Financial/Institutional Sustainability

The hypothesis was that by reiterating the need for long-term financial sustainability of the deployments, the program would reduce the risk of the deployed technologies being removed at the end of the funding period (as in a field test) or the risk of the sites developing a long-term need for Federal funding to continue. The interviews for this hypothesis were conducted in early 2022.

Table 15. #12 Financial/Institutional Sustainability

Financial Sustainability Emphasis Would Extend Continued Operations
The interview responses suggest that some sites did better at increasing the likelihood of maintaining operations. More focused applications relevant to local needs could lead to greater long-term financial and institutional support.

The consensus was that the sites should, by now, have a good idea of what it would take to sustain long-term economic viability of their systems. Multiple interviewees commented that each site brought something unique to the table. One felt that the Tampa Hillsborough Expressway Authority (THEA), in particular, did a great job of using its deployment as a marketing tool to attract more projects downstream, thus increasing the likelihood that the agency would develop funding mechanisms to facilitate long-term deployments. Another felt that Wyoming’s deployment had the best chance of achieving long-term viability because it represented the most focused deployment, addressing a real problem even though the solution was not DSRC-based. This focused approach was most likely to produce successful results, which could then be more easily communicated to decision makers responsible for approving long-term funding. Finally, one felt that it was very unfortunate for New York City that it had such a significant issue with the spectrum. Some comments suggest that USDOT should do a better job encouraging successful pilots to continue their deployments, once the period of performance was over. Finally, one interviewee pointed out that at the onset of the project, the hope was that by the time the project was over, CV market penetration would be higher than what it actually ended up being. The hope was that OEMs would install

DSRC or C-V2X [cellular vehicle to everything] in their vehicles and many new applications would be available. This did not happen. One issue that needs to be resolved is how to make these types of deployments more attractive to OEMs.

Workshop participants were also quick to point out that this program had no funding to continue operations once the period of performance was over. This had been communicated up front to the sites. The fact that one site was moving forward with a Phase 4 (THEA) could be considered a huge success.

USDOT published a lessons-learned document in 2017 that provides a perspective on this topic (*4*). Lessons learned 2.1.2 from that report notes that "the project sustainability and long-term funding goals originally envisioned for the pilot were not fully addressed (e.g., Pilots focused solely on how to lower costs rather than how to find creative approaches for covering the costs, whatever they might be). Long-term funding goals were never identified as a priority other than noting that systems shall continue to be in operation."

#13 Performance Measurement/Evaluation

The hypothesis was that a performance measurement capability would reinforce performance-driven management of the system, allowing impacts to be more easily observed and quantified through an independent evaluation of near-term impacts. The interviews for this hypothesis were conducted in early 2022.

Table 16. #13 Performance Measurement/Evaluation

Performance Measurement Would Reinforce Performance Management
The interview responses suggest that the lack of CV market penetration, the lack of a uniform data structure, and SDC issues hampered performance measurement. Future projects might rely more on lessons learned and institutional challenges that can be transferred to other agencies.

Many interviewees remarked that the low levels of CV market penetration hindered data availability. The lack of a prescriptive data structure exacerbated the issue because data that were available were not consistent across the sites. At least one individual mentioned that a common data structure would have helped the ability to extrapolate (via simulation) the data to a national level.

At least one interviewee speculated on the benefit of a less data-focused evaluation in lieu of a heavier reliance on lessons learned: "If we had to do this again, perhaps it would be better to take less of a scientific approach to the evaluation and have it be more about what are the lessons learned, institutional challenges, nuggets that can be transferred to other agencies."

USDOT published a lessons-learned document in 2017 that provides a perspective on this topic (*4*). Lessons learned 6.1 from that report notes that "the plans for the pilot's impact assessment [were] a major driver of concept development. The sites found it helpful to have the Performance Measurement Plan tailored to identify data flows that would support the evaluation effort."

#14 Outreach/Other Early Deployers

The hypothesis was that getting the word out in a variety of forms, but within a structured and coordinated construct provided by the program, would assist USDOT and the sites transfer knowledge to other early deployers more efficiently. The interviews for this hypothesis were conducted in early 2022.

Table 17. #14 Outreach/Other Early Deployers

Getting Word Out in a Coordinated Manner Would Help Other Sites
The interview responses supported the support of outreach with the sites and with the transportation community at-large.

The vast majority of interviewees felt that the communication worked well. Several comments that support this sentiment are as follows:

- "The schedule for outreach and presentations about the program were…very effective."
- "The dashboards were really effective at communicating results."
- "I think that [the communication process] works very well."

Workshop participants felt that USDOT did a good job with providing outreach not only to the sites but also to the transportation community at-large.

USDOT published a lessons-learned document in 2017 that provides a perspective on this topic (*4*). Lessons learned 2.1.1 from that report notes that outreach was conducted in a number of ways including meetings, flyers, slide decks, and presentations. Lessons learned 2.5 from that report notes that "the first few slides of every public webinar presented the project's missions and goals." Additionally, lessons learned 8.2 from that reported notes that "the sites offered several information sessions for interested stakeholders during the concept development phase to promote the projects and to garner participant interest."

Attainment of Program Vision and Goals

#15 Overall Approach

The hypothesis was that the overall effect of the program's innovative approaches and roadmap of activities resulted in outcomes that were positive to the USDOT Team. The interviews for this hypothesis were conducted in early 2022.

Table 18. #15 Overall Approach

Program's Structure Would Have Positive Outcomes
The interview responses overwhelmingly support the hypothesis that the effect of the program's innovative approaches and roadmap of activities resulted in outcomes that were positive to the USDOT Team. Some other contemporaneous deployments of connected vehicle technology may have been encouraged by the CV Pilot program.

Most felt like the outcomes of the deployment were positive, even mentioning that there was interest in the project on Capitol Hill. The CVPD provided a mechanism for the maturation of technologies, and the sites gained vast knowledge on hardware, software, and apps that will benefit them downstream. Lastly, the CVPD will hopefully encourage other sites and agencies to participate and deploy their own programs. Specific comments from the interviews are as follows:

- "The overall outcome was positive, as it was the most significant connected vehicle deployment ever. We heard that the project is well regarded in Washington, DC, so it made the sites and JPO look good."
- "I think it helped mature the technologies. It also made people more aware of these technologies. Hopefully it also generated interest among other agencies to try and conducting their own CV pilots or their own CV applications."
- "Some agencies who were not selected were encouraged by the CVPD procurement and competition for the award. Colorado DOT may have been one of those."
- "In spite of all the challenges and uncertainty, I think it was a success. I think the CVPD actually inspired a lot of people to get out there and deploy these devices."

Workshop participants overwhelmingly agreed that there were multiple positive outcomes.

#16 Program Vision

The hypothesis was that the CVPD Program met the vision laid out at the onset of the program. The interviews for this hypothesis were conducted in early 2022.

The vision was to spur innovation among early adopters of CV application concepts using the best available and emerging ITS and communications technologies.

The goals were (a) to spur early CV technology deployment, (b) to target improving safety and mobility and environmental impacts and commit to measuring those benefits, and (c) to resolve issues of various deployments.

Table 19. #16 Program Vision

Program Approach Met Vision
The interview responses suggest that CVPD helped generate a buzz about connected vehicle technology and spur connected vehicle technology deployment. Safety and mobility goals remain a work in progress.

Multiple respondents felt that the CVPD Program helped generate a lot of discussion about CV technology, essentially furthering the conversation started by the Transportation Research Board (TRB). Examples include the TRB Committee on Vehicle-Highway Automation and NCHRP projects such as the 20-102 series on Impacts of Connected Vehicles and Automated Vehicles on State and Local Transportation Agencies. Many also felt that the CVPD Program helped spur CV technology development. Interestingly, multiple respondents also felt like the CVPD Program did better at accomplishing goals a and c than they did b. Specific comments from the interviews are as follows:

- "This project created a conversation in the transportation community. CV was the flavor of the day at TRB at one point. TRB gave the topic and the program a global reach."
- "We met goal a and c. But b is still a work in progress. Market penetration really hindered meeting goal b. We need at least 10 percent market penetration."

Workshop participants were quick to point out that meeting these goals is an ongoing process. Even though some applications fell short of meeting their intended mark, it is only through this process that issues can be identified and refinements can be made. Workshop participants also confirmed that market penetration was an issue. Lastly, having realistic expectations and a realistic definition of success is vital to any IT deployment such as this.

Chapter 5. Conclusions, Benefits, and Lessons Learned

This chapter summarizes the findings and conclusions of the research activities performed in assessing program performance and effectiveness. This chapter also highlights the major benefits of lessons learned by USDOT in structuring and administering an advanced technology program to spur innovations and deployment.

Summary of Findings

Solicitation Planning

The new project solicitation and management strategy included extensive pre-solicitation outreach, an emphasis on real-world problem solving, a single solicitation with progress gates encouraged a diversity of proposers, and a phased structure using the systems engineering process that required significant capability to progress through to award.

The interviews indicated that the number of proposals was much greater than anticipated, and interviewees attributed the response to the extensive outreach that ITS JPO did leading up to the request for proposals. The consensus among the interviewees was that because of the extensive outreach effort through multiple channels, ITS JPO was able to reach a lot of potential proposers with relevant information. Interviewees also agreed that having the proposers provide a “problem to solve” when in the proposal process was effective. Interviewees generally noted that the process increased the diversity of the proposals. Finally, interviewees thought the phased structure that used the systems engineering process to describe the deployment process worked well and mitigated the risk of getting untenable deployments.

Even with all the outreach, several interviewees indicated that communication could have been better. The interviewees indicated that ITS JPO may have overestimated the level of maturity of some of the technology applications and did not differentiate clearly to proposers which technologies were mature. Several interviewees felt the lack of maturity of technologies hampered the ability of the sites to put together accurate schedules and costs in Phase 1. Because the sites had to stick with their original federal budget estimates in Phases 2 and 3, sites could not adjust to issues that developed when procuring devices without securing additional funding locally or de-scoping their projects. In addition, the US DOT did not necessarily communicate what level of organizational maturity was needed to carry off a pilot deployment.

Cooperation and Collaboration

The structural emphasis on cooperation among sites as opposed to competition was effective at identifying issues and providing opportunities for informed actions. As an example, conversations initiated at the roundtables sometimes generated further conversations to address issues especially for the technical roundtable. This process was new, but with experience it provided a good opportunity for updates and sharing challenges and lessons learned. The roundtables (technical, performance measurement, and outreach) acted as peer exchanges. There was some feedback that the number of roundtable meetings may have created a workload challenge for the sites at times.

Connected Vehicle Technology Focus

Most respondents acknowledged that there were issues with the lack of maturity of some of the technologies (e.g., dedicated short-range communications issues, onboard unit issues, and application issues) and the deployment challenges of those technologies (such as urban canyon communications). While some thought that these issues were dealt with innovatively, others believe that this lack of maturity was a real problem that caused significant delay. More testing of the technology prior to the deployment could have helped resolve these issues.

Financial Sustainability

Public operating agencies have many competing uses for their limited funding. Demonstration of positive outcomes for their investments is key to achieving sustained financial funding for those services at the local level. For the sites on-road penetration of instrumented vehicles was very low, and that hindered data availability. With limited data and with so few vehicles in the traffic stream, it was too big a challenge to accurately assess the impacts of the deployed technologies and services. The number of instrumented vehicles was too small in comparison to the total volume of traffic to observe an impact at the aggregate level. The lack of that information could be a significant impediment to gathering financial support for sustained operations for public operating agencies.

Attainment of Vision and Goals

The program approach was very helpful in bringing the three selected projects to completion in the face of an emerging marketplace, uncertainty in availability of the communications spectrum, leading-edge technologies, and a global pandemic.

Benefits and Lessons Learned

As noted in the section "Benefits and Lessons Learned" in Chapter 3, the assessment of benefits for this evaluation is a qualitative description that draws from the CVPD Team interviews and the CVPD published documents. These descriptions identify the impacts of the program work that was done while helping the sites overcome deployment challenges. The benefits and lessons learned can be institutionalized for future programs and stakeholders. The benefits and lessons learned are as follows.

Benefits

- There was operational and deployment value in the interoperability testing that occurred at the Turner-Fairbank Highway Research Center. The CVPD Program was able to show that if standards were followed, then multiple vendors could produce devices that were interoperable. The CVPD Program also learned the scope, stakeholders, procedures, and costs associated with this type of interoperability testing.

- Another benefit was that the CVPD Program was able to demonstrate three different deployment models for in-vehicle devices. These devices were in private autos, in government fleet vehicles, and with commercial fleet operators. This success and the details about those deployment models are assets for future initiatives and for advancing the marketplace.
- An important planning benefit for future programs is a more informed understanding of the maturity of the involved technologies and the level of support that the government can provide to support the transition from research to deployment. Future programs might develop a definition of technology deployment readiness and risk that informs all the stakeholders about the challenges of technologies in the context of the program and projects deployed by agencies.
- There were also anecdotal observations that the publicity, outreach, and engagement with the CVPD Program encouraged “spinoff deployments” of CV technologies and services, including by the Colorado Department of Transportation and others who used funding sources such as the Advanced Transportation and Congestion Management Technologies Deployment Program.

Lessons Learned

- From a programmatic perspective, there is an increased understanding about the deployment value of collaboration, the impact of the gated phased program approach, and the difficulties of assessing the performance of pilot deployments. For those topics, some of the comments about future endeavors were that:
    - Collaboration roundtables were effective. However, throughout the project they could have been adjusted for topic, length, and meeting frequency so that they used agency, contractor, and US DOT resources effectively in a busy deployment setting.
    - The gated process using systems engineering was effective but took too “long” in an environment where the technology was rapidly changing.
    - More reliance on site self-evaluations and less on independent evaluations could be appropriate especially when the ability to gather data from new systems is not yet proven and when each site might have unique data gathering capabilities and constraints such as differing perspectives on personally identifiable data.
- Large, complex programs take time to procure, design, deploy, operate, and evaluate. In a rapidly changing environment, they run the risk of facing new challenges that are outside the scope of the project, outside the control of the stakeholders, and that can add delays and expenses. Future projects could consider smaller scopes that have less exposure to external uncertainties and have less risk.
- The definition and concept of technological maturity might be adjusted for these kinds of projects in the future. The dimensions of the definition could include device and process maturity, pilot and demonstration experiences, commercial availability, marketplace penetration, maintenance capabilities, and other aspects helpful to the US DOT and performing agencies. This broad definition could aid stakeholder knowledge and enable better risk management.

Conclusions and Recommendations

The CVPD Program was ambitious in an environment of emerging technology and uncertainty about key elements such as spectrum allocation and commercial availability of systems and components. The program required an impressive level of effort and dedication by all involved—USDOT, public infrastructure operating agencies, stakeholder organizations, and commercial suppliers. Program innovation and flexibility coupled with nimble site adaptations helped to address these marketplace challenges.

The CVPD Program was designed and planned in 2014 with Phase 1 awards in September 2015. This timeline aligns with the 2014 National Highway Traffic Safety Administration Advanced Notice of Proposed Rulemaking (ANPRM) that would require automakers to include vehicle-to-vehicle communications technologies in all new light-duty vehicles. In addition, a key previous vehicle communications project, the Safety Pilot Model Deployment Connected Vehicle Program in Michigan, was concluding in late 2013 and independent evaluations of the project were finalizing in 2014. (*5*) In this environment there was reason to anticipate the resolution of major technology challenges such as use of the 5.9 GHz spectrum for DSRC use with supporting implementations from vehicle manufacturers.

As the program progressed some events reinforced the expectation that these challenges could be successfully addressed. For instance, in December 2016 the U.S. Department of Transportation's (DOT) National Highway Traffic Safety Administration (NHTSA) unveiled its long-awaited proposal for requiring vehicle-to-vehicle (V2V) communications technology in all new vehicles. With that announcement there was added hope the marketplace would adopt the DSRC 5.9 GHz communications approach that had been used in Michigan for the Safety Pilot Model Deployment.

However, a year into the project the telecommunications industry was asking to share the 5.9 GHz spectrum with unlicensed Wi-Fi, NHTSA rulemaking for vehicle-to-vehicle communications had not completed, some companies were proposing a cellular communications approach for vehicle safety instead of the DSRC approach used in Michigan, and the Federal Communications Commission was aware of these viewpoints. This uncertainty contributed to the reluctance of broad industry investment in the DSRC approach. The CVPD sites, their stakeholders, and the US DOT were addressing technology issues with less than full industry engagement. If this program had been on the forefront of a massive industrywide adoption of DSRC technology the results would have been trendsetting. The benefits produced by the new program strategies of extensive pre-solicitation outreach, real-world problem solving, phased selection, collaboration, roundtables, local performance measurement, and financial sustainability were key in achieving the resulting outcomes despite the uncertainties.

Additional factors contributed toward making the deployment build particularly challenging for the sites and the US DOT. Technical issues of DSRC communications in the canyons caused by the buildings in New York had never been experienced and solved before this program. Sharing of detailed vehicle location data outside of immediate use for safety applications was an impediment for evaluation in New York because of concerns about personally identifiable information – but it did not impact the ability of the technology to function. In Wyoming one of two DSRC vendors dropped support for their equipment including vehicle and roadside units in December 2020. Tampa transitioned its deployment into a testing site to bring financial sustainability to their build. In addition, the US DOT faced significant challenges with the security credential management system and the move to a secure data commons approach for datasets.

Despite all these challenges the CVPD Program structure and approach was a success. CV technologies and services were deployed. The deployers and providers were engaged and expanded their knowledge and capabilities. The innovative program was instrumental in bringing a qualified set of deployers to the table who were able to collaboratively face the challenges of the ecosystem.

These types of programs that pilot innovative technologies and techniques to risk-averse, budget-constrained, public-sector agencies are likely to remain challenging. The lessons learned and documentation published by the CVPD Program will be useful in continuing the advancement of transportation capabilities. Wirelessly connected vehicles are already here, even if they all do not broadcast the messages used in the CVPD Program. So even with the end of DSRC there will still be a move to a future where vehicles are increasingly connected. The results of the pilots will be useful to anyone considering “CV” deployments, using DSRC or any other approach.

Chapter 6. References

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