Connected Vehicle Procurement State of the Practice Assessment

Summary Findings Report (Final)

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16. Abstract
In a variety of forums, procurement has surfaced as an important and challenging topic that agencies must address in deploying Connected Vehicle (CV) projects. Due to the emerging nature of this field, most state and local transportation agencies have had limited experience with procuring CV systems. Given the current state of the marketplace for CV vendors and equipment manufacturers, the CV pilot program, the SPaT challenge initiative, and other CV or Connected and Automated Vehicles (CAV) testing and deployment efforts by leading agencies, the United States Department of Transportation (USDOT) commissioned an assessment of the state of the practice for procuring CV equipment and systems. This project addresses the question of how state DOTs and local agencies are purchasing connected vehicle equipment and systems today and what trends are emerging. The research was sponsored by the ITS JPO in cooperation with the Federal Highway Administration's (FHWA's) Office of Operations and was conducted by Noblis.

The research team interviewed agency contacts that have either implemented or are planning to implement CV deployments. These agencies discussed their planned or implemented procurement approaches based on their own experiences. The participating agency contacts provided insight into those approaches and offered their views on best practices, challenges they faced or anticipated in their CV procurements, and future training and technology transfer needs. This report offers a synthesis of this information and provides examples of individual responses. Three CV procurement case studies (Florida DOT's CV program, the Georgia DOT Atlanta project, and the Colorado DOT's I-70 Mountain corridor) are also documented, including the project background, procurement approach used, results, and lessons learned to date.

Most interviewees noted that procuring connected devices was possible using current procedures, but did express concerns regarding the scalability of current procurement methods for large deployments of CV, a general lack of CV technological maturity, interoperability issues between devices, evolving standards and policy as well as technological uncertainty regarding communication technologies such as DSRC and 5G. Several respondents identified limitations of the procurement process that can affect the success or efficiency of the procurement. These limitations generally relate to the fact that traditional procurement mechanisms are not well suited for CV deployment, such as procedures that require low-bid source selection. Respondents also encountered some difficulties with the CV equipment procured, which included slow production times, interoperability issues, and system malfunctions.

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Executive Summary

Encouraging connected vehicle adoption is one of the primary program goals of the current Strategic Plan (2015-2019) of the Intelligent Transportation Systems Joint Program Office (ITS JPO). To meet this goal, state and local transportation agencies must purchase, acquire, or procure connected vehicle technologies, applications, and systems. In doing so, these agencies must follow federal, state, and local laws and regulations, as well as agency-specific policies and procedures for procurement. In a variety of forums, procurement has surfaced as an important and challenging topic that agencies must address in deploying Connected Vehicle (CV) projects. Nearly half of all freeway, arterial, and transit agencies surveyed in the latest national ITS deployment survey answered that technology procurement assistance would help them to accelerate their timetable for deploying CV applications; besides funding, technology procurement was the most frequently selected type of assistance needed out of a list of 7 potential resources[1]. Given the current state of the marketplace for CV vendors and equipment manufacturers, the CV pilot program, the SPaT challenge initiative, and other CV or Connected and Automated Vehicles (CAV) testing and deployment efforts by leading agencies, the United States Department of Transportation (USDOT) commissioned an assessment of the state of the practice for procuring CV equipment and systems.

The purpose of this CV Procurement Assessment was to research and assess the current state of the practice on the procurement of connected vehicle technologies by transportation agencies, determine initial lessons learned from early deployers, and identify next steps and recommended activities toward improving the likelihood that agencies will successfully procure connected vehicle projects. This research was sponsored by the ITS JPO in cooperation with the Federal Highway Administration's (FHWA's) Office of Operations and was conducted by Noblis.

Due to the emerging nature of this field, most state and local transportation agencies have had limited experience with procuring CV systems and as a result, very little on this topic has been documented or fully known and assimilated by the USDOT. The research team targeted local and state agencies that have implemented or have planned CV deployments. These agencies provided their planned or implemented procurement approaches based on their own experiences. The participating agency contacts provided insight into their approaches and offered their views on challenges they faced or anticipated in their CV procurement.

Prior to the interviews, Noblis conducted a literature scan of existing guidance, training, and resource materials related to CV procurement. The main purpose of the procurement literature scan was to understand the important factors and decisions related to procuring advanced ITS systems such as connected vehicle technologies, as well as to document relevant lessons learned and recommendations from planned and ongoing deployments.

In coordination with the USDOT project leads, the research team developed, tested, and revised a survey questionnaire that was sent to project contacts and used for the interviews. The research team

[1] 2016-2017 ITS Deployment Survey, https://www.itsdeployment.its.dot.gov/cv_fm2.asp

and the project leads followed an outreach plan to schedule and conduct interviews, and documented the findings. These interviews focused on gathering information about the interviewee's experience with connected vehicles, with an emphasis on procurement, identified best practices, challenges encountered, and recommendations to USDOT regarding related future training and technology transfer needs.

In total, 11 individuals/groups representing different locations and projects agreed to participate in the study and were interviewed. Several agencies explicitly declined due to either limited CV procurement experience or how early in the process they were with their CV projects. All interviewees had experience in procuring CV equipment for demonstration and/or research purposes, some in partnership with local universities and transportation research centers, or as part of broader state or national initiatives, including the Signal Phase and Timing (SPaT) Challenge, the Advanced Transportation and Congestion Management Technologies Deployment Program (ATCMTD), or the Connected Vehicle Pooled Fund Study. Most interviewees noted that procuring connected devices was possible using current procedures. Interviewees did express concerns regarding the scalability of current procurement methods for large deployments of CV (such as the vendors ability to provide large volumes of units), a general lack of CV technological maturity, interoperability issues between devices, evolving standards and policy as well as technological uncertainty regarding communication technologies such as DSRC and 5G.

The research team, via the literature review and stakeholder interviews, found that while substantial information exists on ITS implementation, procurement, and best practices, very little is readily available regarding the actual procurement of CV systems. Materials from the CV Pilot sites (Wyoming, New York City, and Tampa, Florida) provided the most published information related to procuring CV systems. Most of the available literature focuses on the technical aspects of CV projects, including standards, System Engineering Management Plans (SEMP), experience and lessons learned, and system development approaches taken by the CV Pilots sites. Interviewed agencies expressed the importance of having this reference material available as they continue to pursue CV projects that focus on safety and efficiency benefits. Importantly, none of the respondents stated that any roadblocks or "show stopping" regulations or requirements in procurement were blocking their pursuit of CV projects.

On the other hand, several respondents identified limitations of the procurement process, whether real or perceived, that can affect the success or efficiency of the procurement. These limitations generally relate to the fact that traditional procurement mechanisms are not well suited for CV deployment, such as low-bid source selection requirements. Respondents encountered some difficulties with the CV equipment procured, which included slow production times, interoperability issues, and system malfunctions. Flexibility in technologies and equipment specified in procurement documentation was deemed important, while also utilizing the best development approach for your project, i.e. a phased or agile approach to address an ever-changing CV marketplace. As the issues described above are symptoms of emerging technologies and new-to-market products, remediation options mentioned by respondents included budgeting time and money for additional vendor support after initial deployment, integration activities and software development, as well as opportunities to test potential offerors' equipment.

From a regulatory and federal-aid perspective, CV projects are ITS projects; as such, if funded in part by the Highway Trust Fund, they are subject to the same requirements (e.g., 23 CFR Part 940, ITS Architecture and Standards, which requires ITS projects to be based on a systems engineering analysis and consistent with the regional ITS architecture). Existing and future ITS procurement guidance and training resources apply just as well to CV projects, although CV projects have some particular aspects that go beyond traditional ITS procurement topics, such as the need to purchase, install, test, and perform software updates to equipment in vehicles.

For initial CV deployments, most agencies are using a design, bid, build approach, which is a more familiar mechanism to most Departments of Transportation (DOT). However, as deployments are expanded and larger projects are contemplated or enabled by federal grants, the overall trend is to procure CV systems using a design – build or a derivative approach (design – build – transfer or design – build – operate – transfer) approach, in which the same contractor team designs the system, procures or purchases the equipment, develops needed software, installs, and potentially integrates the equipment.

An important conclusion of this study is that different procurement approaches have been and will be successfully used for purchasing CV equipment, systems, and services. There's no single best approach or correct way to do it.

Based on the results of the interviews and other project findings, the research team selected three sites (Florida DOT's CV program, the Georgia DOT Atlanta project, and the Colorado DOT's I-70 Mountain corridor) for a short case study write up of the project background, procurement approach used, results, and lessons learned to date. The research team selected these three cases because they represented diversity and innovation from the perspective of CV procurement.

In this very early stage of connected vehicles and automated vehicles, it is important to remember that many transportation agencies still do not have direct experience with CV procurements. Even those agencies that do have experience with the CV procurements generally only have two to three project or program managers with that experience. As agencies initiate or begin to expand their CV systems both geographically and functionally, the lessons learned and best practices for effective CV procurements need to be shared with many more agency staff. The knowledge transfer recommendations provided in this report may assist with this task.

The detailed study findings and recommendations are documented in this report. Outreach is planned to describe the study, share the results with the community, and solicit further discussion.

1 Introduction

The purpose of this CV Procurement Assessment was to research and assess the current state of the practice on the procurement of connected vehicle technologies by transportation agencies, determine initial lessons learned from early deployers, and identify next steps and recommended activities toward improving the likelihood that agencies will successfully procure connected vehicle projects such as vehicle-to-infrastructure (V2I) applications. This research was sponsored by the ITS JPO in cooperation with the FHWA's Office of Operations and was conducted by Noblis.

The major objectives of the research effort are to:

1. Explore, assess, and document the state-of-practice, lessons learned, and current gaps (information needs, training needed, or guidance desired) related to procurement strategies and approaches for buying transportation agency equipment; software; computer hardware; information management systems and services; functions-as-a-service, and other devices, and systems to enable connected vehicles and related applications.
2. Recognize trends and likely adaptations of these procurement strategies and approaches to near-term future (3-5 years) emerging technologies and techniques for enabling connected vehicles through transportation agencies as highway system infrastructure owners and operators and transit agencies.
3. Study and document agency-specific experiences (brief case studies); to provide actual examples of CV procurement approaches.

The report is organized as follows:

- Section 2 presents the study approach and discusses the summary findings of the literature scan.
- Section 3 provides a short overview of the process used to identify and select potential interviewees.
- Section 4 presents the summary of findings from the survey and interviews.
- Section 5 documents three CV procurement case studies.
- Section 6 provides an overall synthesis of findings and recommendations for further work, training, and guidance.
- Appendix A contains the detailed findings of the ITS CV Procurement Literature Scan.
- Appendix B contains the references for the report.
- Appendix C provides a table of acronyms.
- Appendix D provides a copy of the questionnaire used as an interview guide by the research team.

2 Study Approach

This study was undertaken to better understand the current state of the practice involved with procuring connected vehicle related technologies. Due to the emerging nature of this field, most state and local transportation agencies have had limited experience with procuring CV systems and as a result, very little on this topic has been documented or fully understood by the United States Department of Transportation (USDOT). In order to gain a greater understanding of this area, the research team interviewed local and state agencies that have implemented or have planned CV deployments. These agencies provided their planned or implemented procurement approaches based on their own experiences. The participating agency contacts provided insight into their approaches and offered their views on challenges they faced or anticipated in their CV procurement. The findings from these interviews are a primary output of this study. **Figure 1** below summarizes the study approach.

Prior to the interviews, Noblis conducted a literature scan of existing guidance, training, and resource materials related to CV procurement. The scan included material from the USDOT, Transportation Research Board (TRB), American Association of State Highway Transportation Officials (AASHTO), Institute of Transportation Engineers (ITE), USDOT CV Pilot Deployment Program webpages, and other national sources. The main purpose of the procurement literature scan was to understand the important factors and decisions related to procuring advanced ITS systems such as connected vehicle technologies, as well as to document relevant lessons learned and recommendations from planned and ongoing deployments. Section 2.1 summarizes the findings from this literature scan.

In coordination with the USDOT project leads, the research team developed, tested, and revised a survey questionnaire that was used to interview state and local transportation agency participants. After appropriate changes were incorporated, the research team and the project leads followed an outreach plan (described in Section 3), to schedule and conduct interviews, and documented the findings. Based on the results of the interviews and other project findings, the research team selected three sites for a short case study write up of the procurement approach used, results and lessons learned to date. From the findings, the research team prepared recommendations on next steps, related research needs, and associated training and technical assistance needs.

The study findings and recommendations are documented in this report and will be discussed in a national webinar sometime in FY 2019. Based on the findings, outreach will be conducted to describe the study, solicit further participation, and share the results with the community.

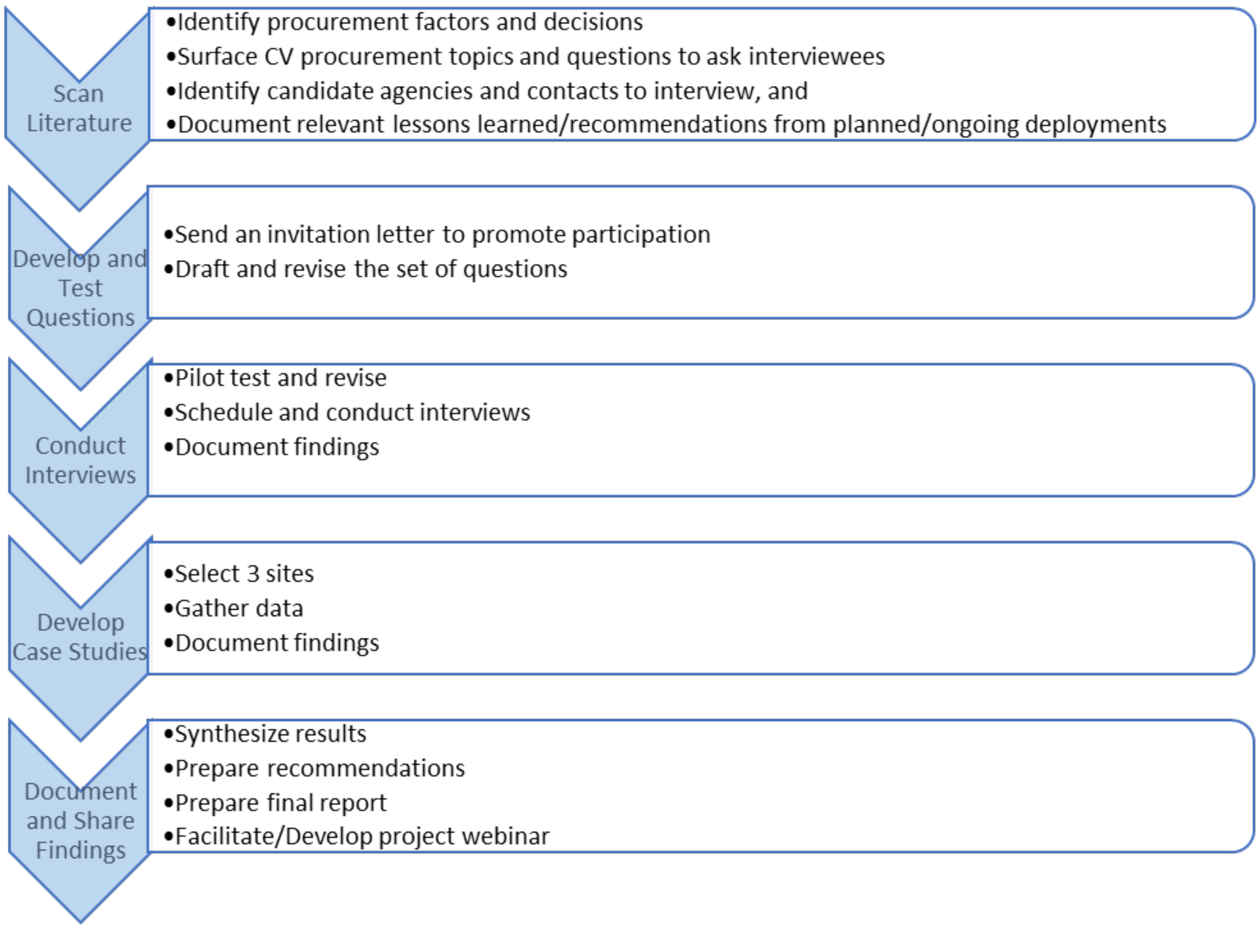

Figure 1. Overview of CV Procurement Assessment Research Methodology (Source: Noblis 2017)

2.1 ITS CV Procurement Literature Scan Findings

The Noblis Research Team (referred to as the research team hereafter) was tasked by the project leads to perform a literature scan of existing connected vehicle materials regarding procurement, lessons learned, and deployment experiences nationwide. The research team performed analysis on publicly available reports and materials pertaining to connected vehicles (CV) developed for the United States Department of Transportation (USDOT) CV Pilots, ITS Professional Capacity Building (PCB) Program, and the ITS Knowledge Resources websites. Additional research was performed on Transportation Research Board (TRB), American Association of State Highway Transportation Officials (AASHTO), Institute of Transportation Engineers (ITE), the National Operations Center of Excellence (NOCoE), and the National Highways Institute (NHI). The research team established the following objectives for resources that are summarized in this literature review:

a) Document ITS procurement models that will serve as a framework for CV procurement practices to be discussed;
b) Assist with developing topics and questions to ask interviewees about related to CV procurement;
c) Identify candidate agencies and contacts to interview;

d) Document relevant lessons learned/recommendations from planned/ongoing deployments.

The research team found that resources identified in our initial scan met the above objectives, and that while substantial information exists on ITS implementation, procurement, and best practices, very little is readily available regarding the actual procurement of CV systems. Materials from the CV Pilot sites (Wyoming, New York City, and Tampa, Florida) provided the most information related to procuring CV systems, mostly by way of challenges and lessons learned documented in project deliverables or webinars. Appendix A contains a summary of findings from the most relevant sources investigated and how they relate to the topic of CV procurement. Information on references used, including links to the source documentation where possible, is contained in Appendix B.

3 Survey and Interview Selection Process

The research team undertook a nationwide scan of potential CV projects and developed a list of approximately 25 individuals from agencies representing 35 targeted projects / activities; some individuals were the point of contact on more than one project. The scan identified projects led by all levels of government from state to local agencies and municipalities, including projects captured on the SPaT challenge website[2], as well as federal projects such as the CV Pilots, and relevant ATCMTD grant program awardees. Initial outreach involved an email distribution from the USDOT task manager John Corbin to Federal Highway Administration (FHWA) state Division staff to inform them of the project, make them aware of the research activities and to solicit additional feedback in the form of other known projects and contact information.

Following the initial email from John Corbin, the research team distributed a general email to the individuals identified as leaders of their respective CV projects. FHWA Division staff, typically ITS or Operations Specialists, were included in this correspondence and invited to participate in the study. The general email was followed by a project-specific email, intended to clarify the project of interest and establish a commitment to participate by scheduling an interview time. The project-specific email was more personalized in requesting participation and provided a high-level background on the intent and purpose of this effort. Each of the emailed requests to participate contained both a fillable PDF survey instrument as well as a link to an online scheduling site where participants could select interview times at their convenience. Participants were asked to fill out the survey and provide it to the research team prior to the scheduled interview. A copy of the survey questionnaire tool is provided in Appendix D.

To clarify answers and better understand the perspectives of the individuals that agreed to participate, and to obtain information from those who did not fill out the survey, the research team conducted interviews. These interviews followed the survey questionnaire as a basis and focused on gathering information about the interviewee's experience with connected vehicles, with an emphasis on procurement, identified best practices, challenges encountered, and recommendations to USDOT regarding future training and technology transfer needs.

The results of this recruiting process are outlined below:

- 11 individuals/groups agreed to participate in the study and were interviewed (44% successful response rate).
- Several agencies explicitly declined due to either limited CV procurement experience or how early in the process they were with their CV projects.
- The remainder offered no explanation as to why they didn't participate.
- The interviews lasted approximately 45-50 minutes and typically included state or local level staff with management responsibility for the CV project or program. In many cases, FHWA

[2] The SPaT challenge website, https://transportationops.org/spatchallenge, sponsored by the National Operations Center of Excellence, was extremely valuable in identifying points of contact for the study.

Division Office representatives participated in the interviews. A map and listing of individuals/agencies interviewed is provided below in **Table 1** and **Figure 2**. Given the limited number of CV deployment projects and applications in the United States, a sample size of 11 may be considered at least somewhat reflective of the population (excluding the three CV pilot sites). Because participation was self-selecting, it is possible that some of those participating had either very negative or very positive experiences with CV procurement, which may have served as motivation to share their experiences with the research team.

Table 1. Individuals and agencies participating in CV procurement state of the practice study. ***(Source: Noblis 2018)***

Individual/Agency	City/County/Project	State
Faisal Saleem (MCDOT)	Maricopa County	Arizona
Matthew McAllister (City of Denver)	Denver Public Works (ATCMTD Grant)	Colorado
Tyler Svitak and CDOT CV Team	I-70 Corridor and Statewide	Colorado
Raj Ponnaluri (FDOT)	Tallahassee	Florida
Jeremy Dilmore (FDOT)	FDOT District 5 (Osceola County, FRAME)	Florida
Mark Kopko (PADOT)	Statewide	Pennsylvania
Alan Davis (GDOT)	Atlanta	Georgia
Blaine Leonard (UDOT)	Salt Lake City	Utah
Virginia Lingham (VDOT)**/ Cathy McGee**	Northern Virginia and Statewide	Commonwealth of Virginia
Collin Castle (MDOT)	Statewide	Michigan
Eric Phillips (City of Marysville Economic Devel. Dir.) **and Team**	Marysville (ATCMTD Grant)	Ohio

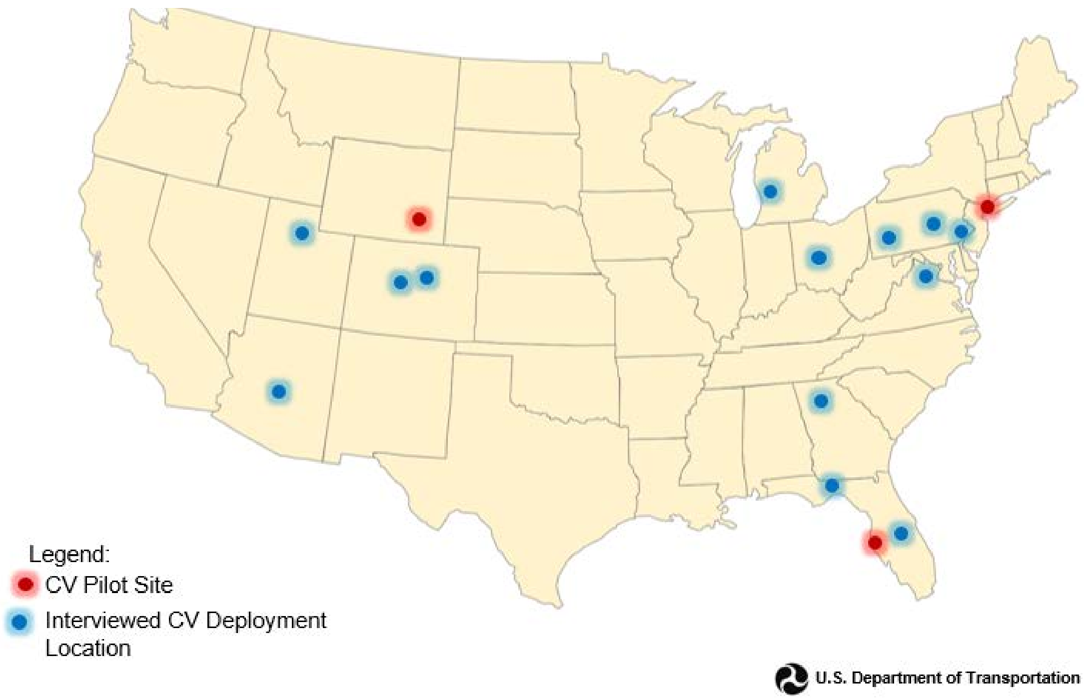

Figure 2. Map of Participating CV Locations. (Source: Noblis 2018)

4 Summary of Findings from Questionnaire and Interviews

This section contains an overview of the survey findings and participant interviews of those individuals listed in the previous section. It is divided into six subsections, following the general sequence of the interviews conducted, and provides an overview of the general themes and feedback identified from interviewees and their experiences with CV procurement and deployment.

All interviewees had experience in procuring CV equipment for demonstration or research purposes, some in partnership with local universities and transportation research centers, or as part of broader state or national initiatives, including the Signal Phase and Timing (SPaT) Challenge, the ATCMTD grant program, or the Connected Vehicle Pooled Fund Study. Most interviewees noted that procuring connected devices was possible using current procedures. Interviewees did express concerns regarding the scalability of current procurement methods for large deployments of CV (such as the vendors ability to provide units), a general lack of CV technological maturity, general interoperability issues between devices, evolving standards and technological uncertainty regarding communication technologies such as DSRC and 5G mobile networks.

4.1 Connected Vehicle Project Background

This section discusses the background of the projects discussed during the interviews. CV projects varied in size and for the purposes of this study, the research team divided projects into two groups: small projects and large projects. Additional details regarding the characteristics of small and large CV projects can be found in **Table 2** below.

Table 2. Small and Large CV Project Characteristics (Source: Noblis 2018)

Small CV Projects	Large CV Projects
• Tend to include a limited deployment of RSUs (less than 10) and a limited number of vehicles (less than 10) with OBUs • State and City project sponsors tend to partner with a local university for research development of CV applications and installation of RSUs and OBUs • Utilizes state, regional, or local funding sources, and in some cases ITS or other federal grants.	• Usually part of a large deployment of RSUs (greater than 20) and a large number of vehicles (greater than 20) are equipped with OBUs • State and City project sponsors tend to partner with a private firm for deployment of CV applications and installation of RSUs and OBUs • Utilizes a mixture of Federal aid funds, Federal grants, state, regional, or local funding sources, and has increased private sector participation

4.1.1 Types of Projects and Development Stage

The projects the research team interviewed varied in scope, size, and status of the deployment. Although several interviewees had responsibility over multiple projects, the interview typically focused on one or two specific examples, so to simplify the analysis, a single "most representative" project was selected for each interviewee. This most representative project was likely to be one that the interviewee was currently working on or had recently completed, often representing a larger deployment rather than an initial research or testing effort (the most representative project concept was only needed for project-based analysis, as described below).

The research team found that, across the sites interviewed, stakeholders plan to equip over **243 intersections** with CV technology**, 1,049 RSUs** to be installed on roads, highways, and intersections and, at least **5,999 vehicles** equipped with onboard units over the next five years.

Of the 11 projects analyzed, one was in the initial project planning stage, two were in the design stage, two were in the installation and systems integration stage, and six were operational and were being maintained. See **Figure 3** for an illustration on project status. The size of the CV deployments also varied between projects. Some of the operational systems are currently small in size, but plans are in place to expand them in the near term by increasing the number of intersections and vehicles equipped. At the time of the interviews, relatively low numbers of vehicles had been equipped with onboard units (OBUs). Most respondents stated that the small number of operational intersections and equipped vehicles were often related to their use for research or demonstrative purposes. These demonstrations where either part of broader research projects with local universities, demonstrations for conferences such as the ITS World Congress, participation with the SPaT Challenge, or for other demonstrative purposes to show the benefits of CV technology to interested stakeholders, including government officials and representatives. Despite the current limited penetration of CV, most respondents stated that they expected their localities to expand the number of RSUs and equipped vehicles in the near-term as part of broader safety-based and mobility-based initiatives at the city and state level. The research team found that across the sites interviewed, over 243 intersections will be equipped with CV technology, at least 1,049 RSUs will be installed on roads, highways, and intersections and, at least 5,999 vehicles will be equipped with onboard units over the next five years.

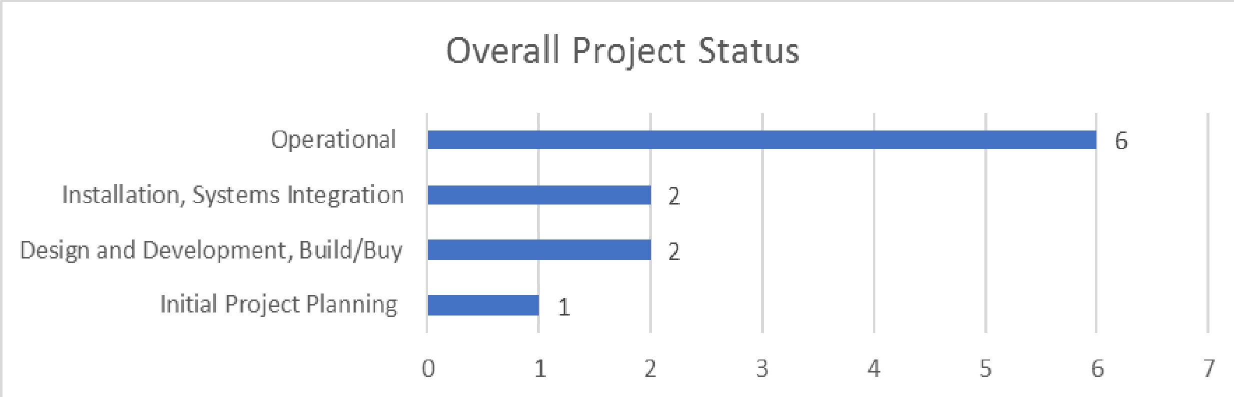

Figure 3. Lifecycle Status of CV Projects[3] Analyzed. (n=11) (Source: Noblis 2018)

4.1.2 Types of Funding and Financing Sources

Respondents reported that project funding can be a challenge. Current and future small-scale deployments of CV have used or expect to use state, regional, or local funding sources, and in some cases ITS or other federal grants, as well. Respondents of future large-scale deployments, such as those being deployed as part of an ATCMTD grant, stated that they expect to use a mixture of Federal aid funds, state, regional, or local funding sources, and usually have increased private sector funding.[4]

In terms of funding sources, state, regional, and local funding was the most frequently cited source of funding. This is particularly true for operations funding, although interviewees noted that some private sector funding is anticipated. **Figure 4** below provides a visual representation of funding source types (the blue bars represent project deployment funding and orange bars represents current or future operations and maintenance funding.) For most sites, multiple funding sources are being used. During the interviews and within the survey, respondents could select more than one source of funding. Most respondents noted that they were using a combination of state, regional or local funds and as well as ITS or other Federal grant for the initial development of CV projects. Respondents anticipated state, regional, or local funds to be used to support the on-going maintenance and future operations of their projects. Respondents generally believed that it was in the purview of the state and local government to fund the on-going maintenance and operations of the CV system, similar to funding models used for their traffic signals and roads.

Some respondents noted that they expected the state and local funding for the maintenance and operations of the CV system to be supplemented by the private sector. In these cases, the private sector would likely work with the public sector in a service-oriented partnership. Such an entity could monetize the data collected and transmitted as part of a broader subscription-based model or user fees. For example, a company could use the data to provide real-time travel times, bill for miles traveled, or provide additional sensory and weather or environmental data for autonomous vehicles.

The types of funding used or anticipated also varied by CV project size. For small sized CV projects, in both the research and operational stages, respondents reported that they primarily used state, regional,

[3] Selected one "most-representative" CV project for each interviewee.

[4] Respondents noted that a cost match and mixed use of funding resources is required as part of the initial ATCMTD application

and local funding sources, and federal funding sources when applicable. Large CV projects, the majority of which are in the planning phase, are utilizing a combination of state, regional, and local funds, federal aid funds, ITS or federal grants (e.g., ATCMTD grant recipients) and private sector funding. Colorado Department of Transportation's I-70 Mountain Corridor Project was the sole respondent whose project is a partnership with a private organization (Panasonic) and expects that private sector funding will play a major role in realizing the project (the Colorado case study presented in Colorado Department of Transportation I-70 CV Procurement Case Study will provide more information on this partnership).

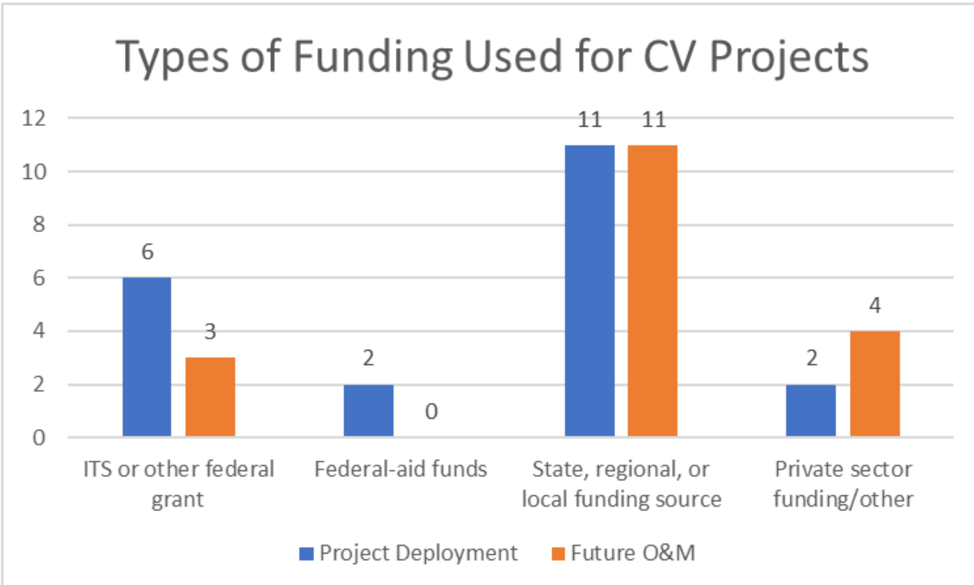

Figure 4. Categories of funding used for deployment and operations of CV projects. (n=11) (Source: Noblis 2018)

4.2 Connected Vehicle Project Planning

4.2.1 Connected Vehicle Project Motivators and Applications

Respondents reported an array of motivations, various types of stakeholders, and differing CV applications for their current and planned CV projects. Often, respondents noted that positive safety and mobility outcomes of CV technology were the primary motivators behind their interest and investment in CV technologies. Respondents stated that there is increased motivation at both the local and state, where officials understand the importance of getting ahead of new and emerging technologies, from both an economic and business perspective. Additionally, CV technology and the infrastructure upgrades and investments are expected to be an important foundation for future automated vehicles. Infrastructure upgrades that include OBUs/RSUs along roadways and intersections are expected to serve as sensor redundancy for future automated vehicles. Notable comments and observations from respondents are categorized by their motivating factors and captured in **Table 3**.

Table 3. Motivators that Spur Connected Vehicle Deployments *(Source: Noblis 2018)*

Motivator	Feedback Received
Safety	• *We need to move the needle on pedestrian fatalities, and connected (vehicle) technologies seems to be way to do that.* • *Infrastructure-to-vehicle messages could really help our drivers on curve speeds and ice roadway warnings.* • *At a state level, we understand that connected vehicle technology can address most of our safety and congestion issues.* • *The safety benefits make CV deployment a high priority and is a real motivating factor.* • *CV will help us increase the safety of our roads, specifically for signal priority for emergency vehicles and snowplows and weather detection.*
Mobility	• *CVs and the applications deployed will meet the needs of our numerous rural communities and improve mobility and access to employment along the corridor.* • *From our limited CV deployment on transit vehicles, we've increased the efficiency and schedule adherence of our transit vehicles from the mid-80s to 94%.* • *CV could help with our signal operations, where we could assign signal priority based on position, type of vehicle, whether that be freight or transit.* • *CV could really help us decrease congestion along our highways.*
Connected Infrastructure for Future Automated Vehicle Testing and Deployment	• *We see that CV data could be useful as sensory redundancy for automated vehicles, beyond their current lidar capabilities.* • *Our Governor and Secretary of Transportation have expressed the importance of pursuing CV as part of a broader strategy to position the state to be at the forefront of AV research.* • *SPaT is an essential step for AVs at intersections, vendors have expressed that they like the redundancy of CV at intersections and along roadways.* • *Connected Vehicles are the stepping stone to automation, CV and the roadside infrastructure investment required will support future AVs.*
Economic Competitiveness	• *Our State level officials, Department of Community Development, and Turnpike have all expressed interest in these types of investments.* • *Getting workforce experience in CV is another benefit of pursuing CV and AV technologies.* • *We continue to have the support of upper management for our CV research program; we're bringing the benefits of this technology to the Commonwealth and showing that our state is open for business.* • *The vendor reached out to us to become the proving ground for a robust CV ecosystem, they understand the need to make this right.*
Support Agency Goals and Direction	• *We see CV as the future and want to be out in front.* • *Our leadership and upper management are very supportive of CV technologies.* • *We wanted to test the new technologies/equipment.* • *We wanted to participate in the SPaT challenge and go beyond it.*

The research team categorized respondent's current and planned CV applications into four general categories: safety, mobility, environmental, and data environment. Interviewees are planning to procure the largest number of applications in the safety and mobility areas. In addition, several participants mentioned the importance of the data environment to the success of their CV programs. The list of specific applications grouped by category can be found in **Table 4** below.

Table 4. Consolidated list of CV Applications being Procured or Planned *(Source: Noblis 2018)*

Focus Area	Connected Vehicle Project Applications
Safety	• Pedestrian crossing/bike safety • Red light violation warning and enforcement • School zone/work zone warning • First responder preemption • Spot weather warning • Curve speed warning
Mobility	• Multimodal Intelligent Traffic Signal Systems (MMITSS) • Adaptive signal control • Transit priority • Snowplow priority • Speed harmonization • Queue warning • Traveler information • Dynamic ridesharing • Virtual Active Traffic Management
Data Environment	• SPaT/MAP • Probe-enabled traffic monitoring • Integrated data environment
Environmental	• Eco-approach and departure

4.2.2 Stakeholder Roles

Stakeholder types and their roles within the project varied by project size. CV projects that were smaller (generally with one to three equipped intersections or smaller length connected corridors), had public agency stakeholders and university partners. The sponsorship and the project management role was primarily held by the public agency/entity and the university performing the CV research. In some cases, the university partners developed the CV applications and served as the systems integrator. In most cases, the university partner or an outside contractor performed the installation of CV equipment at intersections and in fleet vehicles. Additional information regarding the stakeholders and the corresponding roles can be found in **Table 5** below.

Table 5. Small CV Project Stakeholders and Roles *(Source: Noblis 2018)*

Stakeholders	Small CV Project Roles
Public Agencies (City, MPOs, State-level Officials)	• Are the project sponsor, and selects the location of the CV project, goals, and the applications deployed • Establishes partnership with local university to develop CV applications and test equipment • Provides funding for the project (usually matched by university) • Are the primary stakeholders for the CV project • In some cases, installs CV equipment (OBUs/RSU) with staff or contractor at intersections/corridors and on fleet vehicles
Universities	• Establishes partnership via Inter-government agreement/Memorandum of Understanding for CV project with locality or project sponsor • May serve as the primary systems developer, inclusive of CV application development and testing CV equipment • Procures a limited number of RSUs/OBUs for research, development and testing purposes • In some cases, installs OBUs on to fleet vehicles and RSU at intersections
Private Sector Firms/ Consultants	• Has a limited role in small scale CV projects. Roles are divided by service and product provided: o RSU/OBU vendor: are the equipment provider and manufacturer and provides RSUs and OBUs, in some cases is systems integrator o Consultant/Engineering Firm: Performs required measurements and mapping for installation of RSUs and OBUs.

Whereas in large-scale deployments, including the ATCMTD grantees, stakeholders ranged from private sector partners, such as original equipment manufacturers (OEM) and Tier One manufacturers, to technology, consultant and engineering firms, public agency officials, metropolitan planning organizations, and federal-level officials. Additional information on large scale deployments can be found in ***Table 6*** below.

Table 6. Large Sized Project Stakeholders and Roles *(Source: Noblis 2018)*

Stakeholders	Large CV Project Roles
Public Agencies (City, MPOs, State-level Officials, Business)	• Are the project sponsor and selects the location of the CV project, goals, and the applications deployed • Establishes partnerships with private sector firms and consultants for large scale CV projects • Provides partial funding for the CV project, usually paired with state level funding, and/or Federal funding via ATCMTD or other Federal ITS Grants • Are the primary CV project stakeholder and coordinates intra-governmental and private sector coordination (i.e. coordination with the MPO, City and State Level Departments of Transportation, and City Officials, and Economic Development Organizations) • Utilizes City or State-level contract for private sector development, deployment, and installation of CV-related equipment

Stakeholders	Large CV Project Roles

Universities	• Establish partnership via Inter-government agreement/Memorandum of Understanding for CV project
	• In some cases, serves as the systems developer, inclusive of CV application development and testing CV equipment
	• In some cases, performs installation of:
	  o RSUs at intersections and along corridors.
	  o OBUs on city/state owned fleet vehicles, transit, and emergency response vehicles.

Private Sector Firms/ Consultants	• Develops and provides RSUs, OBUs, and other CV-related equipment.
	• Are systems integrator and/or systems manager.
	• In some cases, performs installation of:
	  o RSUs at intersections and along corridors.
	  o OBUs on city/state owned fleet vehicles, transit, and emergency response vehicles.
	  o OBUs on privately-owned vehicles.
	• In cases where an ATCMTD Grant or Other Federal ITS Grant, the private sector provides funding mechanisms, usually in the form of in-kind services, such as systems development or equipment.

4.2.3 Connected Vehicle Project Size

With the exception of larger USDOT-funded CV Pilot Deployment program sites in New York, NY, Tampa, FL, Wyoming, and the testbed in Michigan, today's connected vehicle projects are generally small in size. However, over the next five years, respondents reported that the number of active CV projects is expected to increase substantially, especially when considering ATCMTD grant recipients, State-sponsored CV projects, and the potential of partnerships. The consensus from respondents was that as infrastructure is replaced in high congestion or incident areas, states should ensure that signal and other related infrastructure be CV-ready to reap the benefits of CV technology and be prepared for future automated vehicles. One respondent noted that the State DOT recently instituted a policy that requires that as signals are upgraded (signal modernization projects) DSRC enabled controllers will be installed. This policy is expected to equip about 50 signals yearly (MDOT). Another respondent noted that the State DOT is planning on using CV as part of their smart corridors projects to mitigate congestion and increase safety along heavily used roads and highways (PennDOT). The research team found that across the 11 project locations interviewed and surveyed, at least 1,049 RSUs will be installed on roads, highways, and intersections and, at least 5,999 vehicles will be equipped with OBUs over the next five years.

Figure 5 and **Figure 6** provide an overview of the number of RSUs and vehicle OBUs planned in the various project locations. These numbers are for informational purposes only and should be considered preliminary; some interviewees pointed out that the numbers are subject to change as the costs become clearer. The figures below show that that Michigan and Pittsburgh are deploying a sizable number of RSUs, while 8 of the projects are currently planning 100 or fewer RSUs. Of the sites, only four are planning to have 100 or more OBUs, and two of the top three are ATCMTD grant locations. It is important to note that many of the locations are using vehicles primarily for testing and verification and validation purposes to check that the SPaT/MAP and other supported messages are being properly transmitted. Because of this, they do not need to equip a large number of vehicles. An observation made by the research team is that projects that are scoped to meet the SPaT challenge generally will not require many vehicle OBUs.

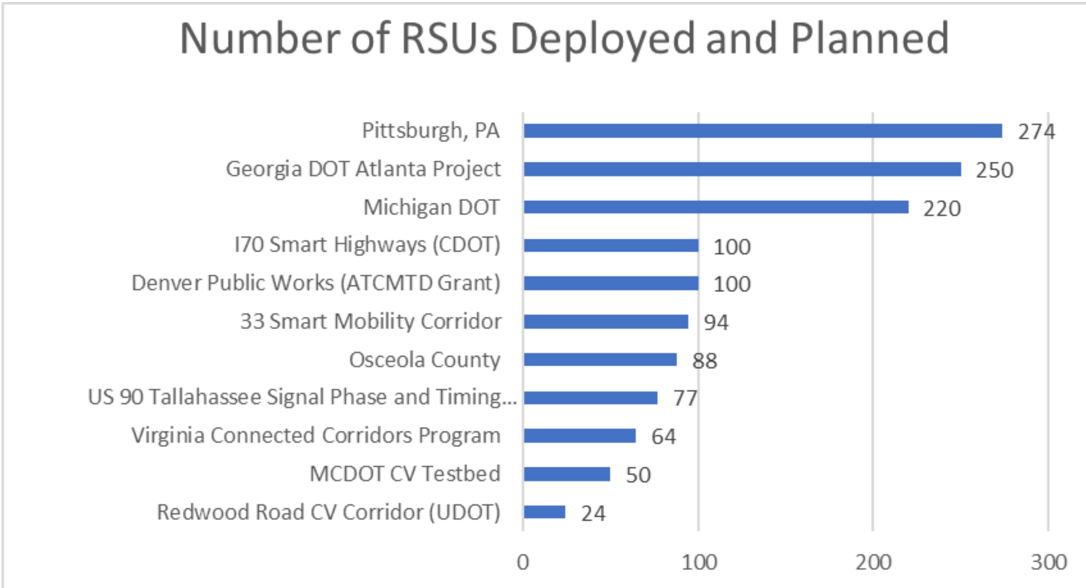

Figure 5. Total Number of RSUs Deployed and Planned by Project Location, Sorted by Number (Source: Noblis 2018)

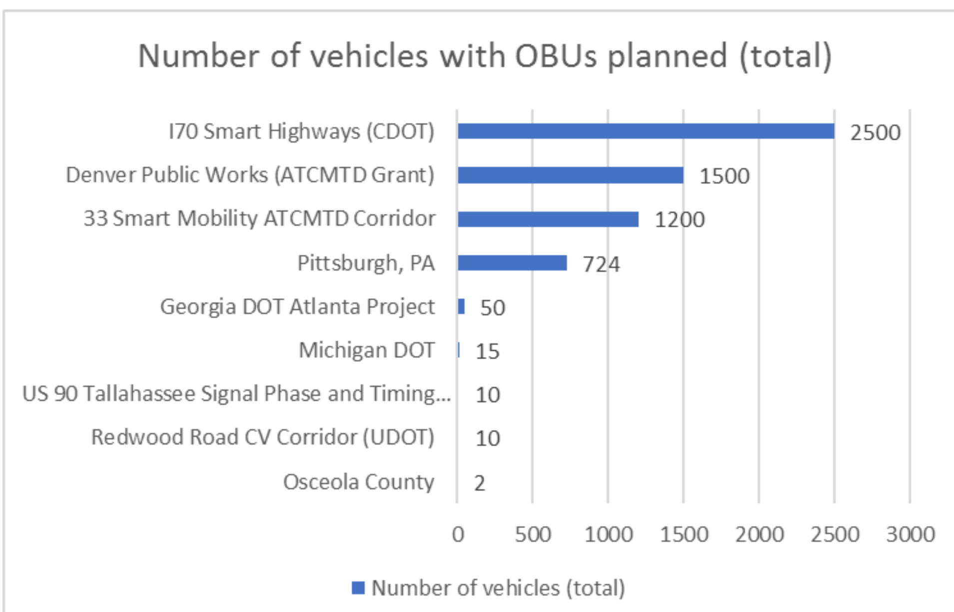

Figure 6. Total Number of Vehicles with On-Board Units (OBUs) Planned by Project, Sorted by Number (Source: Noblis 2018)

4.2.4 Software Development Needs

Respondents noted that the procurement approach used is dependent upon the software and hardware development needs of the project. In relation to this, the research team asked about the level of custom software development needed for the CV project (question 28 in Appendix D). The choices included “very little software development required”, “moderate software development needs”, “substantial software development needs”, and “this project is largely a software development effort”. Of the ten respondents that answered this question, seven projects were categorized as “moderate software development needs” and three projects were categorized as having “substantial software development requirements”. No projects were categorized as having “very little” software or being a “largely software development project”. One participant mentioned the advantages of open-source software, but this topic was not addressed in the survey or interviews. Generally, CV projects tend to have moderate to substantial software development needs that can be explained by the ever-increasing role that information communications technologies have in these projects. Respondents noted their CV projects included the installation of “networked infrastructure” for connected vehicles and their corresponding applications, which increased the complexity of the project’s software development needs when compared to other standard infrastructure improvements. The research team also found that projects that use or expected to use Agile/Scrum development methodology was related to the software development needs of the project. Agile/Scrum as discussed further in the subsection below.

4.2.5 Systems Development Approaches Used

CV projects varied by size and stage of development. Interviewees generally used the standard Vee systems engineering approach. Of note, CV projects that will receive or are receiving federally-funded grants, such as ATCMTD recipients, are required to use a systems engineering approach. Sites did report that they were using or expected to follow USDOT guidance documentation developed from the CV Pilot Sites in New York, NY, Tampa, FL, and Wyoming for various aspects of the projects. Projects in the state of Florida noted that they had reach back support and had used the institutional knowledge from the Tampa CV Pilot Site throughout the development of CV projects within the state. The exception to the general trends of the systems development approach were sites in Colorado, whose projects are expected to utilize a combination of the Vee and Agile/Scrum, and would be determined by the needs of the project. Colorado’s respondents expected to use the Vee Systems Engineering approach for infrastructure improvements, signal control, and other safety critical systems/components, whereas they expected to use Agile/Scrum methods for software-heavy components, i.e. their data clearing warehouse/publishing, and “City Operating System” (part of Denver’s ATCMTD Grant application). One respondent noted that they had not selected their systems development approach due to the early stage of their project, but did expect their contractor to select the best approach for the project.

Respondents noted the importance of documentation and best practices from the CV Pilot sites, stating that they were aware of USDOT CV resources and were in some cases able to use the concept of operations documentation in their own project. One site reported that they expected to use a contractor-specific approach, as the firm was hired to design, build/install, and operate the CV system, though they believed that this approach most likely mirrored the Vee model. For CV projects that were software oriented or had increased private sector interest or investments, respondents expected to utilize a phased approach, coupled with Agile/Scrum methods. Additional details can be found in **Figure 7** below.

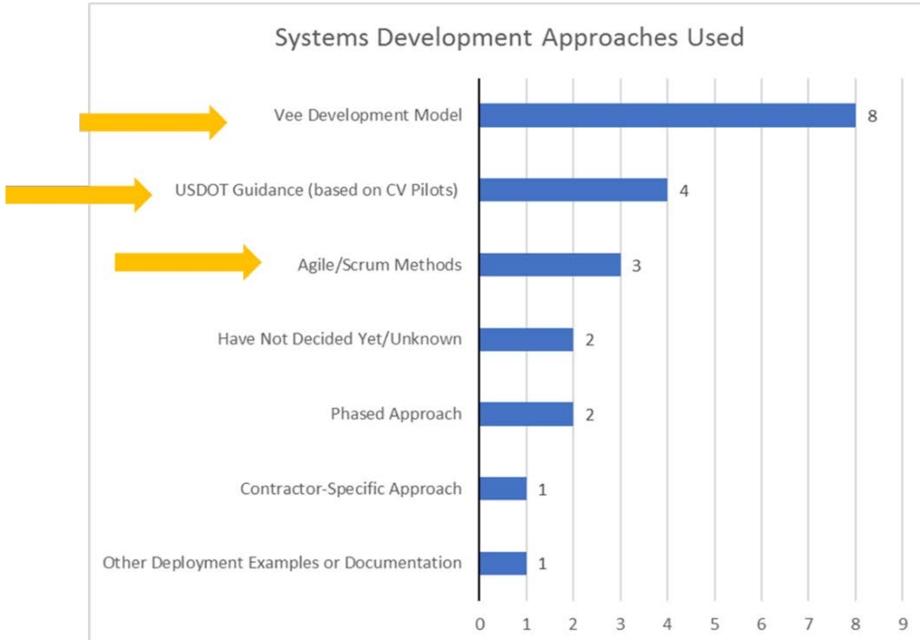

Figure 7. Systems Development Approaches used by Respondents to Manage CV Projects (n=11)[5] (Source: Noblis 2018)

4.3 Procurement Approach Familiarity

Many agencies are using familiar procurement approaches to purchase CV systems and services. Most respondents had at least some experience using their agency's procurement approach. Of the 11 respondents, six reported that they used the procurement approach often to purchase CV equipment. Although the procurement approach may be familiar, writing specifications for "new to market" products, such as DSRC devices, OBUs, RSUs, and software remains a challenge. While, in theory, there might be a better approach to use, agencies are making do with familiar procurement approaches. Only two participants reported that their agencies had never used the implemented or planned procurement approach for their CV project before. **Figure 8** depicts this information.

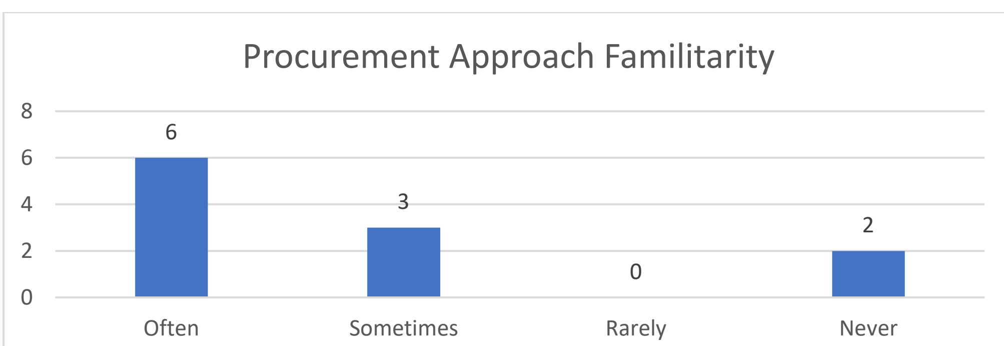

Figure 8. Agency experience with selected procurement approach for CV projects. (Has your agency used this procurement approach in the past?) (n=11) (Source: Noblis 2018)

[5] Respondents could select multiple answers.

4.3.1 Procurement Roles and Responsibilities

See **Figure 9** for a look at how agencies are generally handling their level of involvement in managing subcontractors and writing specifications for equipment and software. Six agencies are still using a design, bid, build approach, which is more traditional. Four agencies are using a design–build approach, in which the same contractor team designs the system, procures or purchases the equipment, develops needed software and installs the equipment, and usually performs initial operations before transferring the system to the DOT. This can be referred to as a design – build – (operate-transfer) DB(OT) job, depending on the responsibilities given to the contractor team. At the time of the interview, one of the agencies was still undecided as to how they would proceed with allocating the work for their project.

There are advantages and disadvantages to both procurement models (design, bid, build approach verse design – build – (operate-transfer)). In a more traditional design, bid, build approach, the procuring agency has more control over the specifications and direct access to the contractors (who would otherwise be a subcontractor) which might be advantageous in certain circumstances. On the other hand, managing all the contractors and coordinating their schedules requires a level of expertise in contract management as well as the domain of connected vehicle technology. In a DB(OT) environment, the hired prime contractor has responsibility for the subcontract management and likely will have more responsibility for the equipment and software specifications, perhaps giving the prime contractor more flexibility in getting the job done. In this approach, the procuring agency may lose some control over specifications and must be willing to accept the performance of the prime contractor in project management.

There are differences in how the operations and maintenance (O&M) responsibilities are transferred from the contractor team (usually a system integrator) to the responsible operating or procuring agency after system acceptance, usually involving some training. However, it does not appear that private firms are being used for ongoing system operations and maintenance in a substantial way.

There was one project that had a slightly different approach. The Colorado DOT's (CDOT) procurement approach is based on a partnership with Panasonic to deploy connected vehicle technology in Colorado. It is essentially a DB (OT) model, except that Panasonic will continue to operate and provide lifetime updates to CDOT’s CV Data Ecosystem. This arrangement is essentially a service model for connected vehicle implementation (or “CV as a service”).

In the Colorado project, Panasonic is installing and maintaining the equipment for the duration of the contract, but CDOT still retains ownership. As CDOT expands their CV infrastructure, it plans to own, operate, construct, and maintain all equipment. The Data Ecosystem is the only part of the project that Panasonic will operate and maintain for CDOT once the contract is finished. An advantage to this procurement approach is that CDOT does not have to maintain and upgrade the software code for the data ecosystem, which could prove to be costly over the lifespan of the project. See the CDOT case study writeup in Section 5.3 for more information on this procurement.

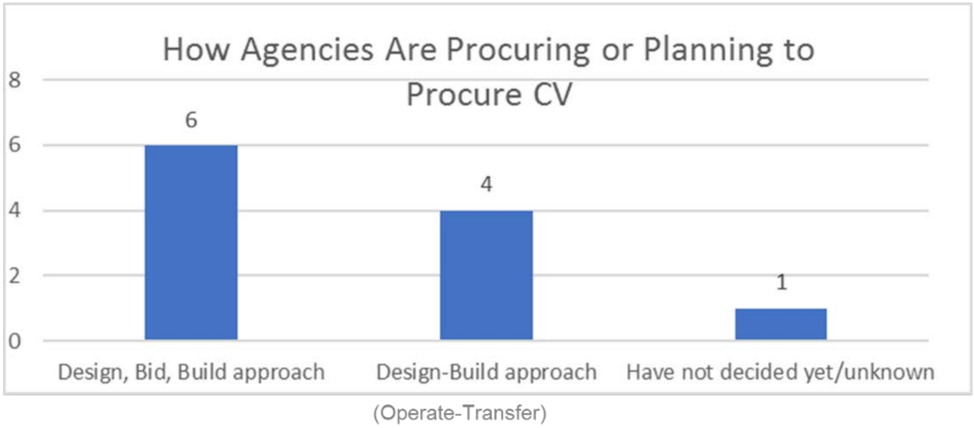

Figure 9. Overall Approach to Procuring CV Project Elements. (n=11) (Source: Noblis 2018)

4.3.1.1 Small Scale CV Projects and Procurement

Small-scale CV projects, inclusive of those that are research oriented or are preliminary testing demonstration phased projects and those that are planning installation of CV at a limited number of intersections and vehicles, often partnered with a university or transportation research center for project procurement and engineering. In these cases, the university would procure the CV-related equipment through an intragovernmental agreement. In turn, the locality would perform the installation and maintenance of the CV equipment, and the university or a contractor would perform systems integration.

In some small-scale CV projects, respondents added that the project's total value was under the ceiling dollar value requirements for any required competition and bid processes and that they had sole sourced the procurement of CV equipment. In these cases, the agency would either perform the systems installation, integration, and maintenance itself or utilize an outside contracting firm for these duties.

In other small CV projects, the locality used a State DOT contract to ensure adequate competition from private sector firms. A standard request for proposal (RFP) process was used and a firm or equipment manufacturer was selected to provide the CV equipment, perform installation, and provide system maintenance.

4.3.1.2 Large CV Projects and Procurement

For large scale CV projects, procurement and deployment remains relatively unchartered. Respondents noted that they had very little or no previous experience in procuring CV for large-scale projects. Despite these limitations, a few respondents provided insight into how they had procured CV equipment for testbeds and (state) pilot projects. One respondent stated that, for their CV testbed and related projects, they had used multiple procurement techniques, and were still trying to find an approach that got them the best final product. The respondent noted that they used multiple options, including sole source contracts, releasing task orders via the standard procurement process, using firms on an Indefinite Delivery, Indefinite Quantity-like (IDIQs) on-call contract, as well as procuring the CV equipment themselves. With all these approaches, the agency used a consultant for parts of systems development, installation, and systems integration activities.

For CV projects that are part of an ATCMTD or other Federal Grant program, respondents noted that either their initial proposals included a private sector partner that will provide the CV equipment and engineering services or that they were still defining their procurement approach. Respondents expressed the necessity to clearly define project requirements, have a flexible development approach, and build in extra time in contracts to ensure that the needs of the CV project and users are met.

Multiple respondents added that CV technology continues to advance and that it has proven difficult for government procurement offices to change their approaches from physical infrastructure works, to software-based and communications technology projects.

4.3.2 Systems Manager/Systems Integrator

One of the questions asked whether a systems manager or systems integrator were going to be used by the agency for the project procurement and system development. The results are depicted in **Figure 10**. The overall takeaway is that procuring agencies are outsourcing a lot of the work on CV deployment. This is not surprising given the staffing limitations and shortages at most agencies as well as a lack of experience in the public sector with the CV technology.

In general, the systems manager helps with project planning and preparing appropriate procurement specifications, and sometimes overseeing the work of the other contractors such as installers and the systems integrator. The systems integrator may help with installation and tying the system together, making sure that everything works together. The systems integrator often makes sure the devices are compatible with existing legacy equipment and troubleshoots deployment issues. Multiple systems integrators may be needed if a separate contractor is used to perform system integration tasks for the vehicle OBUs, for example. In this case, you have one integrator for the infrastructure side and one for the vehicle side of the project. The Tampa CV pilot project is an example.

The research team found that the exact roles of a system manager and systems integrator vary by project. Some agencies use both. In some cases, a single contract team is given roles that combine tasking typically associated with either of the systems manager or system integrator roles. In other cases, an on-call ITS contractor performs some of the systems management or systems integration roles.

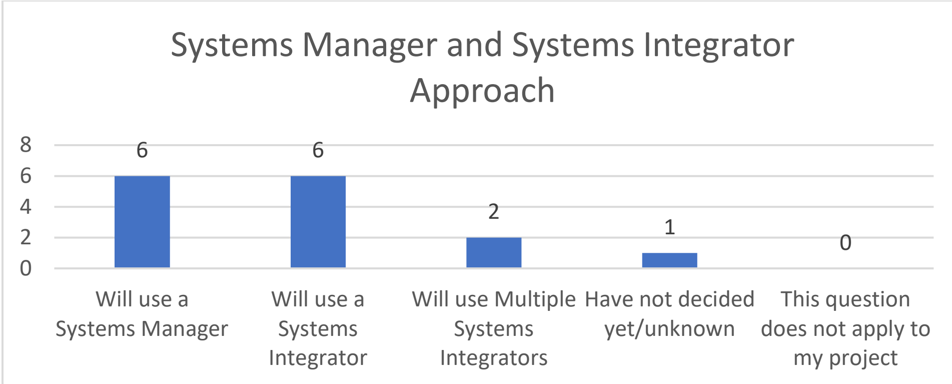

Figure 10. Reported Use of Outsourced Systems Managers and Systems Integrators. (n=11)[6] (Source: Noblis 2018)

4.3.3 Planned Use of Consultant Assistance

Figure 11 conveys the planned use of consultant assistance for assisting with CV system planning, preparing procurement specifications, and overseeing the work. Most agencies are utilizing consultants for these functions. These functions are commonly performed by a systems manager, which may indicate that while agencies use consultants to perform these functions, some do not refer to the consultant as a systems manager. In addition, they may be using different contractors or consultants for the different functions.

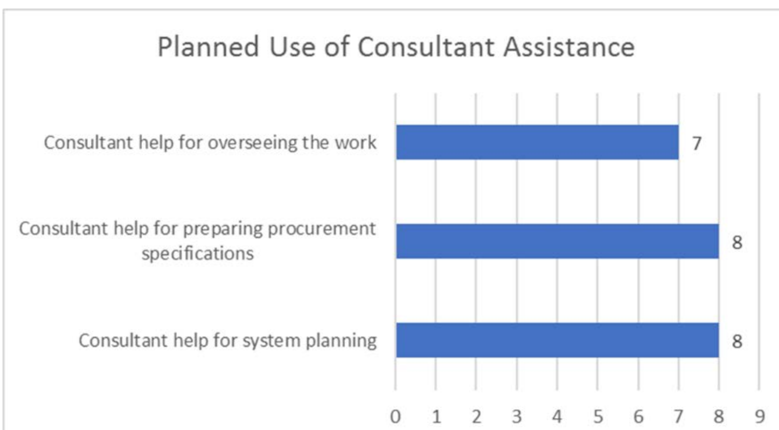

Figure 11. Planned Use of Consultant Assistance for CV Procurement. (n=11)[7] (Source: Noblis 2018)

4.3.4 Contract Types and Method of Award

Even though many uncertainties exist regarding CV deployments and future needs, the research team found that most agencies are using fixed-price contracting (at least for base tasks). The reasons for this were not explored in depth, but one contributing factor to explain the high usage of fixed-price

[6] Respondents could select multiple answers.
[7] Respondent could select multiple answers.

contracting is that agencies are managing to a specific not-to-exceed budget. The next most frequently used type of contract is the time and materials (T&M) contract. In cases where optional tasks were included, those tasks also tended to be ordered using a time and materials approach.

The method of award for most CV project contracts included both qualifications and cost factors. This implies that most agencies have been able to avoid the low-bid only method of award, which has traditionally been viewed as a less than optimal approach for ITS projects. In one case, a sole source contract was awarded to a firm after the state DOT had sought other sources and met other requirements according to state policies and procedures. While the method of award being used did not appear to be a problem for the survey respondents, several respondents indicated that the traditional preference for a low-bid approach was a limitation that had to be overcome, as discussed in the subsection on limitations below.

4.3.5 Procurement Process Limitations or Challenges

CV project managers noted that though procurement is a challenge, it is not an impediment to project success. The project managers interviewed by the research team noted that they generally had to work directly with the contracts office to ensure that RFPs and SOWs were written in a precise manner to ensure that the firms that were ultimately selected could complete the work successfully. Other project challenges that were noted by interviewees were the FCC licensing process, lack of experience in contracting with large IT companies in state and city level projects, and broader limitations on procurement policy and its inability to meet an ever-changing and evolving technological landscape. Additional limitations noted from the study participants can be found in **Table 7**.

Table 7. Procurement Process Limitations and Challenges for CV Projects *(Source: Noblis 2018)*

Limitation Category	Comments and Feedback Received
Industry Participation	• *Generally, large technology companies tend not contract with State DOTs and don't have experience with state and city-level clients.* • *Vendors of RSUs and OBUs did not have the capacity and staff to supply the required devices for our project, which delayed our project six months.*
Federal Policy	• *The FCC licensing process has been a real challenge for us, we've devoted substantial resources to receiving approval.* • *The lack of a federal mandate for DSRC has limited our procurement forecast, vendors want to make sure the technology will be used prior to investing additional money into research and development.*
Procurement Process	• *Traditional mechanisms for procurement that DOTs follow don't fit well with software/technology-heavy projects; we're used to procurement for physical infrastructure, like pavement and snow plows.* • *Takes too much time and requires lots of communication between technical and procurement office staff.* • *We're required to use lowest bid contractors/equipment for our projects.* • *We had to work with our contracts office to ensure that the technical requirements were met when selecting a selecting a vendor/consultant.*

Funding	• *Funding continues to be an area of concern. It doesn't seem like there are (many) funding opportunities for large-scale CV projects.*
Technological Maturity and Interoperability	• *Technological maturity is of concern. The units we procured required substantial technical support from the vendor during our initial deployment.* • *Interoperability doesn't fully exist yet even though vendors say their equipment is compatible. It usually requires at least some troubleshooting.* • *Standards and technology continue to evolve, causing the specifications to be a moving target.* • *The owners of our signals vary from city to city in our state, with over 6 different models in use. Selecting an RSU vendor that is compatible with all of the varying signal models has been a challenge.*
Systems Development Approach	• *Sequential engineering approaches tend not to work as well on technology-heavy projects like CV, we've had to adapt agile approaches to meet these needs.* • *We're primarily used to building physical infrastructure and using the standard systems engineering approach. For more technology-oriented projects, we've had to adapt the systems engineering and agile approaches for our project.*

It is important to note that some of the respondents believe that their existing procurement process is adequate, and that it did not pose any major impediments to successful CV procurement. A few respondents answered that it was *too soon to tell* whether CV-specific limitations existed.

4.4 Lessons Learned and Best Practices

Despite the challenges noted in the previous subsection, CV project managers and stakeholders noted that none of the challenges were insurmountable. By utilizing both state and federal resources, along with assistance from their procurement/contracts office and consultant help, most projects have either been successfully implemented or are at least are beyond the design stage. Additional lessons learned, recommendations, and best practices can be found in the **Table 8** below.

Table 8. Recommendations and Best Practices for CV Procurement *(Source: Noblis 2018)*

Category	Comments and Feedback Received
New Partnerships and Policy	• *As a department, we partnered with our State DOT colleagues and used their contracting expertise and consultants. This helped us in selecting a vendor and ensuring the right consultant was used.* • *We've worked closely with the ITS JPO and referred to CV Pilot Documentation for our city and state level CV projects.* • *We have a great relationship with our local university and have an intragovernmental agreement with them. The university provided research*

Category	Comments and Feedback Received
	and development for our CV projects and was even able to do initial testing of CV equipment. • *For FCC licensing, we were able to use a state-level expert who understood the FCC licensing process. This greatly reduced the time and effort needed to receive final FCC approval.*
Federal/Other CV Resources	• *Make use of CV resources offered by the ITS JPO, FHWA, National Operations Center of Excellence, AASHTO, etc.* o *Staff expertise* o *Model documentation (CV pilot program, SPaT challenge resources)* o *ITS Public Data Hub* o *Participate in CV/CAV -related peer exchanges* o *Take advantage of training opportunities (ITS PCB program, webinars)*
Procurement and Project Resourcing	• *Prior to releasing an RFP to RSU vendors, we held a plugfest to test vendor equipment with our signal equipment and controllers. We were able to immediately see which vendors were truly interoperable which greatly assisted us when we released our final RFP.* • *For our CV RFPs, we were able to have project requirements vetted by SMEs. This has helped us contract with better qualified consultants and ultimately receive a better final product.* • *We have a team of on-site and off-site CV experts that help us with our CV project. Having that expertise to verify deliverable accuracy and ensure that we're meeting program goals and system requirements has been an excellent resource.* • *We budgeted extra time for software development and equipment testing in our initial RFP.* • *Ensure that your contracting and procurement personnel are involved from the beginning of the project.* • *Consider viewing connected vehicle services through the lens of the service provider model. The service provider model offers more flexibility in choice of technologies and deployment strategies.* • *Make sure your procurement documentation has an approach to support future technology developments and standards.*
Project Development Approach	• *We're planning on using an agile approach to the software and application components of our CV project, while also using the traditional systems engineering approach where applicable.* • *We've used a systems manager approach, with a lump sum fixed priced contract for our CV work, which has helped us reduce risk and keep project costs in check.*

Category	Comments and Feedback Received
	• *We found that breaking the project up into smaller ones (phased approach) helped us complete the project more easily.*
Contract Vehicles	• *Explore contractual options beyond your own agency's that may be available to purchase CV equipment, such as statewide IT services and communications contracts; city, county, and regional contracts; and university contracts.*

4.5 Participant Recommendations to USDOT

One of the final questions from the survey (Question 35) instructed them to rank in order a set of six knowledge transfer approaches the USDOT could offer from their perspective as most important to least important. Current CV resources, such as studies and documentation from the USDOT CV Pilot Sites, New York, NY, Tampa, FL, and Wyoming were deemed useful, and in some cases used as model documentation for state and local CV projects. Interviewees expressed interest in USDOT technical assistance and training efforts, but seemed to give higher priority to technical peer exchanges on CV-related topics. Providing guidance and model documentation also surfaced as important knowledge transfer areas of interest. Providing funding opportunities was ranked lower than the other topics, but this may reflect the current state of the ITS CV program (providing funding for future CV pilots is not expected, although various grant programs do provide federal funding opportunities).

During the interviews, CV Project managers and stakeholders emphasized the importance of USDOT leadership for connected vehicles, adding that the resources that are readily available from the CV Pilot sites have been of substantial value. The research team found that several respondents recommended a cohort-like group, facilitated by USDOT for CV deployers. Participants also noted the importance of guidance and procurement documentation for CV and finalizing the rulemaking of DSRC or providing clarity of the Government's position on use of 5.9 GHz DSRC versus other communications technologies.

Additional recommendations for USDOT and comments from participants are provided in **Table 9**. Many of these recommendations extend beyond the topic of procurement but relate to general education about CV technologies and their deployment.

Table 9. Participant Recommendations for U.S. DOT Consideration *(Source: Noblis 2018)*

Category	Comments and Feedback Received[8]
Training and Education	• *Provide training on network infrastructure and technology behind CV* • *Educate agencies across the country on CV and AV technologies*
Peer Exchanges	• *Facilitate a cyber security cohort and other peer exchanges for CV deployers* • *Support peer exchange of data to consolidate and share information*

[8] Participant feedback and comments provided in italics. Quotations represent actual statements made in support of the recommendation.

Category	Comments and Feedback Received[8]
	• *Continue to pull out effective things that are learned in the CV Pilots* • *Serve in a technical advisor role by highlighting best practices*
Procurement Guidance and Examples	• *Provide model procurement documentation and guidance* *"CV Pilot documentation has been very helpful in our state & local projects."* • *Develop a contracting approach and mechanism that works well for projects developed using Agile/Scrum methods* • *Develop how-to guidance/factsheets on FCC licensing process*
Project Justification and Cost Estimates	• *Provide additional CV benefits and cost data to assist deployers in estimating project costs* *"This would help us make the case for CV/AV projects to leadership."*
Policy	• *Clarify USDOT position on DSRC and other new CV communication technologies* *"As an agency we've had difficulty justifying continued investment in DSRC without a federal mandate."* • *Stabilize standards and certification environment*
Funding	• *Sponsor additional USDOT CV projects to assist agencies in understanding the undertaking of CV projects and their corresponding benefits* • *Develop factsheets explaining potential near term funding sources for CV deployment* • *Focus more resources for large-scale CV deployments, based on CV-Pilot experiences*

4.6 Views on Connected Vehicles and Automation

Although not related to CV procurement per se, at the end of every interview, the research team asked the participants a general question about how their agency viewed the relationship between CV and automated vehicles (AV) (or automated driving systems). Most participants believe there will be a complementary relationship between connected vehicles and automated driving systems in the future, since CV and AV systems can serve as a supplemental/backup system for the other system to prevent crashes. Most of the early CV deployers we talked to believe that deploying connected vehicle technologies is a step on the way towards Connected and Automated Vehicles (CAV), and that CV is a stepping stone towards automated driving. A sample of the responses are provided below.

As a department, we're focusing on installing smart infrastructure at intersections and crosswalks so that we can easily rollover the technological benefits from CV to AV.

- *We see connected vehicles as the stepping stone toward automated vehicles. We believe that investments in smart and connected infrastructure will ultimately support enhanced automated driving systems while providing the net-safety benefits almost immediately.*

- *As a state, we've already defined our safety use cases for connected and automated vehicles. Implementing these new technologies, even at a small scale, will help develop our capabilities for future large AV deployments.*
- *Implementing connected infrastructure will provide SPaT and MAP data to vehicles regardless if they are CVs or AVs, which will have safety benefits. OEMs and auto manufacturers have expressed interest in having this redundancy as a backup and augmentation of lidar and CCTV on the AVs.*
- *Automation and automated vehicles generally falls under the department of transit. They have expressed interest in using AVs for first-mile-last-mile and low speed shuttle service.*
- *Automation is tied to CAVs and having connected infrastructure will be key. From the city perspective, the policy needs rely on leadership from the State and Federal Government.*
- *We believe CAVs are the future and we're doing everything possible to meet the future needs of CAVs. We believe that our connected infrastructure will provide additional awareness to CAVs beyond today's standard AV technologies (e.g., lidar).*

5 Case Studies

As discussed in Sections 1 and 2, one of the objectives of this study was to document up to three specific cases to serve as different examples of the procurement of CV technology. While the results from Section 4 cover the combined input from all sites and interviewees, the case studies allowed us to shine a spotlight on one example at a time, providing context for their utilized procurement approach. This section describes the three case studies chosen by the research team; Florida DOT CV program, Georgia DOT Atlanta project, and the Colorado DOT I-70 Mountain corridor. Out of the 11 interviews conducted, the research team selected these three cases because they represented diversity and innovation from the perspective of CV procurement, as discussed below:

- Florida DOT has a very active CV program, with many projects still in the development stage. FDOT has had the opportunity to evolve the procurement model being used and apply lessons learned to subsequent projects. FDOT also sponsors a research project on introducing more innovation into the procurement process for CV. The CV projects under development cover a variety of urban, interurban, and rural environments.
- Georgia DOT's Atlanta project grew from a simple desire to meet the SPaT challenge, but the resulting project covers several CV applications and is moderately large in terms of an infrastructure footprint. The project has just recently turned on and is in the initial operations phase.
- Colorado DOT's I-70 Mountain corridor project was selected because it represents a slightly different model of procurement than all the others; the project is built on a partnership with Panasonic, and a shared vision of the CV-data infrastructure called the CV Data Ecosystem. Since Panasonic will continue to operate the CV Data Ecosystem beyond the completion of the project and is obligated to provide CDOT upgrades and enhancements to the ecosystem over time, this case study also provided an opportunity to investigate a service model for connected vehicle implementation ("CV as a service").

Although the exact format varies in the three cases, the general format of the case studies includes:

- Background section, highlighting the reasons for the deployment and the point of contact
- Specific details about the project(s) reviewed
- CV Procurement Approach section, highlighting procurement roles and responsibilities, contract type, and overall approach to purchasing the CV system
- Procurement profile table with additional detail and lessons learned from the agency
- Where appropriate, a discussion of next steps and future vision

The draft versions of the case studies were provided to each highlighted project team (the key person(s) interviewed) for review and verification to ensure that the procurement approach was properly captured. Based on this review, the case studies were revised as appropriate.

5.1 Florida DOT CV Procurement Case Study

5.1.1 Background on Connected Vehicle (CV) Projects in Florida

The Florida Department of Transportation (FDOT) began its formal CV Initiative in 2017, having already created their statewide Automated Vehicles (AV) initiative in 2012[9] and since 2013, their continued participation at the annual Florida AV summits. In 2011 the FDOT unveiled their first major CV initiative, the CV Affiliated Testbed along I-4, at the ITS World Congress in Orlando. By 2014, the FDOT had created working groups, and developed plans for continued CV efforts, including the research and planning for the Tampa CV Pilot Program, in coordination with the CV Pilot leader, the Tampa Hillsborough Expressway Authority (THEA). See **Figure 12** below for a map and listing of CV projects in Florida. As shown, Florida is currently very active in CV deployment, with approximately 14 projects in the planning and design/implementation phases and two currently operational. This map and additional information is available on the FDOT website[10].

5.1.2 Specific Connected Vehicle Projects Reviewed

The specific CV projects interviewees discussed with the research team are detailed below:

- **Osceola County CV**. Osceola County implemented CV technology by deploying Roadside Units (RSU) at two signalized intersections. The deployment was sponsored by the Federal Highway Administration (FHWA) as a pilot project to test Dedicated Short Range Communications (DSRC) equipment and intersection processing equipment to gain experience and compile lessons learned in the deployment of CV infrastructure and applications. The RSUs were deployed at the intersection of W. Osceola Parkway and S. Orange Blossom Trail, and the intersection of S Orange Blossom Trail and S. Poinciana Blvd. The project has been completed and is operational.

- **US 90 Signal Phase and Timing Tallahassee**. Under FDOT's Transportation Systems Management and Operations (TSM&O) Program, arterial traffic management solutions are receiving renewed focus, especially given the technology advances offered by connected vehicles (CV). A 22-intersection Signal Phase and Timing (SPaT) project using DSRC technology is underway at the City of Tallahassee, on US 90 Mahan Drive. FDOT and City of Tallahassee our partnering to install Roadside units to broadcast SPaT information 24x7 for vehicle onboard units (OBUs) to test reception. This project became operational earlier this year.

[9] http://www.automatedfl.com/Documents/Policy-WG-White-Paper%20(1).pdf
[10] http://www.fdot.gov/traffic/its/projects_deploy/cv/Connected_Vehicles.shtm

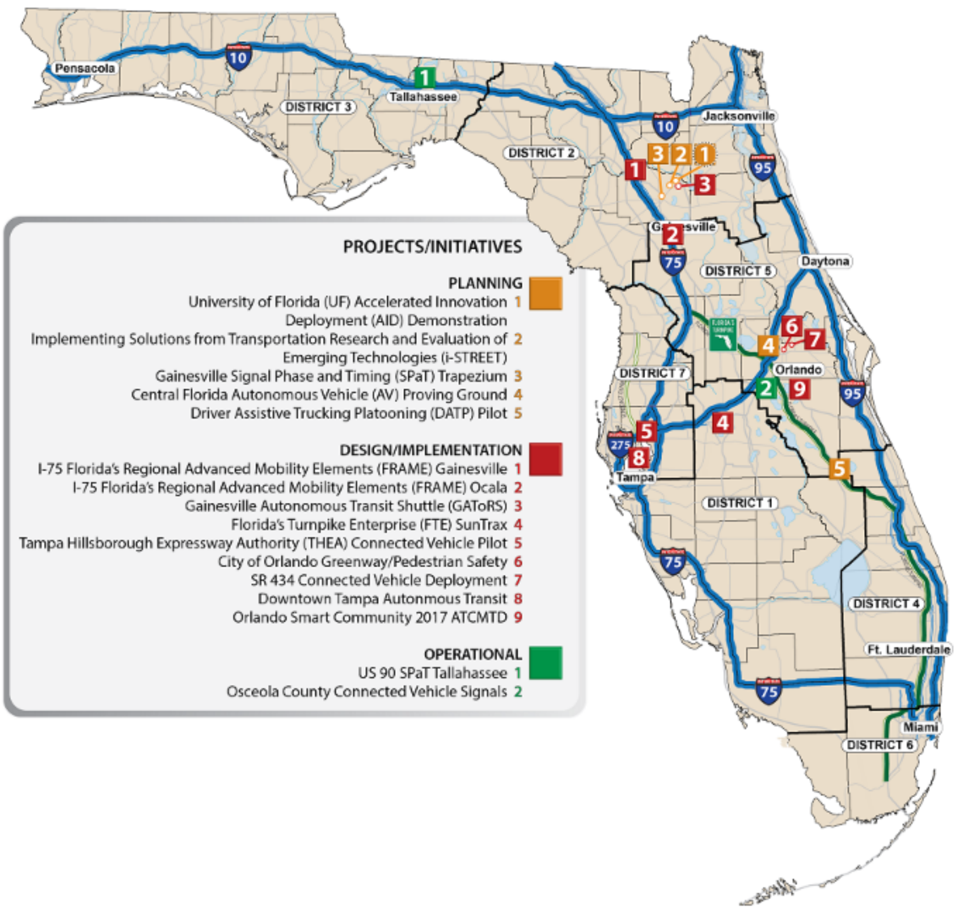

Figure 12. Florida DOT Connected Vehicles Initiative (Source: Florida DOT 2018)[11]

- **I-75 Florida's Regional Advanced Mobility Elements (FRAME)** project will deploy emerging technologies to better manage, operate, and maintain the multi-modal transportation system and create an Integrated Corridor Management solution on I-75 and state highway systems in the Cities of Gainesville and Ocala. The emerging technologies proposed in this project are Automated Traffic Signal Performance Measures and CV technologies such as RSUs and OBUs for effective traffic operations; Transit Signal Priority and Freight Signal Priority. The goal of the project is to disseminate real-time information to the motorists during freeway incidents. This project was developed for the 2016 USDOT Advanced Transportation and Congestion Management Technologies Deployment Program (ATCMTD) grant program.
- **State Road 434 CV Deployment.** This project spans seven signals and is located in Seminole County, north of the University of Central Florida (UCF) on SR 434, from north of McCulloch Road to east Mitchell Hammock Road. This CV pilot serves as a starting point for the PedSafe Greenway Deployment Project. This project will include CV technologies (DSRC, RSU, OBU) with CV applications like Pre-emption, Transit Priority Signal, Signal Performance Metrics and SPaT.

[11] Map can be found at http://www.fdot.gov/traffic/ITS/Projects_Deploy/CV/Connected_Vehicles.shtm

- **Pedestrian Safe GreenWays Project.** Orlando Smart Community ATCMTD winning Application for 2017. The GreenWay Project is designed to better utilize the multimodal transportation system by actively managing over 1,000 traffic signals within the region to make travel times more consistent and help reduce congestion.

The testing and implementation of SPaT at select intersections around Florida are designed to support the advancement of Vehicle-to-Infrastructure (V2I) capabilities, especially related to intersection safety applications. It will also give FDOT and local agency staff the opportunity to gain experience in the operation and maintenance of CV infrastructure and applications.

5.1.3 FDOT's Connected Vehicle Technologies Procurement Approach

The overall trend in Florida is to hire a systems manager to assist FDOT with planning, developing, and implementing their CV projects. FDOT is working to keep the procurement process as competitive as possible, while meeting strategic needs, such as interoperability. Because the deployments span different jurisdictions, FDOT is working with at least four different signal controller manufacturers. Because of this, compatibility and interoperability of various RSUs with the different controller equipment is paramount. To reduce the risk of procuring devices that are not interoperable with the various controllers, FDOT has incorporated device testing into their procurement approach and source election process. Refer to **Table 10** for more details of the FDOT CV procurement approach.

The initial two SPaT Challenge related CV projects (Osceola County and Tallahassee US 90) were carried out predominantly by FDOT staff as a design – bid – build, using their standard request for proposal (RFP) process. In Tallahassee, for example, FDOT served as the system manager, undertaking all the work to get the project started, managed and integrated. The installation of RSUs was done by City of Tallahassee. The device vendor demonstrated their equipment was operational, provided training and participated in some integration activities where necessary. Testing was carried out by FDOT and the vendor together. Overall system integration duties were carried out by FDOT (using consultant help).

As the scope of the proposed CV projects has increased, FDOT has migrated to hiring a systems manager and using a design-build implementation method. Florida's FHWA Division ITS and Operations staff played an instrumental role in advising FDOT on the pros and cons of this procurement approach. For the upcoming Gainesville FRAME CV project, the vendor will furnish, install, integrate, and test with support from City of Gainesville.

Table 10. Florida DOT CV Projects Procurement Profile *(Source: Noblis 2018)*

Topic	Additional Information
CV Project Motivators	• **Safety**, particularly for pedestrians. The number of bicycle and pedestrian fatalities is higher in Florida than any other state. Florida is working hard on the vision zero goal (the objective is to address the safety problem from many different angles). CV offers an opportunity to "move the needle on safety". • **Mobility** and efficiency. • Ability to **manage congestion**. • **Leadership**/ upper management **support**.

Topic	Additional Information
Procurement Details	• **Stated challenges**: interoperability, standards, systems architecture, security credentials management system, process taking longer than usual, Federal Communications Commission (FCC) licensing process is resource intensive and not well understood. • **Types of Contracts Used**: Firm Fixed Price (for base tasks) and Time & Materials (T&M) for optional work tasks. T&M for Systems Manager of FRAME project. • **Method of Award**: Qualifications and cost considered. • **Conducted device interoperability testing** of potential offerors with our signal equipment and controllers. FDOT could see which vendors were truly interoperable which assisted in their evaluation. • **Procurement Process Evaluation** – FDOT is using three different approaches to contracting and taking different approaches for the design-build phase of I-75 FRAME Project to see which approach works best. • FDOT is sponsoring and conducting research on **introducing more innovation and creativity in the CV procurement process** in conjunction with University researchers. • **Managing Technology Uncertainty -** FDOT is working with both DSRC and cellular 4G technology to minimize risk of obsolescence and to have a seamless upgrade path for each.
Procurement Lessons	• Need to be creative, yet follow traditional process. Initial step was to use Request for Information (RFI) and then issue RFP, used clear contract language and specific application of the CV process. • System testing and security testing always takes longer than anticipated. • Procurement process in Florida seems to be working. Requiring testing from the consultant /device vendor has led to better results. • Systems manager approach allows more risk to be transferred to the contractor, but the FDOT must partner and manage for mutual success. • Understanding and executing FCC licensing process requires expertise and resources. • Development of CV projects in Florida benefitted from the reach-back support and institutional knowledge from the Tampa CV Pilot Site. • Consider targeting individuals & subject matter experts in addition to asking all stakeholders for feedback/comments on procurement related materials such as draft statements of work, RFPs, etc., since you are not likely to get substantive feedback without doing so.

5.1.4 FDOT Future Vision

FDOT is interested in encouraging partnerships with the private sector to help accelerate CV implementation. From a recent Request for Information (RFI) that was issued, FDOT reports that more than 20 vendors showed an interest in partnering with FDOT on CV testing and implementation in the areas of data, CV infrastructure, system security, and other functions. FDOT is considering collaborating with these vendors and providing them with access to a test bed or corridor for them to test their technology.

FDOT will continue moving forward on CV-related deployments and implementation. FDOT wants to develop solid use cases on safety and mobility, including linking other ITS-related and multi-modal TSM&O projects together with the CV deployments. FDOT also realizes the synergy between connected vehicles and automated driving systems. The Central Florida Automated Vehicle Partnership applied for and was approved by the United States Department of Transportation (USDOT) as a proving ground to become one of the nation's premiere cluster for research and development of automated vehicle technology across all modes of travel. The City of Orlando led the effort in partnership with FDOT, Central Florida Expressway Authority, University of Central Florida, Florida Polytechnic University, Florida A&M University, Florida State University, Lynx, and NASA.

FDOT staff interviewed:
Raj Ponnaluri, State Connected Vehicles and Arterial Management Engineer (3/14/18)
Jeremy Dilmore, TSM&O Engineer, FDOT District 5 (3/7/18)

5.2 Georgia Department of Transportation Connected Vehicle Technologies Procurement Case Study: Atlanta Project

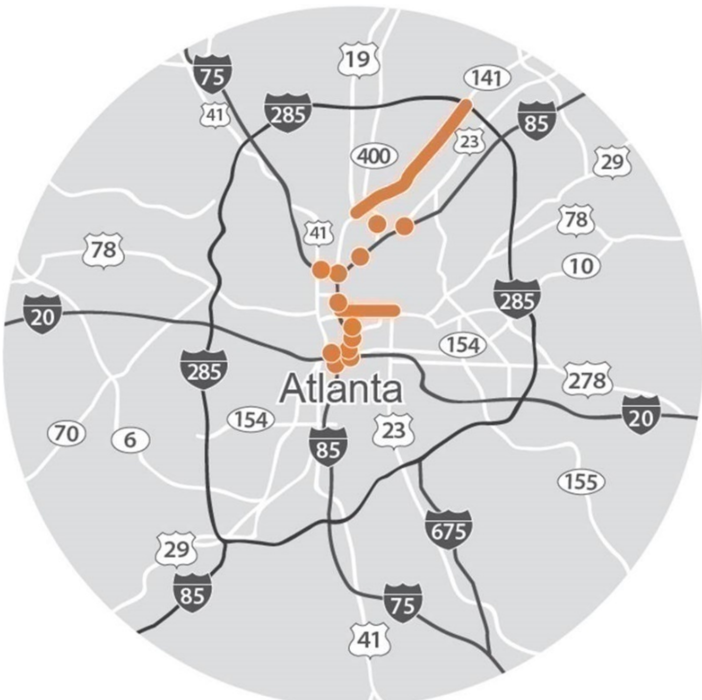

Figure 13. Map of Georgia Department of Transportation Atlanta CV Project (Source: GDOT 2018)

GDOT CV Project Description:
Dedicated Short Range Communications (DSRC) installation at 54 signalized intersections and 12 freeway locations (ramp meter signals) in Atlanta for broadcasting signal phase and timing (SPaT) messaging and receiving BSM data; system integration for output of signal data for public availability of SPaT data (for third party use).

Project Location (see Figure 13):
Atlanta, GA:
SR 141 from SR 9 to I-285,
SR 8 from SR 9 to SR 42,
I-75/85.

Planned deployment and initial operations occurred in Summer 2018. Project includes 50 on-board units (OBUs) to be installed in GDOT fleet vehicles and the vehicles of several participating consultants. The OBUs will be used primarily for validation considerations.

5.2.1 Background

The Georgia Department of Transportation (GDOT) wanted to participate in the Signal Phase and Timing (SPaT) Challenge, and identified locations that would allow for easy demonstrations, while addressing actual mobility and safety problems using applications beyond the SPaT/MAP messages.

In the initial phase, the work scope includes deploying four applications out of the box, that will be deployed at all 54 signalized intersections chosen for the study. Those applications include:

(1) red light violation warning,

(2) SPaT/MAP

(3) a simplified pedestrian in signalized cross walk (will broadcast when the button is pushed), and

(4) a scaled down Eco-Approach and Departure application (will provide users with the coordinated signal speed).

In addition to intersections, GDOT identified twelve ramp locations which are configured slightly differently than the intersections. The initial intention with these locations is to show vehicles what the ramp meter displays are showing. The next step (on major interstate corridors) will be to receive messages from the vehicles themselves, which will be used for extended research activities.

In the upcoming deployment phase, outreach and securing third party participation is a major focus area. GDOTs goal is to add external resources to the CV deployments that will address safety problems and for staff to conduct further CV research. GDOT has had initial conversations with Original Equipment Manufacturers (OEMs) with headquarters in Georgia, various research organizations, and regional distributors/delivery companies.

The City of Atlanta has undertaken their own adjacent DSRC deployment in downtown, which includes 20 intersections along North Avenue, and is working with GDOT to ensure compatibility.

5.2.2 GDOT's CV Technologies Procurement Approach

Refer to **Table 11** for details on the GDOT CV procurement profile, which contains information on the project motivators, the procurement approach used by GDOT, and lessons learned from GDOT's experience.

GDOT's primary reason for initiating CV projects was to improve safety on Georgia's roads. The number of roadway fatalities in Georgia has increased by 33%[12], from a recent low of 1,170 annual fatalities in 2014 to 1,561 annual fatalities in 2016 and an estimated 1,550 fatalities in 2017. In addition to the potential safety improvements made possible by widespread vehicle-to-vehicle (V2V) communications, GDOT envisions eventually having the ability to broadcast information to vehicles which could improve safety by alerting drivers on issues such as icy conditions ahead or to provide drivers with curve speed warnings. Other potential anticipated benefits come through improving the personal mobility of Georgia's citizens and others who travel on Georgia's roadways. GDOT's participation in the SPaT challenge served as an initial motivator for beginning this research.

To move this project from concept to reality, GDOT obtained funding from the federally-funded Congestion Mitigation and Air Quality (CMAQ) Program, which is coordinated by the regional metropolitan planning organization (MPO), along with a local financial match. GDOT is using a single contractor team to design, build, install, integrate, test and train GDOT staff before transferring the system back to the agency. GDOT used a best value approach as the method of award, and considered the qualifications of proposers as well as cost. The resulting contract is being managed on a firm fixed price basis.

GDOT's overall approach is to stay flexible with respect to the communications technology used between equipped vehicles and the equipment on the roadside. GDOT pointed out several procurement-related lessons from their experience to date. These lessons are captured in **Table 11**.

In developing the Systems Engineering (SE) documentation for the project, GDOT and their consultant originally looked at the New York City CV Pilot Documentation, but realized that some of the information

[12] http://www.dot.ga.gov/BuildSmart/performance/Pages/Fatalities.aspx

was not applicable. GDOT and the consultant then designed their own specific SE documentation approach tailored to their needs.

Table 12. Georgia DOT CV Project Procurement Profile (Atlanta Project). ***(Source: Noblis 2018)***

Topic	Additional Information
CV Project Motivators	• **Safety**. The number of roadway fatalities in Georgia increased 33% from 2014 to 2016. GDOT would like to use CV safety-related applications to address this problem. • **Mobility and efficiency**, to have a positive impact on operations. • Meet the **SPaT Challenge**.
Procurement Approach Highlights	• **Allocation of Work Effort**: GDOT released a request for proposal (RFP) for a design-build 'turn key solution' to establish, develop, install, and integrate the DSRC radios at intersections and freeways with ramp meters. GDOT is using a single contract with the design-build team, who is also responsible for the application software installation. • **Funding**: Using Congestion Mitigation and Air Quality (CMAQ) funding with local funding match through the Atlanta Regional Commission (ARC), the regional MPO. • **Stated challenges**: Interoperability, the use of correct standards, and that state procurement code language can be difficult to work with. • **Types of Contract Used**: Firm Fixed Price (for base tasks) • **Method of Award**: Best-value: qualifications and cost considered. • **Managing Technology Uncertainty:** GDOT's approach is to write procurement specifications that are general enough to support multiple roadside communications technologies between the vehicle and infrastructure to minimize the risk of obsolescence and allow support for technology evolution.

Procurement Lessons	• **Stay current on CV knowledge** by participating in related committees, industry meetings, webinars, pooled fund studies, trade shows; also, utilize the expertise of your consultants.
	• **CV Pilots are a great resource** for sample project documentation, but realize that you ***may need to simplify or adjust the methodology*** to right-size it for your project.
	• Look for realistic, yet innovative ways to **validate CV applications**
	  o Do they do what they said they would do?
	  o Do they meet the user needs?

Topic	Additional Information
	o Can we measure their impact? • **Don't put all your eggs in one technology basket** (e.g., DSRC 802-11.p vs. cellular V2X (C-V2X) or LTE communications). o Make sure any communications messages are technology independent, to the extent possible. o Build the back-end infrastructure to support whatever is coming.

5.2.3 GDOT Next Steps

Given the initial success of this deployment, GDOT is planning to extend the Atlanta area deployment geographically to cover more intersections and freeway segments. In fact, GDOT plans call for 250 more RSUs to be installed and operational by the end of 2018. GDOT then plans to rapidly deploy many more RSUs, for a total of 1,700 RSUs by June 2020. **Figure 14** shows the full deployment plan through June 2020. The deployment is focused on intersections along the major arterials in the metropolitan Atlanta area, many of which parallel and can serve as alternate routes to the interstates. The various colors on the map represent different operational groups, corresponding to transportation corridors within the area. For example, the green operational group covers the major arterials and state roads in the I-75 North travel corridor, including U.S. 19, U.S. 41, State Highway 9 and State Highway 92, among others. To expand the population of OBU-equipped vehicles, GDOT is focusing on partnerships with other organizations.

Figure 14. Map of Full Deployment Plans for Atlanta CV Program (Source: GDOT 2018)

GDOT staff interviewed:

Alan Davis, PE, PTOE, Assistant State Traffic Engineer, Georgia DOT aladavis@dot.ga.gov (Date of interview: 3/21/2018)

5.3 Colorado Department of Transportation I-70 CV Procurement Case Study

5.3.1 Background and Summary:

The Colorado Department of Transportation (CDOT) entered into a partnership with Panasonic of North America in 2016 for the development of a statewide Connected Vehicle (CV) Data Ecosystem and deployment of V2X infrastructure along 90 miles of the I-70 Mountain Corridor (I-70 Corridor).[13] It is the first and largest contract of its type for development of a CV ecosystem capable of commercial scale CV deployment. In the agreement between CDOT and Panasonic, CDOT owns the V2X data and hardware, including onboard and roadside units. The intellectual property developed by Panasonic to turn the V2X data into actionable information will be provided to CDOT in the form of a lifetime license with upgrades to the Vehicle to Everything (V2X) Ecosystem in perpetuity. This arrangement contrasts other CV projects across the U.S., where the software development and coding to enable CV applications is developed with open source code that can be provided to other entities. This business model will still provide open data through APIs with any interested third party, interoperability with other hardware, and an open development platform so other companies (or CDOT itself) can build new applications and expand functionality without Panasonic. The operating system itself and the business analytics used to process the V2X data are intellectual property that Panasonic is investing in, in addition to the $72 million contract to develop and sell to other customers. This provides both shared risk and investment

Figure 15. CDOT V2X Deployment Program (Source: CDOT 2018)

[13] https://www.codot.gov/about/transportation-commission/documents/2017%20Commission/june-2017/6-technology-committee.pdf

to bring a product to CDOT and to the market that can enable commercial-scale CV adoption and deployment, and it alleviates the need for CDOT to invest in maintenance and upgrades in the future by using a subscription model.

With the I-70 Corridor deployment, CDOT and Panasonic entered into a modified time and materials agreement that allowed a limited design build-operate-transfer (DBOT) mechanism adopting a "CV as a Service" model, with Panasonic and its partners performing all aspects of installation and operations of CV equipment as well as developing the real-time CDOT-Panasonic V2X Ecosystem. CDOT will have access to the real-time sensory data from the V2X Ecosystem for traffic management purposes, including traffic operations, situational awareness, maintenance, and winter operations. The Panasonic CV equipment is expected to transmit safety messages and other CV-related information to CV capable vehicles, or vehicles with aftermarket CV devices. The CV applications developed as part of their agreement with CDOT is expected to be used by Panasonic for future CV work with other DOTs. Panasonic is installing and maintaining the equipment for the duration of the contract, but CDOT still owns it and is not leasing it from Panasonic. As CDOT grows CV infrastructure, it plans to own, operate, construct, and maintain it all. The subscription to the data ecosystem is the only thing that will remain for Panasonic to operate and maintain, but CDOT will buildout the hardware network itself. Additional information regarding the differences between the traditional CV deployment mode and the CDOT approach can be found in the **Table 12** found below.

Table 13. Connected Vehicle Deployment Models (Source: Noblis 2018)

Traditional Connected Vehicle Deployment Model	CV as a Service Model
• The Infrastructure Owner and Operator (IOO)/agency issues requests for purchase to procure CV equipment. • IOO/agency or an outside firm is contracted to perform installation and integration of CV equipment. • IOO/agency operates, owns, and maintains the CV equipment. • IOO/agency maintains the CV ecosystem, including data collection and transmission of CV messages.	• The IOO/agency enters into an agreement with a private firm or team for the installation, operation, and maintenance of CV infrastructure and/or the broader CV ecosystem, essentially becoming a service provider for the duration of the agreement. • The IOO/agency can maintain ownership of the CV equipment and related infrastructure/system components. • The private firm provides data from the CV ecosystem to the IOO/agency for transportation management & operations, research, and planning purposes. • The private firm can monetize CV system, whether that be via usage fees, monthly charges, or other subscription based fees for the duration of the agreement.

The CV ecosystem is expected to have the capability of using either Dedicated Short Range Communications (DSRC) 5.9 GHz radio technology or Cellular Vehicle-to-Everything (C-V2X) communications technologies, made possible through a telecommunication equipment organization joining the partnership (see below). CDOT noted that the project is "technology agnostic," and primarily focused on the real-world and wide-scale deployment of CV for immediate safety and mobility benefits, using whatever the best communications solution may be. A total of 100-140 Roadside Units (RSUs) will be installed along the I-70 Corridor and at least 2,500 vehicles will be equipped with Onboard Units

(OBUs). However, the scalable V2X Data Ecosystem will be able to accommodate an expansion of RSUs along every roadway in the state. On June 1st, 2018, Panasonic added the mobile technology and telecommunications equipment company, Qualcomm, and the vehicle manufacturer, Ford, to their partnership with CDOT for the deployment of C-V2X and installation of OBUs on fleet vehicles.[14] The project will take an evolutionary approach to traffic management, by providing CDOT with additional sensory data, and allow a "bi-directional path to the vehicle for holistic situational awareness and traffic operations." The project is currently in Phase 1 and has a total of six phases (0-5), described below in **Table 13**, with an anticipated full deployment date of 2019.

Table 14. Phases of I-70 Corridor and CV Systems Development and Deployment (Source: CDOT 2018)

Phase	Development and Deployment Activity
Phase 0	Project Planning & System Design • Develop Phase 0 Baseline Schedule • Define & Initiate Program Management • Complete System Engineering Planning • Select Project Vendors & Partners • Build Panasonic V2X Test Environment • Develop Phases 1-5 Preliminary Schedule • Develop Phase 0 final Report defining Phases 1-5
Phase 1	Vehicle-to-Infrastructure (V2I) Communications – Collect Data
Phase 2	Infrastructure-to-Vehicle (I2V) Communications – Disseminate Data
Phase 3	Vehicle-to-Vehicle (V2V) Communications
Phase 4	Enhance Data Analytics – Import Other Data Groups
Phase 5	End-to-End System Deployment – Starting on I-70 Corridor - Integration and Training of CDOT Staff

[14] https://www.qualcomm.com/news/releases/2018/06/01/panasonic-qualcomm-and-ford-join-forces-first-us-deployment-c-v2x-vehicle

Table 15. CDOT Phases and Funding (Source: CDOT 2018)

Phase	Timeframe	Funding
Phase 0	Feb 2017 - Dec. 2017	**$7.5M**
Phase 1	**Jan 2018 - Mar 2019**	**$12M**
Phases 2	Oct 2018 - Mar 2020	**$17M**
Phase 3/4	**Oct 2019 - Mar 2020**	**$17M**
Phase 5	**Oct 2020 - Mar 2022**	**$17M**

5.3.2 CDOT's Procurement Approach

The total cost of the project according to CDOT is $71.8 million. CDOT has secured $22.5 million for Phases 0 and 1 of the project. CDOT is pursuing a variety of State and Federal funding resources for the future phases of the project, which include state Transportation Systems Management & Operations (TSM&O) funding as well as FHWA, ITS-JPO, and FAST Act funding resources.

CDOT followed all state and federal procurement requirements for this project. CDOT began the process by developing a Request for Invitation and then an Invitation for Bid to respond to a list of Functional and Non-Functional System requirements. However, only one company responded with a technical and cost proposal. After careful evaluation of both proposals, CDOT awarded the contract to Panasonic. Per the contract, Panasonic and its partners are expected to perform most of the software development and infrastructure work along the I-70 Corridor, including the development of an "iOS" like marketplace for CV applications, as well as the CDOT Panasonic V2X Ecosystem and the transmission of CV data.

CDOT has a time and materials master task order contract with Panasonic with specific task orders representing the detailed work of each phase of the contract. CDOT's agreement with Panasonic provides flexibility and latitude for Panasonic for meeting contract requirements via a phased approach. This master contract includes the installation of OBUs on fleet vehicles, RSUs on the I-70 Corridor, and other communications and sensor upgrades. The agreement between CDOT and Panasonic requires that the CV environment be interoperable with multiple Original Equipment Manufacturers, and Tier I equipment suppliers, CDOT's own state-wide ITS architecture, and the capability of interoperability with other local, state, and national systems. During the deployment, the lessons learned and benefits will be documented to assist CDOT and Panasonic in expanding the V2X Ecosystem beyond government-owned fleet vehicles to include opt-in vehicles from local governments and the public. The project team is working to determine how to expand the CV Ecosystem to future jurisdictions/states.

CDOT noted that the current procurement approach built off their previous experience with CV, but that current standard procurement mechanisms are not ideal for software and technology heavy projects. CV and related technologies continue to evolve quickly, which means that contract and software requirements written at the beginning of the project may become outdated quickly, and procurement staff may not be subject matter experts in CV or information technology, resulting in procurement documentation that doesn't meet the needs and specifications of the project. By utilizing a master contract with Panasonic and being flexible, CDOT and Panasonic will be able to utilize agile contracting methods, ensuring Panasonic has the leeway to seek skillsets, project partners and technologies to maximize available resources. CDOT stated that one of the biggest constraints for procurement in this project was understanding intellectual property law and how to apply it in their agreement with Panasonic, which required multiple iterations. Generally, CDOT stated that large technology and software firms have limited experience with State DOTs and that there was a learning curve in both the project mindset and procurement requirements. Their biggest recommendation from CDOT to other localities seeking to implement CV was to use the CV as a service model. They believe their CV as a service model allows DOTs to focus on their primary objectives of increasing safety and efficiency, and provides an outside firm with enough flexibility to build and operate the CV system. This frees up the DOT from having to manage multiple contracts with CV equipment vendors and outside firms or having to identify internal resources to perform installation and operations of the CV system. It also takes the burden away from CDOT of having to maintain or change a software platform and its associated software applications.

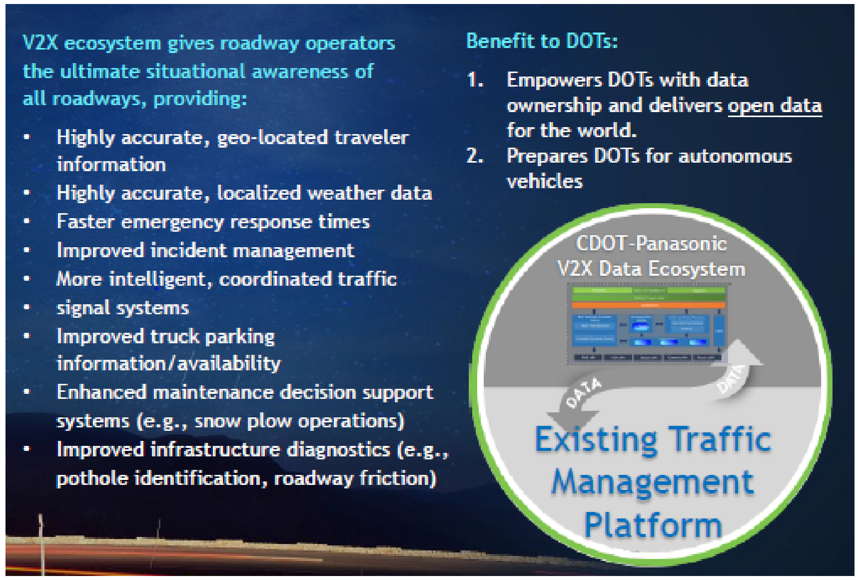

Figure 16. CDOT V2X Ecosystem (Source: CDOT 2018)

5.3.3 Engineering and Software Development Approach

The project will use agile project management standards merged with traditional systems engineering "Vee" approaches in accordance with state and federal requirements. For the CV data environment and related software development initiatives, Panasonic will work in collaboration with CDOT's Office of the Chief Information Officer and will use an Agile/Scrum approach to develop the data ecosystem. CDOT is using a non-prescriptive approach for the systems engineering and software development portions of the project for increased flexibility with Panasonic and are essentially co-developing various aspects of this project.

5.3.4 Springboard for Future CV Deployments and Automated Vehicles

CDOT and Panasonic have the shared vision that application development and the use of the CV data will be dependent upon adoption of CV-capable vehicles, while keeping the overall V2X Ecosystem "technology" agnostic. In the current project, CDOT will own the data from the system. Panasonic is expecting to use the experience gained from the I-70 Mountain Corridor project to assist with the develop of market-ready CV products and services that are interoperable with multiple vendors and assist DOTs for CV deployments and future automated vehicle deployments across the U.S.

Table 16. CDOT Procurement Profile (Source: Noblis 2018)

Topic	Additional Information
CV Project Motivators	• **Safety** is primary motivator. CDOT noted that CV technologies are beyond the research and development stage and need to be deployed to bring the immediate safety benefits to the public. • **Mobility** and efficiency are second largest motivators. The I-70 Corridor is one of the busiest highways in Colorado and faces significant weather and congestion challenges throughout the year. • **Congestion Management** and implementation of an improved traffic management platform with real-time data from the CDOT-Panasonic V2X Data Ecosystem can bring immediate benefits.
Procurement Details	• **Stated challenges**: o The need to have legal expertise that understands intellectual property law when dealing with information technology companies. o The need to have contracting and federal regulations expertise on the project during contract and task order development. o There is a learning curve with IT firms, which requires flexibility, since they have limited experience with DOTs. o Traditional contracting mechanisms and systems engineering approaches have difficulty meeting the changing landscape of CV technologies. • **Managing Technology Uncertainty –** CDOT's approach is technology agnostic, they are going to use both DSRC and C-V2X technology to minimize risk of obsolescence and will ensure a seamless upgrade path for each.
Procurement Lessons	• Need to be creative, yet follow traditional process, and use clear contracting language. The initial step was to use RFI and then issue Invitation for Bid for the project to gauge vendor's interest in pursuing this project. • Don't create restrictive contract documents for technology deployments, allow space for innovation and create partnership with vendor for the development of the system and project.

Topic	Additional Information
	• New approaches to contracting are needed. The service model of procurement seems to be a good fit for CV deployments. There isn't a need to lock yourself into a "one-and-done contract" with separate vendors to perform installation, upgrades, and equipment swap outs. • CDOT is using a non-prescriptive and co-development strategy with Panasonic on this project. • An Agile/Scrum Contracting Mechanisms would be helpful in working with technology companies on software development heavy projects.

CDOT staff interviewed:

Peter Kozinski, RoadX Program Director
Tyler Svitak, Connected and Autonomous Technology Program Manager
Wes Maurer, ITS Project Manager
Benjamin Acimovic, V2X Deployment Project Manager
Interviewed on 03/28/2018

6 Synthesis of Findings and Recommendations for Knowledge Transfer Activities

6.1 Synthesis of CV Procurement Literature and Interview Results

The research team, via the literature review and stakeholder interviews, found that while substantial information exists on ITS implementation, procurement, and best practices, very little is readily available regarding the actual procurement of CV systems. Materials from the CV Pilot sites (Wyoming, New York City, and Tampa, Florida) provided the most published information related to procuring CV systems. Most of the available literature focuses on the technical aspects of CV projects, including standards, System Engineering Management Plans (SEMP), experience and lessons learned, and system development approaches taken by the CV Pilots sites[15]. Interviewed agencies expressed the importance of having this reference material available as they continue to pursue CV projects that focus on safety and efficiency benefits.

From a regulatory and federal-aid perspective, CV projects are ITS projects; as such, if funded in part by the Highway Trust Fund, they are subject to the same requirements (e.g., 23 CFR Part 940, ITS Architecture and Standards, which requires ITS projects to be based on a systems engineering analysis and consistent with the regional ITS architecture). In addition, existing and future ITS procurement guidance and training resources apply just as well to CV projects, although CV projects have some characteristics that go beyond traditional ITS procurement topics, such as the need to purchase, install, test, and perform software updates to equipment in vehicles. Importantly, none of the respondents stated that any roadblocks or “show stopping” regulations or requirements in procurement were blocking their pursuit of CV projects.

On the other hand, several respondents identified limitations of the procurement process, whether real or perceived, that can affect the success or efficiency of the procurement. These limitations generally relate to the fact that traditional procurement mechanisms are not well suited for CV deployment, such as low-bid source selection requirements. Agencies have broad experience with procuring goods and services related to operations, maintenance and construction of roadways and highways, including stoplights, signal controllers, asphalt, dynamic message signs, etc., but less experience with new CV-related information technology products and services such as OBUs, RSUs, or other CV-related services. Deploying agencies reported that they overcame these challenges and adapted their corresponding

[15] Since the time that the literature review was completed, additional documentation from the three CV pilot sites regarding procurement approaches, acquisition, and comprehensive installation plans has become available in reports and webinars. See the CV Pilot publications page for more information.

procurement approaches, documentation, and requirements to meet the needs of their CV projects, while also meeting local, state and federal laws and regulations. Respondents noted that engaging CV Experts (e.g., FHWA Staff at Division Offices or Resource Centers) assisted them in understanding potential funding mechanisms and procurement approaches to CV projects. Additional engagement conducted by the CV project sponsor regarding specific procurement needs and rationale to their state and local procurement and contracts staff increased institutional buy-in and had positive project results.

Despite the general success of CV-related procurements, respondents encountered some difficulties with the CV equipment procured, which included slow production times, interoperability issues, and system malfunctions. Flexibility in technologies and equipment specified in procurement documentation was deemed important, while also utilizing the best approach for your project, i.e. a phased or agile approach to address an ever-changing CV marketplace. As the issues described above are symptoms of emerging technologies and new-to-market products, remediation options mentioned by respondents included budgeting time and money for additional vendor support after initial deployment, integration and software development, as well as opportunities to test potential offerors' equipment.

For initial CV deployments, most agencies are using a design, bid, build approach, which is a more familiar mechanism to most DOTs. However, as deployments are expanded and larger projects are contemplated or enabled by federal grants, the overall trend is to procure CV systems using a design – build or a derivative approach (design – build – transfer or design – build – operate – transfer) approach, in which the same contractor team designs the system, procures or purchases the equipment, develops needed software, and installs and potentially integrates the equipment. Some agencies, including Florida and Michigan DOTs, have used both approaches for different CV projects.

Contracting methods and business models have an important role in determining how CV procurements are structured and their long-term financial viability. As noted in the case studies in Section 5 of this document, agencies are seeking contractor and consultant assistance for multiple aspects of their projects, including planning, oversight, system development, installation, and maintenance of CV-related equipment and systems. In doing so, DOTs are sharing the overall risk and reward of the project, while continuing in their traditional role as the program manager. In addition to augmenting the CV expertise of the procuring agency, use of consultants can facilitate the sharing of CV expertise from previous projects to be applied in other projects across the country. Design-build and related procurement approaches can also free up the DOT from having to manage multiple contracts with CV equipment vendors and outside firms or having to identify internal resources to perform installation and troubleshoot initial operations of the CV system.

An important conclusion of this study is that different procurement approaches have been and will be successfully used for purchasing CV equipment, systems, and services. There's no single best approach or correct way to do it.

Utilizing a service-oriented approach, the "CV as a service" business model, as noted in the Colorado Department of Transportation I-70 CV Procurement Case Study, can provide more flexibility for DOTs in the choice of technologies and deployment strategies than are allowed in the traditional contracting methods. In this case, CDOT plans to work with Panasonic to design the CV data ecosystem (or data environment), which Panasonic will continue to operate and maintain, while CDOT will buildout the hardware network. One advantage of this approach is that CDOT does not have to maintain and upgrade the software code for the data ecosystem, yet the agency will receive lifetime upgrades to the system. Technological uncertainty, specifically DSRC in the 5.9 GHz Band, and lack of the V2V Mandate, was of concern to respondents. Some respondents noted that the uncertainty had delayed additional procurements of DSRC-related equipment and the expansion of their CV project. However, multiple respondents are taking a more technology-neutral approach, and are taking steps to develop their projects to be compatible regardless of the communications technology used.

Overall, the results of the research scan and interviews conducted demonstrate that agencies are continuing their investments in research and deployment of CV technology, despite the difficulties noted above.

6.2 Recommendations to USDOT Regarding Knowledge and Technology Transfer (KTT) Activities

One of the goals of this research was to make recommendations to USDOT regarding future potential KTT Activities. In support of this goal, respondents were asked to prioritize or rank order the most beneficial KTT activities (see Q 35 in Appendix D); the results can be found in **Figure 17**.[16] The highest priority role or type of USDOT sponsored KTT program or activity was to provide model documentation, factsheets, case studies and project examples, similar to those already available on the [CV Pilots Website](). The implication of this finding is that other case studies and project examples should be highlighted, beyond the CV pilots, such as the Florida, Georgia, and Colorado cases identified in Section 5. Respondents also recommended that USDOT develop or facilitate a cohort-like group, where peer exchanges, and best practices could be easily shared regarding CV, deployment, and cybersecurity. Additional KTT activities noted were providing additional funding opportunities and trainings.

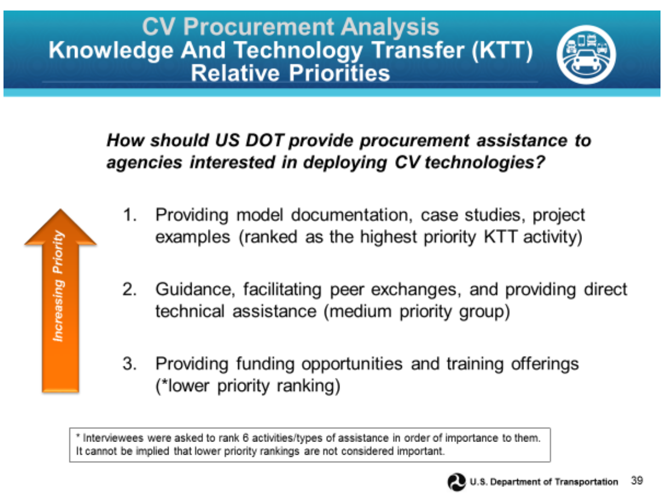

Figure 17. CV Procurement Analysis Knowledge and Technology Transfer Relative Priorities (Source: Noblis 2018)

Deployers beyond the CV Pilot Sites have experience from their CV projects that is worth sharing. In fact, it can be argued that these implementations are more representative of future CV projects, because they are not funded by large grants and are not provided the level of technical assistance that the CV pilots experienced. The federal role, as mentioned by multiple respondents,

[16] The research team did not uniformly collect this data from each participant; for those who did not fill out the questionnaire, judgment was used to assess and assign rankings based on the interview findings and related statements made by the interviewee. As a result, the collected information was merged into 3 categories of increasing relative priority.

should continue as both a facilitator and technical advisor role of CV experience, including project best practices and approaches. Most participants reported that their CV projects primarily consists of “smart infrastructure” improvements, i.e. installation of RSUs, CV-capable signals and pedestrian crossings, and other related equipment. Equipping city fleets or transit vehicles is usually performed later and agencies understand that they will need to be ready for future privately owned CV-capable vehicles. Participants also expressed interest in future USDOT KTT programs that focused on the infrastructure side of CV.

In this very early stage of connected and automated vehicles, it is important to remember that many transportation agencies still do not have direct experience with CV procurements. Even those agencies that do have experience with the CV procurements generally only have two to three project or program managers with that experience. As agencies initiate or begin to expand their CV systems both geographically and functionally, the lessons learned and best practices for effective CV procurements need to be shared with many more agency staff. The knowledge transfer recommendations provided in this report may assist with this task.

Appendix A: ITS CV Procurement Literature Scan Findings

1. USDOT Guidance for Connected Vehicle Deployments: Institutional and Business Issues and Financial Sustainability (2016)

The *USDOT Guidance Summary for Connected Vehicles Deployments: Institutional and Business Issues and Financial Sustainability* provides guidance material on the institutional and business issues, as well as the financial sustainability for the USDOT CV Pilots Deployment Concept Development Phase. The document emphasizes the importance of identifying risks and mitigation actions associated with a broad range of institutional and financial issues related to the Pilot deployments with an understanding that institutional issues can be more challenging than technical ones. The report also emphasizes the importance of documenting the business processes and institutional models as CV deployment moves from the baseline ("As Is") case to the desired ("To Be") case and ultimately to deployment ("Implemented"). Tools for capturing these changes include narratives and diagrams concerning an extension of the Capability Maturity Model (CMM), a macroscopic version of the relevant institutional framework, and a microscopic version of the business processes that reflect specific CV applications.

The *USDOT Guidance Summary for Connected Vehicles Deployments: Institutional and Business Issues and Financial Sustainability* provides materials and processes that CV Pilot sites or other CV projects can follow to achieve successful deployment and financial sustainability. Though the document does not provide specific information on CV procurement, it provides an overview of the institutional issues, business models, project development lifecycle, and other issues that could affect procurement at the macro and micro level. The document notes that a systems engineering approach should be followed, that procurement staff should be involved throughout the project lifecycle, and should follow current procurement practices from the private and public sector for the acquisition of equipment and services. Additionally, the document identifies funding and financing mechanisms, including those from the federal, state, and private sector that could affect procurement.

2. National Highways Institute ITS Procurement Course (2016)

The *National Highways Institute (NHI) ITS Procurement Course* provides an overview of procurement in the ITS context, specifically how best to procure equipment, system components, software, and to build physical infrastructure. The course details how agencies should:

- Select the ideal approach for a given procurement (construction, engineering and design services, or common grant rule)
- How to structure the work (how to bundle aspects of an ITS project)

- How to select a contractor (method of award, i.e. cost-based, qualifications-based, or sole-source)
- How to select the type of contract used (fixed-price, cost reimbursement-cost plus fixed fee and time and materials, incentives/disincentives-target-cost based and award fee), and other tools (IQC, IQC for goods and Task Order) for ITS procurement success
- How to structure on-going services such as warranties, software licenses, and on-going maintenance and support services

Although the course does not mention connected vehicles directly, the course successfully contrasts ITS procurement approaches to highway/roadway construction and maintenance procurements, which can be applied to connected vehicle procurements.

The course is divided into five modules and provides information on how to define and communicate system and equipment requirements, match procurement approaches to the type of service and/or equipment needed, undertake contractor or consultant selection, and post-procurement activities, such as maintenance, warranty, and service contracts. The course also notes that ITS projects require the adaptation of traditional procurement processes used for the construction and operations, and maintenance of highways and roadways. The course provides tools to develop key aspects of a request for quote (RFQ), invitation for bid (IFB), or goods contract advertisement to ensure successful procurement. Utilizing the Systems Engineering approach is considered a best practice which reduces project overruns, ensures that user needs are met, and increases the likelihood of a successful project implementation.

3. ATCMTD Program Information (2016, 2017)

The *Advanced Transportation and Congestion Management Technologies Deployment Program (ATCMTD)* seeks grant applications that "accelerate the deployment of vehicle-to-vehicle, vehicle-to-infrastructure, autonomous vehicles, and other technologies" and "collect, disseminate, and use real-time traffic, transit, parking, and other transportation-related information to improve mobility, reduce congestion, and provide for more efficient and accessible transportation." Though ATCMTD documentation does not provide procurement information related specifically to connected vehicles, the purpose of the grant program is to provide applicants with funds to perform large-scale deployments of new technologies. Specifically, awards from the 2016 and 2017 applications include grantees that have included aspects of connected vehicle technologies and are of value to this research effort since they will be early deployers of CV. Connected vehicle technologies included by grantees in the last two project award cycles include congestion control and freight movement at ports or through smart corridors, pedestrian safety at intersections or bus stops, and several other V2I safety or mobility applications. Additional information regarding ATCMTD Grant Program can be found below.

Established by the Fixing America's Transportation System (FAST) Act, the ATCMTD is a competitive grant program that provides funding for the large-scale installations and deployments of new transportation technologies that improve safety, efficiency, system performance, and infrastructure return on investments. Criteria that was used to award selections included proposed deployments that:

- Reduce costs and improve return on investments, including through the enhanced use of existing transportation capacity;

- Deliver environmental benefits that alleviate congestion and streamline traffic flow;
- Measure and improve the operational performance of the applicable transportation network;
- Reduce the number and severity of traffic crashes and increase driver, passenger, and pedestrian safety;
- Collect, disseminate, and use real-time traffic, transit, parking, and other transportation-related information to improve mobility, reduce congestion, and provide for more efficient and accessible transportation;
- Monitor transportation assets to improve infrastructure management, reduce maintenance costs, prioritize investment decisions, and ensure a state of good repair;
- Deliver economic benefits by reducing delays, improving system performance, and providing for the efficient and reliable movement of goods and services; or
- Accelerate the deployment of vehicle-to-vehicle, vehicle-to-infrastructure, autonomous vehicles, and other technologies.

Eligible program applicants included: state or local governments, transit agencies, metropolitan planning organizations (MPOs), multijurisdictional groups, and consortia of research or academic institutions. Competitive selection criteria was developed by the Office of the Secretary of Transportation, including that no single grantee can receive more than 20% of program funds for the fiscal year. Since 2016, a total of 18 projects have been selected to receive funding.

4. 2015 FHWA Vehicle-to-Infrastructure Deployment Guidance and Products (2015)

The *2015 FHWA Vehicle-to-Infrastructure (V2I) Deployment Guidance and Products* document was developed by the United States Department of Transportation (USDOT) to assist Federal Highway Administration (FHWA) staff and transportation system owner and operators to deploy V2I technology, not only in terms of Federal-aid Highway program requirements but also practices to help ensure interoperability and efficient & effective planning /procurement & operations. The guidance provides a list of actions that that are considered key to quality deployments and provide a list of steps that should be considered prior to, and during the V2I procurement process. These steps are broad, and relate overarching themes including procurement related issues.

While this guidance document is not specific to only procurement processes, it provides an overview for agencies to consider when initiating deployment of CV technologies, what the authors consider “key areas of deployment guidance”. The content in this document provide the groundwork for pre-procurement efforts. A deploying agency would be able to use this work to help get the organization to begin discussions on implementing and procuring CV technologies within their community. The document identifies key actions that are needed for a quality deployment.

Findings and Lessons Relevant to CV Procurement:

- Identifying what existing assets are candidates for modification to reduce the costs for delivery of power and communications...
- Consulting the ITS Costs Database for comparisons and ranges of unit and system costs.

- Consulting with agencies that manage the statewide acquisition of information technology products to streamline the acquisition of connected vehicle assets (similar to procuring other ITS assets.)

This document does not specifically note any actual examples of deployments but it does suggest consulting the ITS Costs Database (http://www.itscosts.its.dot.gov/) for comparisons and ranges of unit and system costs. It notes that once CV test beds and pilot sites proliferate this information will be updated.

5. Applying Scrum Methods to ITS Projects (2017)

The *Applying Scrum Methods to ITS Projects* provides an overview on how to apply agile methodologies to ITS projects. With Agile methodologies becoming mainstay in the information technology (IT) and software sectors, the document identifies how they can be applied to ITS projects, and have the potential to speed up project delivery. The document was developed to mitigate confusion over what Agile software development is and to assist stakeholders in the application of Agile throughout the ITS project lifecycle to achieve successful implementation.

Though the document does not directly mention connected vehicles, and primarily focuses on ITS, the content is geared toward ITS decision makers, managers, and consultants and can be applied to connected vehicle projects. Specifically, the document lays out information on considerations for project procurement of software solutions for software intensive systems. Chapter 8 contains a chapter dedicated to Scrum procurement/contracting considerations. The document provides the following considerations identified below, for applying Agile and Scrum methods to ITS projects.

Findings and Lessons Relevant to CV Procurement:

- Don’t start project development unless all project staff are trained in systems engineering and Scrum. Project teams have also found that recurrent training on Scrum is useful.
- Don’t use Scrum-only on safety-critical applications! Use combined Scrum with systems engineering for non-safety-critical system components. Software development is performed within the Scrum while overall planning, high-level requirements and architecture development, and final product integration are performed following the Systems Engineering process. This combination ensures requirements and design changes are documented, incorporated into the design, and verified and validated. Additionally, the combined methods can improve communication and coordination among requirements, design/implementation, and test teams.
- Begin using Scrum with systems engineering no sooner than when system requirements and high-level design are completed. This helps deployers define what they need and sets the stage for using Scrum methods. Use combined Scrum with systems engineering for software development only.
- ITS Contracts and Finance Specialists need to consider policies to address Scrum in contracts, and receive training on Scrum.
- Need to support short development and delivery timelines, including agency participation, review, and feedback.
- Contract needs to support refining requirements throughout the Agile development process.
- Contract should allow for prioritizing scope functions within a budget limit.

- The agency and contractor are working together on the development with daily interaction and collaboration.
- A services-based contract provides the procuring agency flexibility to change or re-prioritize the requirements continuously as needed.
- The procurement specification should also clearly define the roles and responsibilities for all parties expected to be involved in the development process.
- The procurement specification must provide flexibility to allow the agency to update their requirements as system development progresses, and allow the contractor to propose different processes that they feel will best fulfill those requirements.
- The procurement specification should provide flexibility to allow the agency and contractor to adjust the project milestones and delivery dates.
- If Scrum will be used, the procurement specification should identify the expectations in terms of development cycles, roles and responsibilities, adjustments to development cycles, and demonstration of new capabilities after each development cycle.
- For qualifications, consider asking for Scrum experience and use of documented processes to identify how the Scrum process will be implemented to fulfill contractual requirements.
- Use Scrum to increase opportunities for communication among all project team members (stakeholders, agency, the system engineering, software development, and testing teams).
- Employ Scrum management and software development tools that facilitate real-time access to project status.
- Frequent software demonstrations at the end of sprints leads to stakeholder confidence in product delivery commitments (quality, cost, and schedule) made by the software teams.

6. Systems Engineering for Intelligent Transportation Systems: An Introduction for Transportation Professionals (2007)

The *Systems Engineering for Intelligent Transportation Systems: An Introduction for Transportation Professionals* document provides an overview of systems engineering and standard industry practices and how they can be applied to the planning, design, and implementation stages of ITS projects. Additionally, the guide outlines different procurement approaches, such as low-bid, negotiated (qualifications-base award), sole source, best-value (qualifications based), and a hybrid approach, and they can be applied to varying stages and components of ITS projects. The guide is geared toward those interested in planning and deploying complex systems including ITS projects.

Although the document doesn't specifically mention connected vehicles, and is focused on ITS, the findings can be applied to connected vehicle projects given that they will face similar limitations. The guide recommends tailoring procurement strategies based on the type project being pursued, the maturity of the technology being implemented, and to not assume that procurement needs to be done the same way. It notes that low-bid contractors are often best suited for projects that have well understood requirements, where as a low-bid contractor may not be suited for projects that have new requirements, changing technologies and environments, as well as shifting priorities. The document notes that low-bid source selection should not be used when creating custom software.

Findings and Lessons Relevant to CV Procurement:

- The Wrong Procurement Method Can Tie Your Hands – The traditional procurement methods that have been used for decades in highway construction are often not suitable for ITS projects. For example, the low-bid method uses a consultant to prepare a design specification that is then implemented by a contractor who submits the lowest bid. This method works well for building roads, but experience shows that it does not work well for many ITS projects that frequently require collaboration and iteration between the design and implementation phases. It is vital to select the right procurement method so that you can implement the right systems engineering approach for your project.
- Procure off-the-shelf products – Off-the-shelf products are procured based on the product specifications developed in the detailed design step. Delay procurement until the products are actually required to support the implementation. Too much lead time can result in hardware or software that becomes outdated before it can be integrated into the project. Too little lead time could cause procurement delays that impact the project schedule.
- A poorly chosen procurement strategy can adversely impact a project just as much as the lack of a sound systems engineering approach. It is important to tailor the procurement strategy based on the type of ITS project and not to assume that it always has to be done the same way. The traditional approach of putting a specification on the street and awarding the implementation to the low-bid contractor may work well for projects with extremely well understood requirements. However, the complications of inexperienced personnel, new requirements and technologies, changing environments, and shifting priorities lead to the need for newer approaches for many ITS system acquisitions. This is particularly true when a project includes custom software development.

7. Integrated Corridor Management: Implementation Guide and Lessons Learned Version 2.0 (2015)

The *Integrated Corridor Management: Implementation Guide and Lessons Learned* document provides the lessons learned from the USDOT Integrated Corridor Management (ICM) research initiatives. Each site used a systems engineering approach to define the needs for ICM within their corridor and the needs and requirements for an ICMS to support ICM. This guide offers suggestions for each stage of an implementation effort for an ICMs, and assists other agencies in benefitting from the research done to date and from the experiences of the Pioneer Demonstration Sites.

Though there is no mention of connected vehicle technologies, the document does provide substantial information on the implementation of ITS technologies for ICM and has lessons learned that can be applied to the future procurement of connected vehicle technologies.

Findings and Lessons Relevant to CV Procurement:

- Multiple procurements from multiple agencies are a challenging endeavor. If, as a part of an ICM project, one of the stakeholder agencies slips schedule or misses requirements in selection and procurement, this can affect the entire project. Procuring systems prematurely (prior to defining the requirements) could also significantly impact the cost and schedule of the project.
- If the agency leading the procurement effort does not have standard templates for systems engineering documentation, it should consider specifying the IEEE standard that relates to the relevant document (e.g., IEEE Std. 1362 for a Concept of Operations document; IEEE 1471 for

System Architecture Descriptions) and asking that the delivered document conform to that standard.

- If the agency is going to acquire hardware as part of the ICM procurement process, consider whether to include a technology refresh option to ensure that the acquired hardware technology does not quickly become obsolete.
- When acquiring services, such as systems engineering support and project management support, look for individuals proposed who have both experience and certifications. Certifications alone are not sufficient. Experience can overcome the lack of certification, but a combination of the two is best.
- Procurement of replacement system hardware is typically every 3-5 years.

8. The Road to Successful ITS Software Acquisition: Volume I: Overview and Themes (1998)

The Road to Successful ITS Software Acquisition: Volume I: Overview and Themes document assembles best practices and presents practical advice on how to acquire the software components of ITS. The intended audience is the "customer" whether a project leader, technical contract manager, decision maker, or consultant--who is responsible for one or more ITS systems or projects. Since connected vehicles represent advanced ITS systems, this document applies just as well to CV projects. CV projects are likely to be software intensive, particularly those implementing CV applications, so even though the report is nearly two decades old, the information presented is still very relevant.

The document presents a series of "themes" that serve as guiding principles for building a successful acquisition. Included are people themes of collaboration, team building, open communications, and active customer involvement, which have been likened to partnering; management themes of flexibility, "no silver bullets", and up-front planning; and system themes of "Don't build if you can buy" and "Take bite-size pieces". Software acquisition activities that build upon these themes are presented in subsequent chapters. Among the activities covered are building a team, developing requirements, making build/buy decisions and checklists to facilitate use of the material. The document concludes with short stand-alone topic sheets that introduce various relevant software topics.

The build/buy decisions, resolving the intellectual property rights, acceptance testing, and project and risk management are very relevant to CV projects. Also included are "war stories" to illustrate the various points, as well as key point summaries.

9. Guide to Contracting ITS Projects: NCHRP Report 560 (2006)

The *Guide to Contracting ITS Projects: NCHRP Report 560* provides guidance on the procurement of ITS, including variable message signs, traffic detectors, signal controllers, and a variety of other hardware and software that entails applications of advanced electronics and information management to regulate and facilitate traffic flow. This guide is intended to be used by government officials, traffic engineers, system integrators, and others involved in the specification and purchasing of ITS installations. Although the source does not provide specific information on projects with connected vehicles elements, it is still

a useful framework for thinking through CV procurement choices. The guide uses a Decision Model as a step-by-step procedure for agencies to follow and includes eight steps that must be performed to complete the process of defining the most appropriate procurement approach for your project. See Table 16. **Eight-Step Decision Model for Contracting ITS Projects (Source: Guide to Contracting ITS Projects: NCHRP Report 560, 2006)**
for a listing of the 8 steps and some comments regarding relevance to CV projects.

Table 17. Eight-Step Decision Model for Contracting ITS Projects (Source: Guide to Contracting ITS Projects: NCHRP Report 560, 2006)

Step 1—Make Initial Decisions: Step 1 assists in making fundamental procurement decisions that will ultimately affect the overall procurement strategy. These fundamental decisions consider the possibility of outsourcing and the procurement of consultant services. This step also directs you to skip to Step 7 of the Decision Model if either outsourcing or consultant services are used.
Step 2—Determine Work Distribution (Structure): Step 2 will help you determine whether the procurement should be performed as a single contract or multiple contracts. *For CV projects, is likely that you will need multiple contracts and use different models for various procurement packages.*
Step 3—Define Project Category: Step 3 involves categorizing your project with respect to complexity and risk. Understanding project complexity and risks is critical to determining an appropriate procurement package. *For now, most CV projects should be considered complex and risky.*
Step 4—Determine Agency Capability Level: Step 4 involves assessing your agency's resources and capabilities as well as the environment in which your project will be procured. *A careful and thorough assessment is important. Major ITS projects with significant software development, hardware integration, and, long-term operations and maintenance support can be challenging for even the most experienced agency. It might also be prudent to bring on additional consultant resources. If possible, you should contact peer agencies to acquire lessons learned from their experience procuring a similar system that your agency is interested in procuring.* *For CV projects, it is likely that the agency will need the help from engineering firms/consultants that may have more experience with CV deployment to specify and procure such a system The agency should also assess its capabilities for operating and maintaining the CV system post deployment.*
Step 5—Select Applicable Systems Engineering Process and Candidate Procurement Packages: Step 5 uses the results of Steps 3 and 4 to select applicable systems engineering processes and candidate procurement packages. *For CV projects, be sure to incorporate feedback and iteration into the system engineering process followed to allow and manage changes to needs and requirements.*
Step 6—Apply Differentiators: Step 6 applies differentiators to the candidate procurement packages to help you reduce the number of procurement packages identified in Step 5.
Step 7—Assess Package and Make Final Selection: This step suggests the involvement of agency procurement personnel to assist in making the final selection of the most appropriate procurement package.
Step 8—Define Contract Scope and Terms and Conditions: The final step will assist you with the selection of the necessary terms and conditions to be included in the contract(s).

10. Connected Vehicle Pilot Deployment Program Phase 1 Lessons Learned (2017)

The Connected Vehicle Pilot Deployment (CV Pilots) Program seeks to spur innovation among early adopters of connected vehicle application concepts. Pilot deployment awards were given to three sites, New York City, Wyoming, and Tampa, FL. The CV Pilot sites are expected to integrate connected vehicle research concepts into practical and effective elements, enhancing current operational capabilities. Each pilot deployment site is expected to be developed in three distinct phases: Phase 1 Concept Development, Phase 2 Design/Build/Test, and Phase 3 Operate and Maintain.

The *Connected Vehicle Pilot Deployment Program Phase 1 Lessons Learned* document covers lessons learned from the USDOT, its technical support team, and the pilot deployment sites during Phase 1 of the CV Pilot Program. *While Phase 1 is early in the procurement life cycle, a significant amount of procurement planning had to be done either in this phase or in advance of the following phases.* The objective of concept development in Phase 1 was to set the stage for a connected vehicle pilot deployment that had an observable measurable near-term impact, deployed on-time and within budget. The three pilot deployment sites were awarded contracts to continue their work in Phases 2 and 3. As of October 2017, the three pilot sites were in the midst of Phase 2 (Design/Build/Test). Phase 2 began in September 2016 and will last up to 20 months (through May 2018). Phase 3 entails a required minimum 18-month operations and maintenance period for the pilot deployment. Noblis gathered observations and insights from the CV Pilot team including both federal and pilot deployment site team members. Observations include lessons learned and recommendations for both future USDOT and early deployer projects and efforts.

Findings and Lessons Relevant to CV Procurement:

- Investigate data ownership and subpoena issues in detail prior to the solicitation development process – and provide this detail in the solicitation.
- Be as frank and transparent as possible regarding technological maturity of deployment-related systems and resources.
- Emphasize financial sustainability in concept development.
- Be aware that while privacy is built-in by design from the ground up, data requirements for the performance measurement element can violate the protection of user privacy.
- Understand that privacy is a legal construct that demands close participation from attorneys; communicate the workload to attorneys that are involved.
- Convey upfront what the requirements are regarding the privacy element to avoid any misunderstanding of data privacy and the institutional issues that can follow.
- Utilize the systems engineering process.
- Be mindful that concept development takes time to conduct prior to procuring, designing, and installing equipment.
- Use standards (intelligently) to help advance the deployment’s systems engineering
- Develop a good understanding of what is available from the Security Credential Management System (SCMS) and vendors for Roadside Unit (RSU)/ On-board Unit (OBU) device capabilities and software integration.

- Conceive measures that are straightforward, explainable, that quantify the project benefits, and that are achievable given data availability.
- Start exploring equipment suppliers early. Building agreements with equipment suppliers is a long and uncertain activity.
- Engage procurement and contracting personnel early.
    - For procurement, questions like management of inventory for on-board equipment need to be resolved early, especially when non-agency fleets are involved.
- Clarify the maturity of CV applications in solicitations/ requests for information (RFI) etc.
    - The sites were a little surprised that the applications were not as mature as expected. To address the non-deployment ready nature of the applications, at least one site explicitly stated in their RFI that they were interested in purchasing turn-key applications, and that any necessary application development would be the responsibility of the vendors.

11. Safety Pilot Model Deployment: Lessons Learned and Recommendations for Future Connected Vehicle Activities (2015)

The *Safety Pilot Model Deployment: Lessons Learned and Recommendations for Future Connected Vehicle Activities* document provides information on the outcomes of the Connected Vehicle Safety Pilot, which was part of a major scientific research program run jointly by the USDOT and its research and development partners in private industry. This research initiative was a multi-modal effort led by the ITS JPO and the National Highway Traffic Safety Administration (NHTSA), with research support from several agencies, including Federal Highway Administration (FHWA), Federal Motor Carrier Safety Administration (FMCSA), and Federal Transit Administration (FTA). This one-year, real-world deployment was launched in August 2012 in Ann Arbor, Michigan. The deployment utilized connected vehicle technology in over 2,800 vehicles and at 29 infrastructure sites at a total cost of over $50 million dollars to test the effectiveness of the connected vehicle crash avoidance systems. Overall, the Safety Pilot Program was a major success and led the USDOT to initiate rulemaking that proposed to create a new Federal Motor Vehicle Safety Standard (FMVSS) to require V2V communication capability for all light vehicles and to create minimum performance requirements for V2V devices and messages.

The Volpe National Transportation Systems Center conducted a study sponsored by the ITS JPO to gather observations and insights from the Safety Pilot Model Deployment. The report represents an analysis of activities across all stages of the Safety Pilot Model Deployment including scoping, acquisitions, planning, execution, and evaluation. The analysis aimed to identify specific accomplishments, effective activities and strategies, activities or areas needing additional effort, unintended outcomes, and any limitations and obstacles encountered throughout the Model Deployment. It also assessed the roles of organizations and the interactions among these organizations in the project. It is anticipated that findings from this study will be valuable to future USDOT research programs and early adopters of connected vehicle technology.

The report contains numerous lessons across many topics, including program management, outreach and showcase, experiment setup, DSRC device development, device deployment and monitoring, and data management. Though the development of connected vehicle applications and CV standards have progressed since the time of the Safety Pilot Model Deployment, most of the lessons still apply to current CV procurement activities. Findings and lessons learned from this source that are generally relevant to procurement of projects with CV elements are presented below.

Findings and Lessons Relevant to CV Procurement:

- Use a modular project structure and focus on high priority objectives and project components when deploying complex ITS projects such as those with connected vehicle technologies -- break it up into manageable pieces.
- Ensure that all contractors are aware of the prioritized objectives and the relationships of the critical supporting tasks and activity dependencies during the planning phase.
- Plan and conduct in-person working meetings leading up to all key events to coordinate activities and quickly resolve any issues. Ensure that all the key project stakeholders are involved in the meetings to ensure real-time decision-making.
- USDOT encouraged an open exchange of information across the development community using weekly technical coordination meetings, sample functional testing events, plugfests, and other activities aimed at rapidly increasing the developers' experience. The primary purpose of this open exchange was to ensure that the devices produced by the developers were interoperable with each other.
- Tailor device requirements on a project by project basis depending on the intended use of the devices and current device maturity level. Clearly communicate requirements to device developers and incorporate the appropriate functionality for less mature devices, such as test capabilities and functions to monitor device up-time.
- Utilize an iterative process for developing device requirements that incorporates cycles of industry input and device testing. Complete the requirement generation and Qualified Product Lists (QPLs) prior to all device and system use. If it is anticipated that the requirements will be updated after testing based on field deployment, incorporate enough time in the schedule to procure updated components and retest.
- Institutionalize and formalize all testing procedures for the QPL. Provide clear and unambiguous qualification test procedures, with pass/fail criteria, as part of the test plan.
- Provide testing specifications covering the performance of all components, to allow common understanding and expectation, and allow sufficient time for iteration.
- Develop application tests that are specific to the type of technology being deployed, and place emphasis on false positive scenarios.
- Analyze the need to purchase spare devices. If the budget allows, procure a sufficient inventory of spares to replace non-functional units as part of the recall process plan. Work with suppliers to determine replacement times to better estimate how many spares would be required.
- Include state of health monitoring requirements and supporting processes for each type of device. Implement remote monitoring and device reset capabilities to reduce the number of devices that need to be physically recalled from the field.
- Define and document requirements and steps for all interoperability testing participants and data users.
- Implement a full dry run that includes all installation, operation and interoperability requirements for all devices, infrastructure, and systems. Incorporate sufficient time into the schedule to ensure that all devices and systems are in a stable state prior to implementing a full dry run.
- Ensure that in-depth system testing requirements, updates, and retest cycles are well-understood, and are appropriately resourced in time and budget. Plan for several iterations of component, subsystem, and total pilot system testing within the dry run. Depending on the number of system

components (devices, infrastructure, data collection and backhaul connections, security implementation, etc.), this could take several weeks to several months.

- Be prepared to encounter field issues that were not discovered during the qualification testing, interoperability testing, and dry run testing.

12. CV Pilots Webinars, Insights, Challenges, and Lessons Learned from the Concept Development Phase I Findings (2016)

In August of 2016, the USDOT hosted three free public webinars with the CV Pilot sites, Wyoming, Tampa, and New York, all part of the CV Pilot Deployment Program, where all three pilot sites provided information on insights, challenges, and lessons learned from the Concept Development phase from each of the CV Pilot Sites.

The research team has reviewed these files for relevant information regarding or relating to CV procurement. Many of those findings and lessons learned are captured below.

Findings and Lessons Relevant to CV Procurement:

Procurement Process, Acquisition, and Installation:

- Negotiate with vendors and ensure flexibility where needed.
- Work with vendors on design and deployment "issues" – build this process into procurement.
- Break procurement into two phases - prototype phase (limited number to get the kinks out) and then a production phase.
- After the hardware platform is accepted ensure that management applications have time for continued development/refinement.
- Security - Integration with existing security systems/policies can be a time-consuming challenge. Existing infrastructure such as IT networks and equipment may be affected.
- Standards are the tools for building the next generation CV system; however, they need to be deployed and tested. It takes time to gain this experience
- Be sure to allocate enough time for your procurement cycle.
- Vehicle installation time is a primary driver of the schedule.
  - Deployers can only estimate installation times now – need to measure during prototype phase.

Budget Challenges

- Plan for the long-term:
  - Understand the continued operations and maintenance costs.
  - Consider vehicle fleet turnover – requires reinstallation of equipment
  - Spare devices and installation kits
- Prepare for ongoing outreach expenses
- Know the contract instruments - strengths, and weaknesses
  - Federal contracting
  - City contracting and procurement
- Understand Subcontracting procedures

  - Creates complex relationships
- Plan for the unexpected
  - Over $1M for non-CV data collection to address performance evaluation and confounding factors.
- Invite your stakeholders to participate in vendor demonstrations! NYC had vendors demonstrating varying CV applications and RSU and ASD hardware.
- Vendor demonstrations Confirmed the need for parameter profiles based on facility types, location, driver preferences.
- Interview vendors and negotiate with them etc. Ensure that they can respond to contracting approach.

13. CV Pilot Webinars (Phase 2: System Design Webinar) (2017)

The CV Pilot Systems Design Webinars for the Wyoming, Tampa and New York pilot sites were part of the technology transfer information sharing component of the CV pilot deployment program. During these webinars, which were held after important project milestones, the CV pilot sites provided good information on lessons learned and challenges that they faced during certain portions of the program. The Phase 2 System Design Webinar for each of the 3 sites was conducted in September 2017.

The research team has reviewed these files for relevant information regarding or relating to CV procurement. Many of those findings and lessons learned are captured below.

Findings and Lessons Relevant to CV Procurement:

<u>Wyoming</u>

- Approaches to manage for security are still in development: Evolving SCMS integration plan and outside credentials management require flexibility in development of associated interfaces.
- Utilize existing standards as a part of the system architecture and design process: The use of standards helped create a solid deployment effort in Phase 2, simplified technical documentation, and assisted with interoperability. (IEEE 1609 series, SAE J2735, 2945, etc.)
- Reserve an appropriate amount of time in the schedule to account for testing, both test planning and test execution: Detailed test planning is dependent on many other factors including equipment availability, so the development of detailed test plans can be a lengthy process while uncertainties are nailed down. Build in time for integration and testing.
- Detailed testing is required for OBU and RSU software: Much of the software is not yet created or not created completely.
- Partnerships between different disciplines enhances system development.

<u>Tampa</u>

- Recommend using a professional firm to manage and perform privately owned vehicle installs.
- Standards
  - Design using standards published on Jan 1, 2017. Do not rely on unpublished standards in progress.
  - If a USA standard does not exist, design using international standards.
  - If no standard exists, refer to USDOT V2I Hub publication for documentation.

In-Vehicle equipment:

- Multiple tech scans using RFPs (with on the road testing) to identify promising suppliers who can meet system, cost and project timing, critical to scrutinize and select the best suppliers
- *Early sourcing of suppliers is key to creating a collaborative environment*
  - To understand how system requirements are implemented in the design
  - To source suppliers who are willing to participate in developing open specifications
  - Who can meet aggressive timing with quality as they have adequate development time. always aspects requiring customization of off the shelf technology/standard
- New development efforts -OTA and security -need to be piloted, i.e. tested early in the program
- Adequate incentives with community/media support engage the driver/consumer community
- Recognize the need for a complete and experienced project team -systems, infrastructure, vehicle systems, performance measurement, etc.

New York City

Challenges faced:

- Privacy -- critical issue for New York stakeholders. Complex. Need privacy by design. Had to show stakeholder groups that we actually CAN'T Get the PII b/c of the design.
- Security – address in all aspects of system
- ASD Procurement – Aftermarket Safety Device – limited vendors, performance requirements were lacking, - consider user equipment - fleet versus private vehicles
- Location - GPS accuracy in urban canyon is challenging – test, require supporting techniques
- CV Application Tuning -- balance alerts versus false alarms
- Traffic Signal Controller Interface-- used draft standard NTCIP 1202 V3

Challenges still outstanding:

- SCMS
- interoperability – BSM, MAP -- mapping crosswalks, SPaT, SCMS, etc.
- CAN bus integration
- location referencing

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Appendix C: Table of Acronyms

Acronym	Definition
AASHTO	American Association of State Highway and Transportation Officials
ARC	Atlanta Regional Council
ASD	Aftermarket Safety Device
ATCMTD	Advanced Transportation and Congestion Management Technologies Deployment Program
BSM	Basic Safety Message
CAN	Controller Area Network
CAV	Connected and Automated Vehicles
CCTV	Circuit Television
CDOT	Colorado Department of Transportation
CFR	Code of Federal Regulations
CMAQ	Congestion Mitigation and Air Quality Improvement Program
CMM	Capability Maturity Model
COTS	Commercial off-the-shelf
CV	Connected Vehicle
C-V2X	Cellular V2X
CVP	Connected Vehicle Pilot Program
DBOT	Design build-operate-transfer
DOT	Department of Transportation
DSRC	Dedicated Short Range Communications
FAST Act	Fixing America's Surface Transportation Act
FCC	Federal Communications Commission
FDOT	Florida Department of Transportation
FHWA	Federal Highway Administration
FMCSA	Federal Motor Carrier Safety Administration
FMVSS	Federal Motor Vehicle Safety Standards
FRAME	Florida's Regional Advanced Mobility Elements
FTA	Federal Transit Administration
GDOT	Georgia Department of Transportation
GPS	Global Positioning System
I2V	Infrastructure-to-Vehicle
ICM	Integrated Corridor Management
ICMS	Integrated Corridor Management System
IEEE	Institute of Electrical and Electronics Engineers
IFB	Invitation for Bid
IOO	Infrastructure Owner Operator
IQC	Indefinite Quantity Contract
ITE	Institute of Transportation Engineers
ITS	Intelligent Transportation Systems
ITS-JPO	Intelligent Transportation Systems Joint Program Office

JPO	Joint Program Office
KTT	Knowledge and Technology Transfer
LTE	Long Term Evolution
MCDOT	Maricopa County Department of Transportation
MDOT	Michigan Department of Transportation
MMITSS	Multi Modal Intelligent Traffic Signal System
MPO	Metropolitan Planning Organization
NCHRP	National Cooperative Highway Research Program
NHI	National Highways Institute
NHTSA	National Highway Traffic Safety Administration
NTCIP	National Transportation Communications for ITS Protocol
NYCDOT	New York City Department of Transportation
OBU	Onboard Unit
OEM	Original Equipment Manufacturer
OTA	Over-the-Air Updates
PADOT	Pennsylvania Department of Transportation
PCB	Professional Capacity Building
PII	Personally Identifiable Information
RFI	Request for Information
RFP	Request for Proposal
RFQ	Request for Quote
RSU	Roadside Unit
SAE	Society of Automotive Engineers
SCMS	Security Credential Management System
SEMP	System Engineering Management Plans
SEP	System Engineering Plan
THEA	Tampa Hillsborough Expressway Authority
TRB	Transportation Research Board
TSM&O (TSMO)	Transportation Systems Management and Operations
UCF	University of Central Florida
UDOT	Utah Department of Transportation
USDOT	U.S. Department of Transportation
V2I	Vehicle-to-Infrastructure
V2V	Vehicle-to-Vehicle
V2X	Vehicle-to-Everything
VDOT	Virginia Department of Transportation

Appendix D: CV Procurement State of the Practice Survey/Interview Tool

Connected Vehicle Technology Procurement Questions

Introduction - Who is being surveyed?

Welcome to the Connected Vehicle (CV) Procurement Survey! By completing the survey, you will be helping US DOT with understanding how transportation agencies purchase (or plan to purchase) ITS CV equipment, systems, and services. Your assistance is greatly appreciated and will help US DOT with understanding actions that could improve the likelihood of successful CV procurements.

If you have any questions about this effort, please contact John Corbin (FHWA) at john.corbin@dot.gov. If you have questions about the survey, or prefer to provide answers in a phone interview format, please contact Greg Hatcher at greg.hatcher.ctr@dot.gov or by phone at (202) 366-2359. If you have project documentation that answers some of these questions, please email to Greg Hatcher and reference the documentation in your survey response. Please submit completed surveys to Greg Hatcher at greg.hatcher.ctr@dot.gov.

Thank you very much for your participation!

* 1. Name(s):

* 2. Agency:

3. Position/title:

4. Date:

Connected Vehicle Technology Procurement Questions

CV Project Background

This section asks about the background, funding, and development stage of the CV project.

* 5. What is the name of the CV-related project that you would like to discuss?

6. What is your primary role in the project (Project Manager, Lead Associate, etc.)?

* 7. What is the status (of the CV-related portions) of the project in the overall procurement life-cycle, and when do you expect CV applications will be operational (if not implemented)?

- ○ Initial Project Planning (including ConOps, High-level Requirements)
- ○ Design and Development, Build/Buy
- ○ Installation, System Integration, and Testing
- ○ Operational

When do you expect the system to be operational?/Other comments

8. What funding and financing sources (SEP 14/15, TIFIA, etc.) are you using for your project? (Check all that apply)

- ☐ ITS or other federal grant
- ☐ Federal-aid funds
- ☐ State, regional, or local funding source
- ☐ Private sector funding
- ☐ Financing sources

☐ Other (please specify)

Connected Vehicle Technology Procurement Questions

CV Project Planning

This section asks for information about the project, why it was initiated, which CV apps are being deployed, and the project size and scope.

* 9. What is the motivation behind your agency's interest in the implementation of CV technologies?

10. What other stakeholders are involved in the project and what are their respective roles?

Other public agencies (City, MPOs, State, Federal)

Private Sector firms/ consultants

Equipment manufacturers vendors

Organizations/ Universities

Other

* 11. Which CV applications are your agency planning to procure or upgrade in this project? (See https://www.its.dot.gov/pilots/cv_pilot_apps.htm for a listing of potential CV applications)

* 12. What is the approximate size and scope of the project your agency has procured or is planning to procure?

What geographic area will be covered with the system?

If field equipment (RSUs) will be installed, approximately how many installations, or how many intersections will be equipped?

If vehicles will be equipped, what type of vehicles (agency-owned fleet, private fleets, privately-owned vehicles, commercial vehicles) will be equipped and approximately how many?

13. What examples, guidance, or systems development approaches are your agency and partners following or are planning to follow for the CV portions of the project? (Check all that apply)

- ☐ Vee Development Model (system is designed and built in an environment that includes iterative feedback and evolutionary development)
- ☐ Agile/Scrum methods (frequent interaction with development team, gradual capability development)
- ☐ Phased (system is developed and built in major steps or stages, allowing feedback to subsequent stages, e.g. Build 1, Build 2, Build 3)
- ☐ US DOT guidance (based on CV Pilots documentation)
- ☐ Other deployment examples or documentation
- ☐ Contractor-specific development approach
- ☐ Have not decided yet/unknown

Other or Comments

14. Which funding sources is your agency planning to use to fund ongoing operations and maintenance of the system post-deployment? (Check all that apply)

- ☐ ITS or other federal grant
- ☐ Federal-aid funds
- ☐ State, regional, or local funds
- ☐ Private sector funding
- ☐ Not sure yet
- ☐ Not applicable to my project
- ☐ Other (please specify)

Connected Vehicle Technology Procurement Questions

CV Procurement Questions

These questions are designed to discover your procurement approach and related decisions.

* 15. How is your agency purchasing the CV-related portions of the project? Please provide an overview.

16. Has your agency used this procurement approach in the past?

- Often
- Sometimes
- Rarely
- Never

Comments:

17. Is your agency planning to use one contract or multiple contracts?

18. How is the work being allocated to the contracts? (What is the planned work structure?)

19. Will your agency use a systems manager or systems integrator(s)? (Check all that apply)

- Will use a Systems Manager (responsibilities may include all project activities associated with a systems acquisition except for the provision of equipment, electrical contracting, and construction contracting)
- Will use a Systems Integrator (provides all of the services associated with the system implementation except for the provision of equipment, electrical contracting, and construction--typically not involved in planning or early design phases)
- Will use Multiple Systems Integrators (e.g., a separate firm for the vehicle installations)
- Have not decided yet/unknown
- This question does not apply to my project

Comments:

20. Which approach best describes how your agency is buying/planning to buy the system?

- ◯ Design, Bid, Build approach (after design, agency puts out specifications for parts of the system, then contractor/systems integrator makes sure it all works together)
- ◯ Design-Build approach (a single contractor provides for the design, procurement of needed equipment, and implementation of system)
- ◯ Public Private Partnership (agency works with a private firm or group who designs, builds, operates, and maintains the CV equipment or system)
- ◯ Have not decided yet/unknown

Other (please specify)

21. Do you have consultant help for system planning, preparing procurement specifications, and overseeing the work? (check all that apply)

- ☐ Consultant help for system planning
- ☐ Consultant help for preparing procurement specifications
- ☐ Consultant help for overseeing the work

22. What contract type(s) is your agency planning for the CV portions of the project? (Check all that apply)

- ☐ Fixed price
- ☐ Cost reimbursable
- ☐ Incentive
- ☐ Time & Materials
- ☐ Have not decided yet/unknown

If multiple types are being used, please clarify which types apply to which work effort./Other Comments

23. What methods of award are planned/being used to select contractors/vendors? (Check all that apply)

- [ ] Qualifications
- [ ] Cost
- [ ] Sole source
- [ ] Combinations and variations of these
- [ ] Have not decided yet/unknown

Other (please specify)

24. What tools (e.g., software, checklists, etc.) is your agency using to assist with CV procurements?

25. Is your agency breaking up the procurement into different stages or build phases? How?

26. How did/will your agency select potential technologies and vendors for the project?

27. How are partner agencies participating in the procurement of the system?

28. Are the CV equipment and applications you are specifying mainly COTS or is customized software development required? Pick only one. Please explain.

- Vendor equipment/products mainly COTS with very little software development required
- Vendor equipment/products mainly COTS with some moderate software development needs
- Some vendor products are COTS but substantial software/hardware development is required
- This project is largely a software or hardware development effort
- Other (please specify)

29. Does your regional ITS architecture address the provision of CV applications?

- Yes
- Not yet
- Not sure

Other (please specify)

30. Is your agency using or planning to use ITS/CV standards to facilitate the integration and interoperability of the system? Which ones? Are you planning to use those standards to assist with writing the procurement specifications?

Connected Vehicle Technology Procurement Questions

Reflection Questions/Lessons Learned

These final questions ask for your thoughts regarding CV procurement challenges and what US DOT might be able to do to assist agencies in overcoming them.

* 31. Can you identify any limitations in your procurement processes that affected or may affect the success or efficiency of the CV procurement?

- ◯ Yes (Please provide explanation below and answer the next question.)
- ◯ No
- ◯ Not sure
- ◯ Too soon to tell at this point

Please elaborate.

32. If you answered yes to Q31, how did your agency address/overcome these limitations, or how are you planning to address them?

33. Were new business processes or practices required to enable/facilitate CV procurement?

- ◯ Yes
- ◯ No
- ◯ Not sure
- ◯ Too soon to tell at this point

Please elaborate/add your comments here

* 34. What is the biggest procurement-related challenge that must be addressed to achieve broader CV adoption?

* 35. How would you recommend the USDOT provide procurement assistance to agencies interested in deploying CV technologies? (Please rank from most important (1) to least important (6))

6	Training
6	Guidance
6	Technical assistance
6	Funding opportunities
6	Provide model documentation, case studies, or project examples
6	Facilitate peer exchanges on the topic

* 36. Based on your experience to date, what is one important lessons learned or recommendation on approaches to procurement of CV technology that you think would be of value to peer agencies?

37. Can you provide us with your contact information (email address, phone number) in case we have questions about your answers?

Email Address

Phone Number

38. OC1: Can you provide us with contact information for others inside or outside of your agency that we should interview to get a range of perspectives on CV-procurement plans/experiences for this project?

Name

Company/Organization

Email Address

Phone Number

39. OC2: Can you provide us with contact information for others inside or outside of your agency that we should interview to get a range of perspectives on CV-procurement plans/experiences for this project?

Name	
Company/Organization	
Email Address	
Phone Number	