Exploring the Modified Procurement Framework for Expediting Florida Connected Vehicle (CV) Deployments

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DISCLAIMER

The opinions, findings, and conclusions, expressed in this publication are those of the authors and not necessarily those of the State of Florida Department of Transportation.

APPROXIMATE CONVERSIONS TO SI UNITS

SYMBOL	WHEN YOU KNOW	MULTIPLY BY	TO FIND	SYMBOL
LENGTH				
in	inches	25.4	millimeters	mm
ft	feet	0.305	meters	m
yd	yards	0.914	meters	m
mi	miles	1.61	kilometers	km
AREA				
in^2	squareinches	645.2	square millimeters	mm^2
ft^2	squarefeet	0.093	square meters	m^2
yd^2	square yard	0.836	square meters	m^2
ac	acres	0.405	hectares	ha
mi^2	square miles	2.59	square kilometers	km^2
VOLUME				
fl oz	fluid ounces	29.57	milliliters	mL
gal	gallons	3.785	liters	L
ft^3	cubic feet	0.028	cubic meters	m^3
yd^3	cubic yards	0.765	cubic meters	m^3
NOTE: volumes greater than 1000 L shall be shown in m^3				
MASS				
oz	ounces	28.35	grams	g
lb	pounds	0.454	kilograms	kg
T	short tons (2000 lb)	0.907	megagrams (or "metric ton")	Mg (or "t")
TEMPERATURE (exact degrees)				
ºF	Fahrenheit	5 (F-32)/9 or (F-32)/1.8	Celsius	ºC
ILLUMINATION				
fc	foot-candles	10.76	lux	lx
fl	foot-Lamberts	3.426	candela/m^2	cd/m^2
FORCE and PRESSURE or STRESS				
lbf	poundforce	4.45	newtons	N
lbf/in^2	poundforce per square inch	6.89	kilopascals	kPa

*SI is the symbol for the International System of Units.

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16. Abstract

This study examined the current procurement framework of connected vehicle (CV) deployments in Florida to provide guidance for expediting CV projects. A brief review of the current state-of-the-practice of CV deployment at the regional, national, and international level was conducted. Ongoing and operational CV projects included in the Florida Department of Transportation (FDOT) Florida CV Initiative, as of December 2018, were also reviewed. To explore the current state-of-the-practice of CV deployments in Florida, FDOT project managers from Districts Two and Five, the Central Office, the Florida Turnpike Enterprise (FTE), and the City of Gainesville (District Two) were interviewed to share their experiences with the procurement process, lessons learned, and best practices identified from CV deployments in their respective jurisdictions. A second survey was conducted to explore lessons learned and best practices used in CV deployments by transportation agencies in other states. The information gathered from the two surveys was combined to develop suggested procurement framework guidelines to assist CV project managers with future CV deployments. Key factors to consider when deploying CV technologies include project scheduling issues, the need for additional post-planning work, system component testing and procurement options, Federal Communications Commission (FCC) approval for CV devices, and security management of the system. Since CV deployments are still fairly new in Florida, it is expected that additional guidelines geared at improving the procurement framework will be developed as FDOT expands its Connected and Automated Vehicle (CAV) program.

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EXECUTIVE SUMMARY

As the need to improve travel reliability, efficiency, and safety increases on highway networks, emerging Intelligent Transportation System (ITS) technologies, such as connected vehicle (CV), are being deployed by a number of state agencies in the United States (U.S.). Florida Department of Transportation (FDOT) is among the state agencies that are advancing their smart transportation efforts through Connected and Automated Vehicle (CAV) applications. Implementing CV strategies also supports one of several key focus areas identified in the FDOT Transportation Systems Management and Operations (TSM&O) Strategic Plan.

Since the adoption of the 2017 TSM&O Strategic Plan, FDOT has developed the Florida CV Initiative, which includes 18 CAV projects in various stages of deployment, as of December 2018. Although CV deployments are technology-based and similar to ITS projects, CV applications involve emerging technologies. This presents unique challenges for TSM&O project managers in the development of CV projects, especially pertaining to the procurement process. As a result, FDOT recognized the need to examine the procurement framework currently being used for its CV projects to assist in expediting the procurement process in future CV deployments.

This study examined the current procurement framework of CV deployments in Florida, as of January 2019, to provide guidance for expediting the deployment of CV technologies. Research tasks were completed by the University of North Florida (UNF) and Florida International University (FIU) under the direction of the FDOT Central Office.

Tasks included an initial review of the current state-of-the-practice of CV deployment at the regional, national, and international level. Ongoing and operational CV projects included in the Florida CV Initiative, as of December 2018, were also reviewed. However, Autonomous/Automated Vehicle (AV) projects were not included in this study.

To explore the current state-of-the-practice of CV deployments in Florida, project managers from FDOT Districts Two and Five, the Central Office, the Florida Turnpike Enterprise (FTE), and the City of Gainesville (District Two) were surveyed via interviews in May 2018 to discuss the procurement process and issues, lessons learned, and best practices experienced with CV deployments in their respective jurisdictions.

A second survey was conducted in September 2018 to explore lessons learned and best practices adopted in CV deployments by transportation agencies outside of Florida. The survey was administered to TSM&O and ITS project managers in each of the 50 states in the U.S. Nine agencies responded to the questionnaire. Wherever possible, follow-up interviews were conducted with survey participants to expand on, or add to, their survey responses.

The information gathered from the two surveys was combined to develop suggested procurement framework guidelines to assist TSM&O project managers with future CV deployments. Key factors to consider when deploying CV technologies include project scheduling issues, the need for additional post-planning work, system component testing and procurement options, Federal Communications Commission (FCC) approval for CV devices, and security management of the system.

Many activities associated with a CV deployment overlap among various phases of the project. Suggested procurement activities during the CV project development process include:

- *Planning Phase*
    - Establish the need for the project
    - Explore current technologies
    - Evaluate system readiness
    - Refer to the Architecture Reference for Cooperative and Intelligent Transportation (ARC-IT) for guidance
    - Acquire Federal Communications Commission (FCC) initial approval
- *Post-Planning Phase*
    - Develop Concept of Operations (ConOps)
    - Engage vendors; request information
    - Issue request for information (RFI), if needed
    - Explore interoperability of products
    - Perform National Environmental Policy Act (NEPA) study, if required
    - Determine the systems development approach
    - Determine contracting method
    - Identify the CEI Contractor
- *Begin Procurement Process*
    - Procure systems manager
    - Evaluate existing system components
    - Issue request for proposal (RFP)
    - Procure design-build Contractor
- *Design Phase*
    - Request test units
    - Test system equipment/applications
    - Develop technical special provisions
    - Develop plan for vendor support and training
    - Procure systems integrator
- *Implementation Phase*
    - Purchase infrastructure and software components
    - Acquire FCC approval
    - Install, integrate, and verify the system
    - Purchase/build vehicle equipment
    - Security management of the system
    - Construction and inspection (CEI) participation
- *Operations & Maintenance Phase*

- Train for operation and maintenance of the system
- Validate and operate the system
- Collect data
- Develop data user agreements

Based on findings from this research effort, suggested recommendations for FDOT to consider include:

- Distribute the CV procurement process flowchart statewide to assist FDOT CV project managers.
- Share the CV procurement framework flowchart with local agencies to assist them with CV initiatives in their jurisdictions.
- Schedule regular meetings or webinars among CV project managers statewide to share project experiences and CV knowledge.
- Consider obtaining a statewide Federal Communications Commission (FCC) license to expedite the licensing and registration process for future CV devices.

Recommendations presented in a recently completed study, *Evaluation of Project Processes in Relation to Transportation System Management and Operations (TSM&O)*, FDOT Project No. BDV34-977-07, were also reviewed to determine if revisions should be considered to include information pertaining to CV and CV-related deployments. Suggested revisions to recommendations noted in the previous TSM&O study include:

- Consider developing a formalized procedure for CV project development, including the procurement process.
- Consider including CV information and examples in the TSM&O education efforts within the FDOT to promote a better understanding of CV strategies.
- Consider including CV as a TSM&O strategy in FDOT design guidelines containing TSM&O language.

While each CV deployment is unique to some degree, a better understanding of the procurement process, coupled with a better development methodology, may be beneficial in expediting future deployments. Since CV deployments are still fairly new in Florida, it is expected that additional guidelines geared at improving the procurement framework will be developed as FDOT expands its CAV program.

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ACRONYMS/ABBREVIATIONS

AASHTO	American Association of State Highway and Transportation Officials
ADOT	Arizona Department of Transportation
AID	Accelerated Innovations Deployment
APL	Approved Product List
ARC-IT	Architecture Reference for Cooperative and Intelligent Transportation
ASD	Aftermarket Safety Device
AST	Agency for State Technology
ATCMTD	Advanced Transportation and Congestion Management Technologies Deployment
ATIS	Advanced Traveler Information Systems
ATMS	Advanced Traffic Management Systems
AV	Autonomous/Automated Vehicle
AVL	Automated Vehicle Location
BRT	Bus Rapid Transit
BSM	Basic Safety Message
BSW	Blind Spot Warning
C-ITS	Cooperative Connected and Automated Mobility ITS
Caltrans	California Department of Transportation
CAV	Connected and Automated Vehicle
CCTV	Closed-Circuit Television
CEI	Construction and Inspection
CICAS	Cooperative Intersection Collision Avoidance Systems
CMU	Carnegie Mellon University
ConOps	Concept of Operations
COTS	Commercial-off-the-shelf
CV	Connected Vehicles
CVII	Commercial Vehicle Infrastructure Integration
CVPDP	Connected Vehicle Pilot Deployment Program
DATP	Driving Assistive Truck Platooning Pilot
DB	Design-Build
DBB	Design-Bid-Build
DN	Distress Notification
DOT	Department of Transportation
DSRC	Dedicated Short Range Communication
EEBL	Emergency Electronic Brake Light
EV	Electric Vehicles
EVP	Emergency Vehicle Preemption
FCC	Federal Communications Commission
FCW	Forward Collision Warning
FDOT	Florida Department of Transportation
FHP	Florida Highway Patrol

FHWA	Federal Highway Administration
FIU	Florida International University
FRAME	Florida's Regional Advanced Mobility Elements
FTE	Florida Turnpike Enterprise
GDOT	Georgia Department of Transportation
GE	General Electric
GEC	General Engineering Consultant
GPS	Global Positioning System
HART	Hillsborough Area Regional Transit
HAV	Highly Autonomous Vehicle
HOV	High Occupancy Vehicle
HOT	High Occupancy Toll
I2V	Infrastructure-to-Vehicle
I2P	Infrastructure-to-Pedestrian
ICM	Integrated Corridor Management
IMA	Intersection Movement Assist
ITS	Intelligent Transportation System
ITS JPO	Intelligent Transportation System Joint Program Office
LCA	Lane Change Warning/Assist
LED	Light Emitting Diode
LiDAR	Light Detection and Ranging
LRTP	Long-Range Transportation Plan
MAP	Map Data Message
MCDOT	Maricopa County Department of Transportation
MDOT	Michigan Department of Transportation
MLFF	Multi-Lane Free Flow
MMITSS	Multi-Modal Intelligent Traffic Safety Systems
MnDOT	Minnesota Department of Transportation
MORPC	Mid-Ohio Regional Planning Commission
MPO	Metropolitan Planning Organization
MTA	Metropolitan Transportation Authority
NCDOT	North Carolina Department of Transportation
NCHRP	National Cooperative Highway Research Program
NCSL	National Conference of State Legislature
NEPA	National Environmental Policy Act
NHTSA	National Highway Traffic Safety Administration
NYC	New York City
NYSDOT	New York State Department of Transportation
NYCDOT	New York City Department of Transportation
O&M	Operations & Maintenance
OEM	Original Equipment Manufacturer
ORT	Open Road Tooling
OBU	Onboard Unit

P3	Public Private Partnership
PD&E	Project Development and Environment
PEDSIG	Mobile Accessible Pedestrian Signal System
PennDOT	Pennsylvania Department of Transportation
PID	Pedestrian Information Device
R&D	Research and Development
RFI	Request for Information
RFP	Request for Proposal
RSU	Roadside Unit
RTMC	Regional Traffic Management Center
RTS	Regional Transit System
SAE	Society of Automotive Engineers
SCC	Smart-City Challenge
SE	Systems Engineering
SI	Systems Integrator
SM	Systems Manager
SPaT	Signal Phase and Timing
SPM	Signal Performance Metrics
SRM	Signal Request Message
SSM	Signal Status Message
SVA	Stationary Vehicle Ahead
SWIW	Spot Weather Impact Warning
Tech Specs	Technical Special Provisions
TECO	Tampa Electric Company
TEN-T	Trans-European Transport Network
TERL	Traffic Engineering Research Lab
THEA	Tampa Hillsborough Expressway Authority
TIM	Traffic Information Message
TMC	Traffic Management Center
TSM&O	Transportation Systems Management and Operations
TSP	Transit Signal Priority
TxDOT	Texas Department of Transportation
UCF	University of Central Florida
UDOT	Utah Department of Transportation
UF	University of Florida
UFTI	University of Florida Transportation Institute
UPS	United Postal Service
USDOT	United States Department of Transportation
V2I	Vehicle-to-infrastructure
V2V	Vehicle-to-vehicle
V2X	Vehicle-to-everything
VCC	Virginia Connected Corridor
VDOT	Virginia Department of Transportation

VRU	Vulnerable Road User
WSDOT	Washington State Department of Transportation
WYDOT	Wyoming Department of Transportation
WZW	Work Zone Warnings

1 - INTRODUCTION

Following the launch of the Connected Vehicle (CV) Pilot Deployment Program by the United States Department of Transportation (USDOT) (USDOT, 2018a), transportation agencies throughout the U.S. are considering strategies involving CV technologies to improve travel reliability, efficiency, and safety for motorists. Florida Department of Transportation (FDOT) is among the agencies actively pursuing Connected and Automated Vehicle (CAV) strategies with the Florida CV Initiative. As of December 2018, the FDOT CAV program includes 18 projects statewide in various stages of development (FDOT, 2018a).

Although CV deployments are technology-based, FDOT Transportation Systems Management and Operations (TSM&O) project managers have experienced unique challenges with CV deployments which they have not encountered with other Intelligent Transportation System (ITS) projects. These challenges are primarily related to the procurement of CV components and the resulting effects on the project development process. The objective of this study was to examine the modified procurement framework associated with CV deployments in Florida to provide guidance for expediting CV projects.

1.1 Study Methodology

A brief review of the current state-of-the-practice of CV deployment at the regional, national, and international level was conducted. Ongoing and operational CV projects included in the Florida CV Initiative as of December 2018, were also reviewed. However, research on Autonomous/Automated Vehicle (AV) projects was not addressed in this study.

To explore the current state-of-the-practice of CV deployments in Florida, FDOT project managers from Districts Two and Five, the Central Office, and the Florida Turnpike Enterprise (FTE) were interviewed in May 2018 to discuss the procurement process and issues, lessons learned, and best practices experienced with ongoing or operational CV deployments in their respective district. One project manager from the City of Gainesville (District Two) was also interviewed.

A review of recommendations presented in a previous study, *Evaluation of Project Processes in Relation to Transportation System Management and Operations (TSM&O)*, FDOT Project No. BDV34-977-07 (FDOT, 2018b), was also conducted to evaluate the need for inclusion of CV language and suggest revisions, if needed.

A second survey was conducted in September 2018 to explore lessons learned and best practices used in CV deployments by transportation agencies outside of Florida. The survey was administered to TSM&O and ITS project managers in each of the 50 states in the U.S., and nine agencies responded. Wherever possible, follow-up interviews were conducted with survey participants to expand on, or add to, their survey responses.

The information gathered from both surveys was combined to present aspects of the project development process and the procurement framework associated with CV deployments. Suggestions are also presented that may assist TSM&O project managers with future CV deployments.

1.2 Report Organization

This report presents the study findings, and is organized as follows:

- Chapter 2 reviews the current state-of-the-practice of CAV deployments.
- Chapter 3 presents the findings from interviews with FDOT project managers involved in CV projects in Florida.
- Chapter 4 presents the findings from a survey administered to CV project managers in other states.
- Chapter 5 discusses lessons learned from Florida CV deployments.
- Chapter 6 discusses best practices identified from Florida CV deployments.
- Chapter 7 reviews recommendations from FDOT Project No. BDV34-977-07 in regards to CV inclusion.
- Chapter 8 discusses the CV project development process.
- Chapter 9 discusses the procurement framework for CV deployments.
- Chapter 10 provides a summary of the study findings and suggested recommendations.

2 – CURRENT STATE-OF-THE-PRACTICE REVIEW

This Chapter focuses on the current state-of-the-practice of CV deployments at the regional, national, and international level. Research findings are presented in the following sections:

- Section 2.1 provides a brief introduction to CV technology.
- Section 2.2 discusses the U.S. CV Pilot Deployment Program (CVPDP).
- Section 2.3 discusses several recently completed CV deployment efforts in the U.S.
- Section 2.4 discusses CV deployment efforts at the international level.
- Section 2.5 discusses Public Private Partnerships (P3s) with universities.
- Section 2.6 presents the existing regulations pertaining to CV deployments in the U.S.
- Section 2.7 discusses ongoing CV deployments in Florida in various phases of deployment.
- Section 2.8 reviews completed CV deployments in Florida.
- Section 2.9 briefly discusses data user agreements.

2.1 Background

CV technology allows for the exchange of information between vehicles, drivers, bicyclists, pedestrians, and roadside infrastructure. Communication can occur in the form of vehicle-to-vehicle (V2V), vehicle-to-infrastructure (V2I), infrastructure-to-vehicle (I2V), or vehicle-to-everything (V2X) (FDOT, 2018a). The USDOT connected vehicle network transmits digital code over one or more government-licensed radio-frequency channels near 5.9 GHz, which is often referred to as dedicated short-range communication (DSRC) (CAR, 2017). The language dictionary (SAE J2735), standardized by the Society of Automotive Engineers (SAE) International, is primarily used to communicate in the DSRC network platform. Basic safety messages (BSMs), the most common data element, broadcasts the vehicles' location, speed, direction, and other information, ten times each second (Center for Automotive Research [CAR], 2017).

CV deployments often consist of roadside units (RSUs) and onboard units (OBUs), working together, to quickly identify and alert drivers of roadway hazards and delays. AV technology generally consists of vehicles equipped with advanced sensors (radar, Light Detection and Ranging (LiDAR), cameras, etc.) and computing abilities to perceive surroundings and activate vehicle actions, such as steering, braking, and acceleration, without operator input (FDOT, 2018a). All modes of transportation may benefit in improved safety and mobility with the use of AV and CV applications. Among others, these technologies include:

- Wireless Communications
- Basic Safety Messages (BSMs)
- Signal Phase and Timing (SPaT)
- Freight Signal Priority
- Transit Signal Priority (TSP)

- Emergency Vehicle Preemption (EVP)
- Vehicle Sensors
- Global Positioning System (GPS) Navigation

The CV industry is quickly evolving from ideas and concepts to implementation and operation. In recent years, research and deployment of emerging technologies have proliferated the transportation industry. This rapid growth is not limited to the U.S.; in fact, many countries around the world have initiated research and implementation efforts of CV technologies (National Cooperative Highway Research Program [NCHRP], 2015). The industry has also been developing various applications and products to expedite real-world connected and automated transportation operations (NCHRP, 2015). Several agencies including the National Highway Traffic Safety Administration (NHTSA), NCHRP, the American Association of State Highway and Transportation Officials (AASHTO), the Federal Highway Administration (FHWA), and state DOTs have published roadmaps, guidelines, and vision statements related to vehicle connectivity and automation and the deployment of emerging technologies (NHTSA, 2016).

Despite abundant research, established national and international programs, and numerous Concept of Operations (ConOps) and vision proposals, comprehensive CV deployments remain few in number. Nonetheless, efforts have been increasing to implement various CV-related applications. Each of these efforts have a different focus and consist of a wide variety of applications. CAV deployments in the U.S. range from federal programs to P3s collaborating with universities. Activities range from small-scale temporary pilots to substantial investments at the national level. In general, these activities are classified into the following five categories:

1. Connected Vehicle Pilot Deployment Program (CVPDP),
2. CV Test bed,
3. USDOT Automated-vehicle Proving Ground,
4. Smart-City Challenge (SCC), and
5. University-driven effort.

The development of information and communication technologies and equipping automobiles with wireless communication abilities is expected to revolutionize the automotive industry. Connected vehicles are proactive, cooperative, well-informed, and coordinated, and will help to inspire other applications focused on road safety (e.g., collision detection and avoidance, lane change warning, and cooperative merging), smart and green transportation (e.g., traffic signal control, intelligent traffic scheduling, and fleet management), location-dependent services, and in-vehicle internet access (Lu et al., 2014).

The market of connected vehicles is accelerating, and the global market is expected to reach $131.9 Billion by 2019 (Transparency Market Research, 2013). The two primary driving forces for developing wireless connectivity in vehicles are the urgent need to improve efficiency and safety on roadway systems and the increasing mobile data demand by today’s road users (Balasubramanian et al., 2008). Increasing traffic congestion and its consequences in terms of greater economic cost and environmental issues can have a significant impact on the quality of life. CV technology provides a promising alternative to manage traffic congestion through intelligent traffic control and management, as well as improving road safety using in-vehicle advanced warning and driving assistance systems (Olaverri-Monreal et al., 2010). Moreover, applications that connect vehicles to the internet can be envisioned to meet not only the mobile data demand, but also enrich safety-related applications, such as online diagnosis (Lin, et al., 2009) and intelligent anti-theft and tracking applications (Ramadan et al., 2012).

2.2 U.S. CV Pilot Deployment Program

On September 1, 2016, the USDOT awarded three cooperative agreements, collectively worth more than $45 Million, to initiate a Design/Build/Test phase of the CV Pilot Deployment Program (CVPDP) in three locations (see Figure 2.1): New York City, NY, Wyoming, and Tampa, FL (USDOT, 2018b). CVPDP is a national effort sponsored by the USDOT Intelligent Transportation Systems Joint Program Office (ITS JPO) to deploy, test, and operationalize cutting-edge mobile and roadside technologies, and enable multiple CV applications. These innovative technologies and applications have the potential for immediate useful impacts, and are designed to save lives, improve personal mobility, enhance economic productivity, reduce environmental impacts, and transform public agency operations (USDOT, 2018b).

Each USDOT pilot project consists of three phases: Phase 1 - Concept Development, Phase 2 - Design/Build/Test, and Phase 3 - Maintain/Operate (USDOT, 2018a). Phase 1, where each site prepared a comprehensive deployment concept to ensure a rapid and efficient connected vehicle capability, was completed for all three pilots prior to the projects being awarded in September 2016. In Phase 2, nearing completion, the three sites are working to design, build, and test some of the most complex and extensive deployments of integrated wireless in-vehicle, mobile device, and roadside technologies in the nation. Once Phase 2 is completed, a 19-month phase (Phase 3) will focus on operations and maintenance (USDOT, 2018a). Table 2.1 provides the federal funding and the site’s cost share estimates for Phase 2 and Phase 3 for the three sites.

Agencies leading the CVPDP initiatives at the three pilot locations are the New York City DOT (NYCDOT), Wyoming DOT (WYDOT), and the Tampa Hillsborough Expressway Authority (THEA) (USDOT, 2018b). The following sections briefly discuss each project.

Figure 2.1: Regional CV Pilot Study Sites
(Source: WYDOT, 2017)

Table 2.1: Notice of Funding Opportunity

CV Pilot Site	Phase 2		Phase 3		Total
	Federal Funding (Est.)	Site Cost Share (Est.)	Federal Funding (Est.)	Site Cost Share (Est.)	
Tampa/THEA	$13,340,283	$3,335,071	$1,921,133	$480,283	$19,076,770
New York City DOT	$13,694,163	$3,423,541	$3,304,150	$826,038	$21,247,892
Wyoming DOT	$3,200,565	$800,141	$1,238,928	$309,732	$5,549,366
Total	$30,235,011	$7,558,753	$6,464,211	$1,616,053	$45,874,028

Source: Amendment 1 to Notice of Funding Opportunity # DTFH6116RA00007 CV Pilot Deployment Program.

2.2.1 New York City Pilot Study, New York

The City of New York (NYC) looked to CV technology as a new tool to help the City reach its *Vision Zero* goal of eliminating traffic fatalities and reducing traffic injuries and damage to both vehicles and infrastructure. The NYC pilot deployment is primarily focused on safety applications which rely on V2V, V2I, and infrastructure-to-pedestrian (I2P) communications

(NYCDOT, 2018). These applications provide drivers with alerts so that the driver can take action to avoid a crash or to reduce injury severity or damage to vehicles and infrastructure.

Approximately 300 RSUs will be installed in Manhattan, along Flatbush Avenue in Brooklyn, and at other strategic locations, such as bus depots, fleet vehicle storage facilities, river crossings, and airports. Figure 2.2 shows the study area of the pilot project. RSUs will also be installed along portions of FDR Drive to support applications, such as curve speed warning and over dimension vehicle warnings (over height and prohibited commercial vehicles) (NYCDOT, 2018). Table 2.2 lists the needs identified by NYCDOT and the corresponding CV applications being considered in the pilot project. The devices and equipment being installed are listed in Table 2.3.

Figure 2.2: NYC Pilot Project Study Area
(Source: NYCDOT, 2018)

Table 2.2: NYCDOT's Needs and Corresponding CV Applications

Need	CV Application
Discourage spot speeding	Modified Eco-Speed Harmonization
Reduce crashes at intersection locations	Red Light Violation Warning
Improve pedestrian safety on heavily traveled bus routes	Pedestrian in Signalized Cross Walk Warning, Vehicle Turning Right in Front of Bus Warning
Improve safety of visually impaired pedestrians	Mobile Accessible Pedestrian Signal System (PEDSIG)
Improve truck safety	Curve Speed Warning
Address bridge low clearance issues	Freight-Specific Dynamic Travel Tool
Enforce truck route restrictions	Freight-Specific Dynamic Travel Tool
Improve work zone safety	Reduced Speed/ Work Zone Warning
Balance mobility	Intelligent Traffic Signal System (i-SIG) In-Vehicle Information Potential
Reduce crashes, injuries, and delays	Forward Collision Warning (FCW)
	Emergency Electronic Brake Light (EEBL)
	Blind Spot Warning (BSW)
	Lane Change Warning/Assist (LCA)
	Intersection Movement Assist (IMA)
	Stationary Vehicle Ahead (SVA)

Source: NYCDOT, 2018

Table 2.3: Proposed CV Devices and Equipment

CV Devices and Equipment	Estimated Number
RSU at Manhattan and Brooklyn Intersections and FDR Drive	353
Taxi Equipped with Aftermarket Safety Device (ASD)	5,850
Metropolitan Transportation Authority (MTA) Fleet Equipped with ASD	1,250
United Postal Service (UPS) Truck Equipped with ASD	400
NYCDOT Fleet Equipped with ASD	250
DSNY Fleet Equipped with ASD	250
Vulnerable Road User (VRU) Device for pedestrians/bicyclists	100
Pedestrian detection system	10 + 1 spare
Total Equipped Vehicles	8,000

Source: NYCDOT, 2018

The project is divided into three phases. The first phase, the planning phase, was completed in September 2016, and included a ConOps and system requirements, a safety plan, a benefits evaluation plan, a security management plan, and a deployment plan (NYCDOT, 2018). The 20-month long second phase, design/build/test phase, began in September 2016 and includes the detailed design, field equipment development and procurement, software development, integration, and the installation of in-vehicle devices and roadside infrastructure. The third phase (18-months) is the operations and maintenance phase, and consists of an operating period during which the applications will be active, providing alerts to the drivers. The City plans to install the CV technology in approximately 8,000 vehicles which frequent the streets of Manhattan, including approximately 1,250 Metropolitan Transportation Authority (MTA) buses, 400 United Postal Service (UPS) local delivery trucks, 500 DOT and sanitation vehicles, and 5,850 yellow taxicabs (NYCDOT, 2018). These vehicles represent about one million vehicle miles traveled per day (NYCDOT, 2018).

2.2.2 Wyoming I-80 Pilot Study

For the Wyoming CV pilot project, WYDOT will use V2V, V2I, and I2V connectivity to improve monitoring and reporting of road conditions to vehicles along the I-80 corridor, as shown in Figure 2.3. Table 2.4 lists the CV applications that are being considered, and Table 2.5 lists the proposed CV devices and equipment that are being deployed for the project.

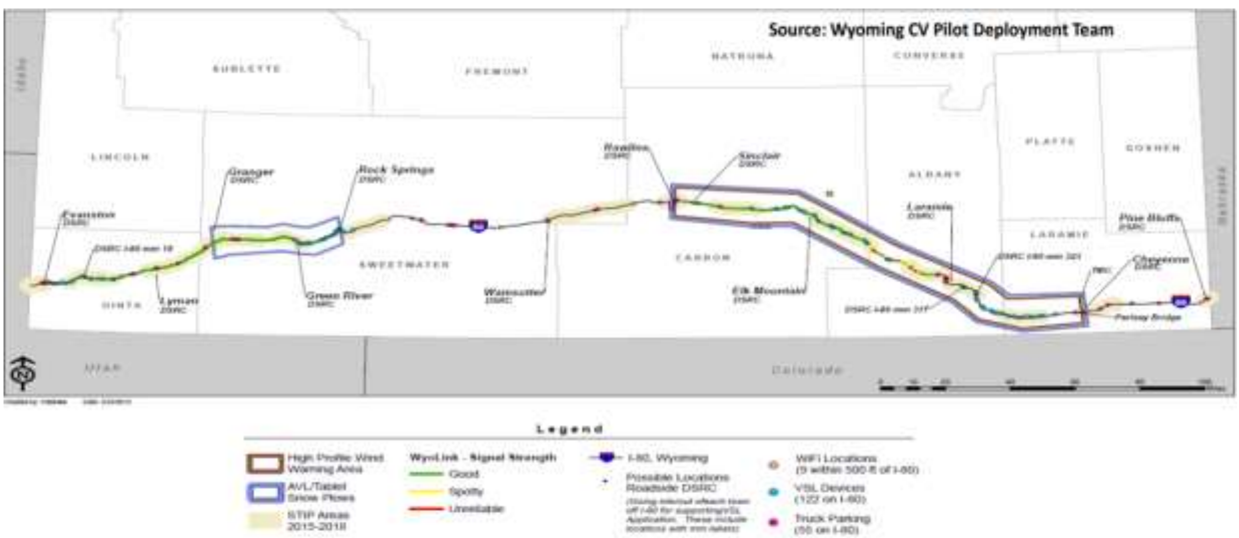

Figure 2.3: Wyoming I-80 Corridor CV Pilot Study Location
(Source: WYDOT, 2017)

Table 2.4: CV Application Components for Wyoming Pilot Study

Category	**ICF/WYDOT – CV Application**
V2V Safety	Forward Collision Warning (FCW)
V2I/I2V Safety	I2V Situational Awareness
	Work Zone Warnings (WZW)
	Spot Weather Impact Warning (SWIW)
V2I and V2V Safety	Distress Notification (DN)

Source: WYDOT, 2017

Table 2.5: Wyoming Proposed CV Devices and Equipment

ICF/WYDOT – Devices	Estimated Number
Roadside Unit (RSU)	75
WYDOT Fleet Subsystem onboard unit (OBU)	100
Integrated Commercial Truck Subsystem OBU	150
Retrofit Vehicle Subsystem OBU	25
Basic Vehicle Subsystem OBU	125
Total Equipped Vehicles	400

Source: WYDOT, 2017

The V2V, V2I, and I2V applications developed by WYDOT will support a flexible range of services. Information from these applications will be made available directly to fleets participating in the pilot, or through WYDOT's traveler information resources. The pilot study features the following applications (WYDOT, 2017):

- *Forward Collision Warning (FCW)*: This application issues an alert if there is a threat of a front-end collision with another vehicle in the same travel lane and direction. FCW will help drivers avoid or reduce the severity of front-to-rear vehicle collisions. However, the system does not take control of the vehicle to avoid a collision.

- *I2V Situational Awareness:* This application provides relevant road condition information, including weather alerts, speed restrictions, vehicle restrictions, roadway conditions, incidents, parking, and road closures. The information is broadcasted from the RSUs and received by the connected vehicles.

- *Work Zone Warning (WZW):* This application communicates information to approaching vehicles about work zone conditions ahead. Approaching vehicles receive information about work zone activities or restriction information that could present unsafe conditions, such as travel lane obstructions, lane closures, lane shifts, speed reductions, or vehicles entering or exiting the work zone.

- *Spot Weather Impact Warning (SWIW):* This application enables localized road condition information, such as fog or icy roads, to be broadcasted from the RSUs and received by the connected vehicles.

- *Distress Notification (DN):* This application allows a connected vehicle to communicate a distress status when sensors in the vehicle detect something that might require assistance from others. Distress status can also be activated manually.

2.2.3 Tampa Hillsborough Expressway Authority (THEA) Pilot Study

The Tampa Hillsborough Expressway Authority (THEA) CV Pilot Program is one of the three CV pilot programs awarded by the USDOT. The program utilizes CV technology to address the many safety and mobility concerns around Tampa's central business district in downtown

Tampa, and aims to equip both public transit and personal vehicles with CV technology to allow V2V and V2I communications. Figure 2.4 illustrates the focus area in Tampa, and Table 2.6 lists the estimated number of CV devices and equipment included in the deployment.

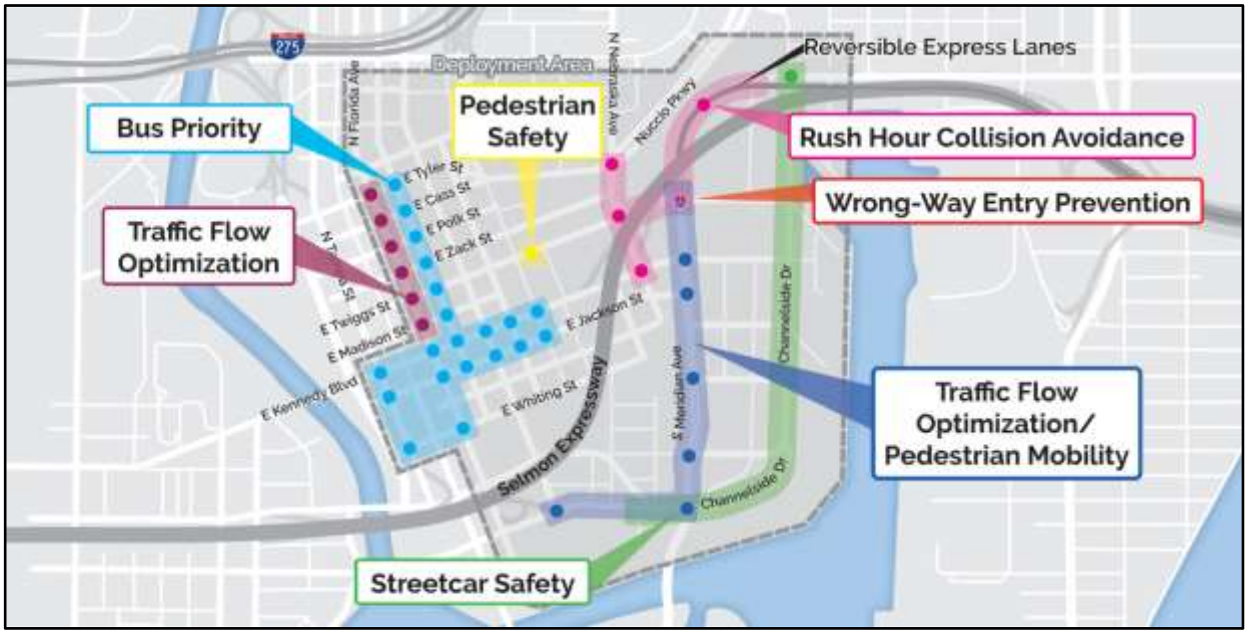

Figure 2.4: CV Deployment Area for City of Tampa
(Source: THEA, 2017)

Table 2.6: Tampa (THEA) Proposed CV Devices and Equipment

Tampa (THEA) - Devices	**Estimated Number**
Roadside Unit (RSU) at Intersection	40
Vehicle Equipped with Onboard Unit (OBU)	1,600
Pedestrian Equipped with App in Smartphone	500
HART Transit Bus Equipped with OBU	10
TECO Line Street Car Equipped with OBU	10
Total Equipped Vehicles	1,620

Source: THEA, 2017

The three focus areas of the THEA Pilot Program are to address safety, mobility, and vehicle emissions using CV technology (THEA, 2017). Table 2.7 lists the key CV applications being deployed in this pilot study to address the following issues:

- *Morning Backups*: A high number of rear-end crashes occur at the intersection of East Twiggs Street and Meridian Avenue, increasing morning backups at this intersection (THEA, 2017). Drivers participating in the Tampa CV Pilot will receive warnings when motorists ahead have suddenly slowed or come to a complete stop. OBUs will also alert the drivers when they are approaching the curve at an unsafe speed (THEA, 2017).

- *Pedestrian Safety:* CV technology will be installed at the midblock crosswalk on East Twiggs Street at the Hillsborough County Courthouse to improve pedestrian safety. When sensors detect a pedestrian in the crosswalk, the roadside equipment will broadcast that information to connected vehicles in the vicinity, alerting drivers of the pedestrian (THEA, 2017).

- *Transit Signal Priority*: Congestion in downtown Tampa is currently preventing the Hillsborough Area Regional Transit (HART) buses from reaching their stops on time, and thus falling behind schedule. Transit Signal Priority (TSP) will be adopted to address this issue to prioritize bus movements, as needed, to keep buses on schedule. A total of 10 HART buses will be equipped with OBUs that will enable them to communicate with traffic signals on their routes (THEA, 2017).

- *Streetcar Conflicts:* The Tampa Electric Company (TECO) Line streetcar system is an electric trolley line that roughly follows Channelside Drive between downtown Tampa and Ybor City. TECO Line streetcars will be equipped with devices that enable them to communicate wirelessly with other connected vehicles and pedestrians. Streetcar operators will receive a cautionary alert when a connected vehicle or a pedestrian is about to cross the track, reducing the risk of a collision (THEA, 2017).

- *Traffic Progression:* Connected vehicles will communicate with some traffic signals on Meridian, North Nebraska, and Florida avenues to optimize signal timing and improve traffic flow based on real-time traffic conditions (THEA, 2017). The CV drivers will also receive a warning when it is not safe to enter an intersection. Additionally, the City of Tampa's TMC will capture traffic data to improve system-wide performance.

Table 2.7: CV Applications in Tampa (THEA) Pilot Study

Category	Tampa (THEA) – CV Application
V2I Safety	• End of Ramp Deceleration Warning (ERDW) • Pedestrian in Signalized Crosswalk Warning (PED-X) • Wrong-way Entry (WWE)
V2V Safety	• Emergency Electronic Brake Lights (EEBL) • Forward Collision Warning (FCW) • Intersection Movement Assist (IMA) • Vehicle Turning Right in Front of a Transit Vehicle (VTRFTV)
Mobility	• Mobile Accessible Pedestrian Signal System (PED-SIG) • Intelligent Traffic Signal System (I-SIG) • Transit Signal Priority (TSP)

Source: THEA, 2017

2.3 Completed CV Deployments in the U.S.

The objective of the USDOT CV Program is to promote information sharing, testing, and cooperative development of CV technologies. The program also encourages DSRC applications in the vehicular environment. Since 2009, several test beds across the nation have been funded through the USDOT Pooled Fund studies. The following sections discuss two ongoing projects in the Connected Vehicle Pooled Fund study. Note that several cities and universities are also participating in this program.

2.3.1 Anthem, Arizona

The Maricopa County Department of Transportation (MCDOT) test bed for SMARTDrive Program was developed in collaboration with MCDOT, Arizona DOT, and the University of Arizona. The program aims to test different AV and CV applications, such as advance multiple vehicle signal priority technology, with deployment on emergency response vehicles (Omidvar et al., 2017). Additionally, some of the most notable projects include MCDOT and the University of Arizona Priority-based Traffic Signal Control for Electric Vehicles (EV) and Transit, performance improvements of traffic controllers by data fusion and analysis (InFusion), and Smartphone signal alert status (SmartCross) (Omidvar et al., 2017).

Started in 2007 and upgraded in 2012, the test bed spans a 2.3-mile section of an arterial roadway in Anthem, AZ, and consists of DSRC devices at 11 signalized intersections, six freeway interchanges, and 10 basic freeway locations. The site also features integrated Wi-Fi and Bluetooth connections, Closed-Circuit Television (CCTV) cameras, traffic detection software, data collection software, fiber optic systems, and communication connections to the MCDOT Traffic Management Center (TMC) (Omidvar et al., 2017).

2.3.2 Palo Alto, California

Introduced in 2005 and upgraded in 2014, the DSRC test bed in Palo Alto, CA was the nation's first test bed. Developed to assess and evaluate real world implementations of vehicle infrastructure integration, as well as to inform future investment decisions on system management programs, the test bed spans over 11 consecutive intersections along a 2-mile stretch of SR-82 in Palo Alto, CA. It provides wireless connectivity in an open and operational environment among intersections, roadways, and vehicles. The equipment used at this test bed includes original equipment manufacturers (OEMs), transit buses, commercial trucks, OBUs from multiple vendors, infrastructure components (RSUs, PC104, signal sniffer, 2070 signal controllers), and backend servers (SDN @ 511 TIC in Oakland, Health Monitoring and management, Signage server) (Omidvar et al., 2017). CAV applications include (Omidvar et al., 2017):

- Traveler Information (using 511),
- Electronic Payment and Toll Collection,
- Ramp Metering,

- Cooperative Intersection Collision Avoidance System (CICAS),
- Curve Over-Speed Warning,
- Auto Industry Applications (i.e., customer relations and vehicle diagnostics),
- Multi-Modal Intelligent Traffic Signal System
- At-grade Light Rail Crossing Safety Research, and
- Intelligent Transit Stop Information System.

2.3.3 Long Island, New York

In Long Island, New York (NY), a CV project was launched in 2008 and upgraded from 2009-2011. The study location includes 13 miles along the I-87 Spring Valley Corridor and 42 miles along the I-495 Long Island Expressway. Features include a Commercial Vehicle Infrastructure Integration (CVII) compliant 5.9 GHz DSRC OBU system, CVII DSRC applications (CV driver identification and verification), wireless vehicle safety inspection (brake condition, tire pressure, light status, etc.), and CV to maintenance vehicles communication (Omidvar et al., 2017).

Also implemented was testing of grade crossing driver warnings (in-vehicle signage and crossing signal activation), heavy vehicle to light vehicle driver safety warnings, and real-time routing with driver warning (Omidvar et al., 2017). Other components include a fleet of four plow trucks (Mack & International), OBUs (retrofitted 5.9 GHz DSRC) plus 20 aftermarket devices, infrastructure components (31 RSUs on the freeway and eight RSUs on arterials at traffic signals), and an enhanced e-screening site with two RSUs along I-40, Greensboro, NC, for CVII testing) (Dennis & Spulber, 2016). In addition to the DSRC and RSUs that were already installed, an additional 13 DSRC units were deployed along I-87 in NY, and, two DSRC units along I-90.

Specific deployments on the corridor include:

- travel time information,
- DMS messages,
- emissions calculations,
- intersection safety,
- transit priority,
- multimodal information,
- CV probe data,
- work zone safety warning,
- warning sign enhancement,
- curve warning,
- commercial vehicle routing information, and
- vehicle restrictions.

2.3.4 Minnesota

The Minnesota CV Pilot Deployment Project primarily focuses on improving the operating efficiency of maintenance and transit vehicles. A secondary focus is on addressing real-world transportation issues to improve safety, mobility, efficiency, and provide travelers with real-time information to reduce delay. Several proposed pilot projects in Minnesota include:

- *Clarus*: The Clarus Initiative was established in 2004 by the USDOT FHWA in conjunction with the ITS JPO to assist transportation managers with reducing the impact of adverse weather conditions, such as fatalities, injuries, and delays, along U.S. roadways (USDOT, 2018c). The Clarus tool aims at using CV data to improve mobility, safety, productivity, and operations during adverse weather conditions by providing weather information to all transportation managers and users (USDOT, 2018c). The Minnesota CV pilot project focuses on collecting, processing, and using mobile weather data. The equipment includes a fleet of 500 volunteer vehicles for the first pilot; "driver clinic" type demo for the second pilot, and 80 Minnesota DOT (MnDOT) snow plows for the Clarus program. The Clarus Initiative offers a nationally open data sharing system that can provide near real-time weather and pavement data based on surface transportation weather observations in North America. The inclusion of CV data allows location-specific weather forecasting and recommendations. In addition, OBUs include Android platform DSRC equipment and an AV location system with cellular communications (Nanyang Technological University [NTU], 2016).

- *Minnesota Road Fee Test*: This pilot project examines the technical feasibility and flexibility of in-vehicle signage and collection of anonymous traveler information from consumer devices (Omidvar et al., 2017).

2.3.5 Northern Virginia, Virginia

The Northern Virginia CV Test Bed and Virginia Connected Corridor (VCC) evaluate CV technologies in congested urban areas. The corridor is equipped with 46 RSU-DSRC radio units which receive and relay data along I-66, I-495, and Routes 29 and 50, and includes access to dedicated high occupancy toll (HOT) lanes in conjunction with partner company, Transurban (Omidvar et al., 2017). This test bed provides initial testing on two closed-loop facilities: Smart Road and Virginia International Raceway test track. Upon approval, each test will migrate to the Virginia CV test bed in Northern Virginia. The test bed offers research technologies and means to conduct phased testing and safety analysis. The test fleet includes 12 vehicles (six cars, four motorcycles, a bus, and a semi-truck). These vehicles collect information, such as acceleration, braking, curve handling, and emissions. Some of the featured components of the test bed include: metro stations, HOT and high occupancy vehicle (HOV) lanes, hospitals, major merge/diverge locations, emergency services, multiple schools, mixed-use commercial/residential areas, major roadway construction, and over 60 RSUs for CV communication (Omidvar et al., 2017).

2.3.6 Denver, Colorado

This pilot project, launched in 2009, demonstrates multi-lane free flow (MLFF), open road tolling (ORT), and high performance tolling and enforcement. The system being used is based on 5.9 GHz DSRC to communicate between roadside tolling systems and vehicles. It was installed on three lanes next to an existing toll plaza on the E-470 highway for evaluating tolling systems. The installation also includes in-vehicle units, cameras with illumination units, overview cameras with external infrared (IR)-flashes, and laser units (Omidvar et al., 2017). Some of the applications included in this pilot project are: toll tags and detectors, vehicle detection and classification, and automatic license plate recognition solutions.

2.4 CV Deployment Efforts outside the U.S.

Over 30 countries have been exploring CAV technologies. Deployments in Europe and Japan, as well as other pilot projects have proven the capability of CAV in improving transportation systems. Activities in Europe typically involve large-scale coalitions of governments, as well as academia and industry. Japan has already deployed a CV network using cellular, infrared, and DSRC communication. The following sections discuss the CV deployment efforts in Europe, East Asia, and other regions outside the U.S.

2.4.1 Europe

The European Union has several major initiatives and guidelines on cooperative, connected, and automated mobility. In 2013, the Trans-European Transport Network (TEN-T) was adopted, which set the framework for the development of cooperative intelligent transportation systems (C-ITS) through 2030 (Dennis & Spulber, 2016). Additionally, the European Commission has initiated an automated and connected vehicle working group. This group will advise the Commission on potential regulatory actions and investments to facilitate the beneficial adoption of connected and automated vehicles (Dennis & Spulber, 2016). Key projects involving C-ITS and driving automation across Europe are: the C-ITS Platform of the European Commission, Horizon 2020, and the Austria/Germany/Netherlands C-ITS Eco-AT Corridor (Dennis & Spulber, 2016).

2.4.2 East Asia

Chinese authorities have only recently started supporting the development of automated vehicle technology. They are however making considerable progress (Dennis & Spulber, 2016). In November 2015, Shanghai unveiled a 3.6 km (2 miles) road section for testing self-driving vehicles, the first of its kind in China. Shortly after, similar test sites in Beijing and Chongqing, and in the provinces of Hebei and Zhejiang were approved by the Ministry of Industry and Information Technology (Ti, 2016). In November 2015, Japan's Prime Minister announced an initiative to provide transport services using unmanned vehicles and to make automated driving possible on expressways by the 2020 Tokyo Olympics and Paralympics (Itsubo, 2016).

2.4.3 Other Regions

In August 2016, Australia published its National Policy Framework for Land Transport Technology, containing policy principles and a 2016-2019 Action Plan. The Australian government aims to support the deployment of CAV technology through policy leadership, supporting investment in digital infrastructure, providing access to transportation data, creating a supportive regulatory environment, and investing in Research and Development (R&D) (Commonwealth of Australia, 2016). South Australia became the first Australian state to allow testing of automated vehicles on its roadways in March 2016. Companies looking to test technologies must submit plans for approval to the Transport and Infrastructure Ministry.

2.5 Public Private Partnerships with Universities

Universities and academic institutions play an important role in the development of various research studies, pilot projects, etc. Universities often take part and sometimes lead the planning, design, build, and deployment phases of CV projects. The following sections discuss a few university-led pilot projects:

2.5.1 Carnegie Mellon University (CMU)

The CMU, Cranberry Township, the City of Pittsburgh, and Pennsylvania DOT (PennDOT) established a partnership in 2015 to improve transportation safety and mobility. The CMU Cranberry Township and Pittsburgh test bed included 11 traffic signals in Cranberry Township and 24 traffic signals in Pittsburgh, all equipped with DSRC. The PennDOT Ross Township Test Bed was deployed in 2014 through an FHWA Accelerated Innovations Deployment (AID) grant (Omidvar et al., 2017).

2.5.2 Ohio State University

The Ohio State University Center for Automotive Research has teamed up with the CISCO Company, the City of Columbus, the General Electric (GE) Company, the Mid-Ohio Regional Planning Commission (MORPC), and others to address the first mile/last mile challenge (Omidvar et al., 2017). The first mile to the bus stop and the last mile from the bus stop in the western portion of campus includes CAVs to move passengers on scheduled service vehicles or on-demand. These service vehicles are to be fully automated with V2V communication abilities for driving, and with smart light emitting diodes (LEDs).

2.5.3 University of Michigan

Working in partnership with automotive manufacturers, such as General Motors and Ford, the University of Michigan, the Road Commission for Oakland County, and a number of other partners, Michigan Department of Transportation (MDOT) has set a vision and is investing in V2I deployment in Southeast Michigan. The V2I applications being considered by MDOT are:

- red-light violation warning,

- work zone warning and management,
- road weather management, and
- pavement condition.

2.5.4 University of Florida

The University of Florida (UF) and its Transportation Institute (UFTI), along with FDOT and the City of Gainesville, are cooperating to develop a smart transportation test bed on the UF main campus and adjoining city streets. It is envisioned that the test bed will transform the transportation network on campus to support cross-communication between personal and mass transit vehicles, pedestrians, and traffic signals along critical routes (Omidvar, et al., 2017).

With the support of FDOT, the City of Gainesville, Regional Transit System (RTS), and participating industry partners, autonomous/connected vehicles and other advanced communication and data analysis technologies will be introduced to optimize traffic operations and increase safety within the campus and surrounding areas (Omidvar, et al., 2017).

2.6 CV Regulations

2.6.1 Florida

Passed in 2012, legislation in Florida declared the intent to encourage the safe development, testing, and operation of motor vehicles with autonomous technology on the state's public roads. In other words, Florida does not prohibit nor specifically regulate the testing or operation of autonomous technology in motor vehicles on public roads. Florida's 2016 legislation expands the allowed operation of autonomous vehicles on public roads and eliminates requirements related to the testing of autonomous vehicles and the presence of a driver in the vehicle (National Conference of State Legislature (NCSL), 2018).

2.6.2 National

With the rapid development of emerging technologies for connected vehicles, states and local governments are considering the potential impacts of such vehicles on the highway system. As shown in Figure 2.5, a number of states have enacted legislation or executive orders related to autonomous and connected vehicles. In September 2016, the USDOT published the Federal Automated Vehicle Policy for the safe development of highly autonomous vehicles (HAVs). The policy is primarily composed of the following four components (NCSL, 2018):

- *Vehicle Performance Guidance for Automated Vehicles*: This guidance is for manufacturers, developers, and other organizations, and outlines a 15 point "Safety Assessment" for the safe design, development, testing, and deployment of automated vehicles.

- *Model State Policy:* This section presents a clear distinction between Federal and State responsibilities for regulation of HAVs, and suggests recommended policy areas for states to consider with the goal of generating a consistent national framework for the testing and deployment of HAVs.

- *Current Regulatory Tools:* This discussion outlines USDOT's current regulatory tools that can be used to accelerate the safe development of HAVs, such as interpreting current rules to allow for greater flexibility in design and providing limited exemptions to allow for testing of nontraditional vehicle designs in a timely fashion.

- *Modern Regulatory Tools:* This discussion identifies potential new regulatory tools and statutory authorities that may aid in the safe and efficient deployment of new lifesaving technologies.

Portions of the policy report also apply to lower levels of automation, referring to driver-assistance systems already being deployed by auto manufacturers.

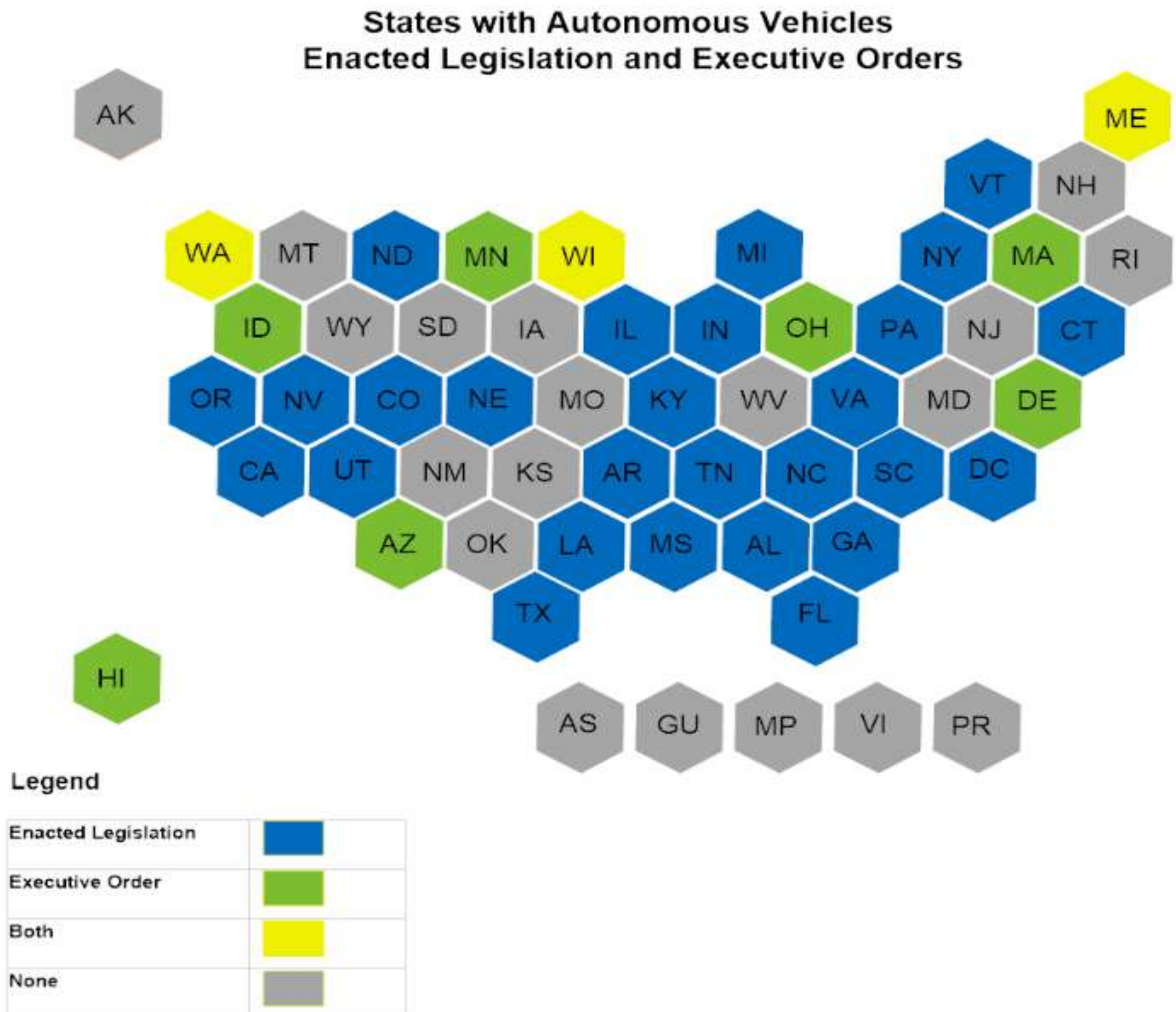

Figure 2.5: States with Enacted Autonomous Vehicle Legislation
(Source: NCSL, 2018)

2.7 Ongoing Florida CV Deployments

As of December 2018, the Florida CV Initiative included 18 CAV projects across the state (FDOT, 2018a). As shown in Figure 2.6, four projects are in the planning phase, 12 in the design or implementation phase, and two projects are operational. Specifics for each project in the Florida CAV program are listed in Table A.1, Appendix A. The following sections discuss details pertaining to ongoing CV projects in the program.

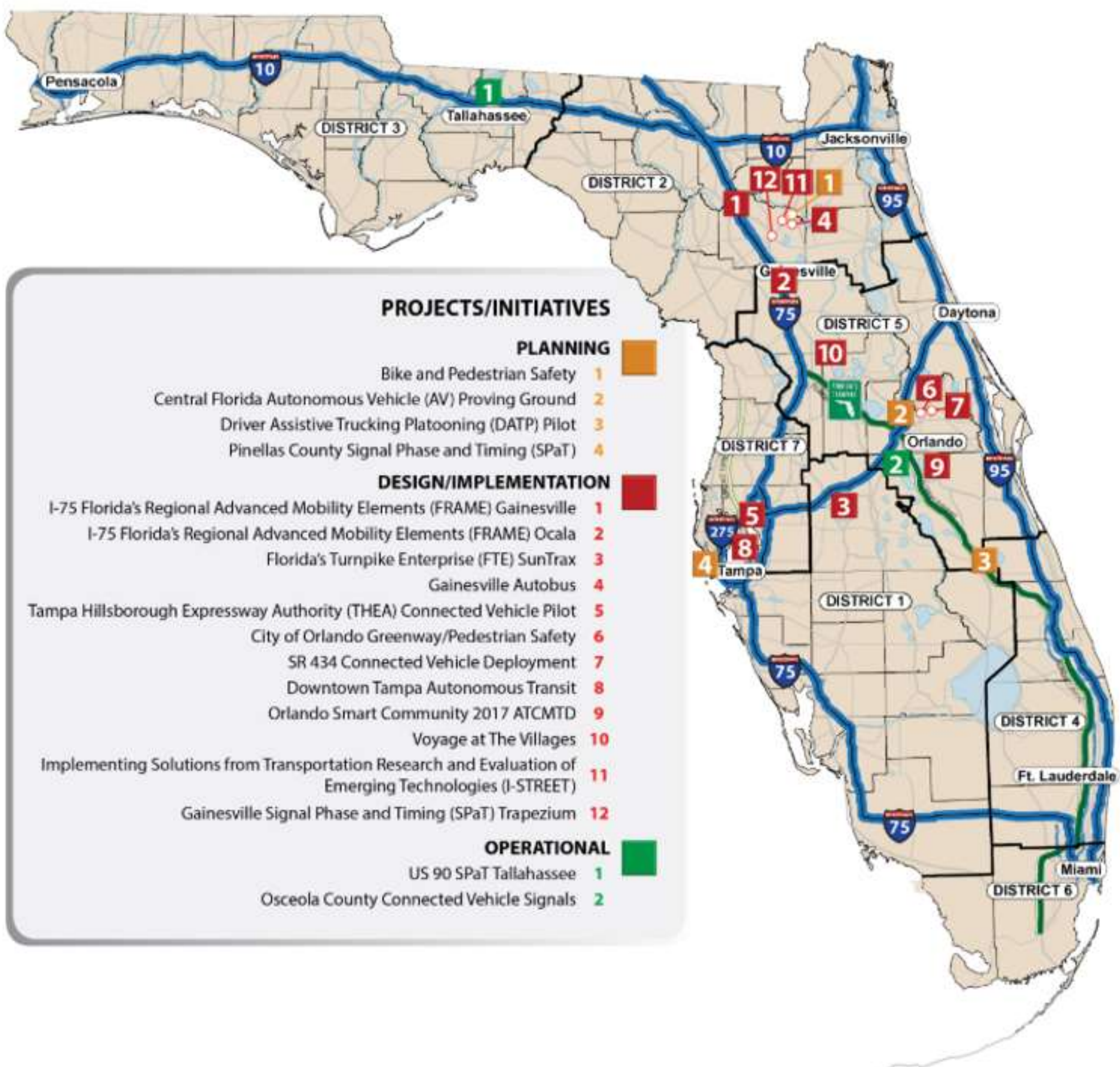

Figure 2.6: CV Projects in Florida
(Source: FDOT, 2018a)

2.7.1 Bike and Pedestrian Safety

Currently in the planning phase, the UF AID project is a CV pilot project in District Two that focuses on the safety of Vulnerable Road Users (VRUs), such as pedestrians and bicyclists

(FDOT, 2018a). The goal of the project is to reduce pedestrian and bicycle crashes and conflicts with vehicles and transit. The project includes 13 intersections and seven mid-block crossings located within the UF campus, as shown in Figure 2.7. SPaT data will broadcast with active pedestrian/bicyclist detection to cell phones and in-car dash units, also known as OBUs. Other CV applications include passive pedestrian/bicyclist detection and real-time notification to transit, motorists, and pedestrian/bicyclists. Up to 20 RSUs and 20 passive pedestrian detection systems will be installed on the corridors (FDOT, 2018a). Although this is a pilot project for Florida, other states have deployed this type of CV application to improve the safety of VRUs.

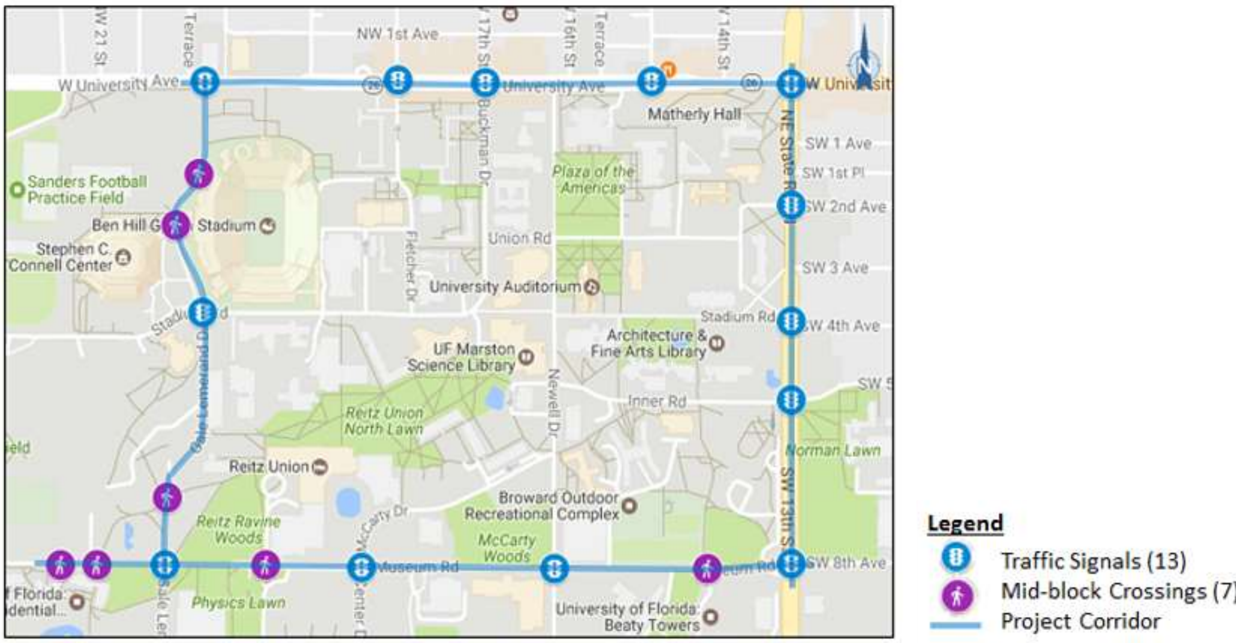

Figure 2.7: UF AID Project Map
(Source: FDOT, 2018a)

2.7.2 Pinellas County Signal Phase and Timing (SPaT)

The Pinellas County SPaT project is a Florida CV initiative located in District Seven, and currently in the planning phase. Partnering with Pinellas County, the project will deploy CV technology at 23 signalized intersections along the US 90 corridor, as shown in Figure 2.8 (FDOT, 2018a). SPaT information will broadcast at 11 traffic signals along US 90 and 12 traffic signals on adjacent frontage roads along the corridor (FDOT, 2018a).

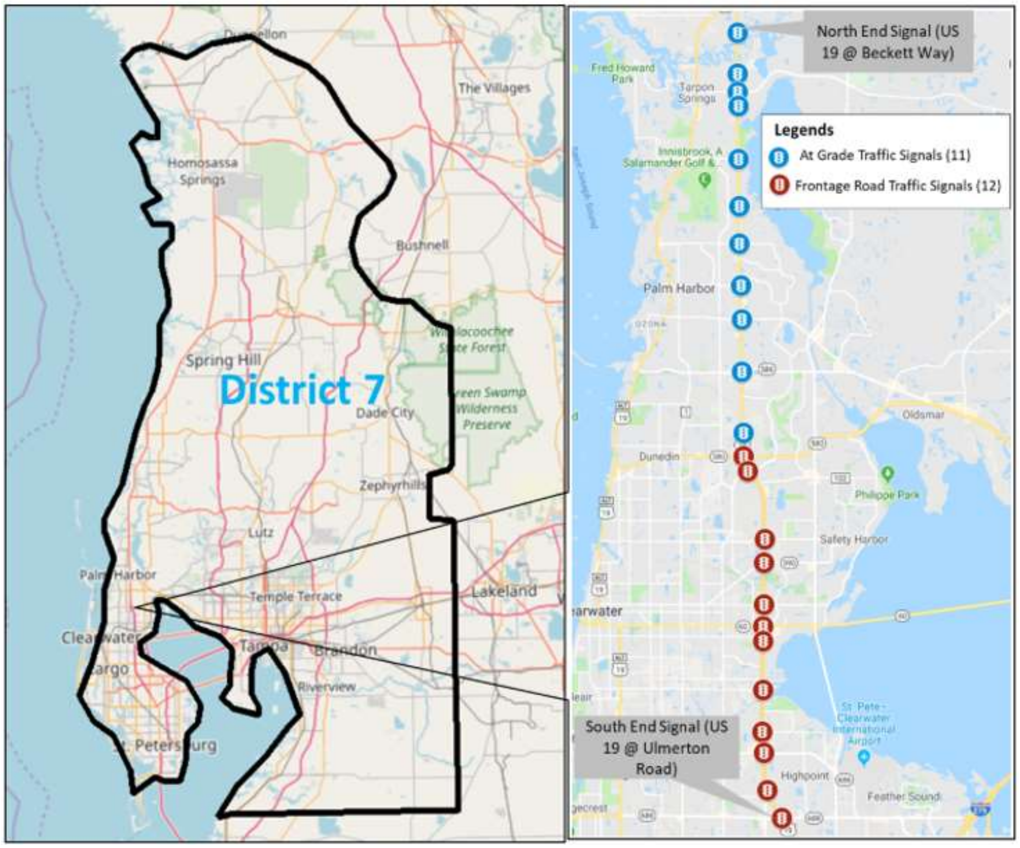

Figure 2.8: Pinellas County SPaT Project Map
(Source: FDOT, 2018a)

2.7.3 I-75 Florida's Regional Advanced Mobility Elements (FRAME)

The I-75 Florida's Regional Advanced Mobility Elements (FRAME) project seeks to optimize the use of transportation infrastructure for improved safety and mobility along sections of the I-75 corridor identified in an earlier FDOT study. The project originated based on the need to detour traffic resulting from an incident on the corridor in Districts Two and Five. The I-75 corridor also serves as an important emergency evacuation route for the Tampa and Miami areas.

The project will deploy emerging technologies to better manage, operate, and maintain the multi-modal transportation system, and create an Integrated Corridor Management (ICM) solution on I-75 and state highway systems in the Cities of Gainesville and Ocala (FDOT, 2018b). As shown in Figure 2.9, the project limits span from Wildwood in District Five to Alachua in District Two. Each District will manage their portion of the project separately, resulting in essentially two projects: I-75 FRAME Gainesville (District Two) and I-75 FRAME Ocala (District Five).

The I-75 FRAME project is currently in the design phase and will use developing technologies, such as automated traffic signal performance measures and CV technologies involving RSUs and OBUs, for effective traffic operations, transit signal priority, and freight signal priority (FDOT, 2018b). The project will deploy RSUs every two miles along I-75 in Alachua County at existing CCTV locations. RSUs will also be installed every two miles along a 50-mile rural segment of US 301/US 441 at planned CCTV locations, and at signalized intersections with Multi-Modal Intelligent Traffic Safety Systems (MMITSS) (FDOT, 2018b). A total of approximately 150 RSUs are planned for installation along this section of I-75 with the goal of disseminating real-time information to motorists during freeway incidents (FDOT, 2018b). RSUs will send and receive messages to and from connected vehicles, transit, freight, and emergency vehicles, and other RSUs using the 5.9 GHz DSRC (Omidvar et al., 2017). Additionally, the I-75 FRAME will deploy 50 miles of fiber optic cables along the US 301/US 441 corridor (FDOT, 2018b).

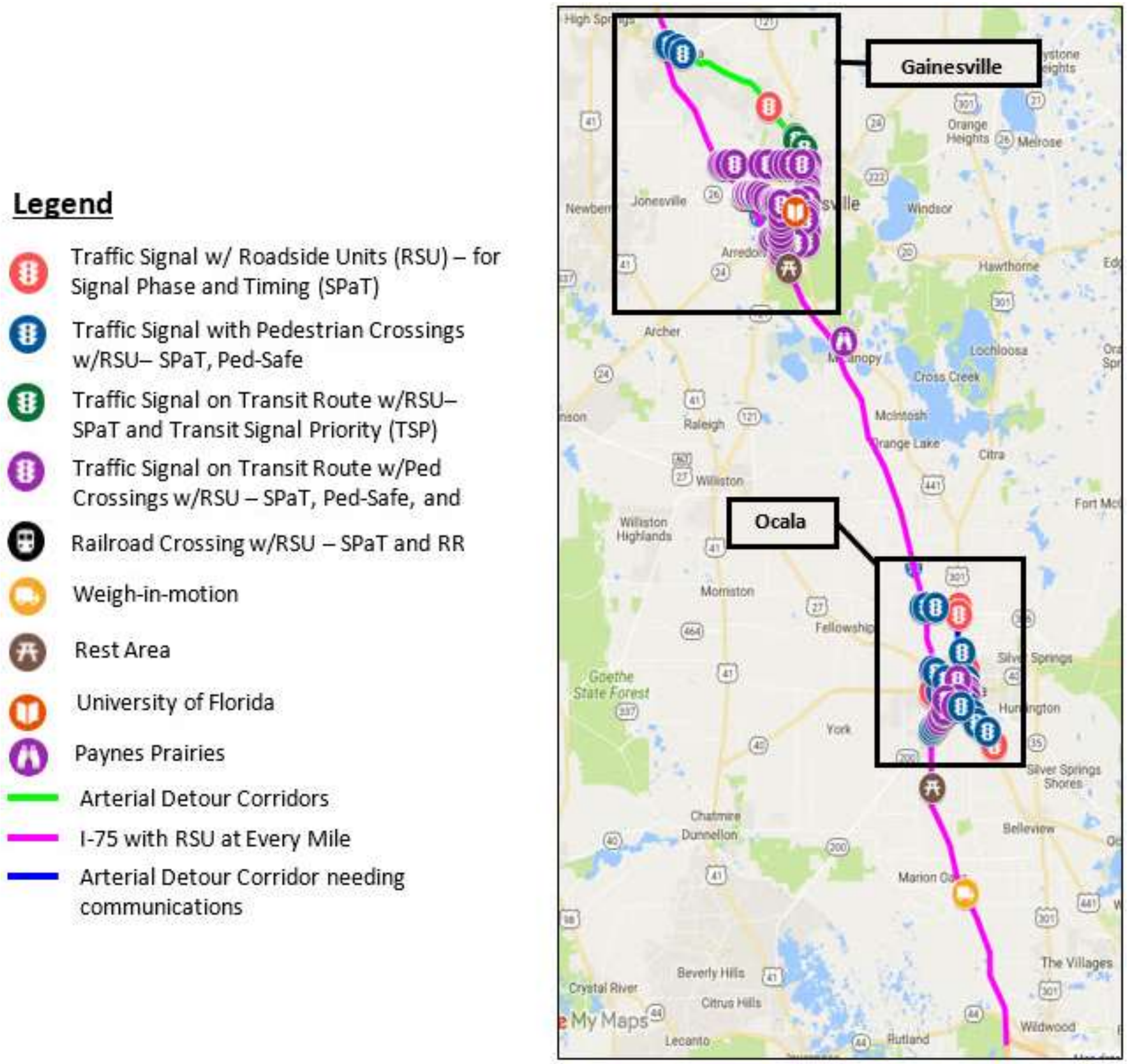

Figure 2.9: I-75 FRAME Project Limits
(Source: FDOT, 2018b)

2.7.4 Tampa Hillsborough Expressway Authority (THEA) Pilot Study

The Tampa Hillsborough Expressway Authority (THEA) CV Pilot Program is one of the three CV pilot programs awarded by the USDOT (see Figure 2.1). Refer to Section 2.2.3 for details.

2.7.5 City of Orlando Greenway/Pedestrian Safety

Located in District Five, the Greenway/Pedestrian Safety project consists of two separate, but connected, projects in the City of Orlando. The pedestrian safety component, also called the "PedSafe" component, will use CV technologies to reduce the occurrence of pedestrian and bicycle crashes. A pedestrian collision avoidance system will be implemented within the University of Central Florida (UCF) campus and along SR 50 from Hiawassee Road to Silverton Street/Pete Parrich Boulevard. CV components will include RSUs, and OBUs, and audible basic safety messages using DSRC. Advanced sensor technology will also be used to produce real-time turning movement counts, saturation flow rates, right on red, and permissive yellows (FDOT, 2018a). CV applications being deployed include: EVP, TSP, and SPaT.

The Greenway component of the project seeks to increase throughput capacity and reduce congestion along with improving the multimodal movement of people and goods and optimizing existing traffic operations, in terms of flow rate and safety, for all multimodal traffic during peak travel times and special events (FDOT, 2018a). Advanced Sensor Technology with future DSRC capability will be deployed at nearly 250 signalized intersections (FDOT, 2018a).

Other elements of the project include the installation of CCTV cameras for a Parking Availability System and a Transit User Verification System to be utilized at UCF. The parking availability system will provide real-time information on parking availability for UCF student parking lots, and the transit user verification system will determine the presence of students waiting for buses.

2.7.6 SR 434 Connected Vehicle Deployment

The SR 434 CV project is located in Seminole County, north of UCF on SR 434, from McCulloch Road to E Mitchell Hammock Road, as shown in Figure 2.10. The project also serves as the starting point of the Orlando Greenway/PedSafe project.

This project includes approximately eight RSUs, utilizing SPaT, EVP, and TSP applications along SR 434 (FDOT, 2018a). Signal performance metrics (SPM) will also be implemented with data captured through a retrofit technology (FDOT, 2018a). The project is expected to be operational by early 2019.

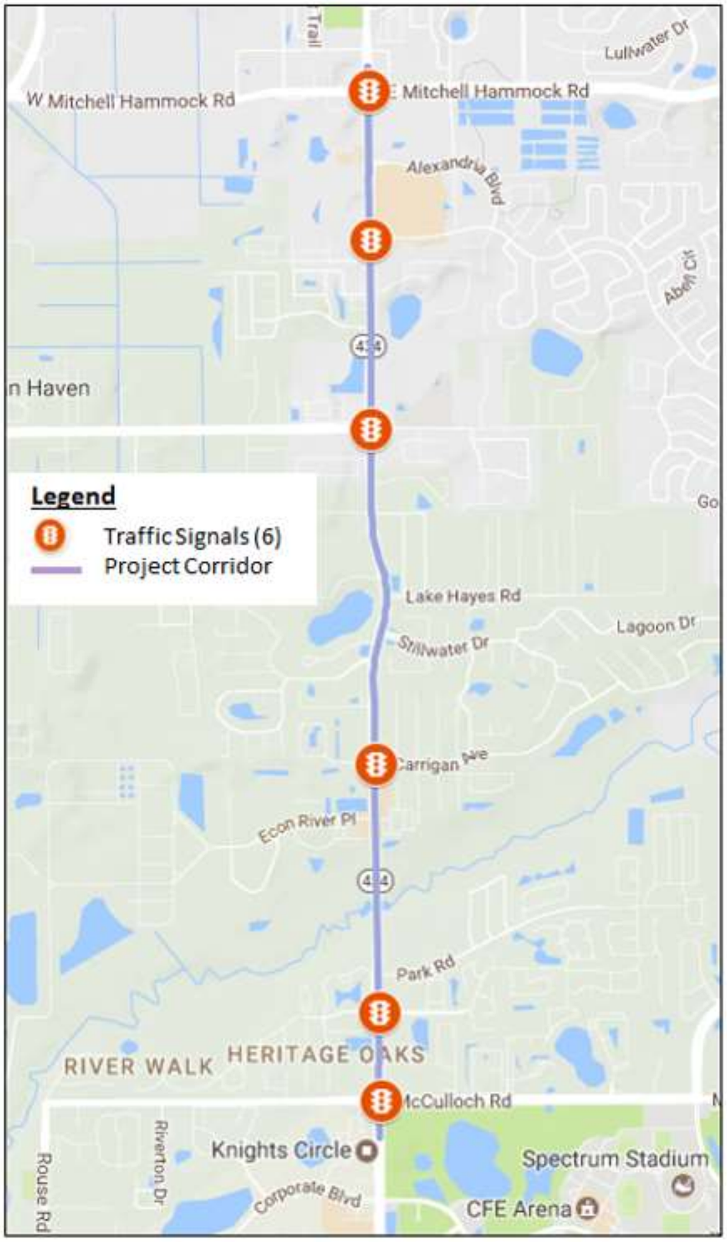

Figure 2.10: SR 434 CV Project Map
(Source: FDOT, 2018a)

2.7.7 Gainesville Signal Phase and Timing (SPaT) Trapezium

The Gainesville SPaT project will deploy and test CV technologies and applications along four corridors (SR 121, SR 26, US 441, and SR 24) forming a trapezium surrounding the University of Florida main campus in Gainesville, as shown in Figure 2.11. The project includes approximately 45 RSUs and 27 signalized intersections broadcasting SPaT information using DSRC, with the goal of improving travel time reliability, safety, throughput, and traveler information (FDOT, 2018a). Pedestrian and bicyclist safety applications also will be deployed for both web-based and smartphone-based applications (FDOT, 2018a). The project is anticipated to become operational by late 2018 (FDOT, 2018a).

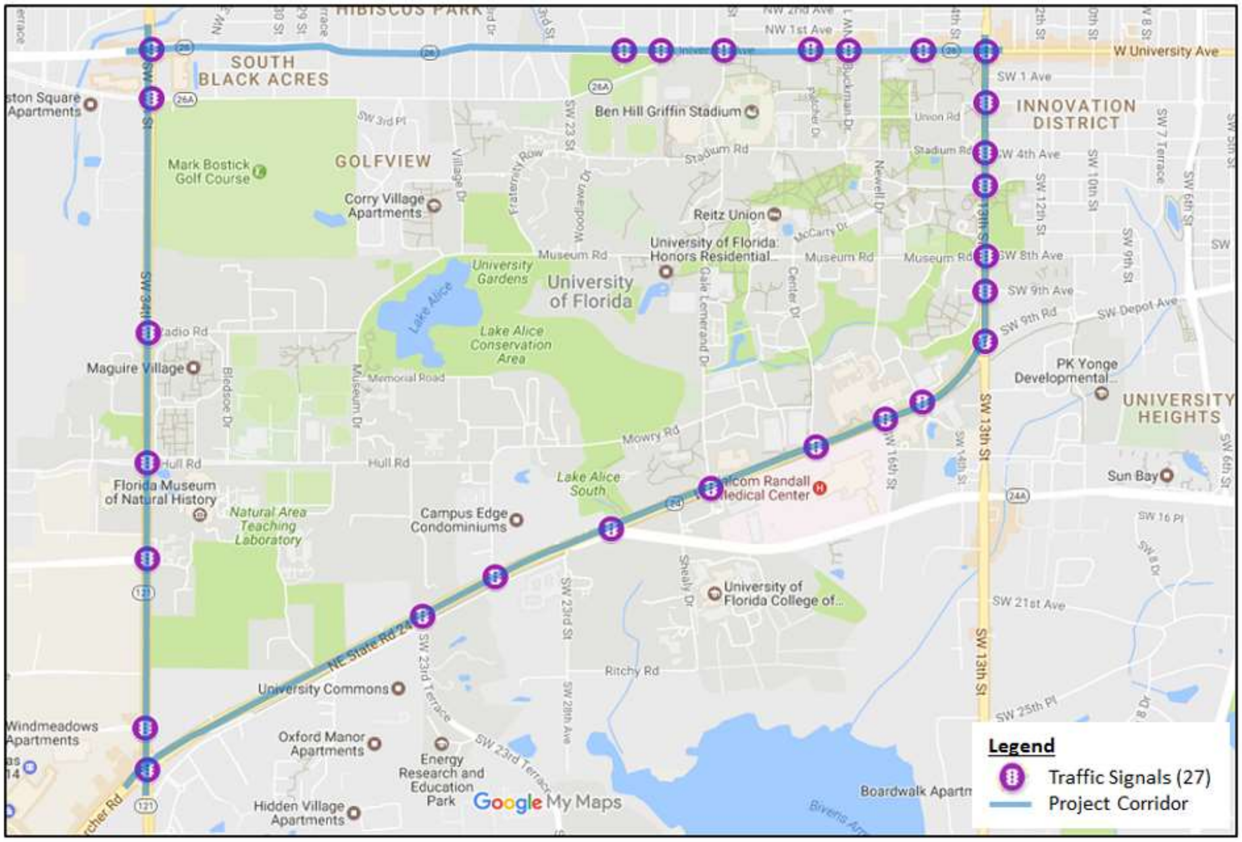

Figure 2.11: Gainesville SPaT Trapezium Project Map
(Source: FDOT, 2018a)

2.8 Completed Florida CV Deployments

Two CV projects in the Florida CV Initiative are operational (see Figure 2.6). The US 90 SPaT project in Tallahassee became fully operational in 2018, while an earlier project, the Osceola County CV Signals, became operational in April 2016. A third project, the Connected Vehicle Affiliated Test Bed along I-4 in Orlando, was the earliest implementation of CV technology in Florida and served as a precursor to the FDOT CAV program. The following sections describe these three CV projects.

2.8.1 US 90 SPaT Tallahassee

To meet the AASHTO SPaT Challenge (AASHTO, 2017) for DSRC deployment, an approximately eight-mile segment along US 90 (Mahan Drive) in Tallahassee was selected to deploy CV technologies at 22 intersections (see Figure 2.12). The project is expect to be operational in 2018 with SPaT information continuously broadcasting using DSRC to vehicle OBUs in the form of BSMs and Traffic Information Messages (TIMs).

From research performed by Florida State University, in collaboration with FDOT, a Security Credential Management System (SCMS) will also be deployed to protect the system by verifying the legitimacy of V2V and I2V messages. The deployment of the SCMS marks a significant step in Florida's CV Initiative, as it will be the first SCMS deployed anywhere in the country, outside of the three USDOT pilot projects shown in Figure 2.1.

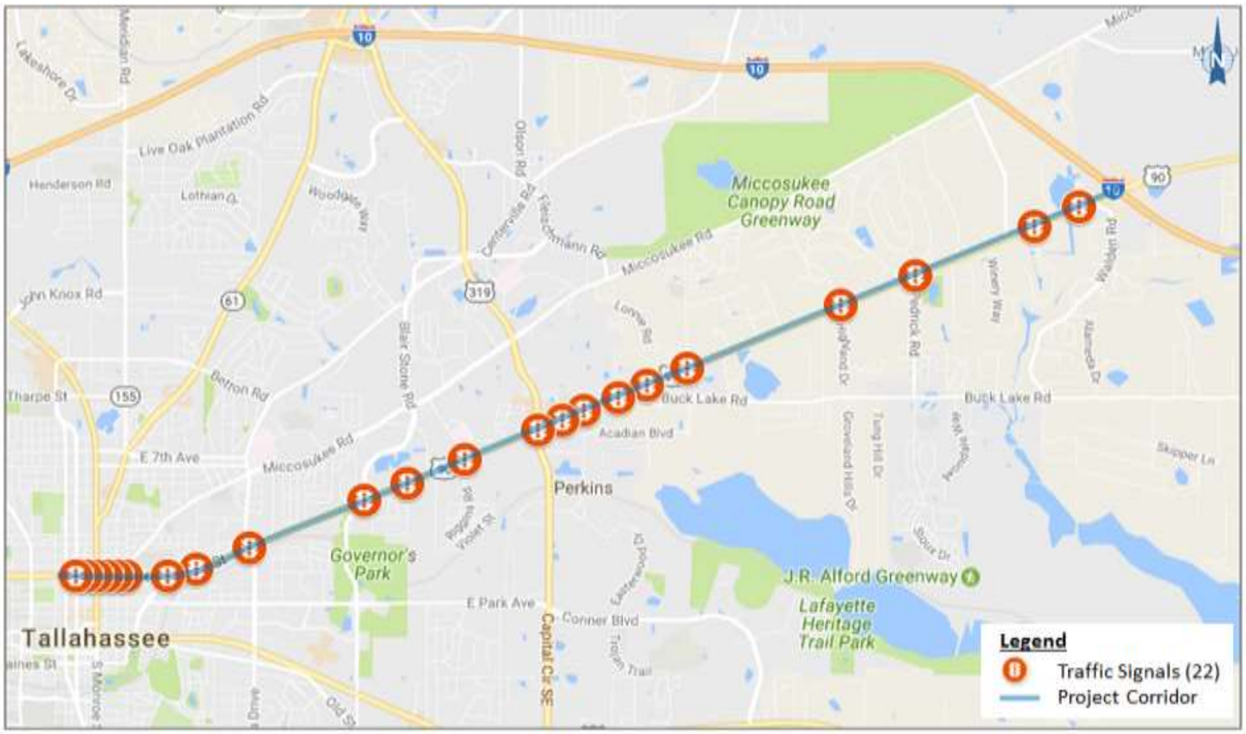

Figure 2.12: US 90 SPaT Tallahassee Project Map
(Source: FDOT, 2018a)

2.8.2 Osceola County CV Signals

Sponsored by FHWA, this project served as a pilot project to test DSRC equipment intersection processing equipment at two intersections in Osceola County (FDOT, 2018a). The purpose of the project was to gain experience and compile lessons learned in the deployment of CV infrastructure and applications (FDOT, 2018a). RSUs were deployed at one intersection containing mast arm signals (Orange Blossom Trail and Poinciana), and one intersection containing span wire signals (Osceola Parkway and Orange Blossom Trail) (FDOT, 2018a). Depicted in Figure 2.13, these locations were selected based on the existing controller types and the availability of communications.

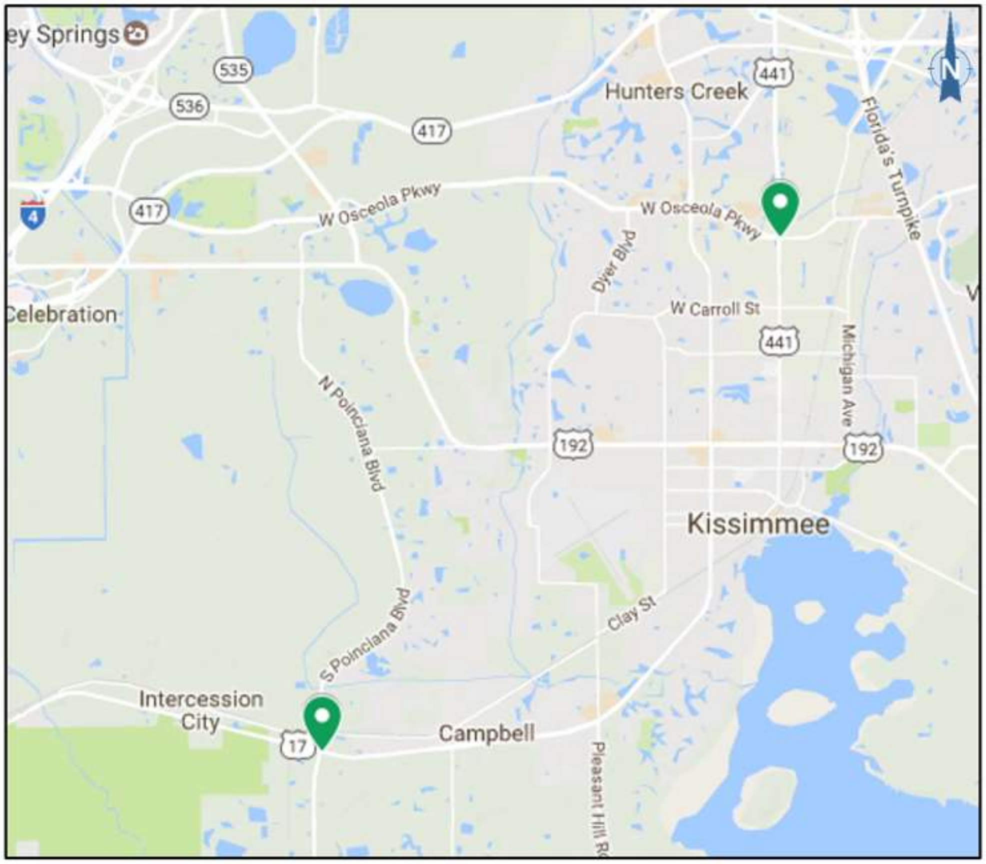

Figure 2.13: Osceola County CV Signals Project Map
(Source: FDOT, 2018a)

2.8.3 Orlando CV Project

The Connected Vehicle Affiliated Test Bed along I-4 in Orlando, launched in 2011 for the ITS World Congress, is one of the earliest CV initiatives in Florida. Figure 2.14 shows the study limits of the project. FDOT established the test bed to find the best options to continuously and swiftly communicate information between the OBUs and RSUs. The site featured 29 radio RSU devices connected to FDOT's existing fiber optic network (Omidvar et al., 2017). Location and speed information was collected from the vehicles, and basic safety messages were sent to the equipped vehicles using DSRC. The RSUs relayed messages to/from the FDOT Orlando Regional Traffic Management Center (RTMC) via the fiber optic network (Omidvar et al., 2017). Vehicles were equipped with a two-way OBU radio, a GPS-based Vehicle Awareness Device, and a small computer that receives and displays information in the form of BSMs from the RTMC (Omidvar et al., 2017). The test bed featured a total of 11 RSUs along I-4.

Figure 2.14: Scope of CV Test Bed in Orlando
(Source: Omidvar et al., 2017)

The RSUs provide V2I communication, data analytics, data transmission to SunGuide software, and can broadcast travel advisory messages. The test bed is currently functional, and the RTMC collects traffic data, namely speed and flow data, from over 400 devices and 240 CCTV traffic cameras along 33 roadways (Omidvar et al., 2017). Road Rangers and the Florida Highway Patrol (FHP) are also able to communicate with the RTMC.

2.9 CV-related Florida Projects

2.9.1 AV/CV Beachline Pilot Deployment (FTE)

The Beachline CAV pilot project is a test corridor developed for connected vehicles on Beachline Expressway (SR 528) between I-4 and the easternmost limits of the corridor. Currently in the planning phase, the project's CV components include DSRC radios and field sensor technology. Applications, such as dynamic speed management, lane departure warnings, curve warnings, incident and construction zone warnings, as well as weather-related warnings, will be used. OBUs will also be installed in pool vehicles and Road Rangers.

An after-deployment study will evaluate message content, data requirements, and network impacts to ensure seamless bi-directional traffic can be accommodated across the Turnpike's ITS network. Results from the study will help FTE project managers determine what is needed to manage the data, as current estimates indicate that up to one terabyte of data may be required per vehicle per day.

2.9.2 Connected Vehicle Readiness Study: Implementation Plan (FTE)

Currently in the planning phase, FTE is working closely with other District TSM&O groups and the Central Office to conduct a CV readiness study to determine the readiness of the Turnpike to deploy CV technology. Results from the study will help FTE project managers identify appropriate deployment strategies and develop a deployment plan.

2.9.3 Data User Agreements

A data user agreement is a CV-related element that allows for the sharing of data obtained from CV systems between state and local agencies/organizations and equipment vendors, manufacturers, or technology companies. Currently there are several ongoing agreements in District Two between the City of Gainesville and private companies that provide traffic signal data to a number of automotive manufacturers. Although the data user agreements are between the City and the data providers, UF and FDOT are included as entities allowed to receive the data collected. FDOT is working toward developing standard data user agreements, as well as including a data component in the Florida CV Initiative.

3 – PROCUREMENT SURVEY – FLORIDA

FDOT project managers from Districts Two and Five, the Central Office, and FTE were interviewed in May 2018 to discuss the procurement process used for the CV projects in their districts. One project manager from the City of Gainesville was also interviewed. Questions asked ranged from the procurement approach, the amount of time and resources required by FDOT project managers and staff to lessons learned and best practices realized from the procurement process (see Appendix B). Discussions focused on the following projects:

- US 90 SPaT Tallahassee (Central Office)
- Gainesville SPaT Trapezium (District Two)
- I-75 FRAME Gainesville (District Two)
- I-75 FRAME Ocala (District Five)
- SR 434 Connected Vehicle Deployment (District Five)
- City of Orlando Greenway/Pedestrian Safety (District Five)
- Osceola County CV Signals (District Five)

Sections 3.1 through 3.7 discuss available information related to the procurement process, time and resources required, purchasing of system components, challenges, and lessons learned for the above listed projects. Section 3.8 discusses the guidelines and references used by project managers during the procurement process, in general. Note that FDOT time and resources, challenges, and lessons learned on the I-75 FRAME Ocala project in District Five (Sections 3.3.3 – 3.3.5) also apply to the two other ongoing CV deployments in the district (SR 434 CV Deployment and City of Orlando Greenway/Pedestrian Safety). A brief description of each project can be found in Section 2.7 of this report.

3.1 US 90 SPaT Tallahassee (Central Office)

3.1.1 Procurement Process

Spearheaded by the FDOT Central Office, the TSM&O group used a hybrid systems development approach consisting of combination of a “Vee” development model (see Figure 8.2) and the Agile method, with iterative adjustments made as the project progressed. The procurement process began with the development of the Request for Proposal (RFP) with assistance from the FDOT Procurement Office and General Engineering Consultant (GEC). The RFP, although standard boiler-plate, was distinctive in that a testing component was included as prequalification measure, requiring each responding contractor to successfully demonstrate that their system worked prior to opening the bid proposals.

Four vendors responded to the RFP. After evaluating and scoring each technical proposal, three vendors were short-listed and invited to demonstrate their systems for FDOT (i.e., the testing component in the RFP). Only two vendors responded to the testing invitation, and only one vendor passed the test, and so was awarded the contract after the bid opening.

Solely state funded, FDOT was the primary stakeholder, as the project owner, sponsor, and administrator. The equipment was furnished by the contractor and installed by the City of Tallahassee. The GEC for FDOT worked as the Systems Integrator (SI) for the project, with some collaboration with the City and the vendor, and all parties were involved in the testing and evaluation phase. Training on the system components will be conducted by the selected vendor.

3.1.2 Purchasing Approach

The approach used in purchasing the system for the US 90 SPaT project was similar to a Design-Bid-Build (DBB) approach. In a typical DBB project, the sponsor develops the design, issues a RFP, and the selected contractor/vendor builds the project without help from other stakeholders. For the US 90 SPaT project, a great deal of support was provided to vendor by the TSM&O project manager, FDOT's GEC, and the City of Tallahassee. This method provided valuable experience and knowledge with CV deployments to all parties involved.

3.1.3 FDOT Time and Resources

A considerable amount of time was required by the TSM&O project manager during the procurement phase of the US 90 SPaT project, beginning with the development of the RFP. Approximately 2-4 hours per week were required prior to, and up to 15 hours per week were required during the procurement phase of scoring the technical proposals, evaluating the system through a testing component, and developing the contract with the selected vendor. Following the procurement phase, the time required to manage the project reduced to approximately four hours per week for the remaining six months of the project.

3.1.4 Challenges

With emerging technologies, knowing what applications and/or equipment that is available or suitable to meet the project goals can be challenging for project managers, especially without vendor input. Upfront work to develop a better understanding of current technologies is often required during the planning phase, and can minimize contract development challenges. For the US 90 SPaT project, this upfront work was conducted by the TSM&O team prior to issuing the RFP; however, the team later realized that more information would have been useful. Although the project went well in this case, future CV projects may benefit from adding a Request for Information (RFI) in the RFP, or some form of RFI process.

The security of system is always a concern for traffic engineers. To address this issue, a Security Credential Management System (SCMS), developed with Florida State University, will also be deployed to protect the system. The SCMS works by verifying the legitimacy of all V2V and I2V messages. Upon completion of the US 90 SPaT project, a separate contract will be obtained with a company that specializes in security credential management. The deployment of the SCMS marks a significant step in Florida's CV Initiative, as it will be the first SCMS deployed anywhere in the country, outside of the three USDOT pilot projects. The results of this effort could potentially lead to the SCMS being implemented in other CV projects throughout the state.

3.1.5 Lessons Learned

Map data is an essential component of any CV project, and accurate coding of the geo-data is crucial for the system to work properly. For the US 90 SPaT project, FDOT provided the three short-listed vendors with the map data of the corridor, developed in-house with their GEC. Although FDOT had verified that the map data was accurate, the vendors were required to independently verify the accuracy and compatibility with their proposed system prior to the testing phase of the contractor selection process. Two of the three short-listed vendors participated in the testing phase. During the testing demonstration in the field, one vendor was unable to get their system to work and assumed the problem resided with the map data. However, the second vendor was able to demonstrate their system successfully, following a few minor adjustments, and therefore, was awarded the contract. For future CV projects, a preferred approach would be to require prospective vendors/contractors to develop their own map data.

The testing requirement, added in the RFP, was also integral in the success of the project. FDOT could have selected one of the two short-listed vendors based on the qualifications of the company. However, during the testing demonstration, this particular vendor did not pass the test, and so the second vendor was awarded the project after successfully passing the testing element of the selection process.

The procurement of vehicle OBUs for the project was more difficult and time consuming for the contractor than the purchasing of RSUs. The contractor had identified an RSU vendor in their technical proposal; however, OBUs are highly customized based on the project applications deployed. Building custom OBUs require considerable time by the contractor. This realization should be considered by FDOT project managers.

Another lesson learned related to the Federal Communications Commission (FCC) compliance of the proposed equipment. Although the RFP stated that the equipment should be FCC compliant, it was observed that some vendors are not familiar the FCC rules. With the US 90 SPaT project, a problem occurred related to FCC requirements that the selected vendor was unaware of during the RFP process. This issue led to extensive time required by the FDOT TSM&O project manager (8-10 hours per week for one month) to address the problem. The key lesson learned is that both the RSUs and OBUs should be FCC compliant and licensed. For future CV projects, requiring FCC compliance documents in the RFP may help to minimize this type of issue.

3.2 Gainesville SPaT Trapezium (District Two)

3.2.1 Procurement Process

Similar to the US 90 SPaT project, a combination “Vee” development model and the Agile method systems development approach was used for the Gainesville SPaT Trapezium project. Currently in the procurement phase, the stakeholders include UF, City of Gainesville, and FDOT, with FDOT Central Office TSM&O group leading the effort. The procurement process began with the development of the RFP, which specifically calls for the contractor to develop their own map data for the project – a lesson learned from the US 90 SPaT project. Additionally, the RFP calls for the selected vendor/contractor to furnish and install the proposed equipment.

3.2.2 Challenges

Since the Gainesville SPaT project is presently in the procurement process, specific challenges or lessons learned have yet to surface. However, one challenge related to system components has been realized. Recently, FDOT project managers observed that some of the published standards for software have not been adopted by all vendors; as a result, available software is not standardized throughout the industry. This requires that Commercial-off-the-shelf (COTS) products, if used, must be adjusted by the vendor to work with the FDOT's system.

3.3 I-75 FRAME Gainesville (District Two)

3.3.1 Procurement Process

Currently in the design phase, this project is state funded and expected to be operational by May 2019. Stakeholders include FDOT District Two, UF, and the City of Gainesville, with FDOT leading the effort. The systems development approach being used is a phased approach, where the system is developed and built in major steps or stages, allowing feedback to subsequent stages, e.g., Build 1, Build 2, Build 3, etc.

District Two TSM&O project managers are serving as the Systems Manager (SM), and a design consultant was acquired to design the system and develop the design documents. The consultant is also assisting FDOT in the testing of potential products through the FDOT's Traffic Engineering Research Lab (TERL), and SI will be acquired for the implementation of the system. Once testing and evaluation is complete, FDOT will contract with qualified vendors for the CV components, through the FDOT Procurement Office, and FDOT will purchase and provide the equipment to the selected contractor. Although District Two has used the SM/SI approach with previous projects, the method of procuring CV items for the I-75 FRAME project differs from the generally preferred method, where the contractor would furnish and install the equipment.

3.3.2 Purchasing Approach

District Two is doing a 2-step evaluation of the process for the technology that will be deployed on I-75. Because the DSRC antennas, RSUs, and OBUs are typically manufactured by different vendors, many of them pair their products together and guarantee successful operation of the system only with those paired products. Therefore, District Two invited "sets" of vendors to test their products through TERL.

Selected products will then be installed in the field at selected arterial roadway sites within the project limits and evaluated by the City under real-world conditions. CV components will be purchased by FDOT following the testing and evaluation process, and FDOT will contract with vendor(s) for the products. Specific products will be selected, and not limited to the tested sets. It is anticipated that COTS equipment/products will be used in the project, with some software development required. Additionally, FDOT is requiring the vendor to develop the map data of the City for the OBUs.

3.3.3 Challenges

The City of Gainesville already has infrastructure in place, much of which is made by Trafficware. One challenge is considering whether to work with the existing infrastructure or replace some units for the I-75 FRAME project. To make this determination, FDOT designers are working with the City to explore what elements of the current system can be improved, retrofitted, or replaced. Having full control over the selection and purchasing of CV items will allow FDOT to better integrate the project system with the existing infrastructure in the City.

3.3.4 Lessons Learned

At this point in the project, lessons learned involve the testing of equipment. Based on experience gained from the TERL testing process, District Two project managers have learned that technical specifications provided to the contractor in a "furnish and install" contract, may not result in components working together. Therefore, having vendors go through the TERL for testing allows FDOT to verify the compatibility of products before purchasing.

3.4 I-75 FRAME Ocala (District Five)

3.4.1 Procurement Process

A phased systems development approach is also being used for the District Five portion of the I-75 FRAME project (Ocala). However, each stage will consist of an application deployment rather than a physical build element. This enables FDOT to identify potential problems and modify the "Vee" model throughout the deployment stages.

A consultant was selected to serve as the SM to develop the systems engineering management plans and design documents. The use of a SM is new to District Five; however, having the design consultant share in the risks can help to mitigate the risks to FDOT, especially with new initiatives, such as CV deployments. Not only is the SM responsible for developing the design documents, they must also test the hardware and software to make sure the system works, both prior to construction and following the initial round of installations. The project will have a SI for the implementation of the system.

Unlike other FDOT districts, the TSM&O group procures the consultants. Accordingly, the procurement process for the I-75 FRAME Ocala project was initiated by the TSM&O group with the acquisition of the SM.

3.4.2 Purchasing Approach

A DBB approach is being used to purchase the system on the Ocala portion of the I-75 FRAME project. With this approach, after design, specifications for parts of the system are released, then the contractor/systems integrator makes sure that it all works together.

District Five is using technical special provisions for CV-related items, to be included in the plan documents. The contractor, in this case the SI, will select and provide the system components that accommodate the desired functions outlined in the special provisions. Additionally, software for the EVP, TSP, and SPaT applications is expected to be COTS products.

OBUs will be purchased at the time the project becomes operational and installed in vehicles, such as transit and fire services. The total number of OBUs to be purchased can be determined once agreements are established between FDOT and the various agencies.

3.4.3 FDOT Time and Resources

Based on the time and resources expended for the I-75 FRAME Ocala project and other CV deployments, District Five project managers stated that these type of projects require twice the amount of time to manage compared to other projects that they have experienced. Due to the testing involved, CV projects also require more time and personnel for the consultant. As a result, a more realistic value of capital costs for design time may be closer to 20% of the project value for CV projects, compared to the 9-12% allotted for typical transportation projects.

3.4.4 Challenges

Obtaining and testing the necessary project equipment, as well as the coordination effort to verify the equipment works have presented challenges with CV projects. U.S. vendors typically have a limited number of units available for organizations to test. If none are available at the time the agency needs them, international vendors are contacted. In either case, verifying that the equipment works often requires teleconferences with the vendor's technical experts.

Complications can arise with simply scheduling a teleconference, ranging from different time zones, language barriers, and the current work load of vendor. The few number of vendors in the industry creates another challenge with receiving products within a specified time frame. With the I-75 FRAME Ocala project, products for testing were received by District Five over two months later than requested.

Getting FCC approval for the equipment selected for the I-75 FRAME Ocala project is a concern. Much of the information required by the FCC, such as the specific vendor, height and model number, serial number, etc., is unknown until the contractor provides the equipment. Navigating through the FCC licensing process may require considerable time for FDOT. Taking this under consideration, FDOT may elect for the contractor to obtain FCC approval.

FDOT project managers are well acquainted with the process of acquiring a consultant. The recurring challenge with CV projects is acquiring a consultant with sufficient knowledge and exposure with emerging technologies and CV project development processes. Currently, the industry is week in this respect. However, District Five project managers noted that contractors that typically pursue traditional TSM&O projects are working to develop a greater knowledge of CV systems.

3.4.5 Lessons Learned

To determine which CV components would work with the existing controllers operated by local agencies, District Five conducted a market survey to evaluate available products. This effort required more time and resources than anticipated by FDOT. On future CV products, if market research is needed, additional time should be considered to complete the effort.

Currently in the design phase, equipment testing on the I-75 FRAME Ocala project has not been completed. One lesson learned at this point is the effects of the testing process on the project schedule and time spent by FDOT project managers. Moreover, claims made by vendors, referring to the capability of a device, are not always accurate. In future CV deployments, additional time should be allocated to allow the vendor to deploy and demonstrate the capability of their devices, as well as test the interoperability of all devices with the existing infrastructure.

Although applications to be installed consist of EVP, TSP, and SPaT, additional applications are anticipated in the future. Adding more applications to the MMITSS may possibly exceed the capability of the processor on the RSU. This issue has been identified by Utah DOT (UDOT) when assessing their CV deployments. Drawing from UDOT's experience, District Five is planning to conduct performance monitoring with the initial three-application deployment and determine what is needed to move forward with future applications.

3.5 SR 434 Connected Vehicle Deployment (District Five)

3.5.1 Procurement Process

Planning for the SR 434 CV project began during the time when the I-75 FRAME Ocala project entered the planning phase. Therefore, District Five TSM&O project managers decided to use the same project development approach for both of these deployments. An application phased approach, described in Section 3.3.1, was used to develop the system.

A SM was acquired to develop the systems engineering management plans and design documents. Following the testing and evaluation of CV components, a SI will be procured by the TSM&O group.

3.5.2 Purchasing Approach

Similar to the I-75 FRAME Ocala project, a DBB approach is being used to purchase the system, and technical special provisions for CV components will be included in the plan documents.

OBUs will be purchased at time the project becomes operational, and COTS products are anticipated for the EVP, TSP, and SPaT applications.

3.6 City of Orlando Greenway/Pedestrian Safety "PedSafe" Project (District Five)

3.6.1 Procurement Process

Planning on the Greenway/PedSafe project began in early 2017. Since SR 434 serves as a starting point for the PedSafe (CV portion) component of the project, the same systems development approach and procurement process used on the SR 434 CV project were employed. Although separate, the SR 434 and PedSafe projects will essentially be designed together. The system will be developed using an application phased approach, and use a SM and SI.

3.6.2 Purchasing Approach

To coordinate with the SR 434 CV project, a DBB approach is being used to purchase the system, and technical special provisions for CV components will be included in the plan documents. OBUs will be purchased at time the project becomes operational, and a smartphone (affiliated OBU) application will be added at a later time.

3.7 Osceola County CV Signals (District Five)

The Osceola County CV project was an effort between the USDOT and Osceola County. USDOT selected and provided the RSUs and OBUs for the sole purpose of determining development hurdles associated with the installation of CV devices at different types of signalized intersections (mast arm and span wire). FDOT was a stakeholder to Osceola County, and contracted a consultant for the installation and integration.

The project entered the planning phase in the fall of 2014, and became operational in April 2016 transmitting only SPaT messages. Although still active today, there are currently no additional actions planned for the two intersections involved in the project (see Section 2.8.2).

3.8 Guidelines

Currently, there are no standard documents or guidelines referring to the procurement process of CV and CV-related projects. In the development of the RFP for the US 90 SPaT project, some guidance was found from documents used by other DOT agencies, such as UDOT and PennDOT. District Five project managers have also referenced the project management template provided by the Agency for State Technology (AST) as guide for managing their CV projects. However, there are no checklists available to guide project managers through the procurement process for CV and CV-related projects.

4 – PROCUREMENT SURVEY – OTHER STATES

A nationwide survey of CV project managers was conducted in September 2018. Information requested in the survey included a brief description of CV projects in each state with a focus on procurement best practices and lessoned learned (see Appendix C). Nine agencies responded to the survey, all of which have ongoing or operational CV deployments in their state. Agencies that responded to the survey invitation include:

- California Department of Transportation (Caltrans)
- Georgia Department of Transportation (GDOT)
- Maricopa County Department of Transportation, Arizona (MCDOT)
- Minnesota Department of Transportation (MnDOT)
- Pennsylvania Department of Transportation (PennDOT)
- Texas Department of Transportation (TxDOT)
- Utah Department of Transportation (UDOT)
- Virginia Department of Transportation (VDOT)
- Washington State Department of Transportation (WSDOT)

The following sections discuss the responses received from each agency.

4.1 CV Projects in Other States

4.1.1 California

Currently operational, the Caltrans Palo Alto Connected Vehicle Test Bed collects BSMs, SPaT, and Map Data (MAP) messages along an arterial roadway. Future applications include TSP and Eco-Approach and Departure at signalized intersections. DSRC is being used between OBUs and RSUs.

4.1.2 Georgia

GDOT currently has 54 intersections operational with DSRC and cellular communications broadcasting SPaT and MAP messages along both arterial and freeway roadway segments. BSMs will also be collected in the future. Equipment components include both OBUs and RSUs, and the agency is also planning additional deployments consisting of 1700 RSUs in the Atlanta metropolitan area.

4.1.3 Maricopa County, Arizona

MCDOT's Anthem Connected Vehicle Test Bed deployed a MMITSS CV application along arterial roadways in Maricopa County, Arizona. Currently operational, the system collects SPaT and MAP data. However, the agency is not archiving the data at this time. The system consists of OBUs and RSUs using DSRC and GPS communication tools.

4.1.4 Minnesota

One MnDOT CV deployment in Minnesota involves SPaT and snow plow priority applications. Infrastructure equipment consists of RSUs using DSRC and Ethernet 4000 Series switches, and vehicle equipment consists of OBUs installed in snow plows. The project is presently in the implementation phase.

4.1.5 Pennsylvania

The CV project listed in the survey by PennDOT consists of 54 intersections equipped with DSRC and RSUs. Vehicle equipment includes OBUs. Currently operational, the system only broadcasts data to the limited number of connected vehicles in the state. CV applications include SPaT and TSP, with preemption applications presently under consideration. PennDOT is planning to add 205 intersections to the system within the next four years, and is also developing a closed course test track for CV and AV testing.

4.1.6 Texas

TxDOT's Texas Connected Freight Corridors Project is currently in the planning phase. The project will generate and disseminate real-time data for mobility and safety for the freight industry. CV applications will include dynamic routing for fuel savings, work zone warnings, truck parking availability and reservations, border wait times, truck signal priority on arterials, low bridge height warnings, traffic queue warnings, road weather warnings, wrong way driving alerts, as well as traffic and road condition information for truck platooning. Equipment components will consist of OBUs in trucks and RSUs along interstate segments and at intersections using DSRC.

4.1.7 Utah

UDOT listed one CV project already operational and two additional CV deployments expected to be operational by the end of 2018. The Redwood Road CV deployment in Salt Lake City has been operational since November 2017. Applications being used consist of Utah's version of MMITSS (MMITSS-Utah) for conditional TSP. A second CV corridor, the Provo-Orem Bus Rapid Transit (BRT) line, will also run MMITSS-Utah TSP at 47 intersections with 25 city buses and is scheduled to be operational in November 2018. Another CV deployment, expected to be operational in December 2018, includes four corridors in Salt Lake County and consists of 50 intersections and 48 snow plows. This project will provide signal pre-emption for snow plows that are actively plowing.

Data collected at these locations include BSMs, MAP, SPaT, Signal Request Messages (SRMs), Signal Status Messages (SSMs), and SPM. DSRC and GPS will be used with OBUs and single-board processors, with infrastructure equipment consisting of signal controllers.

4.1.8 Virginia

VDOT is using cellular and DSRC modes of communications in their CV deployments along arterial, collector, and freeway segments in the state. Infrastructure equipment includes RSUs, and vehicle equipment will be determined at a later time. BSMs and sensor data are among the types of data currently being collected.

4.1.9 Washington State

WSDOT is in the implementation phase of a CV deployment that will involve sharing SPaT data through DSRC and through a centralized system using a third party data integrator. Equipment is currently being installed in the field cabinets and at the TMC.

4.2 Policy or Procedural Guidelines

Project managers were asked whether their agency has policies or procedural guidelines in place to manage the data being collected on CV projects. Eight of the nine participants responded to this question, with five of the eight indicating that no policies or procedural guidelines currently exist. Two agencies (MnDOT and VDOT) responded as ‘Not sure’, and one agency (TxDOT) indicated that policies/guidelines are being developed for CV deployments.

4.3 Procurement Process

Project managers were asked several questions related to the procurement process used with the CV project mentioned in the survey. Information requested included the number of times the procurement approach had been used for CV deployments, the difficulty in procuring design elements for the project, and if the procurement process differed from other ITS projects they had previously experienced. All nine participants responded to these questions.

Four of the nine participants (Caltrans, MCDOT, PennDOT, and UDOT) stated that the procurement approach used for the referenced CV project had been used *Few* times in their agency for other CV deployments. Participants from GDOT and MnDOT responded as having *Never* used the procurement approach with other CV projects. GDOT also added that the project referenced in the survey is also their first CV deployment. TxDOT replied as not sure, and VDOT stated that their referenced CV project is the only one active at this time. Alternatively, WSDOT has used the same procurement approach *Several* times with other CV projects.

How the procurement process for the each referenced project in the survey differed from other ITS projects yielded varied responses among the participating agencies. GDOT, MCDOT, and WSDOT responded as no difference in the process, suggesting that their agency currently follows ITS project procedures for CV deployments. The remaining six participants indicated that the procurement process for their referenced CV project did differ from other ITS projects previously experienced, with the majority of differences related to the procurement of equipment.

MnDOT stated that “some equipment was difficult to obtain in a timely manner.” Both TxDOT and UDOT expressed the additional efforts required during the procurement process, such as the additional time needed to learn and develop interfaces for the selected equipment, and the need for new specifications and revisions to the standard RFPs, respectively. Caltrans procured the CV elements through the contractor for its Palo Alto CV Test bed project. PennDOT acquired RSUs using purchase orders and existing ITS supply contracts. Since VDOT is at the beginning of incorporating CV technologies in their transportation program, CV deployments are being developed as research projects.

Participants were also asked to rate the level of difficulty in procuring the design elements of the CV project referenced in the survey. Four agencies (Caltrans, GDOT, MCDOT, and PennDOT) indicated little difficulty in procuring design elements for their projects. PennDOT noted that they were able to procure design elements through existing open-end engineering agreements. The agency also currently funds an open-end agreement specifically for CAV deployments.

Three of the nine responding agencies (TxDOT, UDOT, and WSDOT) rated the difficulty in procuring design elements for their referenced CV projects as ‘somewhat difficult’. MnDOT stated that the design consultant procured the elements for their CV project, and VDOT was not sure.

4.4 Lessons Learned

Survey participants were asked to share lessons learned from the procurement process for CV deployments in their state. Eight of the nine participating agencies responded to this question. Two of the eight agencies (MnDOT and TxDOT) stated that the procurement process is ongoing for their referenced CV projects, with the MnDOT project in the implementation phase and the TxDOT project currently in the planning phase.

Neither Caltrans nor WSDOT have encountered lessons learned with their CV projects. Thus far, the contractor has managed the procurement process for Caltrans CV deployments, and WSDOT used a sole source procurement approach.

GDOT noted that although the procurement process for their CV projects is similar to the process used for other ITS deployments, the technical requirements for CV deployments are still rapidly evolving. Accordingly, GDOT has found that ‘having the necessary technical support for deployments is essential’ for the success of CV projects. Systems with technical flexibility are also important to accommodate changes or advancements in technology.

A lesson learned by UDOT is the additional time required for the procurement process of CV deployments compared to ITS projects deployed in the state. Another observation is that the capability of CV products is not always as claimed by vendors. Also mentioned was the current inability for the industry to meet the demand for products or provide adequate support for CV elements.

4.5 Best Practices

Survey participants were asked if any best practices have been identified for CV deployments in their state. Three of the nine agencies shared suggested recommendations.

GDOT noted that validation and testing is important to ensure compliance with current and open standards. MCDOT also expressed the importance of testing, as well as engagement with equipment vendors. MnDOT suggests to start the procurement process early enough to ensure CV components are available when needed for the project.

CV deployments for both MCDOT and PennDOT have been on a relatively small scale at this point in time, with few difficulties. However, MCDOT suggests that "vendors should provide troubleshooting guides and train the agency staff in the integration and maintenance of the equipment."

The licensing of DSRC devices is required by FCC, and may require considerable time for CV project managers to complete. UDOT has streamlined this process by acquiring a statewide license and delegating the registering of all devices to a single staff member familiar with the process.

5 – LESSONS LEARNED

Although Florida's TSM&O program has expanded with the use of emerging technologies as strategies to improve travel reliability, efficiency, and safety for motorists, CV initiatives in the state are still in their infancy. Of the seven focus Florida projects mentioned in Chapter 3, only two are currently operational. The remaining five projects are in the design/implementation phase. Nonetheless, lessons learned thus far may be helpful in expediting future CV deployments. The following sections discuss issues experienced by FDOT project managers during the procurement process of the aforementioned seven focus projects (see Chapter 3).

5.1 Map Data

Map data is an important component of each CV system, where the associated roadway and intersection geometric configuration is established using computer coding and conveyed through the RSU. Accurate coding of the geo-data is vital for CV applications, such as SPaT, to work properly.

Based on experiences gained from the US 90 SPaT project in District Three, providing a prospective or selected vendor with the map data for a CV deployment may result in compatibility issues with the vendor's products. Requiring the vendor to develop their own map data can save time for FDOT project managers and avoid misconceptions related to the operability of the system.

5.2 CV Component Testing

Testing the various components associated with CV deployments is essential prior to purchasing. Equipment and software products must all work together, and oftentimes also work with the existing infrastructure. How and where the testing phase is conducted varies by project and District preference.

For the I-75 FRAME project through Gainesville, District Two project managers elected to use the TERL testing process to test potential CV components. This approach was selected based on previous ITS project experiences that used technical specifications provided to the contractor in a "furnish and install" contract. Using the traditional "furnish and install" approach has, at times, resulted in selected components not working together. Therefore, having vendors go through the TERL process allowed FDOT to verify the compatibility of products before purchasing.

To determine which CV components would work with the existing controllers operated by local agencies, District Five conducted a market survey to evaluate available products for the I-75 FRAME Ocala project. This effort required more time and resources than anticipated by FDOT. Obtaining and testing the necessary equipment proved difficult, as a limited number of testing units are made available to agencies. With the I-75 FRAME Ocala project, some of the testing units were received over two months later than requested. Additional time was also needed to verify that the equipment worked, which required a number of teleconferences with vendors, some of which were located in different time zones or in other countries. In addition, District Five project managers discovered that claims made by vendors related to the capability of a device or product, were not always accurate or ready for testing.

5.3 Procurement of CV Components

Following the testing phase, selected CV components are then procured. During the procurement of vehicle OBUs on the US 90 SPaT project in District Three, project managers learned that the purchasing of OBUs was more difficult and time consuming for the contractor than the purchasing of RSUs. Since RSU equipment is generally more standardized, the contractor had already identified a RSU vendor in their technical proposal. However, OBUs are highly customized per the applications being deployed, and therefore, are built to meet the specific needs of each project. Building custom OBUs for the US 90 SPaT project required more time than initially anticipated by FDOT.

5.4 FCC Approval

Another aspect of the procurement process in CV projects is the approval, or licensure, of equipment by the FCC for use in public rights-of-way. Devices must meet FCC standards for use. The transmitting power or the channel used for communication requires testing, evaluation, and approval by the FCC, and this process can require considerable time.

FCC compliance with the equipment selected for the US 90 SPaT project presented a lesson learned in District Three. Although the RFP stated that the equipment should be FCC compliant, no documentation of such compliance was requested in the RFP. Emerging technologies, by definition, are continuously evolving. Understandably, everyone involved in this industry is trying to keep up with development. On the US 90 SPaT project, a problem occurred related to FCC requirements for the selected project equipment, of which the selected vendor was unaware of at the time the technical proposal was submitted to FDOT. To resolve this issue, considerable time was required of the FDOT TSM&O project manager (8-10 hours per week for one month) to address the problem. The key lesson learned is that FDOT project managers should verify that all equipment (RSUs and OBUs) selected for CV projects meets FCC standards for use in public rights-of-way prior to procurement. Requiring the vendor/contractor to acquire FCC licensure for heavily customized equipment should also be considered.

6 – BEST PRACTICES

Based on discussions with FDOT project managers related to ongoing and operational CV projects, the following preliminary best practices are suggested.

6.1 Map Data

Map data is an important component of CV systems and must be accurate for the system to work properly and deliver the desired results. If FDOT elects to provide the map data, prior verification of accuracy is suggested to avoid potential misconceptions related to system operability. An alternative and preferred approach is to require the selected vendor/contractor to develop their own map data to ensure not only the compatibility with their products, but also the reliability of their system. Moreover, revisions required to the coding may be more easily accomplished by the vendor that supplied the map data.

6.2 CV Component Testing

The testing of equipment and applications involved in CV systems prior to procurement is key for successful operations. Whether project managers elect to test prospective systems in the field or through the TERL testing process, determining the functionality, as well as the compatibility with existing and purchased components is essential. Additional time should be considered to allow the vendor to deploy and demonstrate the capability of their devices, as well as to test the interoperability of all devices with the existing infrastructure.

For the US 90 SPaT project, a testing prerequisite was added in the RFP requiring vendors to successfully demonstrate their systems in the field to be considered for the project. This requirement proved integral in the success of the project.

6.3 Performance Monitoring

Drawing from issues experienced by Utah DOT (UDOT), FDOT District Five is limiting the scope of the initial applications to be deployed on the I-75 FRAME Ocala project to EVP, TSP, and SPaT. Adding too many applications to the Multi-Modal Intelligent Traffic Signal Systems (MMITSS) may possibly exceed the capability of the processor on the RSU. Therefore, District Five is planning to conduct performance monitoring on the initial three applications deployed to determine what is needed to move forward with future applications.

6.4 Procurement of CV Components

Vehicle OBUs are customized for the project applications being deployed. Consequently, custom OBUs may require considerable time to build. This factor should be considered by FDOT project managers when developing the CV project schedule.

Another factor to consider is the ability of software products to work with current or planned infrastructure components. Available software is not standardized throughout the industry. Therefore, COTS products, if used, may require adjustments by the vendor and may affect the project schedule.

6.5 FCC Approval

Components selected for CV deployments should be compliant with FCC standards for use in public rights-of-way prior to being procured. Obtaining FCC licensure may require considerable time by either the contractor or the project manager, and FDOT project managers should consider this factor when developing the project schedule.

6.6 System Readiness

FTE is conducting a CV readiness study to not only answer questions related to CV technology, but also to determine the readiness of the Turnpike to deploy CV strategies. Currently in the planning phase, FTE is taking a proactive approach with the study to increase their knowledge of emerging technologies and explore what may be needed for future CV deployments along the Turnpike. Planning studies can help Districts identify appropriate CV deployment strategies. A process for requesting information, such as issuing a RFI, may also be beneficial in exploring current product options, as well as expanding the knowledge base.

6.7 System Security

FDOT project managers should consider the security of the CV system. To address this issue on the US 90 SPaT project, a Security Credential Management System (SCMS), developed by FDOT with Florida State University, was deployed. The SCMS works by verifying the legitimacy of all V2V and I2V messages. Since the US 90 SPaT project was one of the earliest CV deployments in Florida, the security management of the system required a separate contract with a company that specializes in security credential management. However, all other CV deployments in Florida should consider the security needs of the system prior to going operational.

7 – PREVIOUS RECOMMENDATIONS REVIEW

In a recently completed study, *Evaluation of Project Processes in Relation to Transportation System Management and Operations (TSM&O)*, the state-of-the-practice of FDOT project development processes in relation to TSM&O projects was evaluated (FDOT, 2018c). Suggested recommendations were developed based on a comprehensive review of the current state-of-the-practice of TSM&O throughout the FDOT, including districtwide survey responses from FDOT project managers and staff in each of the seven FDOT Districts and the FTE. Near the time the TSM&O study was completed, FDOT established the Florida CV Initiative. Therefore, information and issues pertaining to CV and CV-related deployments were not included in the TSM&O Final Report (FDOT, 2018c). This Chapter briefly discusses proposed recommendations stated in the TSM&O study and offers suggested revisions to those recommendations to incorporate CV language.

7.1 Alternative Development and Procurement Options

The TSM&O study identified different development and procurement approaches for software- and non-software related TSM&O/ITS projects. Software-related TSM&O/ITS projects may consist of:

- only the software component,
- both software and hardware components,
- primarily software and hardware components with some field devices, or
- primarily field devices with some hardware and some software modifications.

Non-software TSM&O/ITS projects may constitute:

- primarily hardware components with some field devices, or
- primarily field devices with some hardware modifications.

Specific recommendations are discussed in detail in the TSM&O Final Report (FDOT, 2018c). As noted in the TSM&O report, suggested recommendations to consider when developing software-related TSM&O/ITS projects include:

- Consider adopting the Agile method for developing applicable TSM&O/ITS software projects.
- Consider a two-phase development process using the Agile approach for Phase I, and the Waterfall approach for Phase II.
- Involve the end users of the system throughout the project development process.
- Incorporate TSM&O/ITS best practices into contract templates.
- Train applicable FDOT staff in Agile principles.

These recommendations are applicable to CV and CV-related projects, depending on the project needs. Therefore, no additional revisions to the recommendations discussed in the TSM&O Final Report (FDOT, 2018b) are suggested.

7.2 Formalized Process and Procedure

The TSM&O study recommended a formalized internal procedure be developed for TSM&O/ITS projects. Although similar, some aspects of CV deployments differ from other types of ITS projects. Therefore, procedural guidelines applicable to CV projects would also be beneficial to TSM&O project managers and staff.

7.3 Knowledge and Understanding of CV Deployments

Since CV deployments are fairly new to Florida, it is understandable that FDOT staff members, as well as other members of the industry, such as contractors and consultants, are still unfamiliar with many aspects related to CV technologies. As FDOT continues to promote a better understanding of TSM&O throughout the agency and the community, information pertaining to CV applications, objectives, and project examples should also be included to further the knowledge of TSM&O/ITS strategies.

The sharing of knowledge and project experiences among TSM&O staff members should also help to bridge the gap in knowledge. Since CV technologies are continuously evolving, sharing knowledge may require a more concentrated effort. Regularly scheduled webinars, involving the TSM&O groups, to discuss CV technologies and issues may facilitate this effort.

7.4 FDOT Design Guidelines

Suggested revisions to FDOT design guidelines to include language or references to TSM&O strategies or components, as stated in the TSM&O study (FDOT, 2018b), should also include CV project examples and objectives.

8 – CONNECTED VEHICLE PROJECT DEVELOPMENT PROCESS

CV deployments are technology-based; therefore, the project development process is more aligned with the methodology used for other ITS projects. The basic development process follows that shown in Figure 8.1, and consists of four primary phases: *Planning*, *Design*, *Implementation*, and *Operations & Maintenance*.

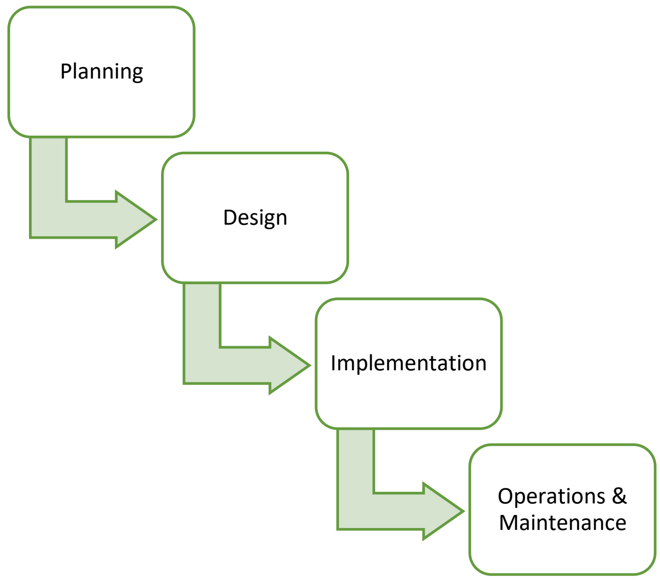

Figure 8.1: CV Project Development Process

Traditional FDOT project development follows the process outlined in Figure 8.2. ITS projects, such as Advanced Traffic Management Systems (ATMS) and Advanced Traveler Information systems (ATIS), involve technology systems, resulting in a development process that is 'systems' oriented. Therefore, ITS deployments follow the Systems Engineering (SE) development approach, illustrated using the "Vee" diagram in Figure 8.2. Since CV systems are technology-based, the SE "Vee" model is also typically used to develop CV projects.

As shown in Figure 8.1, the CV project development process consists of fewer phases compared to the traditional FDOT development process shown in Figure 8.2., and many of the project elements identified in the SE "Vee" are incorporated into these phases.

In addition to establishing the need for a CV deployment, considerable effort is made during the *Planning* phase to investigate current CV technologies applicable to the project. Existing infrastructure and system components, operated or maintained by either FDOT or local agencies or organizations, are also determined.

CV projects are generally stand-alone projects and often do not require a Project Development and Environment (PD&E) phase. However, as with other ITS projects, CV deployments do require a Concept of Operations (ConOps) plan and may require a National Environmental Policy Act (NEPA) study if federally funded.

Although all federally funded CV projects are required to follow the SE "Vee" process, several project elements associated with other ITS projects deviate from the standard "Vee" process (see Figure 8.2) when deploying CV technologies. These deviations primarily involve the sequence of development activities. For example, equipment testing and verification often occurs during the *Design* phase of a CV project, compared to the implementation phase in other ITS projects. However, system testing and verification is conducted during the implementation phase as shown in "Vee" diagram (see Figure 8.2). Along with other design activities, the *Design* phase also serves as a preparation phase to deploy and install system components during the *Implementation* phase.

Construction and Inspection (CEI) is incorporated into the *Implementation* phase of a CV project, and maintains a significant presence during this phase. The CEI is generally identified early in the project development process and supports activities throughout the development process. Security management of the CV system, which is generally not needed in other types of ITS projects, is also addressed during the implementation phase.

The *Operations & Maintenance* phase in a CV project generally agrees with the standard SE "Vee" diagram. Similar to other ITS projects, the system is validated, operated, and maintained during this phase.

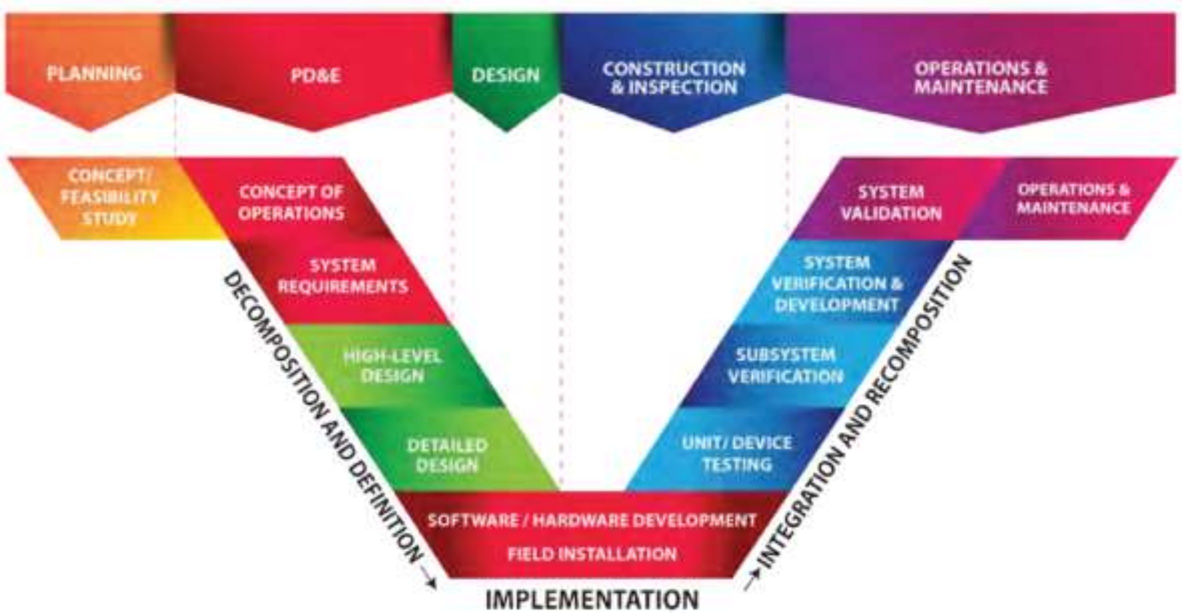

Figure 8.2: FDOT Project Development Process/ Systems Engineering "Vee" Diagram (Source: FDOT, 2017)

8.1 Systems Development Approach

The type and scale of a CV deployment often dictates the preferred systems development approach. Popular methods used in Florida include: the *Vee Development Model*, *Agile/Scrum*, and the *Phased* approach.

The *Vee Development Model* refers to the development process outlined in the SE "Vee" diagram shown in Figure 8.2. The *Agile/Scrum* method involves frequent interaction with the development team and gradual capability development. In the *Phased* approach, system applications are developed and built in major steps or stages, allowing feedback to subsequent stages, e.g., Build 1, Build 2, Build 3, etc.

Oftentimes, two development approaches are used to develop the system. Project managers in Florida and other states have used the *Vee* model for infrastructure elements, and the *Agile/Scrum* or *Phased* approach for the software-related elements of the project. The *Phased* approach is also a conservative method to identify and manage risks with each application deployment.

8.2 CV Project Schedule

8.2.1 Purchasing CV Equipment

One issue related to the purchasing of equipment involves the project schedule for CV deployments. Unlike other ITS projects, CV is relatively new to most transportation agencies, including FDOT. Many agencies have approached CV deployments using familiar ITS project methods, and have learned that procuring CV equipment and components required more time than originally scheduled. Concerns that even more time may be needed to acquire the necessary CV items for large scale deployments was also expressed. A best practice mentioned by a number of project managers, both in Florida and other states, is to start the procurement of CV components early in the process to keep the project on schedule.

Project managers that requested test units to better understand the products and how they worked, also experienced delays in receiving the products. In some cases, test units were requested four months prior to testing, yet arrived nearly two months after the date needed, resulting in nearly a six-month order-and-receive process. Once the test units arrived, more time was expended to coordinate with the vendors to resolve technical issues related to product operation.

Another consideration is the time required to build and deploy the vehicle units, referred to as OBUs, which are project-specific and typically contain highly customized dashboards for drivers to receive messages, such as BSMs or SPaT information. Additional time should be allowed in the project schedule to acquire and deploy the OBUs. Moving forward, FDOT project managers should consider these aspects of CV deployments and develop future deployment project schedules accordingly.

8.2.2 Vendor Support and Guidance

Another aspect of CV deployments relates to the support and guidance received from product vendors selected for the project. Troubleshooting and learning how to integrate and maintain equipment can add additional time to the project schedule. Engaging the vendors early in the project development process to determine what type of support and guidance will be provided may minimize potential delays during the *Implementation* and *Operation* phases of the deployment. A troubleshooting guide must be provided by the selected vendor. Training time for agency staff should also be considered when developing the project schedule.

9 – CONNECTED VEHICLE PROCUREMENT FRAMEWORK

CV deployments are technology-based, and therefore, are similar to other ITS projects. However, the CV procurement process involves project elements not generally associated with traditional ITS projects. Section 9.1 briefly discusses several key project elements related to CV deployments compared to traditional ITS projects.

The procurement framework for CV deployments is also somewhat different from the framework used in ITS deployments. Section 9.2 discusses characteristics of the CV procurement process, including the current procurement framework and overlapping activities. Section 9.3 briefly reviews the procurement framework presented in Section 9.2 in relation to the FDOT project development process and the SE "Vee" model (see Figure 8.2) typically used in federally funded technology-based projects.

9.1 CV versus ITS Projects

ITS projects, such as ATMS and ATIS, have been deployed by FDOT for a number of years. Although technologies and equipment related to ITS projects have improved over time, TSM&O project managers are more familiar with the components involved with traditional ITS deployments. However, CV deployments are still fairly new to the transportation industry, and involve technologies and equipment that may be unfamiliar to TSM&O project managers.

Table 9.1 lists several key project elements associated with CV deployments that are not typically associated with traditional ITS projects. CV deployments involve vehicle equipment (OBUs), the development of new project-specific specifications for components, the need for system testing early in the project development process, and the need for security management of the system.

Table 9.1: Key CV Project Elements

Project Element	CV Project	ITS Project
Communication with vehicles	Yes	No
Vehicle equipment (OBUs)	Yes	No
Customized Dashboards for OBUs	Yes	No
Project-Specific Specifications developed	Yes	*No
System testing prior to implementation	Yes	No
Security credential verification needed	Yes	No

*With the exception of new technology.

Unlike traditional ITS deployments where information is exchanged primarily between the roadside infrastructure and the TMC, CV deployments involve communications with vehicles, pedestrians, and bicyclists. Communications involving V2V, V2I, I2V, or V2X technologies require additional equipment, such as OBUs with customized dashboards and RSUs.

Since CV systems involve emerging technologies and are fairly new to Florida, CV components are currently not listed on the FDOT's Approved Product List (APL) or Innovative Products List (IPL). Therefore, Technical Special Provisions, referred to in this report as Tech Specs, must be developed. Tech Specs describe what functions are needed for the system, and are approved by the FDOT Central Office in the form of developmental special provisions, prior to being included in the project's contract documents.

Testing prospective products early in the project development process is essential with CV deployments. In traditional ITS deployments, integration and testing of system components typically occurs during implementation. However, CV system components must be tested earlier in the project development process to determine not only functionality, but also compatibility with existing infrastructure and system components.

Security credential management is also needed with CV deployments. Unlike traditional ITS deployments, information is exchanged between infrastructure and vehicle units in CV systems. Therefore, CV systems may be vulnerable to potential unauthorized intrusion. All outgoing messages from the controller or the vehicle should be verified before being received by the vehicle or the controller, respectively. To verify the legitimacy of information exchange, a security credential management system must be deployed, preferably before the system is operational.

9.2 Current Procurement Framework for CV Projects

Procurement methods used in CV deployments vary by FDOT District, and are often based not only on project type and scale, but also on District preference and familiarity. Regardless of the contracting method, i.e., Design-Bid-Build (DBB) or Design-Build (DB), a number of activities related to procurement were identified from the information gathered from project managers, both in Florida and other states. Figure 9.1 outlines the procurement framework associated with CV deployments, with respect to the CV project development process, and offers a guideline for suggested activities to consider throughout the procurement process.

The following sections discuss the activities listed in Figure 9.1, including the overlapping among various phases of deployment. Table 9.2 charts the phase overlap for each activity, and is color-coded to correspond with principle activities listed in each phase shown in Figure 9.1.

9.2.1 Planning Phase

Among other activities, the purpose and need for the CV deployment is established during the *Planning* phase of the project. The Architecture Reference for Cooperative and Intelligent Transportation (ARC-IT), developed by the USDOT, provides valuable guidance with project planning, as well as a usable framework for the project development of an ITS deployment (USDOT, 2018d). While not required for non-federally projects, ARC-IT should be used as a deployment resource throughout the project development of CV deployments.

The FCC is notified of the project during the planning phase to obtain an initial approval to proceed. At this point, general project information is provided to the FCC, such as project name, location, planned number of RSUs, etc. More detailed information pertaining to equipment specifics is provided later, during the implementation phase, to register CV devices and seek final FCC approval.

Available products that meet the needs of the CV deployment are also explored during the planning phase. Although project managers consistently strive to stay informed of current CV applications, the CAV industry is continuously evolving. Acquiring information on newer or improved technologies may continue well into the design phase of the project.

System readiness should also be evaluated. A systems readiness study can be performed to gain a clear understanding of what may be required for the CV deployment. This information can also assist the SM or Design Contractor in their review of existing infrastructure equipment and system components.

9.2.2 Post-Planning Phase

While much effort is made to explore applicable CV technologies currently available during the *Planning* phase, vendor participation to introduce or explain CV product capabilities is often missing. Therefore, additional post-planning efforts, also referred to as upfront work, is needed prior to initiating the procurement process. Nearly all of the CV project managers interviewed, both in Florida and other states, stated that upfront work was necessary for each CV deployment.

Suggested upfront work consists of engaging vendors and requesting product information, possibly in the form of a RFI. Obtaining information and coordinating with vendors may continue into the implementation phase of the project. Likewise, although exploring the interoperability of CV components typically occurs during the post-planning effort, this activity may also extend throughout the development process. Addressing these aspects early can help to minimize potential delays later in the project development process.

The ConOps is developed, and the systems development approach and contracting method are determined, during the post-planning phase. The CEI contractor is also identified. Federally funded projects must also address NEPA concerns and other federal regulations pertaining to project development, and must follow the "Vee" model framework discussed in Section 9.3.

9.2.3 Begin Procurement Process

The procurement process in CV deployments is a combination of both procuring consultants or contractors and purchasing CV-related products. Technically, the process begins with the issuance of the RFP or contract with a Design consultant or GEC. Recent CV deployments in Florida have initiated the procurement process by procuring a SM, followed by the procurement of a DB contractor. Although this procedure often requires more time, it has helped to minimize the risks of "unknowns" during the procurement process.

Responsibilities of the SM include all project activities associated with a systems acquisition, except for the provision of equipment and electrical and construction contracting. Several activities performed by the SM include a review of the entire project, i.e., the corridor involved, what is involved geographically, regionally, and technologically. The SM also investigates existing equipment and systems, and explores the status of industry technology that is required to meet the project objectives. The SM may also assist in the development of the RFP for the DB contract, as well as procurement specifications and other planning activities (USDOT, 2018e). Project managers new to CV deployments may elect to use a SM.

The RFP should require potential vendors to develop their own geometry data of the corridor and intersections involved for the CV applications being deployed. Product testing to ensure the map data performs accurately may also be included in the RFP as a requirement in the vendor selection process.

9.2.4 Design Phase

The *Design* phase in CV deployments serves as a preparation phase to install and deploy the system during the *Implementation* phase. Potential system components are tested for capability and interoperability requirements at the beginning of the design phase. This task may continue into the implementation phase prior to purchasing components.

Since CV technologies are still fairly new to most project managers, oftentimes test units are requested from vendors to assist with understanding how an application works and whether it will provide the desired outcome. The number of test units available to agencies are limited, and may require considerable time to obtain. Although this activity is listed in the design phase in Figure 9.1, project managers should consider requesting test units as early as possible in the project development process to avoid project schedule delays.

Tech Specs for CV systems are also developed during the design phase. Tech Specs are project-specific and indicate the desired functionality of the system. Contractors must provide CV equipment that is compatible with the specified software functionality. Currently, there are no CV products available on the FDOT's APL. However, FDOT is actively working on a developmental specification for RSUs.

The need for vendor support and guidance during the integration of the system, as well as with training of local agency staff in the operation and maintenance of equipment was expressed by several project managers from other states. A proactive approach to this issue is to develop a support and training plan with the selected vendor prior to deployment, and further developed during the implementation phase. This plan should be developed during the design phase;

however, exploring vendor support prior to the design phase may provide valuable insight for project managers.

If desired, a SI can be procured. The SI provides all of the services associated with the system implementation, except for the provision of equipment and electrical and construction contracting. The SI is typically not involved in early phases, such as planning or design, yet helps with the installation and integration of system components, and ensures that everything works together (USDOT, 2018e).

9.2.5 Implementation Phase

In the *Implementation* phase, system components are purchased, installed, integrated, and verified. Vendor support with troubleshooting can expedite this process. Since product availability remains an issue with CV deployments, infrastructure and software components should be purchased at the beginning of the implementation phase, and in some cases, may need to be purchased earlier to maintain the project schedule. Several project managers suggested purchasing equipment as early as feasible to avoid project delays.

Following the procurement of system devices, information, such as the vendor, the make and model of the equipment, the placement height, the GPS coordinates, and other specifics, can be provided to the FCC for approval of each device. All CV equipment must be licensed by the FCC prior to entering the *Operations* phase of the project. CV units broadcast information through the airways; therefore, each unit must be licensed and registered with the FCC. For contractor selected equipment, requiring the contractor to be responsible for FCC approval and licensure in the RFP, may save considerable time for FDOT project managers.

Currently, FDOT is addressing FCC license requirements on a project-by-project basis. However, the licensing process may require considerable time for project managers to navigate, resulting in some Districts electing to have the contractor or SI complete the process. A best practice to consider for future CV deployments is for FDOT to acquire a statewide FCC license for CV components to streamline the process. CV units can then be registered for use with the FCC as needed.

Since OBUs are custom built for each CV deployment, the purchasing of these units is often more difficult and time consuming than the procurement of infrastructure equipment. Additionally, depending on the purpose and need of the project, i.e., research or pilot project, agreements must be put in place to install the OBUs in certain service vehicles, such as transit and fire vehicles. Purchasing the OBUs at the beginning of the implementation phase allows for adequate time to coordinate with OBU recipients, as well as ensure that everything is working properly on the RSUs prior to deploying the vehicle components.

Unlike other ITS projects, CV deployments are vulnerable to potential access by unauthorized persons or entities. The security management of the system is essential, and must be addressed prior to the system going operational. Although security management measures are primarily addressed during the implementation phase, the plan should be considered during the design phase and updated as needed during the *Operations & Maintenance* (O&M) phase.

CEI has a significant role in every CV deployment. Primarily involved in the implementation phase to evaluate the testing of system devices and support the integration of the system, CEI also supports procurement and design activities prior to implementation.

9.2.6 Operations & Maintenance Phase

The final phase of a CV deployment consists of O&M activities. During this phase, local agency staff can be trained by the vendor to efficiently operate and maintain the system. A support and training plan developed with the vendor during the design phase of the project can facilitate this process. A troubleshooting guide must be provided by the selected vendor.

Depending on project purpose and need, data may be collected once the system becomes operational. Data User agreements may be needed to share data with other agencies, organizations, or stakeholders. Agreements can be developed at any time during the project development process or following deployment.

9.3 “Vee” Model Procurement Framework

CV projects in Florida that involve federal funds must follow the SE, or “Vee” model, development process and the corresponding development phases shown in Figure 8.2. Activities listed in Figure 9.1 also apply to federally funded CV projects. However, some procedural aspects of the development process differ from the flowchart shown in Figure 9.1, and a greater level of documentation is generally required.

When comparing the framework shown in Figure 9.1 and the “Vee” model framework, the differences pertain primarily to the development phases and the activities associated with each phase. For example, PD&E elements must be addressed in the PD&E phase, and the implementation and integration of the system is completed during the CEI phase (see Figure 8.2), rather than the post-planning and implementation phases referred to in Figure 9.1, respectively.

A key difference between the two frameworks is the testing of system components. While COTS software products may be available for some CV applications, hardware and other system components are generally project-specific and unique to each CV deployment. Until the industry becomes more standardized, testing these system components prior to the implementation phase is essential in reducing costly risks. Conservative measures should be considered if the project requires that the “Vee” model be followed as shown in Figure 8.2.

When discussing CV deployments, some project managers refer to these slight deviations in the “Vee” model as a “modified Vee” process. Nevertheless, since CV projects are technology-based, the SE approach is generally used.

Other activities associated with the planning and post-planning phases listed in Figure 9.1, such as identifying the CEI contractor or determining the systems development approach and contracting method to be used, also apply to CV projects that follow the “Vee” model and should be completed prior to the design phase, either in the planning or PD&E phase per the preference of the project management team. The ARC-IT deployment resource also plays a greater role in federally funded CV projects.

Similar to Figure 9.1, the procurement process in the “Vee” model begins just prior to the design phase of the project. Procurement activities required for the project are considered or excluded based on project objectives and other factors, such as whether the project is included in the Long-Range Transportation Plan (LRTP).

CV deployments that are part of larger scale projects may follow a different procurement process. However, in general, the procurement framework illustrated in Figure 9.1 can serve as a guide for procurement process activities associated with CV deployments regardless of the funding source.

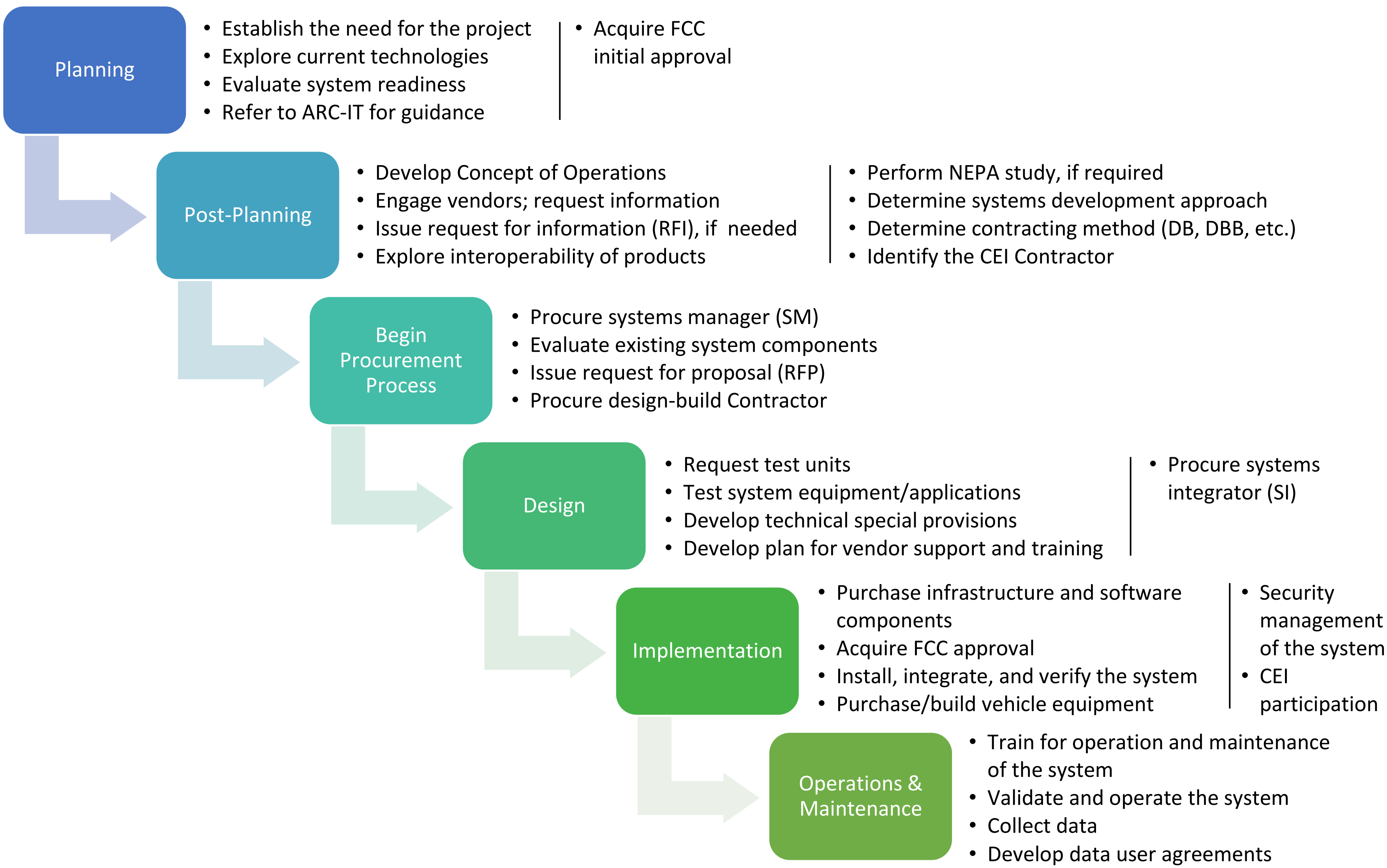

Figure 9.1: Current CV Procurement Framework Guideline, January 2019

Table 9.2: Overlapping CV procurement framework activities.

CV Procurement Framework Activity	Planning	Post-Panning	Begin Procurement	Design	Implementation	O&M
Establish need for the project	•					
Explore current technologies	•	•	•	•		
Evaluate system readiness	•					
Refer to ARC-IT for guidance	•	•	•	•	•	
Acquire FCC initial approval	•					
Develop Concept of Operations		•				
Engage vendors; request information		•	•	•	•	
Issue request for information (RFI), if needed		•	•			
Explore interoperability of products		•	•	•	•	
Perform NEPA study, if required		•				
Determine systems development approach		•				
Determine contracting method (DB, DBB, etc.)		•				
Identify the CEI Contractor		•				
Procure systems manager (SM)			•			
Evaluate existing system components			•	•		
Issue request for proposal (RFP)			•			
Procure design-build Contractor			•			
Request test units		•	•	•	•	
Test system equipment/applications			•	•	•	
Develop technical special provisions			•	•		
Develop plan for vendor support and training			•	•	•	
Procure systems integrator (SI)				•		
Purchase infrastructure and software components				• *	•	
Acquire FCC approval					•	
Install, integrate, and verify the system					•	
Purchase/build vehicle equipment					•	
Security management of the system				•	•	•
CEI participation			•	•	•	
Train for operation and maintenance of the system						•
Validate and operate the system						•
Collect data						•
Develop data user agreements	•	•	•	•	•	•

*Based on product availability

10 – SUMMARY & RECOMMENDATIONS

The goal of this research effort was to examine the CV procurement framework to assist in expediting the procurement process in future CV deployments in Florida. Although similar to the project development process used for ITS deployments, CV project development is somewhat different, especially pertaining to the procurement framework.

Research tasks included a review of the current state-of-the-practice of CV deployment at the regional, national, and international level. Ongoing and operational CV projects included in the Florida CV Initiative as of December 2018, were also reviewed. FDOT project managers were interviewed to discuss the procurement process and issues, and lessons learned experienced with the CV deployments in their respective district. Best practices derived from these experiences were also discussed.

A second survey was conducted to explore lessons learned and best practices used in CV deployments by transportation agencies outside of Florida. The survey was administered to TSM&O and ITS project managers in each of the 50 states in the U.S. Nine agencies responded to the questionnaire.

Based on information gathered, lessons learned from ongoing and operational CV deployments in Florida include:

- Map data must be accurate for applications, such as SPaT, to perform correctly.
- Adequate time should be allowed when procuring customized equipment.
- Obtaining FCC licenses may require considerable time.
- Additional time and resources will be required to complete market research to identify CV devices compatible with existing infrastructure.
- Obtaining and testing of CV devices may require extra time. Testing units may not be available in the specified time needed to keep the project on schedule.
- Vendor claims of product capabilities are not always be accurately represented or ready for testing.
- Technical specifications for CV items may not result in components working together.

Best practices identified from Florida CV deployments to consider moving forward include:

- Include a requirement in the RFP for potential contractors to develop and verify map data.
- Consider adding a testing component to the RFP as a qualification measure to accepting a bid proposal.
- Factor in extra time to build customized OBUs, if applicable.
- Consider requiring FCC compliance documents be provided by potential contractors during the RFP process.

- Allow adequate time in the schedule for obtaining and testing of CV devices.
- Consider the ability of COTS software products to work with current or planned infrastructure components.
- After initial application installation, consider conducting performance monitoring to assess RSU processor capability to identify needs for future applications.
- Consider conducting system readiness studies to assist in determining appropriate CV deployment strategies.
- Consider options to secure the CV system.
- Consider developing a RFI process to learn about current product options.

In addition to many of the lessons learned expressed by FDOT project managers, TSM&O project managers from transportation agencies outside of Florida added the following lessons learned:

- The technical requirements for CV deployments are still rapidly evolving.
- Adequate technical support for deployments is essential.
- Technical flexibility built into CV systems is important to accommodate changes or advancements in technology.
- Current inability for industry to meet the demand for products or provide adequate support for CV components.

Best practices offered by CV project managers in other states include:

- Test CV components to ensure compliance with current and open standards.
- Validate the capability of CV components prior to procurement.
- Engage equipment vendors to better understand available CV technologies.
- Start the procurement process early enough to ensure CV components are available when needed for the project.
- Streamline the FCC licensing process by acquiring a statewide license and designating a staff member to complete the registration of CV devices.

The information gathered from both surveys was combined to develop suggested procurement framework guidelines to assist TSM&O project managers with future CV deployments. Guidelines or factors to consider when deploying CV technologies vary throughout the project development process. Suggested procurement activities during the CV project development process include:

- *Planning Phase*: Establish the need for the project; explore current technologies; evaluate system readiness; refer to the ARC-IT for guidance; acquire FCC initial approval.

- *Post-Planning Phase*: Develop ConOps; engage vendors, request information; issue request for information (RFI), if needed; explore interoperability of products; perform

NEPA study, if required; determine the systems development approach; determine contracting method; identify the CEI Contractor for the project.

- *Begin Procurement Process*: Procure systems manager (SM); evaluate existing system components; issue RFP; procure design-build Contractor.

- *Design Phase*: Request test units; test system equipment/applications; develop technical special provisions; develop plan for vendor support and training; procure systems integrator (SI).

- *Implementation Phase*: Purchase infrastructure and software components; acquire FCC approval; install, integrate, and verify the system; purchase/build vehicle equipment; security management of the system; CEI participation.

- *Operations & Maintenance Phase*: Train for operation and maintenance of the system; validate and operate the system; collect data; develop data user agreements.

Based on findings from this research effort, suggested recommendations for FDOT to consider include:

- Distribute the CV procurement process flowchart statewide to assist FDOT CV project managers.
- Share the CV procurement framework flowchart with local agencies to assist them with CV initiatives in their jurisdictions.
- Schedule regular meetings or webinars among CV project managers statewide to share project experiences and CV knowledge.
- Consider obtaining a statewide FCC license to expedite the licensing and registration process for future CV devices.

Suggested revisions to recommendations provided in the recently completed TSM&O study, *Evaluation of Project Processes in Relation to Transportation System Management and Operations (TSM&O)* (FDOT, 2018c) include:

- Consider developing a formalized procedure for CV project development, including the procurement process.
- Consider including CV information and examples in the TSM&O education efforts within the FDOT to promote a better understanding of CV strategies.
- Consider including CV as a TSM&O strategy in FDOT design guidelines containing TSM&O language.

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APPENDIX A – Florida CV Initiative Project Summary

Table A.1: Florida CV Initiative Project Summary

Florida Connected Vehicle (CV) Deployment Initiatives							
Status	**Project Name**	**Type**	**District**	**County**	**Category**	**Primary CV Goal(s)**	**Additional CV Goal(s)**
Planning	Bike and Pedestrian Safety – University of Florida (UF) Pilot	CV	2	Alachua	Safety	• Passive pedestrian/bicyclist detection • Pedestrian Information Devices (PID) • Real-time notification to transit, vehicles, and pedestrian/bicyclist	• Signal phase and timing data broadcasting with active pedestrian/bicyclist detection
	Central Florida Autonomous Vehicle (AV) Proving Ground	AV	5	Orange	Research	• A partnership for research and development of CV technology across all modes of travel • Proving ground across multiple Central Florida counties	
	Driving Assistive Truck Platooning (DATP) Pilot	CV/ AV	FTE	Osceola	Research	• Evaluate impacts of DATP on surrounding traffic, and infrastructure	• Evaluate feasibility of enforcement on operating DATP trucks • Evaluate administrative impacts
	Pinellas County Signal Phase and Timing (SPaT)	CV	7	Pinellas	Mobility	• Improve travel time reliability, safety, throughput, and traveler information	

Source: (FDOT, 2018a)

Table A.1: Florida CV Initiative Project Summary (continued)

Florida Connected Vehicle (CV) Deployment Initiatives							
Status	**Project Name**	**Type**	**District**	**County**	**Category**	**Primary CV Goal(s)**	**Additional CV Goal(s)**
Design/Implementation	I-75 Florida's Regional Advanced Mobility Elements (FRAME) Gainesville	CV	2	Alachua	Mobility	• Create an Integrated Corridor Management on I-75 and state highway systems in Gainesville	• Disseminate real-time freeway incident information to motorists
	I-75 Florida's Regional Advanced Mobility Elements (FRAME) Ocala	CV	5	Marion	Mobility	• Create an Integrated Corridor Management on I-75 and state highway systems in Ocala	• Disseminate real-time freeway incident information to motorists
	Gainesville Autonomous Transit Shuttle (Autobus)	AV	2	Alachua	Transit	• Automated transit system connecting the City of Gainesville and the UF campus and student housing	
	Florida's Turnpike Enterprise (FTE) SunTrax	AV	1	Polk	Research	• Large-scale test facility for emerging transportation technologies	
	Tampa Hillsborough Expressway Authority (THEA) Connected Vehicle Pilot	CV	7	Hillsborough	Mobility/ Safety	• Multimodal CV applications for streetcars, buses, passenger cars, and pedestrians in and around the City of Tampa	
	City of Orlando Greenway/Pedestrian Safety	CV	5	Orange	Safety/ Mobility	• Pedestrian and bicycle collision avoidance system	• Traffic signal operational improvements in the City of Orlando

Source: (FDOT, 2018a)

Table A.1: Florida CV Initiative Project Summary (continued)

Florida Connected Vehicle (CV) Deployment Initiatives							
Status	**Project Name**	**Type**	**District**	**County**	**Category**	**Primary CV Goal(s)**	**Additional CV Goal(s)**
Design/Implementation	SR 434 Connected Vehicle Deployment	CV	5	Seminole	Mobility	• Implement CV technology and Signal Performance Metrics (SPM)	
	Downtown Tampa Autonomous Transit	AV	7	Hillsborough	Transit	• A low-speed autonomous last-mile shuttle service connecting the transit center and parking to the employment sector	
	Orlando Smart Community 2017 ATCMTD	CV	5	Orange	Mobility/ Safety/ Data	• Pedestrian and bicycle collision avoidance system • *GreenWay* program to better utilize the multimodal system	*Smart Community* program
	Voyage at The Villages	AV	5	Marion/ Lake/ Sumter	Mobility	• Door-to-door self-driving taxi service through Voyage, an autonomous vehicle service company	
	Implementing Solutions from Transportation Research and Evaluation of Emerging Technologies (I-STREET)	CV	2	Alachua	Research	• Partnered research effort • Explore emerging CV technologies and deployment-oriented approaches	• Provide data and other outputs to I-STREET partners

Source: (FDOT, 2018a)

Table A.1: Florida CV Initiative Project Summary (continued)

Florida Connected Vehicle (CV) Deployment Initiatives							
Status	**Project Name**	**Type**	**District**	**County**	**Category**	**Primary CV Goal(s)**	**Additional CV Goal(s)**
Design/ Implementation	Gainesville SPaT Trapezium	CV	2	Alachua	Mobility/ Safety	• Improve travel time reliability, safety, throughput, and traveler information	• Pedestrian/bicyclist safety application for web-based and Smartphone information
Operational	US 90 Signal Phase and Timing (SPaT) Tallahassee	CV	3	Leon	Mobility	• Arterial traffic management through signal phase and timing	• Advance vehicle-to-infrastructure capabilities and experience
	Osceola County Connected Vehicle Signals	CV	5	Osceola	Research	• Test Dedicated Short Range Communications (DSRC) equipment • Test intersection processing equipment	

Source: (FDOT, 2018a)

APPENDIX B – CV Deployment Procurement Questionnaire: FDOT

1. Please provide your information below.

Name: ____

Title: ____

Address: ____

____

____

Phone: ____

Email: ____

District: ____

<u>Project Background Questions</u>

2. Please provide the CV project information below.

Project Name: ____

FDOT Project No.: ____

3. Briefly describe the scope of the project and your role in the project.

4. Please list all other stakeholders and their respective roles.

Other public agencies (City, MPOs, State, Federal): ___________________________________
Private sector firms/consultants: ____
Equipment manufacturers/vendors: ____
Universities/Organizations: ____

5. Is this a pilot project?

☐ Yes
☐ No

6. What phase of deployment is the CV project currently in?

☐ Planning
☐ Design
☐ Implementation
☐ Operational

7. What is the date (*month*/*year*) the project entered the planning phase? What is the date (month/year) the CV applications are expected to become operational

   Planning: ______________________
   Operational: ______________________

8. What type of roadway is involved?

☐ Collector
☐ Arterial
☐ Freeway
☐ Other

9. Why was this location selected for a CV deployment?

10. What specific CV application(s) will the project involve?

11. What type of vehicle equipment is being used?

12. What type of infrastructure equipment is being used?

13. What is the mode of communication?

☐ GPS
☐ Cellular
☐ Bluetooth
☐ Dedicated short-range communications (DSRC)
☐ Other (please specify): ___________________________________

14. What type of data is the vehicle equipment transmitting to the infrastructure equipment?

15. What type of data is the infrastructure equipment transmitting to the vehicle equipment?

16. What systems development approach, or guidance, is being used 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)
☐ Other deployment examples in Florida
☐ Other deployment examples outside of Florida (please specify): ____________________
☐ US DOT guidance (based on CV Pilots documentation)
☐ Contractor-specific development approach
☐ Not decided yet/unknown at this time

17. How is the project being funded? (Check all that apply)

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

Procurement Questions

18. Please give an overview of the procurement process used for the project.

19. Did the procurement process for this project differ from other ITS projects you have experienced? If yes, please elaborate.

20. What was the first steps taken in the procurement process?

21. When did the first steps taken in the procurement process occur?

22. Who initiated the first steps taken in the procurement process?

23. What phase of the project were available/current system technologies and components considered?

☐ Planning
☐ Design
☐ Procurement

24. Please explain the process of how CV-related items being purchased?

25. Please rate the difficulty in procuring the design elements of the project.

☐ Somewhat difficult
☐ Very difficult
☐ Not difficult
☐ Unknown at this time
☐ Not applicable to this project

Please elaborate: ____

26. How much time was required and how many staff members were needed to complete the procurement process?

27. What other departments were involved in the procurement process?

28. Were consultants involved in the procurement process?

29. Is a consultant helping with elements of the project? (Check all that apply)

☐ Consultant helping with system planning
☐ Consultant helping with preparing procurement specifications
☐ Consultant helping with overseeing the work
☐ Other (please specify): ____

30. How many times has this procurement approach been used with other CV projects?

☐ Several
☐ Few
☐ Never

Comments: ____

31. How many contracts were required for the project (one contract or multiple contracts)? Please elaborate.

32. How difficult was contract development?

☐ Somewhat difficult
☐ Very difficult
☐ Not difficult
☐ Unknown at this time

Please elaborate: ____

33. Please describe how the work will be allocated to the contracts.

34. Will a systems manager or systems integrator be used? (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., separate firm for the vehicle installations)
☐ Other deployment examples in Florida
☐ Not decided yet/ unknown at this time
☐ Not applicable to this project

Comments: ____

35. Select the approach that best describes how the system will be purchased.

☐ Design-Bid-Build approach (after design, specifications for parts of the system are released, then contractor/systems integrator makes sure that it all works together)
☐ Design-Build approach (a single contractor provides for the design, procurement of needed equipment, and implementation of the system)
☐ Public Private Partnership (P3) where the agency works with a private firm or group who designs, builds, operates, and maintains the CV equipment or system.
☐ Not decided yet/ unknown at this time
☐ Other (please specify): ____

36. What type(s) of contract will be used for the CV portions of the project? (Check all that apply)

☐ Fixed price
☐ Cost reimbursable
☐ Incentive
☐ Time and Materials
☐ Not decided yet/unknown at this time
☐ Multiple types (please describe): ____
☐ Other (please specify): ____

37. How will contractors/vendors be selected (i.e., methods of award)? (Check all that apply)

☐ Based on Qualifications
☐ Based on Cost
☐ Sole source
☐ A combination of these methods (please specify): ________________________________

☐ Not decided yet/unknown at this time
☐ Other (please specify): ____

38. How will potential technologies and technology vendors be selected? (Please specify)

39. Are tools, such as software, checklists, etc., being used to assist in the procurement process? (Please specify)

40. Does the procurement process consist of different stages or build phases? (Please specify)

41. Are partner agencies participating in the procurement of the system? (Please specify)

42. Does the specified CV equipment and applications being used require customized software development, or is COTS being used? (Select one from the following options)

☐ Vendor equipment/products mainly COTS with very little software development required
☐ Vendor equipment/products mainly COTS with some software development required
☐ Some vendor products are COTS, but substantial software/hardware development is required
☐ This project consists of mainly software and/or hardware development
☐ Other (please specify): ____

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

☐ Yes
☐ Not yet
☐ Not sure
☐ Other (please specify): ____

44. What ITS/CV standards will be used to facilitate the integration and interoperability of the system? (Please specify)

45. Do the previously mentioned standards assist with the writing of procurement specifications? (Please explain)

Issues/Lessons Learned Questions

46. Have you experienced limitations in the procurement process, and how may these limitations affect the success or efficiency of the CV procurement?

☐ Yes (please explain below)
☐ No
☐ Not sure
☐ Too early in the process to tell

Please elaborate: ____

47. If limitations were experienced in the procurement process, how were they addressed?

48. Did the CV procurement require the use of business processes or practices not previously used with other ITS project?

☐ Yes (please explain below)
☐ No
☐ Not sure
☐ Too early in the process to tell

Please elaborate: ____

49. What was the biggest challenge experienced during the procurement process?

50. Please share lessons learned from the procurement process.

51. Please provide all other challenges and/or comments related to CV procurement that may improve the process.

APPENDIX C – CV Deployment Procurement Questionnaire: Other States

1. Please provide your information below.

Name: ____

Title: ____

Address: ____

____

____

Phone: ____

Email: ____

District: ____

2. Are there ongoing or operational CV deployments in your state?

☐ Yes; *If Yes, please proceed with the survey.*
☐ No; *If No, please skip to the end and submit the survey.*
☐ Not sure: *If Not sure, please forward the email invitation to someone in your organization that may be able to participate in this survey.*

3. Please provide the CV project information below.

Project Name: ____

4. What phase of deployment is the CV project currently in?

☐ Planning
☐ Design
☐ Implementation
☐ Operational

5. What type of roadway is involved?

☐ Collector
☐ Arterial
☐ Freeway
☐ Other

6. What type of data is being collected?

7. Do you have a policy/procedure/guidelines in place to manage the data being/to be collected? If yes, please elaborate.

8. What specific CV application(s) will the project involve?

9. What type of vehicle equipment is being used?

10. What type of infrastructure equipment is being used?

11. What is the mode of communication?

☐ GPS
☐ Cellular
☐ Bluetooth
☐ Dedicated short-range communications (DSRC)
☐ Other (please specify): ___________________________________

Procurement Questions

12. Did the procurement process for this project differ from other ITS projects you have experienced? If yes, please elaborate.

13. Please rate the difficulty in procuring the design elements of the project.

☐ Somewhat difficult
☐ Very difficult
☐ Not difficult
☐ Unknown at this time
☐ Not applicable to this project

Please elaborate: ____

14. How many times has this procurement approach been used with other CV projects?

☐ Several
☐ Few
☐ Never

Comments: ____

Issues/Lessons Learned Questions

15. Briefly discuss lessons learned from the procurement process of CV projects

16. Are there any best practices that you would like to share? If Yes, explain

17. Is there anybody in your agency who you would like us to contact for further information on procurement of CV related projects?

    Name
    Email Address
    Phone Number