Connected Vehicle Pilot Deployment Program Phase 1, Concept of Operations (ConOps) – Tampa (THEA)

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16. Abstract

This document describes the Concept of Operations (ConOps) for the Tampa Hillsborough Expressway Authority (THEA) Connected Vehicle (CV) Pilot Deployment. This ConOps describes the current state of operations, establishes the reasons for change, and defines operations for the future in terms of functions/features and supporting operations. This document will be used to present the vision, goals and direction for the project and support the detailed systems engineering development process.

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Draft	12/14/15	THEA	Initial draft release for USDOT review and comment
Revision 1	1/18/16	THEA	Updated to reflect USDOT comments
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1 Purpose of Document

This document describes the Concept of Operations (ConOps) for the Tampa Hillsborough Expressway Authority (THEA) Connected Vehicle (CV) Pilot Deployment. This ConOps describes the current state of operations, establishes the reasons for change, and defines operations for the future in terms of functions/features and supporting operations. This document will be used to present the vision, goals and direction for the project and support the detailed systems engineering development process.

This ConOps provides a vehicle to engage stakeholders in discussions on stakeholder and user needs, provide documentation of those needs and seek to ensure that the development of the proposed system results in a viable, sustainable system that aligns with the identified stakeholder and user needs.

The ConOps will address several fundamental issues:

- The purpose of the project
- Who will use the system and what it will be used for
- How and when the system will be used
- Where the system will be used
- In what environment the system will be used
- Who will maintain the system and how it will be maintained
- What the roles and responsibilities are of the various parties using the system
- How the effectiveness of the system is going to be measured.
- How the new system will impact stakeholder operations

This document will continue to function throughout project phases two and three as well. It will be updated periodically to reflect the evolving system development in greater detail and document changes in operational scenarios that may occur based on future conditions.

2 Project Scope

The THEA CV Pilot Deployment (Herein referred to as the "Pilot") in downtown Tampa aims to create a connected urban environment to measure the effect and impact of CVs in Tampa's vibrant downtown. To the vision of a connected downtown, the proposed Pilot Project offers several CV applications that can be deployed in Tampa's Central Business District (CBD) and environs. This environment has a rich variety of traffic, mobility and safety situations that are amenable to vehicle to vehicle (V2V), vehicle to infrastructure (V2I) and vehicle to "everything" (V2X) solutions, where "everything" includes all communications media (e.g., smartphones). The deployment area is within a busy downtown and offers a tolled expressway with street-level interface, bus and trolley service, high pedestrian/bicycle densities, special event trip generators and high dynamic traffic demand over the course of a typical day. These diverse environments in one concentrated deployment area collectively encompass many traffic situations that allow for deployment and performance testing of CV applications.

The scope of the Pilot will comprise THEA/City of Tampa (CoT) Combined TMC Operations, Hillsborough Area Regional Transit (HART) Bus Operations, CoT signal Operations and Maintenance (O&M), CV-Pilot System Development, CV-Pilot Design, Deployment and O&M, Key Agency Partners, Stakeholders and System Users, and Sustainability Models/Partners.

2.1 Executive Summary

The THEA CV Pilot is funded by a federal grant awarded in September of 2015 by the United States Department of Transportation (USDOT, Joint Program Office (JPO)). The pilot is one of three selected from more than forty applicants and continues the efforts to generate a body of research data from tested utilization of CV applications to address real world issues impacting Safety, Mobility, Environment and Agency Efficiency. Phase 1 of the Pilot began in mid-September 2015 and will run for one year. If all approvals are granted, Phase 2 and 3 would run three more years until November 2019.

The THEA Pilot is based on traffic studies within the pilot area that identified six use cases; issues that can potentially be mitigated through the use of CV technology. These issues were chosen based on availability of historic data demonstrating current untreated scenarios, their impact to the community, and the ability to measure the performance of the applied technology versus the current, untreated conditions.

The use cases selected for this Pilot are identified below along with their locations.

- The intersection of **Twiggs Street and Meridian Avenue at the entrance/exit to the Selmon Expressway Reversible Express Lanes (REL)** has long queues during the morning rush hour due to poor signal progression and right turns onto Twiggs immediately followed by a second right turn onto Nebraska Avenue. This causes the queue to back up onto the Selmon Expressway REL exit and into the curve where rear end crashes and other incidents are occurring. Potential CV technologies proposed for this location are V2I (i.e., Curve Speed Warning [CSW] and Intelligent Traffic Signal System [I-SIG]) and V2V (i.e., Emergency Electronic Brake Light [EEBL] and Forward Collision Warning [FCW]).

- The **Entrance/Exit point of the REL at Meridian Avenue and Twiggs Street** is a potential site for wrong-way entries. Wrong-way drivers have become a significant problem in the Tampa Bay area and are a major safety concern at the State level as well. Potential CV technologies proposed for this location are V2I (I-SIG and Probe Enabled Traffic Monitoring) and V2V (i.e., Intersection Movement Assist [IMA]).
- **Twiggs Street at the Hillsborough County Courthouse** has a mid-block pedestrian crossing combined with no protected left turn into the parking garage for the courthouse. This creates pedestrian safety issues as they traverse Twiggs Street. Additionally, pedestrians are crossing at unmarked locations, further complicating the pedestrian safety concern. Potential CV technologies proposed for this location are: V2I (Pedestrian in Signalized Crosswalk Warning, Mobile Accessible Pedestrian Signal, and I-SIG), and V2X (Smart Phone to Roadside Unit).
- HART operates express, local and Bus Rapid Transit (BRT) routes **along and across the downtown city streets to the Marion Street Transit Station**. BRT routes offer efficiency gains in moving more people; however, during peak periods, the BRT service suffers from poor transit travel time and travel time reliability due to poor signal progression from heavy pedestrian and passenger vehicle volumes and passenger vehicles blocking access to bus stops. Potential CV technologies proposed for this location are V2I (Transit Signal Priority [TSP] and I-SIG).
- **The Amalie Arena/Channelside Drive Area** is a tourist destination and event area. Channelside Drive experiences many types of safety and mobility challenges due to being a part of morning and afternoon peak travel routes, special events, the streetcar trolley and stations and activities associated with the cruise terminal at the Port of Tampa. Depending on the time and day, at least two of the issues identified above have a negative impact on overall travel safety and mobility in the area. One critical potential for conflicts is the TECO Line Trolley that runs through this area. In many cases, the trolley runs parallel to vehicle lanes with a common approach to traffic control signals. The signal will be red for all vehicle phases during the trolley crossing. However, right turn on red is typically a legal move, which may cause a motorist, unaware of the trolley's presence, to turn right into the trolley's path. Similar scenarios occur with the significant pedestrian/bicycle traffic in this area. Potential CV technologies proposed for this location are V2I (I-SIG), V2V (Vehicle Turning Right in Front of Bus Warning), and V2X (Vehicle to Smart Phone).
- The **area of downtown Tampa from the Selmon Express Lanes along Twiggs Avenue to Marion Street and along Meridian Avenue to Channelside Drive** has a significant amount of queuing and congestion during the morning peak periods as well as during special events. Potential CV technologies proposed for this location are V2I (Probe Enabled Traffic Monitoring and I-SIG).

3 References

3.1 Referenced Documents

The following table lists the references used to develop the concepts in this document.

Table 1: References

#	Document **(Title, source, version, date, location)**
1	FHWA, USDOT Guidance Summary for Connected Vehicle Pilot Site Deployers – Concept of Operations and the CVRIA/SET-IT Tool, Draft report: FHWA-JPO-xx-xxx, September 2015.
2	FHWA, USDOT, Broad Agency Announcement No. DTFH6115R00003, January 30, 2015.
3	FHWA, USDOT, Systems Engineering for Intelligent Transportation Systems , An Introduction for Transportation Professionals, http://ops.fhwa.dot.gov/publications/seitsguide/seguide.pdf, January 2007.
4	THEA, Final Needs Summary, November 23, 2015.
5	THEA, Final Stakeholder Review Panel Roster, November 23, 2015.
6	THEA, The Connected Vehicle Pilot Deployment Program, Phase 1, March 26, 2015. (THEA CV Pilot Proposal.)
7	CVRIA website, http: iteris.com/cvria/, accessed November 30, 2015.
8	SET-IT Download Page, *http://www.iteris.com/cvria/html/resources/tools.html,* accessed November 30, 2015.

3.2 Definitions and Acronyms

The following table defines selected project specific terms used throughout this Concept of Operations document.

Table 2: Acronym List

Acronym/Abbreviation	Definition
AET	All Electronic Toll
BAA	Broad Agency Announcement
BRT	Bus Rapid Transit
BSM	Basic Safety Message
CBD	Central Business District
CCTV	Closed Circuit Television
ConOps	Concept of Operations
CV	Connected Vehicle
CVRIA	Connected Vehicle Reference Implementation Architecture
DMS	Dynamic Message Sign
DSRC	Dedicated Short Range Communications
HART	Hillsborough Area Regional Transit
HUA	Human Use Approval
IEEE	Institute of Electrical and Electronics Engineers
IMA	Intersection Movement Assist
IRB	Institutional Review Board
ITS	Intelligent Transportation System
MAFB	MacDill Air Force Base
MOU	Memorandum of Understanding
MUTCD	Manual of Uniform Traffic Control Devices
OBU	Onboard Unit
OEM	Original Equipment Manufacturers
ORDS	Object Registration and Discovery Service
REL	Reversible Express Lane
RSU	Roadside Unit
SCMS	Security Credential Management System
SE	System Engineering
SET-IT	System Engineering Tool for Intelligent Transportation
SM	System Monitoring
SOP	Standard Operating Procedure
SPaT	Signal Phase and Timing

Acronym/Abbreviation	Definition
SRM	Signal Request Message
SSM	Signal Status Message
THEA	Tampa Hillsborough Expressway Authority
TIP	Transportation Incentive Program
TMC	Traffic Management Center
TOD	Time of Day
V2I	Vehicle to Infrastructure
V2V	Vehicle to Vehicle
V2X	Vehicle to Device
VAD	Vehicle Awareness Device
VIN	Vehicle Identification Number

Table 3: Glossary of Terms

Term	Definition
Automobile	A light vehicle (e.g., car or pickup truck), motorcycle, moped, or other powered wheel vehicle that is legal to operate on streets.
App	Software application
Buffer Time	This is the time from when the pedestrian countdown ends and the opposing signals turns green
Center/Agency (TMC)	Stakeholders of the systems located in the TMC, i.e. owners/operators
Center/Agency (MAFB):	Stakeholders of the systems located at MacDill Air Force Base, i.e. owners/operators
Center/Agencies (HART Operations Center):	Stakeholders of the systems located at HART, i.e. owners/operators
Center Connected V2I Management	RSU Management software system located within the TMC that manage a wide area Network of RSUs, and not part of the TMC Regional Traffic Management
Curve Speed Warning (CSW)	An application where alerts are provided to the driver approaching a curve at a speed that may be too high for safe travel.
Emergency Electronic Brake Light (EEBL)	An application where the driver is alerted to hard braking in upstream traffic. This provides downstream drivers with additional time to look for, and assess situations developing ahead.
Forward Collision Warning (FCW)	An application where alerts are presented to the driver to help avoid or mitigate the severity of crashes into the rear end of other vehicles on the road. Forward crash warning responds to a direct and imminent threat ahead of the host vehicle.
Intersection Movement Assist (IMA)	An application that warns the driver when it is not safe to enter an intersection—for example, when something is blocking the driver's view of opposing or crossing traffic.
Intelligent Traffic Signal	An overarching system optimization application accommodating signal priority,

Term	Definition
System (I-SIG)	preemption and pedestrian movements.
Mobile Accessible Pedestrian Signal (PED-I-SIG)	An application that allows for an automated call from the smart phone to the traffic signal, as well as cues to safely navigate the crosswalk.
Probe-enabled Data Monitoring (PeDM)	An application that utilizes communication technology to transmit real time traffic data between vehicles and roadside equipment.
Pedestrian in a Signalized Crosswalk (PED-SIG)	An application that warns drivers when pedestrians, within the crosswalk are in the intended path of the vehicle.
Roadway Signal Control	The traffic signal control software application installed in traffic signal controllers
Tampa Intersection Devices	The physical roadside equipment excluding the THEA RSUs
TERL	Traffic Engineering Research Laboratory, a joint Florida DOT and Florida State University partnership for traffic equipment standards and testing development research
THEA RSU	DSRC roadside radios conforming to USDOT requirements
TMC	The physical TMC room and communications infrastructure; excluding the existing TMC software system.
TMC Intersection Safety	Intersection Safety software system located within the TMC that manages and collects intersection safety data, not the safety application running at the roadside and not part of the TMC Regional Traffic Management
TMC Regional Traffic Management	Traffic Management software system located within the TMC that manages the wide area network of signal controllers, not part of the Center Connected V2I Management
Transit Signal Priority (TSP)	An application that provide signal priority (green) to transit at intersections and along arterial corridors.
Vehicle Turning Right in Front of Transit Vehicle (VTRFTF)	An application that warns transit bus operators of the presence of vehicles attempting to go around the bus to make a right turn as the bus departs from a bus stop.

4 Background

This chapter describes the traffic operations characteristics, traffic signal system and ITS environment in downtown Tampa as it currently exists. Since there is no current CV system, this section describes the situation that motivates development of the proposed THEA CV Pilot. This section provides an introduction to the problem domain enabling understanding of the reasons for the THEA CV Pilot's changes and improvements.

4.1 Background and Objectives

The THEA CV Pilot aims to meet the purposes set forth in the USDOT's Broad Agency Announcement (BAA) to advance and enable safe, interoperable, networked wireless communications among vehicles, the infrastructure, and travelers' personal communications devices and to make surface transportation safer, smarter, and greener. The THEA CV Pilot aims to demonstrate the kinds of improvements that can be made in an urban environment, with Tampa's Central Business District (CBD) as the example site. THEA is deploying site-tailored collections of applications that address specific local needs while laying a foundation for additional local/regional deployment, and providing transferable lessons learned for other prospective deployers across the nation.

THEA has developed partnerships of multiple stakeholders to deploy applications using data captured from multiple sources (e.g., vehicles, mobile devices, and infrastructure) across multiple elements of the surface transportation system (i.e., transit, arterial, and electronically tolled roadways) to support improved system performance. Some data will be collected automatically from devices. It has not been determined which devices (e.g., OBUs, Smart Phones, VADs, RSUs) will be needed for downloading. Task 8, Human Use Approval (HUA) will address as part of the Informed Consent procedure for participants whether bringing in vehicles for data download will be necessary.

Traffic Operations Characteristics:

- THEA owns and maintains the TMC while the City of Tampa staffs the TMC.
- The City of Tampa operates and maintains signing and flashers at the mid-block crossing at the County courthouse. The City of Tampa also operates the parking garage across from the courthouse.
- THEA owns the Meridian Avenue roadway and the City of Tampa operates the Meridian Avenue signals.
- The City of Tampa owns the city streets with the exception of Meridian Avenue and operates the traffic signal system citywide.
- THEA owns and operates the Selmon Expressway, a primary route into downtown and to MacDill Air Force Base (MAFB).
- HART owns, maintains, and operates its transit operations center. HART operates an express route along and through the downtown city streets to the Marion Street Transit Station. The TECO Streetcar line is operated by HART.

Ongoing safety, accessibility, and mobility issues are of concern to THEA, the City of Tampa and HART. In this regard, HNTB has done or has underway a number of Traffic and Safety Studies[1] for THEA in the CV Pilot area including:

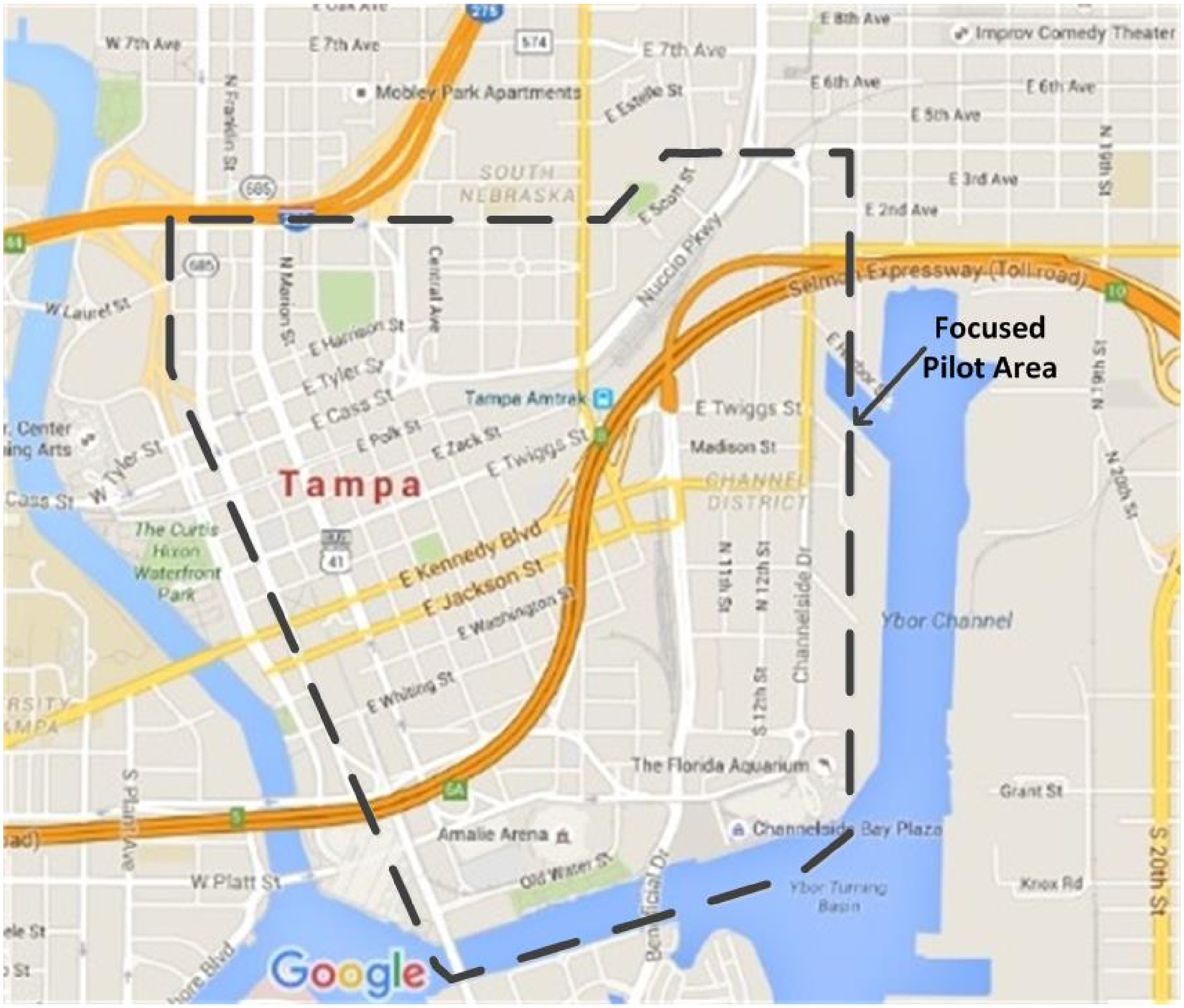
- Arterial Safety Analysis: Selmon Expressway (S.R. 618 Toll) from W Gandy Blvd to Town Center Blvd, Brandon Parkway from Town Center Blvd to Lumsden Rd, Meridian Ave from Channelside Drive to E Twiggs St, Lakewood Drive from Brandon Pkwy to Brandon Blvd, Brandon Main St from Providence Rd to Lakewood Drive Hillsborough County, August 2015.
- Meridian Avenue at Twiggs Street Southbound Right Turn Movement Traffic Analysis, July 2014.
- Plan Sheets for Pedestrian Access at Meridian Avenue and Twiggs Street, June 2015.
- Twiggs Street Operational Analysis of Pedestrian Conflict Issues in the Vicinity of the Courthouse on Twiggs Street, 2014.
- Channelside Drive and Adamo Drive: Pedestrian and Trolley Conflicts, 2013.
- Channelside Area Road Safety Audit: Improving Pedestrian and Bicycle Safety and Accessibility, in preparation (2015).

The THEA CV Pilot environment has been well-studied[1] and there are significant quantitative descriptions of the present situation in those reports that will assist in forming a baseline of current conditions. The study area has intermodal traffic conflicts that have found incomplete resolution with standard methods of traffic systems management. CV applications offer a means of applying new methods to improve traffic safety, accessibility and mobility.

4.2 Description of Current Situation

Downtown Tampa is bordered by Ybor Channel (Cruise Ship and Commercial Port Channel) to the east, Garrison Channel (local waterway) to the south, Florida Avenue to the west, and Scott Street to the north. A virtually flat topography near sea level helps to simplify the evaluation of traffic flow parameters (see Figure 1).

[1] For access to these studies, contact: HNTB Corporation, 201 N Franklin Street, Suite 550, Tampa, FL 33602. 813-498-5111



Source: Googlemaps.com, HNTB

Figure 1: Focused Pilot Area

The main transportation features of the downtown Tampa CBD are:

1. The Tampa Hillsborough Expressway Authority (THEA) owns and operates the Selmon Expressway and the Reversible Express Lanes (REL), a reversible elevated express lane, an all-electronic toll (AET) facility that serves as a main commuter route connecting the community of Brandon (a large residential area to the east with a population of 103,000) and Interstate I-75 with downtown Tampa, the Tampa Cruise and Commercial Port, and MAFB southwest of the downtown area 1 (see Figure 2). REL traffic exits at the intersection of Twiggs Street and Meridian Avenue in downtown. The Selmon Expressway, also AET, runs parallel to the REL and Exits 7 and 8, deposit and collect traffic downtown as well. The final exit is at Dale Mabry Highway, which is the location of MAFB's main gate. Since the spring of 2010, all vehicles on the expressway are tolled electronically as they pass under gantries that hold the tolling equipment. Payment is made through SunPass or license plate-based accounts.
2. THEA's Selmon Expressway was the test bed for connected vehicles on the Audi Autonomous Vehicle Pilot, and THEA is a member of the USDOT Affiliated Test Bed Program for Connected Vehicles.

3. THEA's Selmon Expressway can facilitate real-time traffic tests in a closed-course environment. Taking advantage of this unique functionality, THEA conducted its first automated vehicle test on the REL of the Selmon Expressway that was closed for several days from 10 am–4 pm in late July 2014 while Audi tested its Audi Connect A7 autonomous vehicle.
4. I-275 Exit 44 connects to the study area on the northwest onto N. Orange Avenue and is another significant generator of downtown traffic.
5. Meridian Avenue is a major gateway to downtown Tampa and will be the focal point for several of this pilot's applications. Channelside Drive, on the east and south borders of the test area, connects to Amalie Arena and the Tampa Cruise Ship Terminals.
6. Hillsborough Area Regional Transit (HART) bus lines route through this area and express routes utilize the REL for commuters from the Brandon area. The Marion Transit Center is in the northwest section of the test area on Marion Street at Laurel Street near I-275.
7. The TECO Line Streetcar Line extends through the project area servicing local businesses and the Amalie Arena and Tampa Cruise Ship Terminals that are important special event traffic generators (see Figure 3).
8. Tampa Port Authority operates three International Cruise Ship terminals located in the project area as well as a commercial port area and generates pedestrian tourist traffic with little knowledge of Tampa's street network and transit system.
9. The Tampa CBD has a high volume of pedestrian activity and an active bike share program.
10. There are numerous THEA-leased, City-run and private parking garages/lots in downtown.
11. MacDill Air Force Base is located eight miles south of downtown Tampa adjacent to the western terminus of the Selmon Expressway. A large number of vehicles enter/exit the base daily from the Selmon Expressway and the Tampa street network. Also, the base has a Transportation Incentive Program (TIP) in which about 1,450 base personnel use express bus or van pools. The TIP provides monthly express HART line bus passes to commuters who live in suburban areas east of Tampa. The van pool program provides commuters, in groups of five or more, funding to secure a passenger van for their daily commute.

Figure 2: Selmon Expressway and Environs **Source: THEA, HNTB**

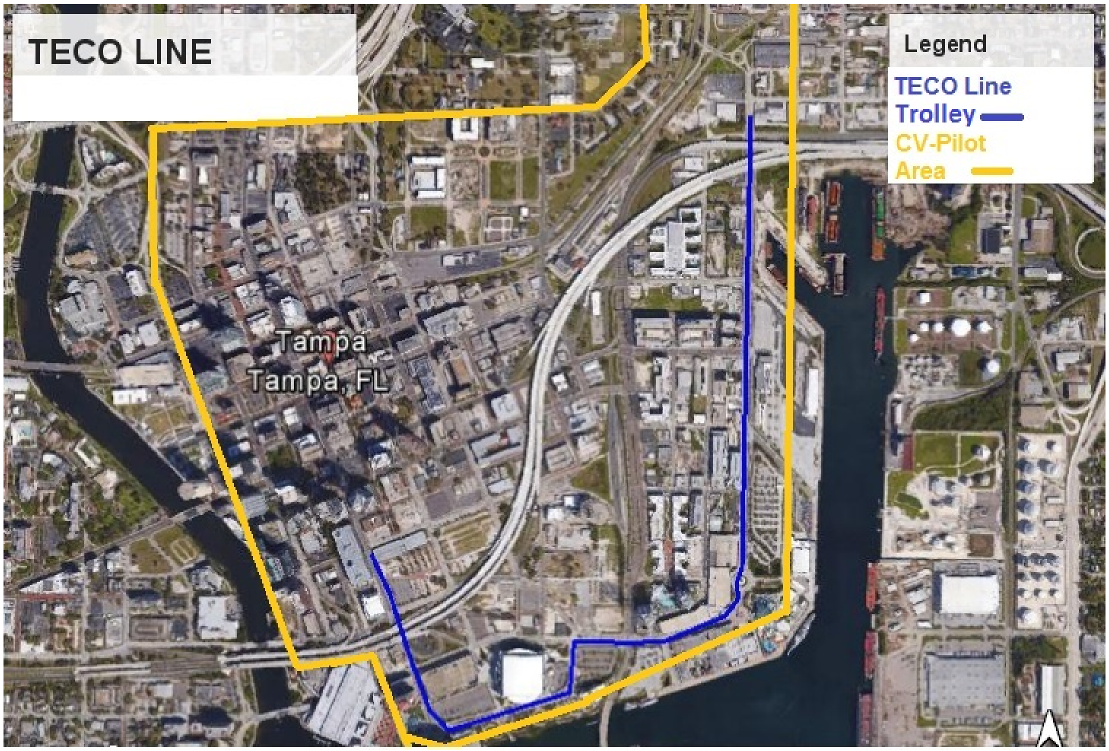


Figure 3: TECO Line Trolley **Source: Googlemaps.com, HNTB**

These transportation features have the following identified issues:

1. The Selmon Expressway's REL morning commute endpoint is at the intersection of Twiggs Street and Meridian Avenue. Twiggs Street and Meridian Avenue are also major routes for HART buses into and out of the downtown Tampa CBD. Drivers experience significant delay during the morning peak hour resulting in, and often caused by, a correspondingly large number of rear-end crashes.
2. At the entry to the Selmon Expressway REL during inbound operations (6:00 AM – 1:30 PM weekdays) there are wrong-way entries.
3. Bus Rapid Transit (BRT) routes offer efficiency gains in moving more people; however, during peak periods, the BRT service suffers from poor signal progression, heavy volumes and passenger vehicles blocking access to bus stops.
4. Meridian Avenue and West Kennedy Blvd experience transit signal delay, pedestrian conflicts and signal coordination issues.
5. At the Hillsborough County Courthouse on Twiggs Street, there is significant competing vehicular and pedestrian traffic during the morning peak hour (7:00 AM – 10:00 AM). There are a significant number of pedestrian-vehicle mishaps.
6. Vehicles and pedestrians conflict with the TECO Line Streetcar Trolley at crossing locations throughout the project area, particularly along Channelside Drive (see Figures 3 and 4).
7. On the east portion of the project area along the Channelside Drive corridor, visitors experience delays associated with arrivals and departures at the International Cruise Ship terminals and the Amalie Arena.
8. MAFB experiences long queue times at controlled access points during the peak morning arrival time. THEA is working with MAFB to add Dynamic Message Signs (DMS) at decision points to facilitate the dissemination of queue time and alternative entry point information. A study is currently underway to determine the best approach to this issue and it is likely that the project will

benefit from this pilot by adding a CV component. MAFB presents an opportunity to create a fleet of vehicle probes for data collection. This is possible through its commuter vehicle population and through its Transportation Incentive Program that has van pool vehicles in addition to HART buses.

5 User-Oriented Concept Operational Description

This section defines the project vision, goals and objectives from a user perspective to enable users, stakeholders, system owners, agency partners and system developers to achieve consensus and understanding of how the new system will operate and benefit their interests.

Existing policies and constraints are also identified to understand how they will affect the pilot and its users. There are a number of different stakeholder types. They are identified by their type and the stakeholder type is defined so one can understand why a stakeholder is classified. The system users are identified and their role defined.

5.1 Project Vision

In the near future, America and indeed the industrialized world will be a equipped with state-of-the-art CV technologies that provide improved mobility, reduced environmental impact and attainment of the USDOT goal of near zero fatalities from vehicle crashes. It is envisioned that the deployed system when expanded will improve mobility and safety, reduce environmental impact, increase operational efficiency for agency stakeholders, decrease lost revenue due to commute related delays, reduce insurance costs and boost tax revenues. The greatest anticipated outcome is an improvement in overall quality of life for Tampa Bay Residents. This pilot project provides valuable insight and research data toward that end, but also positions the Tampa Bay Area as a leader in this technology by deploying actual CV technology for use in treating real world issues within the pilot test-bed area. The system developed, designed, deployed and operated in Downtown Tampa will remain in place and reach sustainability and growth status through business models and partnerships developed throughout the program, thus making Tampa Bay attractive to business expansion and relocation to the area.

5.2 Project Goals and Objectives

The goals and objectives for the THEA CV Pilot are:

Goal 1: Develop and Deploy CV Infrastructure to Support the Applications Identified During Phase 1

Objective 1: Deploy DSRC technologies to support V2V, V2I and V2X applications
Objective 2: Upgrade TMC software to ensure compatibility with CV Applications
Objective 3: Recruit a fleet of transit and private vehicle owners and individuals carrying V2X-enabled mobile devices to participate in the CV Pilot by installing and using CV technology offered in the pilot.

Goal 2: Improve Mobility in the Central Business District (CBD)

Objective 1: Replace existing traffic controllers and control systems at key intersections with intelligent-signal (I-SIG) CV technology to improve traffic progression at identified problem areas.
Objective 2: Provide TSP applications to help HART buses stay on a predictable schedule.
Objective 3: Provide BRT applications to improve overall operation and encourage increased ridership

Goal 3: Reduce the Number of Safety Incidents within the Pilot Area

Objective 1: Provide detection of pedestrians and warnings to drivers of potential pedestrian conflicts.
Objective 2: Provide detection of potential vehicle conflicts and warnings to pedestrians.
Objective 3: Provide early detection of wrong-way drivers and issue warnings to wrong- way drivers and upstream motorists
Objective 4: Give drivers warnings of the REL exit curve and stopped vehicles ahead
Objective 5: Provide detection and warning of potential conflicts between trolley vehicles and autos, pedestrians/bicycles

Goal 4: Reduce Environmental Impacts within the Pilot Area

Objective 1: Provide CV Mobility and Safety applications to improve overall mobility and reduce stops and idle time within the CBD, thus reducing emissions
Objective 2: Provide TSP applications to reduce idle time of HART buses
Objective 3: Provide BRT applications to improve overall operation and encourage increased ridership

Goal 5: Improve Agency Efficiency

Objective 1: Improve traffic data collection capability, reducing the costs of collecting data
Objective 2: Reduce the number of incidents and police and rescue responses to incidents
Objective 3: Reduce crashes and time agencies take to gather data
Objective 4: Improve technology for crash statistics gathering
Objective 5: Improve scheduling and dispatching of HART vehicles with improved trip times and vehicle information
Objective 6: Reduce overhead of THEA responding to wrong-way entries and crashes on REL exit ramp

Goal 6: Develop Business Environment for Sustainability

Objective 1: Work with CAMP, OEM's, and third party developers to develop business cases for advancing CV-ready vehicles
Objective 2: Work with industry sectors that will benefit from CV implementation, e.g.: insurance carriers, fleet managers, safety organizations, etc., to provide education on the benefits and seek support for advancement of the system
Objective 4: Work with Chambers of Commerce and other business organizations to educate members on the return on investment from increased mobility.
Objective 3: Work with state and local Government to encourage positive legislation and funding in support of CV technology.

5.3 Policies

There are a number of policy documents, guidelines and standards that may affect or constrain the development, operation, testing or maintenance of the system:

- THEA Charter for overall system deployment and operations
- THEA Tolling Operations ConOps for operations of REL, wrong way notifications

- THEA Network Security policy
- THEA/City of Tampa Joint TMC MOU and Standard Operating Procedures (SOPs) for CV Pilot training, support, operations, fail safe criteria
- City of Tampa Traffic Operations Department SOPs for CV Pilot training, support, operations, fail safe criteria
- HART SOPs and driver contracts impacts per Human Use and informed consent for app deployment
- MAFB rules concerning privacy, security, app use on base, Human Use informed consent for app use
- Federal guidelines for Human Use Approval (HUA) and Institutional Review Board (IRB) HUA comments
- Federal Information Processing Standards Publication (FIPS PUB 200) - Minimum Security Requirements for Federal Information and Information Systems
- IEEE Standards and Practices and other communications protocols
- FDOT Traffic Engineering Research Laboratory (TERL) findings and testing procedures
- FDOT Standards and Specifications that have precedence over road and signal operations
- Manual of Uniform Traffic Control Devices (MUTCD) for signal placement, warrants, signage and lane demarcations
- AASHTO Green Book for roadway and highway design policies.

5.4 Constraints/Challenges

Operational constraints/challenges include:

- Recruiting and training adequate numbers of drivers to evaluate vehicle safety and mobility applications
- Training TECO Streetcar and HART bus drivers who may vary over the life of the evaluation period
- Training THEA/City of Tampa TMC Operators
- Equipping adequate number of private vehicles accessing downtown Tampa via the Expressway and accessing MAFB
- Training of THEA and City of Tampa maintenance technicians relative to roadside installed with THEA CV Pilot Deployment.
- Timely trouble-shooting and repair of personal portable connectivity devices, roadside equipment and on-board equipment
- Coordination with City of Tampa Police for traffic and pedestrian restrictions during major special events
- Upgrading traffic signal controllers in downtown Tampa to be compatible with roadside equipment
- Definition of pilot data collection and archival requirements as well as primary and secondary data collection and archival servers, data formats and data access for national and local IRB's

5.5 Stakeholders

As part of the project, a Stakeholder Registry was created and delivered identifying the stakeholders for the pilot. A Stakeholder Review Panel Roster (see References in Section 3) was developed from the Stakeholder Registry. A listing of Stakeholders on the review panel and their roles in the project is shown in Table 4.

There are many stakeholders identified for the Pilot. Core team stakeholders are the members of the project team. Key Agency Partners are those agencies that are directly affected by the Pilot Deployment.

Key Stakeholder Agencies and Key Stakeholder Organizations are those agencies/organizations that may interact with the pilot. Key Technology and Vendor Stakeholders are those private companies that may supply hardware or software to be used during the operation of the pilot. Project Originators is the USDOT offices that are overseeing the pilot project. Independent Evaluators are those entities that are supporting the USDOT in conducting the pilot project. Pilot participants such as drivers, pedestrians, bus drivers, and streetcar operators are user stakeholders. Because of the number of participants is large, these participants will be represented by other stakeholders such as TECO Streetcar Line, HART, or MacDill Air Force Base (MAFB) Public Affairs Office.

Table 4: THEA CV Pilot Project Stakeholder Registry Review Panel

Partner/Stakeholder Organization	Stakeholder Category
Tampa Hillsborough Expressway Authority	THEA CV Team (Lead Agency)
HNTB	Core Team Member
Booz Allen Hamilton (BAH)	Core Team Member
University of South Florida Center for Urban Transportation Research (CUTR)	Core Team Member
Global 5 Communication	Core Team Member
Siemens Industry, Inc. Mobility Division Intelligent Transportation Systems	Core Team Member
Tbd	Independent Review Board
City of Tampa (COT) Traffic Engineering/Traffic Management Center (TMC)	Key Agency Partner
Hillsborough Area Regional Transit (HART)	Key Agency Partner
Florida Department of Transportation (FDOT) District 7 (D7)	Key Agency Partner
TECO Streetcar Line	Key Agency Partner
Hillsborough County	Key Stakeholder Agency
Amalie Arena	Key Stakeholder Agency
City of Tampa Police (TPD)	Key Stakeholder Agency
FHP-Tampa	Key Stakeholder Agency
Hillsborough County Sheriff's Office (HCSO)	Key Stakeholder Agency
MacDill Air Force Base (MAFB) Public Affairs Office	Key Stakeholder Agency
Tampa Bay Port Authority (Cargo and Cruise)	Key Stakeholder Agency
Tampa Convention Center	Key Stakeholder Agency
Tampa Downtown Partnership	Key Stakeholder Agency
Tampa Bay Lightning Hockey Team	Key Stakeholder Organization
Tampa Bay Lightning Hockey Club	Key Stakeholder Organization
BMW/GEWI	Key Technology Stakeholder
General Motors (OEM)	Key Technology Stakeholder
Honda (OEM)	Key Technology Stakeholder

Partner/Stakeholder Organization	Stakeholder Category
Metrotech Net, Inc.	Key Vendor Stakeholder
ITS JPO	Project Originator
FHWA	Project Originator
Noblis Tbd	USDOT Support Contractor Independent Evaluator

5.6 System Users

System users will be selected from the general public according to a process to be defined during Task 8, Human Use Approval (HUA). The participants will be tested and selected for their ability to meet minimal criteria for use of CV equipment which is in the test phase in this THEA CV Pilot Deployment. Since this is a naturalistic driving study, where equipment to be used by the general public is in test and evaluation on urban streets and highways, every effort will be made to ensure the safety of the CV Pilot participants and the general public who may or may not be aware of the ongoing study or the equipment in use. On completion of the study it is expected the successful deployment applications and associated CV equipment will remain in use with plans to expand the number of users and add new applications.

System users will use OBUs, VADs and smart phone apps that will provide specific information (e.g., warnings/alerts) to them according to the design of the apps in test. Some apps are passive and need no driver interaction and others require interpretation and active use of the app, including taking appropriate action.

Transit and Streetcar operators are professional drivers who operate buses and streetcars on a daily basis. Their interaction with the pilot equipment and applications is expected to be guided according to procedures in place in the HART and TECO workplaces.

Pedestrians will be using their own smart phones that will be equipped with apps to inform them of potential conflicts when a crosswalk. This information is intended to reduce incidents at key focus areas, such as at the Courthouse and along Channelside Drive.

Auto drivers present the greatest challenge in selection and training. Their job will be to drive as they normally do and interact with the apps as well as take action based on what information the app is providing.

TMC operators, who manage the CoT's signal systems and THEA's REL, will take action based on information some of the apps provide to the TMC. These operators will receive training on what actions are taken when information is received. The Standard Operating Procedures (SOPs) for TMC operations will be updated to reflect the actions associated with CV data received into the TMC.

6 Operational Needs

Currently the THEA/City of Tampa Joint TMC manages opening, closing and directional reversing of the THEA Selmon REL. The TMC also monitors traffic signals in downtown Tampa and throughout the City. The TMC implements special event timing plans for major events in downtown Tampa, Amalie Arena or the Tampa Convention Center. Finally, the TMC dispatches Road Ranger Service Patrol vehicles in response to stalled vehicles or crashes on the REL or local lanes. However, the TMC does not continuously monitor traffic, transit, pedestrian crossings, or the TECO Streetcar line. TMC staffing levels and hours of operations may need to be adjusted based on the requirements to support THEA CV Pilot Deployment. Additional training will need to be conducted for operators.

The operational needs discussed below were identified specifically for each Use Case.

6.1 Morning Peak Hour Queues

TMC operators will monitor queue backups and update the information being sent to drivers about the recommended curve speed as they approach the backup. TMC operators will send a message to the RSU on the exit curve with the recommended speed for broadcasting. TMC operators will monitor the two right turns off of East Twiggs Street and North Nebraska Street and adjust the timing to help address the queuing.

Drivers exiting the REL during morning rush hour will take action based on the information they receive from the onboard applications.

6.2 Wrong-Way Entries

When a wrong way driver is identified, the wrong way driver receives an immediate warning from the RSU that detected the wrong way driver. When a wrong way alert is received in the TMC, an operator will notify law enforcement and send a wrong way warning message to the selected RSUs for broadcasting to the drivers in the area of the wrong way driver.

The wrong way driver should take action when alerted by the onboard system that they are going the wrong way.

Drivers in the vicinity of the wrong way driver should take action when they receive the warning about the wrong way driver.

6.3 Pedestrian Safety

Drivers will become aware of pedestrians nearing their vehicle and will take action to avoid a conflict with the pedestrian.

Pedestrians will become aware of a vehicle nearing them and will take action to avoid a conflict with the vehicle.

6.4 Bus Rapid Transit Signal Priority Optimization, Trip Times and Safety

The roadside application will determine when a bus needs priority and will adjust the signal timing at the intersection to allow the bus to proceed.

The TMC Operator will receive notice that a bus has been given priority and note the occurrence. The transit driver receives notice of the decision that signal priority is granted, not granted, or revoked.

6.5 TECO Line Streetcar Trolley Conflicts

The Streetcar Operator will take action when they receive a notice of a vehicle turning in front of the streetcar.

Pedestrians will take action when they receive notice of a vehicle turning onto the street they may be crossing after exiting the streetcar.

6.6 Enhanced Signal Coordination and Traffic Progression

Using CV data from vehicle probes traversing downtown signal timing will be automatically adjusted at each equipped intersection based on the current traffic conditions. TMC Operators will receive travel times, along the various routes that commuters take through downtown and MAFB gate entrance wait times and provide that information to the commuters. The TMC Operators will utilize signal coordination and traffic progression to improve travel times; especially along Meridian.

Commuters will use the information receive to decide their most effective route and gate to enter MAFB.

7 System Overview

This section describes the key concepts for the THEA CV Pilot Deployment. Although it will cover the THEA CV Pilot Deployment as a whole, it will primarily focus on the new concepts and features. The system is described below from the approach of stating the use cases (sites identified as having documented, measurable issues) and outlining the needs of system users/stakeholders associated with each use case.

7.1 Use Cases with Associated User Needs

The THEA Connected Vehicle Pilot has developed six Use Cases to describe the issues that the pilot is addressing. In some cases, one or more of the Use Cases overlap in the deployment area. However, each Use Case has its own set of user needs discussed below. Each of these Use Cases has multiple identified issues that will require the integration of two or more USDOT CV applications. The User Cases are identified below:

- Morning Rush Hour REL at Twiggs Street
- Wrong Way Entries REL at Twiggs Street
- Pedestrian Conflicts and Safety at Twiggs Street-Courthouse
- BRT Optimization Trip Time Safety BRT-REL to Marion Avenue
- Trolley/Auto/Pedestrian/Bike Conflicts at Channelside Drive
- Traffic Progression at Meridian Avenue

7.1.1 Morning Peak Hour Queues

As vehicles exit the REL onto Meridian Street to make a right turn onto East Twiggs Street, the right turn lane backs up due to local congestion. An additional issue is that many of these vehicles then want to make a right turn onto Nebraska Street which is almost an immediate right turn after turning onto East Twiggs Street. The combination of these issues causes the queue to backup up onto the REL. This backup causes exiting vehicles wanting to turn right to use the shoulder as part of the right turn lane. As vehicles approach the REL exit, they may not be able to anticipate where the end of the queue is for the right turn lane, potentially causing them to hard brake or attempt a rapid lane change. Other vehicles will traverse down the exit in the through lanes waiting until the last minute to squeeze into the right turn lane. This action can cause hard braking in the through lane by vehicles trying to avoid the vehicle waiting to enter the right turn lane (the vehicle may be stopped or partially blocking the lane) These issues can lead to rear end or lane changing crashes, causing safety and mobility concerns. CV technologies V2I (i.e., Curve Speed Warning [CSW] and Intelligent Traffic Signal System [I-SIG]) and V2V (i.e., Emergency Electronic Brake Light [EEBL] and Forward Collision Warning [FCW]) will be used to improve these concerns by informing drivers of the situation they are approaching and improving the signal progression which in turn will more smoothly move traffic through this area. Performance will be measured by delay, queue lengths and crash data compared to pre CV-Pilot conditions.

Table 5: Morning Rush Hour, REL at Twiggs Street Needs

Number	Need
1	REL Drivers exiting downtown at Twiggs/Meridian need to experience less backup and delay.
2	Drivers exiting the REL need to experience fewer crashes where vehicles in front of them or adjacent to them make a sudden stop or lane change.
3	Drivers turning right on East Twiggs Street and/or North Nebraska Street after exiting the REL need to experience reduced delay time.
4	Drivers using the REL for commuting need to have consistent and improved travel time reliability
5	Drivers exiting the Reversible Express Lane need improved right turn wait times at E. Twiggs (1st right turn after exiting REL) and North Nebraska Street (1st right turn after turning right on East Twiggs Street).
6	Drivers approaching the exit curve for the REL need to know what a safe speed to enter the exit curve and where the end of the right turn queue is.
7	Operators at the THEA TMC need to receive real-time data on congestion and backups (i.e. an estimate of where the back of the queue is).
8	Operators at the THEA TMC need to receive real-time data when traffic incidents occur
9	Operators at the THEA TMC need to have the ability to adjust signal timing at the REL exit at Meridian Street and East Twiggs Street and East Twiggs Street and North Nebraska Street.

7.1.2 Wrong Way Entries

At the exit to the REL on East Twiggs Street, there is a relatively easy opportunity for a driver to become confused and attempt to enter the REL going the wrong way. There are no gates or barriers at the REL exit to prevent drivers from entering the REL going the wrong way. Drivers traveling on East Twiggs Street approaching the intersection where the REL ends and Meridian Street begins can mistakenly enter the REL going the wrong way. Drivers approaching this intersection coming from downtown can inadvertently make a left turn onto the REL exit. Conversely, drivers on East Twiggs Street approaching this intersection going towards downtown can inadvertently make a right turn onto the REL exit. Finally, drivers approaching the intersection on Meridian can potentially veer slightly to the left onto the REL exit. Each of these possibilities is a safety concern. CV Technologies, V2I (I-SIG and Probe Enabled Traffic Monitoring) and V2V (i.e., Intersection Movement Assist [IMA]), in conjunction with detection technology will be used to address the safety concerns by detecting drivers entering the expressway the wrong way, warning the wrong way driver that they are headed the wrong way, and warning other drivers in the area that there is a wrong way driver entering the expressway. The THEA TMC operators will be alerted there is a potential wrong way driver and when possible will utilize CCTVs to verify the wrong way driver. The

THEA TMC operators will alert law enforcement of the potential wrong way driver. Performance will be measured by observed wrong-way events and crash data.

Table 6: Wrong Way Entries REL at Twiggs Street Needs

Number	Need
1	Drivers going in the proper direction need real-time accurate warning about approaching wrong-way vehicle.
2	Drivers about to enter the REL the wrong way need real-time warnings that they are about to go the wrong way.
3	Drivers already on the REL going the wrong way need real-time warnings that they are going the wrong way.
4	Operators at the THEA TMC need to receive real-time alerts about wrong way vehicles with precise location information.
5	Law enforcement needs to receive real-time alerts about wrong way vehicles with precise location information.

7.1.3 Pedestrian Safety

There is one primary crosswalk for pedestrians to come and go from the parking garage to the courthouse. The crosswalk is marked and has only a yellow flashing light to warn drivers that they are approaching a crosswalk. This crosswalk is the primary route for jurors, lawyers, and other people to take to get to/from the courthouse. During morning rush hour, there are many people (potential jurors, etc.) trying to get parked and into the courthouse on time. This is compounded on Mondays and Tuesdays when new juror pools of up to 400 persons are required to report during rush hour. Many of these people are not familiar with the area and may not be paying attention to the crosswalk. Lack of attention and/or lack of visibility by drivers cause a safety concern for pedestrians trying to reach the courthouse. To complicate the issue, pedestrians running late may not pay attention to vehicles as they rush into the crosswalk trying to get to the courthouse on time. Finally, some pedestrians may elect to take a shortcut by crossing East Twiggs Street outside the crosswalk. In all cases, there exists a pedestrian safety concern. CV Technologies, V2I (Pedestrian in Signalized Crosswalk Warning, Mobile Accessible Pedestrian Signal, and I-SIG), and V2X (Smart Phone to Roadside Unit), will be used to alert drivers and pedestrians of each other in order to reduce the potential for a pedestrian to get struck by a vehicle. Performance will be measured by the number of recorded alerts, observed and reported conflicts and crash data.

Table 7: Pedestrian Conflicts and Safety at Twiggs - Courthouse Needs

Number	Need

Number	Need
1	Drivers on E. Twiggs Street near courthouse crosswalk need to receive warnings about pedestrians in the crosswalk.
2	Drivers on E. Twiggs Street near the courthouse crosswalk need to receive alerts about pedestrians approaching the crosswalk.
3	Drivers turning left from East Street onto E. Twiggs Street need to receive warnings about pedestrians in the crosswalk.
4	Drivers on E. Twiggs Street near the courthouse need to receive warnings about Pedestrians crossing roadway E. Twiggs Street in non-crosswalk areas.
5	Drivers approaching the crosswalk need to receive notification as to whether they have priority or an approaching pedestrian has priority to enter the crosswalk.
6	Pedestrians in the crosswalk need to receive warnings about vehicles encroaching on the crosswalk.
7	Pedestrians approaching the crosswalk need to receive alerts about vehicles encroaching on the crosswalk.
8	Pedestrians crossing in non-crosswalk areas need to receive a warning about vehicles in vicinity of where the pedestrian is crossing,
9	Pedestrians approaching the crosswalk need to receive notification as to whether they have priority or an approaching vehicle has priority to enter the crosswalk.
10	Infrastructure: Ability to detect pedestrians in marked crossing
11	Infrastructure: Ability to detect pedestrians not in marked crossings
12	Infrastructure: Ability to detect vehicles encroaching on or traveling at rate of speed to create possible pedestrian conflict

7.1.4 Bus Rapid Transit Signal Priority Optimization, Trip Times and Safety

Marion Street, a two lane street, is a primary bus route which on the north end terminates at the Marion Transit Center. HART operates several routes that converge onto Marion Street all headed to the Marion Street Transit Station. Along these routes leading to Marion Street, many of the bus stops are on the approach to an intersection. When there is congestion, buses are unable to reach their stops causing them to potentially fall behind schedule; thus causing a mobility concern. CV Technologies, V2I (Transit Signal Priority [TSP] and I-SIG), will be used to address the mobility concerns. Buses and traffic signals will communicate and if a bus is behind schedule, the traffic signal system will either give the bus priority or flush the queue (i.e., provide a green to move vehicles that are blocking the bus' ability to exit its stop) allowing the bus to reach its stop assuming there are no other higher priorities. Only entities such as emergency responders will have higher priorities. Performance will be measured in reduced trip times and increased route reliability.

Table 8: BRT Optimization Trip Time Safety BRT-REL to Marion Needs

Number	Need
1	Transit Drivers need to be able to maintain published arrival and departure times.
2	Transit Drivers need to receive notification they are given priority.
3	Transit Drivers need to receive notification they do not have priority or priority has been revoked due to higher priority request.
4	Transit Drivers need to be able to reach their physical bus stops with minimal delay.
5	Pedestrians need to receive notice that they cannot cross an intersection where a bus is about to be given priority.
6	Pedestrians need to receive notice that a transit vehicle is departing a stop near the intersection they want to cross.
7	Transit Riders need to be able to rely on consistent travel times.
8	Transit Riders need to be able to rely on on-time arrivals
9	Transit Riders need to be able to rely on on-time departures
10	HART operators need to receive real-time information on transit vehicles' schedule.

7.1.5 TECO Line Streetcar Trolley Conflicts

The TECO Streetcar runs along Channelside Drive from the Amalie Arena area up Channelside Drive, North, past the Selmon Expressway. The streetcar rides on rails, is electrically powered, and is in a dedicated lane. As a result at various stops along the streetcar route, vehicles may have to turn right in front of a stopped street car. As the pedestrians disembark from the streetcar and the streetcar prepares to startup, it is possible a vehicle may turn right in front of the streetcar. Pedestrians/Bicyclists may be crossing the intersection where the vehicle is turning rights as well. The potential of a streetcar and vehicle crash and a pedestrian/bicyclist incident are safety concerns. CV Technologies, V2I (I-SIG), V2V (Vehicle Turning Right in Front of Bus Warning), and V2X (Vehicle to Smart Phone), will be used to provide information to streetcar operators, drivers, and pedestrians/bicyclists to improve safety around these locations. Performance will be measured by the number of alerts when pedestrian/bicyclist warning heeded and not heeded and instances of automated control, observed and reported conflicts and crash data. Total number of incidents for a similar period before and after CV-Pilot will also be compared.

Table 9: Trolley/Auto/PEDESTRIAN/Bike Conflicts at Channelside Drive Needs

Number	Need

Number	Need
1	Streetcar Operators need to be able to safely and efficiently conduct their trips.
2	Streetcar Operators need to be able to safely and efficiently load/unload passengers.
3	Streetcar operators need to be able to safely cross intersections.
4	Streetcar operators need to receive warnings that a vehicle is turning right at the intersection where the streetcar is currently located.
5	Streetcar operators need to be able to receive warnings that pedestrians are crossing the intersection.
6	Drivers need to be alerted to pedestrians crossing the intersection where the streetcar is stopped and the driver is approaching.
7	Drivers need to receive an alert of the status of the streetcar (e.g.; stopped/moving).
8	Pedestrians need to be able to safely cross the intersection at which the streetcar is stopped.
9	Pedestrians need to be able to safely and efficiently board/ de-board the streetcar
10	Pedestrians need to be able to safely and efficiently ingress and egress to tourist venues and arena.

7.1.6 Enhanced Signal Coordination and Traffic Progression

There is significant congestion and delay along Meridian Avenue during morning peak travel periods. Adding to this issue are a large number of MAFB commuters traveling through downtown on the Selmon Expressway or arterial routes, trying to reach one of four MAFB entrance gates without knowledge of the travel times for their route versus other routes and the length of the queue at each gate. As some of these commuters are using surface roads through downtown, they interact with other traffic and pedestrians. With this increase in traffic, the potential for pedestrian incidents increase, creating a safety concern. CV Technologies, V2I (Probe Enabled Traffic Monitoring and I-SIG), will be used to improve the mobility and safety through the downtown area. It is expected that many of these MAFB commuters will be probes as they have VADs and OBUs installed to provide BSMs to the RSUs at equipped intersections. The signal timing for these intersections will be calculated to adjust the length of a green based on the current traffic conditions received from these probes.

THEA is currently funding a study using GPS enabled smart devices to collect, process and distribute real time travel time and queue wait times to MAFB commuters. These probes will enhance the ability to calculate travel times. With this information, their ability to make a better route choice based on travel times and gate queue wait times may result in load balanced routes thus reducing one source of congestion from the downtown area. As this study continues, research on whether load balancing is occurring at the gates will be performed. It is not known at this time what affect this study will have on gate queues. It is expected that this program will be expanded and integrated during the CV-Pilot to affect a synergistic and exponentially greater benefit. Performance will be measured in improved commute times and a reduction in pedestrian incidents.

Table 10: Traffic Progression at Meridian Avenue/MAFB Needs

Number	Need
1	Drivers need safe travel on impacted roadways.
2	Drivers need minimized delays from congestion and incidents.
3	Drivers need efficient and reliable travel times.
4	Drivers need to receive alerts of congested locations to consider alternative routes.
5	MAFB commuters need near real-time, accurate, reliable information to make informed decisions on route selection based on travel times on Meridian Street and Channelside Drive versus the Selmon Expressway.
6	MAFB commuters need to receive reliable wait/queue times for MAFB entrance gates.
7	Pedestrians need safe and efficient crossings of E. Twiggs Street, Meridian Street, Channelside Street, and Marion Street.
8	THEA TMC Operators need reliable travel times to assess the impacts on the various commuter routes.
9	THEA TMC Operator or software needs to be able to detect significant slow-downs (e.g., vehicles stopped) to alert the operator to a potential incident.
10	THEA TMC Operators need to determine where congestion is taking place on impacted roadways and inform drivers.

8 Operational Environment

The Pilot deployment area has several different mobility and safety issues on a daily basis. The project will evaluate the effectiveness of CV technology treatments applied to these issues (see Figure 4). The list below offers CV opportunities in the deployment area:

1. The Selmon Expressway's REL morning commute endpoint is at the intersection of Twiggs Street and Meridian Avenue. Twiggs Street and Meridian Avenue are also major routes for HART buses into and out of the downtown Tampa CBD. Drivers experience significant delay during the morning peak hour resulting in, and often caused by, a correspondingly large number of rear-end crashes.
2. At the entry to the Selmon Expressway REL during inbound operations (6:00 AM – 1:30 PM weekdays) there are wrong-way entries.
3. Bus Rapid Transit (BRT) routes offer efficiency gains in moving more people; however, during peak periods, the BRT service suffers from poor signal progression, heavy volumes and passenger vehicles blocking access to bus stops.
4. Meridian Avenue and West Kennedy Blvd experience transit signal delay, pedestrian conflicts and signal coordination issues.
5. At the Hillsborough County Courthouse on Twiggs Street, there is significant competing vehicular and pedestrian traffic during the morning peak hour (7:00 AM – 10:00 AM). There are a significant number of pedestrian-vehicle mishaps.
6. Vehicles and pedestrians/bicyclists conflict with the TECO Line Streetcar Trolley at crossing locations throughout the project area, particularly along Channelside Drive (see Figures 3 and 4).
7. On the east portion of the project area along the Channelside Drive corridor, visitors experience delays associated with arrivals and departures at the International Cruise Ship terminals and the Amalie Arena.
8. Improve commuter traffic flow through downtown using signal coordination and traffic progression. MAFB commuters elect different routes through downtown with no knowledge of the MAFB gate queue times. It is expected that many of these MAFB commuters will be probes broadcasting BSMs to the RSUs at equipped intersections. The signal timing for these intersections will be calculated to adjust the length of a green based on the current traffic conditions received from these probes
9. MAFB commuters experience long queue times at controlled access points during the peak morning arrival time. THEA is working with MAFB to add Dynamic Message Signs (DMS) at decision points to facilitate the dissemination of queue time and alternative entry point information. A study is currently underway to determine the best approach to this issue and it is likely that the project will benefit from this pilot by adding a CV component. MAFB presents an opportunity to create a fleet of vehicle probes for data collection. This is possible through its commuter vehicle population and through its Transportation Incentive Program that has van pool vehicles in addition to HART buses.

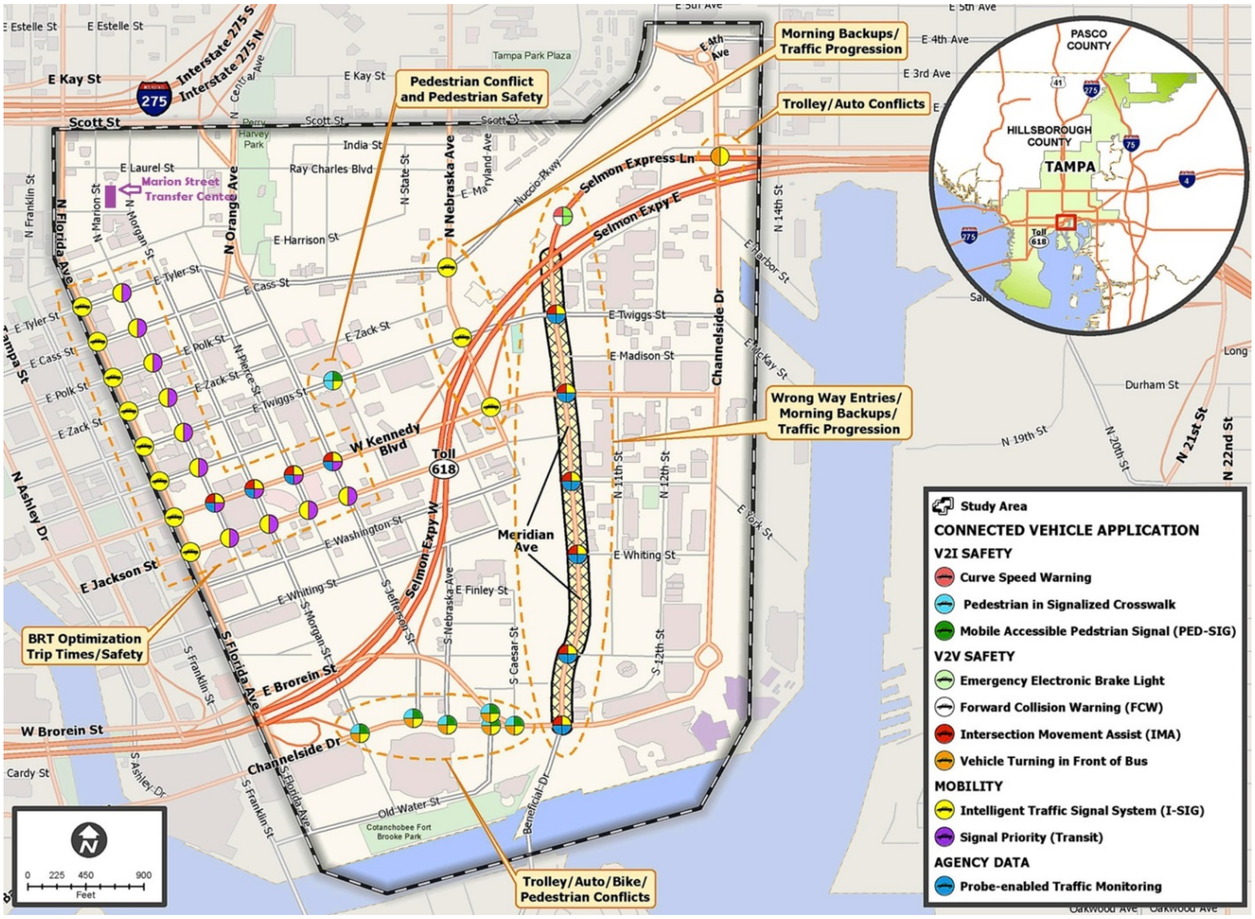


Figure 4: THEA CV Pilot Deployment Locations **Source: Googlemaps.com, HNTB**

The problem situations listed above (1-8) are illustrated in Figure 4 along with app treatments. In the THEA CV Pilot Deployment the problems are treated though six Use Cases:

- Morning Backups – Opportunity 1
- Wrong Way Entries – Opportunity 2
- Pedestrian Conflicts – Opportunity 5-6
- BRT Optimization of Trip Times – Opportunity 1, 3, and 4.
- Streetcar/Auto/Pedestrian/Bicycle Conflicts – Opportunity 6-7.
- Traffic Progression – Opportunity 1-9

The app treatments that make up the Use Cases are also illustrated in Figure 4 as shown in the legend on the lower right of the figure.

Each Use Case makes use of CV apps that are applied together as shown in the multi-colored circles on the map. By combining apps at a focus location (i.e., subarea), the synergy of their actions are designed to treat the problems in the Opportunity List (1-8) above. The geographic information in Figure 4 is organized in Figure 5 to show the synergistic array of ten CV applications that are part of six Use Cases at six focus locations (subareas). The web-like connections between these Use Cases, Applications and the locations create a “Spider Diagram” of these essential categories. How the Use Cases employ apps is discussed at length in Section 6.

In Summary, the Use Cases have multiple objectives that work together to fulfill the needs of the CV Pilot program:

- Morning Backups: Reduce delay during the morning peak hour resulting in, and often caused by, a correspondingly large number of rear-end crashes at the Selmon Expressway’s REL morning commute endpoint at the intersection of Twiggs Street and Meridian Avenue.
- Wrong Way Entries: Reduce wrong way entries into the Selmon Expressway REL during the period between 6:00AM and 1:30 PM when vehicles from the REL transfer to Meridian Avenue in order to enter downtown.
- Pedestrian Conflicts: Improve safety at the Hillsborough County Courthouse on Twiggs Street where there is significant competing vehicular and pedestrian traffic during the morning peak hour (7:00 AM – 10:00 AM).
- BRT Optimization: Reduce transit signal delay, pedestrian conflicts, red light running and signal coordination issues at Meridian Avenue and West Kennedy Blvd.
- Streetcar/Auto/Ped/bike Conflicts: Reduce vehicle and pedestrian/bicyclist conflicts with the TECO Streetcar Line at crossing locations throughout the project area, particularly along Channelside Drive.
- Traffic Progression: Reduce congestion on Meridian Avenue through downtown in route to MAFB using signal coordination and traffic progression.

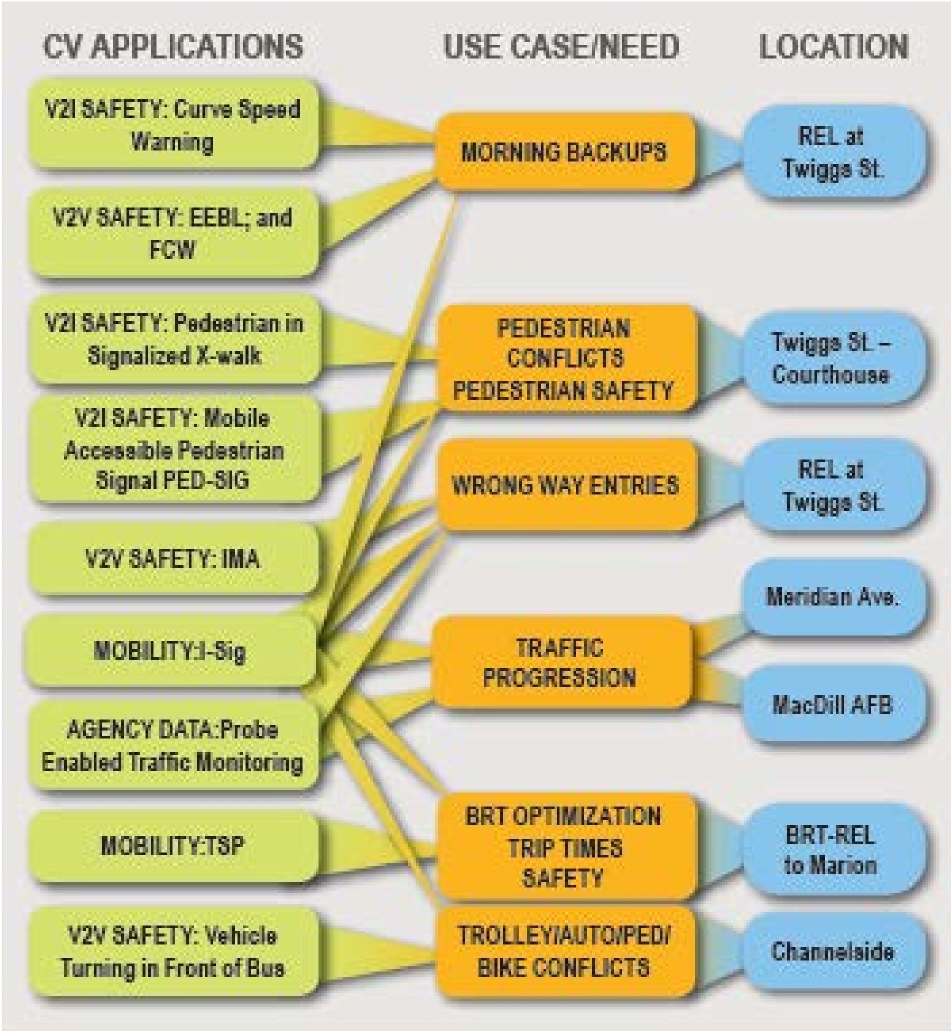


Figure 5: THEA CV Pilot Deployment "Spider Diagram" of CV Applications, Use Cases and Locations

The THEA/CoT combined TMC is the primary facility for the pilot. The TMC is currently equipped with six operator consoles, three of which are currently being used for REL operations and citywide traffic signal operations. The TMC has a 12-cube video display wall for viewing REL status, REL cameras and citywide CCTV cameras. The TMC has an equipment room with racks, communication switches, database and application servers, video wall controller, and uninterruptable power supply (UPS). Both the THEA ITS and Toll fiber networks terminate in the equipment room. The TMC has peripheral offices that are also able to connect to REL and citywide traffic signal software and CCTV cameras.

The TMC will be the central location for operators receiving and sending information as well as archiving data for performance measure evaluation. At least one server with adequate disk space will be used to archive the pilot data. TMC Operators will receive specific training on how to interact with the pilot applications. The current operator skillset requirements are adequate for the operator to participate in the pilot. The TMC operational hours will not be modified for the pilot.

Drivers will have either VADs or OBUs installed in their vehicles. Drivers, whose vehicles are equipped with VADs, will not have any additional duties or actions to take during the pilot. Their vehicles will be used as probes only. Drivers, whose vehicles are equipped with OBUs, will have additional actions they may take when they receive an alert from one of the OBU applications. Drivers with OBU equipped vehicles will require training in order for them to understand what the alert is communicating to them and what actions or options they have. These vehicles will be equipped with OBUs that interface with the driver.

Pedestrians will have pilot apps downloaded on their smart phones. The app will have to be started by the pedestrian prior to entering the pilot area. Pedestrians will require a tutorial on what information the app may alert them to and what actions they may need to take.

Transit drivers will receive a notification that they have priority at the approaching intersection so that they can react accordingly. If the priority is revoked prior to the bus entering the intersection, the transit driver will be notified of the revocation and react accordingly. The transit driver will be trained on how the priority/revocation alerts are communicated, what they mean, and what actions they may need to take. Transit vehicles will be equipped with OBUs that interface with the driver.

Streetcar operators will receive a notification when a pilot equipped vehicle is turning right in front of the streetcar. The streetcar operator will be trained to understand what the notification means and what actions to take in response to the alert. Streetcars will be equipped with OBUs that interface with the operator.

Data collected by the Pilot will become part of the USDOT Research Data Exchange (RDE), and be available to Test Bed Affiliates and other independent evaluators. Prior to becoming part of the RDE data will be scrubbed of personal information. The security issues relating to privacy are discussed in Section 11.3.

9 Support Environment

The support environment includes the physical environment of the study area, equipment, computing hardware and software, and personnel. How these system elements fit together helps to generate the operational procedures which are treated in Chapter 10. This section describes the physical operational environment necessary to operate the deployed system:

- Facilities
- Equipment and computing hardware
- Software
- Participants –
- Personnel.

9.1 Facilities

Facilities include the THEA /CoT TMC, the Selmon Expressway REL, and streets and signals in the City of Tampa. These are already in place. The City of Tampa provides traffic management on city streets and operates the THEA TMC which includes the lane reversal process. THEA owns and operates the Selmon Expressway, the Selmon REL, Brandon Parkway and Meridian Drive.

9.2 Equipment and Computing Hardware

Equipment includes traffic signals, RSUs, OBUs, VADs, smartphones and the TMC computers.

The City of Tampa owns, operates and maintains the signal system. The signal software downtown is a UTCS system, and an upgrade to an ATMS Central System is planned. Outside of downtown, Econolite signals and equipment are in use and managed by Centracs. RSUs, OBUs, VADs will be supplied, installed and maintained by Siemens during the CV Pilot.

Participants will supply their own smartphones to run the Pedestrian Mobility app that will issue alert warnings when a car is approaching or entering a crosswalk. Participants will be informed of the app operations and their duties and rights before they chose participate by signing an Informed Consent form. Informed consent is to be treated in Task 8, Human Use Approval.

The TMC computer is in place and will not to be augmented except with software modules.

9.3 Software

The THEA TMC uses proprietary software to run the TMC called DYNAC. The DYNAC software runs the Selmon Expressway REL gates and controls the CCTV cameras. THEA and CoT are currently evaluating Cameleon and other traffic management software systems for replacement of the current control software.

Software for CV Pilot equipment and TMC alert notifications will be produced or facilitated by Siemens. Siemens will work closely with the TMC software maintenance professionals to add software modules to the TMC software that will classify, count and distribute alerts to operators.

9.4 Participants

Participants in the CV Pilot study will include: drivers, pedestrians, bicyclists, and bus/trolley drivers. For purposes of this pilot, bicyclists will be grouped into pedestrians as their participation would be through using the smart phone app. The recruitment of participants, their training, and involvement will be treated in detail in Tasks 8, Human Use Approval and 9 Participant Training and Stakeholder Education.

9.5 Staff Personnel

9.5.1 TMC

Operators will not need to dedicate significant additional time to the CV pilot beyond their routine duties. TMC staff will perform their standard duties with respect to incident detection, verification and notification. They will follow up on alerts from CV devices just as they would from other sources, such as traffic detectors, CCTV cameras and cellphone calls. The CV Pilot will add no new functions for the TMC personnel to perform. Collection of incident data is an ongoing routine in the TMC and the CV Pilot data processing will be automated.

9.5.2 Maintenance

Maintenance of existing traffic signal systems and communication infrastructure is supported by dedicated staff from the City of Tampa. Maintenance requirements will need to be defined for roadside equipment (RSUs) including Intelligent Traffic Signal System (I-SIG) hardware and software. City maintenance technicians will need to be trained by Siemens and others to maintain new TMC and RSU hardware, software and communication infrastructure. Additionally, any needed maintenance tools, hardware, software and spare replacement parts will need to be provided.

Maintenance of the Selmon Expressway access and tolling system is provided by THEA's maintenance contractor. Any installation or maintenance involving Selmon Expressway infrastructure will include coordination and/or support between Siemens and the THEA maintenance contractor.

Siemens will coordinate with HART to make use of the bus and trolley maintenance staff.

9.5.3 Installers

There will be a need to install OBUs, VADs and RSUs by City of Tampa traffic systems professionals working with Siemens installers.

9 Support Environment

Maintenance of the Selmon Expressway access and tolling system is provided by THEA's maintenance contractor. Any installation or maintenance involving Selmon Expressway infrastructure will include coordination and/or support from the THEA maintenance contractor.

10 Operational Scenarios

In this section, for each of the six Use Cases Operational Scenarios, four states of operation are defined and explained:

1. Normal operations
2. CV Activation Conditions
3. CV Failure/Anomaly/Exception Conditions
4. CV Maintenance Conditions.

These Scenarios establish the What, Where, When, Why, Who and How of the operational condition.

The Scenarios are defined as:

Scenario 1. **Normal Conditions** - a "no problem" or "no issue" perspective, without any initiation of the proposed CV technologies, which is as the system operates today. This establishes a baseline understanding.

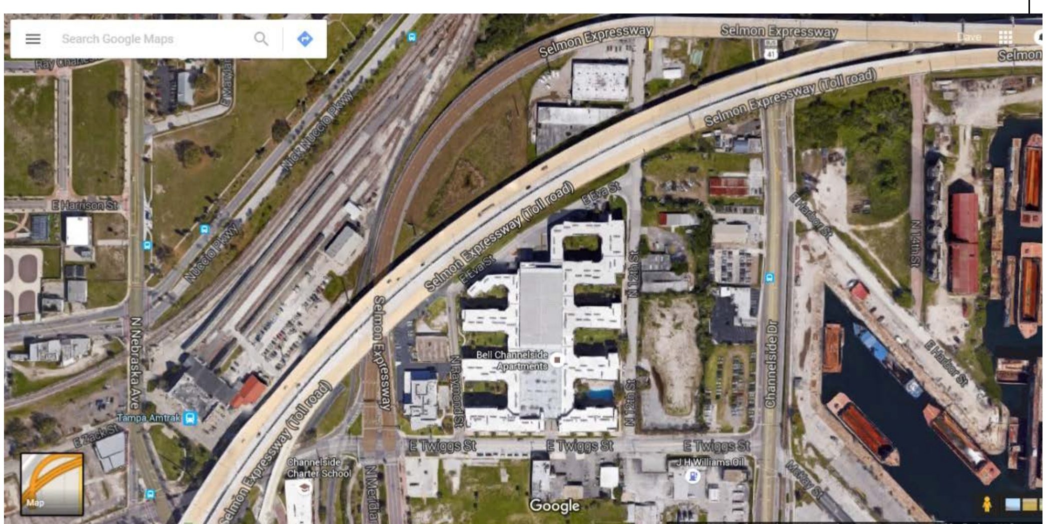
Scenario 2. **CV Application "Activation" Conditions** - conditions that activate or trigger the CV application.

Scenario 3. **Failure/Anomaly/Exception Conditions** - situations that require temporarily "turning off" the CV technology/system/device, such as "false" warnings and any "fail-safe" mode that the system would revert to.

Scenario 4. **Maintenance –** the condition of the system where repair is done for a breakdown of equipment functionality or preventative maintenance.

10.1Use Case 1: Morning Backups

Table 11: Morning Backup Use Case Scenario 1: Normal Conditions

Use Case	*Morning Backups*
Scenario ID & Title	*UC1-S1: CV Normal Conditions*
Scenario Objective	This scenario describes the normal conditions where there is a “no problem” or “no issue” with the Drivers exiting the Selmon Expressway REL at the intersection of Meridian Avenue and Twiggs Street in the morning peak period. Traffic exits the Selmon Expressway REL Monday to Friday 6 – 10 AM plus split operation from 10 AM – 1 PM. Although the site is equipped with the proposed CSW, EEBL and FCW technologies, normal events do not initiate the use of the proposed CV technology in the vehicle. <u>Current Situation</u>: At this site, a driver is proceeding west on the REL exit to a signalized intersection at Meridian Avenue and may turn right or left onto east-west Twiggs Street, or may proceed south through on Meridian without incident.  Source: Google Maps Proceeding west at mile marker 6.2, the REL begins a sweeping left curve while descending to ground level with limited forward visibility towards the queue at the Twiggs Street traffic signal.

<table>
<tr><td></td><td colspan="4">


Source; Google Streetview, September 2015

Under normal traffic conditions, the queue for the signalized intersection at Twiggs and Meridian occupies the straight lanes at ground level without extending onto the REL, offering good visibility for a safe stop.

Meridian Avenue and Twiggs Street Source; Google Streetview, September 2015
</td></tr>
<tr><td>Operational Event(s)</td><td colspan="4">Under “no issue” conditions:

While REL is inbound towards Tampa
Traffic volumes do not exceed the capacity of the signal timing plan
Entire length of the REL exit ramp is free-flowing
REL exit queue length at Twiggs is less than the surface lane length
Overtaking drivers have good visibility of the queue for a safe stop</td></tr>
<tr><td rowspan="3">User(s)</td><td colspan="2">User</td><td colspan="2">Role</td></tr>
<tr><td colspan="2">Drivers</td><td colspan="2">Drivers typically may:
carry a smart mobile device that is not being used while driving
carry a smart mobile device that is temporarily mounted in the cabin for route guidance
use the vehicle navigation system for guidance in the area</td></tr>
<tr><td colspan="2">Drivers</td><td colspan="2">Obey traffic signals, barriers, DMS and regulatory signs</td></tr>
<tr><td>Key Actions and</td><td>Source</td><td>Step</td><td>Key Action</td><td>Comments</td></tr>
</table>

Flow of Events	Drivers	1	Traveling towards Tampa	Inbound TOD schedule
	Drivers	1a	Enter the REL westbound	Tampa and AFB traffic
	Drivers	1b	Observe lighted MUTCD overhead guide sign “Expressway ENDS ½ MILE”, “SIGNAL AHEAD” mounted beside DMS	Normal condition of free flowing traffic, no queue on REL
	Drivers	1c	Begin a sweeping left curve while descending to ground level	At mile marker 6.2
	Drivers	1d	Observe an MUTCD roadside guide sign “Twiggs St NEXT SIGNAL”	At apex of curve
	Drivers	1e	Continue at ground level below overpass	At mile marker 6.0
	Drivers	1f	Observe MUTCD “DO NOT ENTER” above 3 leftmost lanes and MUTCD and “Meridian Ave Aquarium / Seaport / Amalie Arena” over 3 rightmost lanes	REL ends
	Drivers	1g	Arrive at normal vehicle queue for signalized intersection at Twiggs	Signals and queue are visible on straight ground-level lanes, ample time to stop safely for queue
	Traffic Signal	2a	Allows sufficient GREEN phase to prevent queues from extending to REL	Normal traffic volume
	Drivers	2a	Turn or proceed through Twiggs to Meridian	Most traffic proceeds through
	Traffic Signal	2b	Progress along Meridian to final designation	According to signal timing plan
Post-conditions	• No actions taken. • Driver has uninterrupted experience. • Queues are confined to straight ground level lanes with good visibility			
Policies and Business Rules	MUTCD • “Expressway Ends” guide sign • “Signal Ahead” guide sign Florida Statute • Red signal: do not enter intersection			
Traceability	User Needs: Refer to User Needs for this site			
Inputs Summary	None, no data input			
Output Summary	None, not data output			

Table 12: Morning Backup Use Case Scenario 2: CV Activation Conditions

<table>
<tr><td>Use Case</td><td colspan="4">Morning Backups</td></tr>
<tr><td>Scenario ID & Title</td><td colspan="4">UC1-S2: CV Activation Conditions</td></tr>
<tr><td>Scenario Objective</td><td colspan="4">For a driver who exits the Selmon Expressway REL Monday to Friday 6 – 10 AM and during split operation, this scenario describes the activation conditions that activate or trigger the CV apps. The driver is exiting from the Selmon Expressway REL proceeding onto at-grade Meridian Avenue or onto Twiggs Street Traffic.</td></tr>
<tr><td>Operational Event(s)</td><td colspan="4">Under “activation” conditions, CSW, EEBL or FCW begin to issue warnings.
Queues at REL exit extend to the underpass
Last vehicle in queue becomes visible to overtaking traffic with little safety margin in stopping distance
City of Tampa traffic signals on Meridian revert from signal timing plan to adaptive control based on approaching traffic from REL</td></tr>
<tr><td rowspan="2">User(s)</td><td colspan="2">User</td><td colspan="2">Role</td></tr>
<tr><td colspan="2">Drivers</td><td colspan="2">Has CV alert app in OBU (CSW, EEBL, FCW) of any of the following OBU classes:
Class 1: Part of vehicle systems
Class 2: Aftermarket device
Class 3: Mobile device mounted temporarily in vehicle cockpit</td></tr>
<tr><td rowspan="10">Key Actions and Flow of Events</td><td>Source</td><td>Step</td><td>Key Action</td><td>Comments</td></tr>
<tr><td>Drivers</td><td>1</td><td>Traveling towards Tampa</td><td>Inbound TOD schedule</td></tr>
<tr><td>Drivers</td><td>1a</td><td>Enter the REL westbound</td><td>Tampa and AFB traffic</td></tr>
<tr><td>OBU</td><td>1b</td><td>Broadcast BSM</td><td>Location, direction, speed</td></tr>
<tr><td>Unequipped</td><td>1c</td><td>Are detected by detection equipment</td><td>Location, direction, speed</td></tr>
<tr><td>Unequipped</td><td>1d</td><td>Are identified to RSU</td><td>Location, direction, speed</td></tr>
<tr><td>RSU</td><td>1e</td><td>Broadcasts proxy (synthetic) BSM</td><td>Of unequipped vehicles</td></tr>
<tr><td>RSU</td><td>1f</td><td>Receives BSM</td><td>Of all vehicles, proxies</td></tr>
<tr><td>Drivers</td><td>1g</td><td>Observe lighted MUTCD overhead guide sign “Expressway ENDS ½ MILE”, “SIGNAL AHEAD” mounted beside DMS</td><td>Twiggs St. queue extends to the REL, obscured from driver view</td></tr>
<tr><td>Drivers</td><td>1h</td><td>Approach a sweeping left</td><td>At mile marker 6.2</td></tr>
</table>

			curve while descending to ground level	
	RSU	1i	Determine curve speed based on queue length	Based on curve and queue
	RSU	1j	Broadcasts CSW	Based on curve and queue
	OBU	1k	Receives CSW	Curve speed warning
	OBU	1l	Calculates safe speed	From curve geometry, vehicle type, queue length
	Driver	1m	Receives CSW from OBU	If actual speed > CSW
	OBU	1n	Receives BSMs & proxies from RSU and other vehicles	Location, direction, speed
	OBU	1o	Calculates crash trajectory	From all BSM
	Drivers	1p	Receive FCW	With vehicles out of view
	OBU	1q	Sends brake light status (EEBL)	To all OBUs
	OBU	1r	Receives brake light status (EEBL)	From all OBUs
	OBU	1s	ID location of brake lights	Brake lights ahead
	OBU	1t	ID crash with brake lights	That are out of view
	Drivers	1u	Get brake light warning	Before lights visible
	Drivers	1v	Slow to safe speed	Threats still not visible
	Drivers	1w	Observe an MUTCD roadside guide sign “Twiggs St NEXT SIGNAL”	At apex of curve
	RSU	1x	Receives BSM	Approaching traffic
	RSU	1y	Adjusts signal plan (using I-SIG)	For arriving traffic
	Drivers	1z	Continue at ground level below overpass	At mile marker 6.0
	Drivers	1aa	Observe MUTCD “DO NOT ENTER” above 3 leftmost lanes and MUTCD “Meridian Ave Aquarium / Seaport / Amalie Arena” over 3 rightmost lanes	REL ends
	Drivers	1ab	Arrive at vehicle queue for signalized intersection at Twiggs	Last car in extended queue visible with adequate time to stop safely
Post-conditions	• Can terminate when traffic volume falls to eliminate extended queue			

	• Can operate continuously
Policies and Business Rules	MUTCD • “Expressway Ends” guide sign • “Signal Ahead” guide sign Florida Statute • Red signal: do not enter intersection Activation procedure explained to participant as part of Informed Consent.
Traceability	User Needs, CVRIA definitions, HUA
Inputs Summary	None. Apps function with data input. • Class 1 Driver OBU alert is set at time of manufacture or installation. • Class 2 Driver OBU alert is set by aftermarket supplier • Class 3 Driver OBU alert o is downloaded from app store o device must be on with volume on sufficient to hear the alert with traffic.
Output Summary	• Alert message sent from RSU to TMC and data repository o Alert message for each activation o Alert message for each termination • Alert message sent to drivers when activated

Table 13: Morning Backup Use Case Scenario 3: CV Failure/Anomaly/Exception Conditions

Use Case	*Morning Backups*	
Scenario ID & Title	*UC1-S3: CV* Failure/Anomaly/Exception Conditions	
Scenario Objective	This scenario describes the failure/anomaly/exception conditions that could require temporarily “turning off” the CV technology/system/device(s) of the CV app for the Drivers on the Selmon Expressway REL exit during REL operation (6-10 AM weekdays plus split operation), as well as related RSUs and TMC functions.	
Operational Event(s)	Under “failure/anomaly/exception” conditions: • Driver fails to receive Curve Speed Warning (False Negative) • Driver receives an inaccurate Curve Speed Warning (False Positive) • Driver fails to receive Electronic Brake Light Warning (False Negative) • Driver receives a false Electronic Brake Light Warning (False Positive) • Driver fails to receive Forward Collision Warning (False Negative) • Driver receives a false Forward Collision Warning (False Positive)	
User(s)	User	Role
	Drivers	Has CV alert apps in OBU (CSW, EEBL, FCW) of any of the following OBU classes: • Class 1: Part of vehicle systems

				• Class 2: Aftermarket device • Class 3: Mobile device mounted temporarily in vehicle cockpit
Key Actions and Flow of Events	**Source**	**Step**	**Key Action Failure**	**Exception**
	Drivers	1	Traveling towards Tampa	Inbound TOD schedule
	Drivers	1a	Enter the REL westbound	Tampa and AFB traffic
	OBU	1b	No Broadcast BSM Wrong Location	False Negative • 1f, 1m, 1u, 1v False Positive • 1f, 1m, 1u, 1v
	Unequipped	1c	Are not detected by RSU Are erroneously detected	False Negative • 1f, 1m, 1u, 1v False Positive • 1f, 1m, 1u, 1v
	RSU	1d	No Broadcasts proxy BSM	False Negative • 1f, 1m, 1u, 1v
	OBU	1e	No BSM crash trajectories	False Negative • 1f, 1m, 1u, 1v
	Drivers	1f	Receive crash warning	Audible, haptic
	Drivers	1g	Observe lighted MUTCD overhead guide sign "Expressway ENDS ½ MILE", "SIGNAL AHEAD" mounted beside DMS	Twiggs St. queue extends to the REL, obscured from driver view
	Drivers	1h	Approach a sweeping left curve while descending to ground level	At mile marker 6.2
	RSU	1i	Not Receives BSM	False Negative • 1m
	RSU	1j	Not Broadcasts CSW	False Negative • 1m
	OBU	1k	Not Receives CSW	False Negative • 1m
	OBU	1l	Not Calculates safe speed	False Negative • 1m
	Driver	1m	Receives CSW	If actual speed > CSW
	OBU	1n	Not Receives BSM & proxies	False Negative • 1p
	OBU	1o	Not Calculates crash trajectory	False Negative • 1p
	Drivers	1p	Receive FCW	With vehicles out of view
	OBU	1q	Not Sends brake light status	False Negative • 1u, 1v

	OBU	1r	Not Receives brake light status	False Negative • 1u, 1v
	OBU	1s	No location of brake lights	False Negative • 1u, 1v
	OBU	1t	No crash with brake lights	False Negative • 1u, 1v
	Drivers	1u	Get brake light warning	Before lights visible
	Drivers	1v	Slow to safe speed	Threats still not visible
	Drivers	1w	Observe an MUTCD roadside guide sign “Twiggs St NEXT SIGNAL”	At apex of curve
	RSU	1x	Receives BSM	Approaching traffic
	RSU	1y	Adjusts signal plan	For arriving traffic
	Drivers	1z	Continue at ground level below overpass	At mile marker 6.0
	Drivers	1aa	Observe MUTCD “DO NOT ENTER” above 3 leftmost lanes and MUTCD “Meridian Ave Aquarium / Seaport / Amalie Arena” over 3 rightmost lanes	REL ends
	Drivers	1ab	Arrive at vehicle queue for signalized intersection at Twiggs	Last car in extended queue visible with adequate time to stop safely
Post-conditions	• False negative is noticed by driver who arranges maintenance testing and repair • False positive is noticed by driver who arranges maintenance testing and repair			
Policies and Business Rules	MUTCD • “Expressway Ends” guide sign • “Signal Ahead” guide sign Florida Statute • Red signal: do not enter intersection Failure procedure explained to participant as part of Informed Consent.			
Traceability	User Needs, CVRIA definitions, HUA			
Inputs Summary	None. Apps function with data input. • Class 1 Driver OBU alert is set at time of manufacture or installation. • Class 2 Driver OBU alert is set by aftermarket supplier • Class 3 Driver OBU alert o is downloaded from app store device must be on with volume on sufficient to hear the alert with traffic			
Output Summary	• Alert message sent from RSU to TMC and data repository o Alert message for each activation o Alert message for each termination			

	• Alert message sent to drivers when activated

Table 14: Morning Backup Use Case Scenario 4: CV Maintenance Conditions

Use Case	*Morning Backups*
Scenario ID & Title	*UC1-S4: CV* Maintenance Conditions
Scenario Objective	This scenario describes the maintenance conditions that could require temporarily “turning off” the CV technology/system/device(s) of the CV apps for the Drivers on the Selmon Expressway REL exit during REL operation (6-10 AM weekdays plus split operation), as well as related RSUs and TMC functions. There are two basic types of maintenance: 1. Single driver app maintenance for device failure 2. Planned system maintenance.
Operational Event(s)	1. Under “app maintenance” conditions: • A driver approaching the exit curve fails to receive a notification that the curve is approaching or that drivers are stopped ahead. The driver makes an appointment to receive app maintenance. 2. Under “system maintenance” conditions: • TMC sends an announcement to all app users effected, notifying them of planned maintenance.

User(s)	User	Role
	Drivers	Has CV alert apps in OBU (CSW, EEBL, FCW) of any of the following OBU classes: • Class 1: Part of vehicle systems • Class 2: Aftermarket device • Class 3: Mobile device mounted temporarily in vehicle cockpit

Key Actions and Flow of Events	Source	Step	Key Action	Comments
	App Maintenance			
	Driver app BSM	1a	Notices queue extending onto REL ramp or lack of progression on Meridian	Not transmitting BSM
	Driver app BSM	1b	Instructed to update to latest BSM version • Class 1 OBU: OEM • Class 2 OBU: Supplier • Class 3 OBU: App Store	From the device’s app store
	Driver app BSM	1c	Continuing problem, reports symptoms to office or website	Not transmitting BSM
	Office	1d	Acknowledges problem report	Problem logged
	Office	1e	Correlates time and symptoms	Investigation

			with TMC logs from RSU	
	Office	1f	Initiates problem disposition	• No problem found • BSM rev+1 → OEM • BSM rev+1 → Supplier • BSM rev+1 → App store
	System Maintenance			
	TMC	2a	TMC initiates announcement to all app users	• Class 1 OBU: OEM • Class 2 OBU: Supplier • Class 3 OBU: App Store
	TMC	2b	BSM rev + 1 → app store	• IOS and Android
	TMC	2c	BSM rev+1 → OEM	Class 1 OBU: OEM
	TMC	2d	BSM rev+1 → Supplier	Class 2 OBU: Supplier
	TMC	2e	BSM rev+1 → App store	Class 3 OBU: App Stores
Post-conditions	App is replaced/maintained and is operable.			
Policies and Business Rules	MUTCD • “Expressway Ends” guide sign • “Signal Ahead” guide sign Florida Statute • Red signal: do not enter intersection Maintenance procedure explained to participant as part of Informed Consent.			
Traceability	User Needs, CVRIA definitions, HUA			
Inputs Summary	Drivers contact office. No data inputs.			
Output Summary	No data output for maintenance.			

10.2 Wrong Way Entry

Table 15: Wrong-Way Entry Use Case Scenario 1: Normal Conditions

<table>
<tr><td>Use Case</td><td>Wrong Way Entry</td></tr>
<tr><td>Scenario ID & Title</td><td>UC2-S1: CV Normal Conditions</td></tr>
<tr><td>Scenario Objective</td><td>This scenario describes the normal conditions where there is a “no problem” or “no issue” with the Drivers at the intersection of Meridian Avenue and Twiggs Street with the Selmon Expressway REL in the morning peak period when vehicles are exiting the REL at-grade onto Meridian Avenue and Twiggs Street. Traffic exits the Selmon Expressway REL Monday to Friday 6 – 10 AM.

Although the site is equipped with the proposed IMA technologies, normal events do not initiate the use of the proposed CV technology in the vehicle.

<u>Current Situation</u>:

At this site, a driver going north on Meridian Avenue or east-west on Twiggs Street does not try to enter the REL where traffic is outgoing as shown:
Signalized intersection at Twiggs and Meridian
Northbound Meridian terminates at REL ramps located north of Twiggs
MUTCD R5-1 Regulatory “DO NOT ENTER” sign over REL exit ramp
DMS over REL entrance ramp tells the driver that entry to REL is CLOSED
Railroad grade crossing on Twiggs parallels Meridian west of REL access
Barrier gates drop across REL entrance when entrance ramp is closed
REL direction is controlled on a Time of Day (TOD) schedule:
Monday through Friday:
6 AM to 10 AM: Inbound towards Tampa
10 AM to 1 PM: Split Operation
1 PM to 6 AM: Outbound towards Brandon
Weekends and Holidays: Outbound towards Brandon
All times are subject to change

Meridian Avenue and Twiggs Street Source: Google Streetview, September 2015</td></tr>
</table>

Access to REL Google Streetview, April 2015

Operational Event(s)	Under “no issue” conditions: • While REL is outbound from Twiggs towards Brandon o REL entrance ramp barrier gates are raised o DMS indicates REL entrance ramp is open o Traffic enters REL entrance ramp o No traffic exits REL exit ramp o No traffic enters REL exit ramp o Intersection is controlled as 8 Phase with southbound omit • While REL is inbound towards Tampa o REL entrance ramp barrier gates are dropped o DMS indicates REL entrance ramp is closed o No traffic enters REL entrance ramp o Traffic exits REL exit ramp o No traffic enters REL exit ramp o Intersection is controlled as 8 Phase with northbound omit

User(s)	User	Role
	Drivers	Drivers typically may: • carry a smart mobile device that is not being used while driving • carry a smart mobile device that is temporarily mounted in the cabin for route guidance • use the vehicle navigation system for guidance in the area
	Drivers	Obey traffic signals, barriers, DMS and regulatory signs

Key Actions and Flow of Events	Source	Step	Key Action	Comments
	Outbound TOD	1		Includes outbound split
	Barriers	1a	Are raised	By Barrier TOD plan

	DMS	1b	REL entrance is open	By DMS TOD message
	Signals	1c	Are controlled 8 Phase with southbound omit	By signal controller TOD plan
	Drivers	1d	Turn right, left or through to REL	Northbound Meridian Avenue green phase
	Drivers	1e	Turn right, left to REL or though	Eastbound Twiggs Street green phase
	Drivers	1f	Turn right to REL, left or through	Westbound Twiggs Street green phase
	Signals	1g	Omit green phases to westbound Twiggs	When grade crossing preemption is received
	Inbound TOD	2		Includes inbound split
	Barriers	2a	Are dropped	By Barrier TOD plan
	DMS	2b	REL entrance is closed	By DMS TOD message
	Signals	2c	Are controlled 8 Phase with northbound omit	By signal controller TOD plan
	Drivers	2d	Turn right or left	Northbound Meridian Avenue green phase
	Drivers	2e	Turn right or though	Eastbound Twiggs Street green phase
	Drivers	2f	Turn left or through	Westbound Twiggs Street green phase
	Drivers	2g	Turn left, right or through	Southbound REL exit green phase
	Signals	2h	Omit phases to westbound Twiggs	When grade crossing preemption is received

Post-conditions	No actions taken. Driver has uninterrupted experience.
Policies and Business Rules	Florida statute: • Red signal: Do not enter intersection According to MUTCD: • At least one DO NOT ENTER sign shall be conspicuously placed near the downstream end of the exit ramp in positions appropriate for full view of a road user starting to enter wrongly from the crossroad. • DO NOT ENTER indicates that traffic is prohibited from entering the restricted roadway, in this case, the REL exit ramp
Traceability	User Needs: Refer to User Needs for this site
Inputs Summary	None, no data input
Output Summary	None, not data output

Table 16: Wrong-Way Entry Use Case Scenario 2: Activation Conditions

<table>
<tr><td>Use Case</td><td colspan="4">Wrong Way Entry</td></tr>
<tr><td>Scenario ID & Title</td><td colspan="4">UC2-S2: CV Activation Conditions</td></tr>
<tr><td>Scenario Objective</td><td colspan="4">This scenario describes the activation conditions where conditions will activate or trigger the CV app for the driver on Meridian Avenue or on Twiggs Street who attempts to turn into oncoming traffic from the at-grade Selmon Expressway REL exit. Traffic exits the Selmon Expressway REL Monday to Friday 6 – 10 AM and during split operation.</td></tr>
<tr><td>Operational Event(s)</td><td colspan="4">Under “activation” conditions, Wrong Way Entry predicts that a violation of MUTCD or Florida statute will occur issues the following notifications:
1. A driver approaching the intersection receives a notification that
a. Traffic is exiting the Selmon Expressway
b. Driver must not turn into the right-of-way of the Selmon Expressway REL
2. A driver turning into the closed ramp or turning into the exit ramp DO NOT ENTER receives notification to
a. Stop
b. Turn around and exit when safe
3. A driver exiting the REL while a driver is turning into the closed ramp or into the exit ramp receives notification
a. Of a wrong way vehicle approaching
b. To slow and safely use the shoulder</td></tr>
<tr><td rowspan="2">User(s)</td><td colspan="2">User</td><td colspan="2">Role</td></tr>
<tr><td colspan="2">Drivers</td><td colspan="2">Has CV alert app in OBU (IMA) of any of the following OBU classes:
• Class 1: Part of vehicle systems
• Class 2: Aftermarket device
• Class 3: Mobile device mounted temporarily in vehicle cockpit</td></tr>
<tr><td rowspan="7">Key Actions and Flow of Events</td><td>Source</td><td>Step</td><td>Key Action</td><td>Comments</td></tr>
<tr><td>Outbound TOD</td><td>1</td><td></td><td>Includes outbound split</td></tr>
<tr><td>Barriers</td><td>1a</td><td>Are raised</td><td>By Barrier TOD plan</td></tr>
<tr><td>DMS</td><td>1b</td><td>REL entrance is open</td><td>By DMS TOD message</td></tr>
<tr><td>Signals</td><td>1c</td><td>Are controlled 8 Phase with southbound omit</td><td>By signal controller TOD plan</td></tr>
<tr><td>Drivers northbound on Meridian</td><td>1d</td><td>Travel through to DO NOT ENTER</td><td>Activation Notification:
• 2a, 2b, 3a, 3b</td></tr>
<tr><td>Drivers eastbound on</td><td>1e</td><td>Turn left to DO NOT ENTER</td><td>Activation Notification:
• 2a, 2b, 3a, 3b</td></tr>
</table>

	Twiggs			
	Drivers westbound on Twiggs	1f	Turn right to DO NOT ENTER	Activation Notification: • 2a, 2b, 3a, 3b
	Signals	1g	Omit green phases to westbound Twiggs	When grade crossing preemption is received
	Inbound TOD	2		Includes inbound split
	Barriers	2a	Are dropped	By Barrier TOD plan
	DMS	2b	REL entrance is closed	By DMS TOD message
	Signals	2c	Are controlled 8 Phase with northbound omit	By signal controller TOD plan
	Drivers exiting REL	2d	Turn right or left Continue straight	Activation Notification: • 1a, 1b Activation Notification: • 1a, 1b, 2a, 2b, 3a, 3b
	Drivers	2e	Turn right or though Turn left	Activation Notification: • 1a, 1b Activation Notification: • 1a. 1b, 2a, 2b, 3a, 3b
	Drivers	2f	Turn left or through Turn right	Activation Notification: • 1a, 1b Activation Notification: • 1a. 1b, 2a, 2b, 3a, 3b
	Drivers	2g	Turn left, right or through	Southbound REL exit green phase
	Signals	2h	Omit phases to westbound Twiggs	When grade crossing preemption is received
Post-conditions	• Notification 1 is terminated when REL is outbound • Notification 2 is terminated when driver exits in the correct direction • Notification 3 is terminated when all drivers travel in the correct direction			
Policies and Business Rules	Florida statute: • Red signal: Do not enter intersection According to MUTCD: • At least one DO NOT ENTER sign shall be conspicuously placed near the downstream end of the exit ramp in positions appropriate for full view of a road user starting to enter wrongly from the crossroad. • DO NOT ENTER indicates that traffic is prohibited from entering the restricted roadway, in this case, the REL exit ramp Activation procedure explained to participant as part of Informed Consent.			
Traceability	User Needs, CVRIA definitions, HUA			

Inputs Summary	None. Apps function with data input.
	• Class 1 Driver OBU alert is set at time of manufacture of installation.
	• Class 2 Driver OBU alert is set by aftermarket supplier
	• Class 3 Driver OBU alert
	  o is downloaded from app store
	  o device must be on with volume on sufficient to hear the alert with traffic.

Output Summary	• Alert message sent from RSU to TMC and data repository
	  o Alert message for each activation
	  o Alert message for each termination
	• Alert message sent to drivers when activated
	  o Notifications 1a and 1b
	  o Notifications 2a and 2b
	  o Notifications 3a and 3b

Table 17: Wrong-Way Entry Use Case Scenario 3: CV Failure/Anomaly/Exception Conditions

Use Case	*Wrong Way Entry*	
Scenario ID & Title	*UC2-S3: CV* Failure/Anomaly/Exception Conditions	
Scenario Objective	This scenario describes the failure/anomaly/exception conditions that could require temporarily "turning off" the CV technology/system/device(s) of the CV app for the Drivers on Twiggs Street or Meridian Avenue at the Selmon Expressway REL exit during REL operation (6-10 AM weekdays), as well as related RSUs and TMC functions.	
Operational Event(s)	Under "failure/anomaly/exception" conditions: • A driver approaching the intersection fails to receive Notification 1 that traffic is exiting the Selmon Expressway REL (False Negative) • A driver approaching the intersection receives Notification 1 when traffic is not exiting the Selmon Expressway REL (False Positive) • A driver entering the exit ramp or entering the closed ramp fails to receive Notification 2 (False Negative) • A driver not entering the exit ramp nor entering the closed ramp receives Notification 2 (False Positive) • A driver exiting the REL fails to receive Notification 3 when traffic is entering the exit ramp or entering the closed ramp (False Negative) • A driver exiting the REL receives Notification 3 when traffic is not entering the exit ramp nor entering the closed ramp (False Positive)	
User(s)	**User**	**Role**
	Drivers	Has Wrong Way alert app in OBU (IMA) of any of the following OBU classes: • Class 1: Part of vehicle systems • Class 2: Aftermarket device • Class 3: Mobile device mounted temporarily in vehicle cockpit

<table>
<tr><td rowspan="18">Key Actions and Flow of Events</td><th>Source</th><th>Step</th><th>Key Action Failure</th><th>Exceptions</th></tr>
<tr><td>Outbound TOD</td><td>1</td><td></td><td>Includes outbound split</td></tr>
<tr><td>Barriers</td><td>1a</td><td>Are raised</td><td>By Barrier TOD plan</td></tr>
<tr><td>DMS</td><td>1b</td><td>REL entrance is open</td><td>By DMS TOD message</td></tr>
<tr><td>Signals</td><td>1c</td><td>Are controlled 8 Phase with southbound omit</td><td>By signal controller TOD plan</td></tr>
<tr><td>Drivers</td><td>1d</td><td>Not detected traveling through to DO NOT ENTER
Are falsely detected</td><td>False Negative:
• 2a, 2b, 3a, 3b
False Positive:
• 2a, 2b, 3a, 3b</td></tr>
<tr><td>Drivers</td><td>1e</td><td>Not detected turning left to DO NOT ENTER
Are falsely detected</td><td>False Negative:
• 2a, 2b, 3a, 3b
False Positive:
• 2a, 2b, 3a, 3b</td></tr>
<tr><td>Drivers</td><td>1f</td><td>Not detected turning right to DO NOT ENTER
Are falsely detected</td><td>False Negative:
• 2a, 2b, 3a, 3b
False Positive:
• 2a, 2b, 3a, 3b</td></tr>
<tr><td>Signals</td><td>1g</td><td>Omit green phases to westbound Twiggs</td><td>When grade crossing preemption is received</td></tr>
<tr><td>Inbound TOD</td><td>2</td><td></td><td>Includes inbound split</td></tr>
<tr><td>Barriers</td><td>2a</td><td>Are dropped</td><td>By Barrier TOD plan</td></tr>
<tr><td>DMS</td><td>2b</td><td>REL entrance is closed</td><td>By DMS TOD message</td></tr>
<tr><td>Signals</td><td>2c</td><td>Are controlled 8 Phase with northbound omit</td><td>By signal controller TOD plan</td></tr>
<tr><td>Drivers</td><td>2d</td><td>Not detected traveling right or left
Not detected continuing through
Are falsely detected</td><td>False Negative:
• 1a, 1b
False Negative:
• 1a, 1b, 2a, 2b, 3a, 3b
False Positive:
• 1a, 1b, 2a, 2b, 3a, 3b</td></tr>
<tr><td>Drivers</td><td>2e</td><td>Not detected turning right or though
Not detected turning left
Are falsely detected</td><td>False Negative:
• 1a, 1b
False Negative:
• 1a, 1b, 2a, 2b, 3a, 3b
False Positive:
• 1a, 1b, 2a, 2b, 3a, 3b</td></tr>
<tr><td>Drivers</td><td>2f</td><td>Not detected turning left or</td><td>False Negative:</td></tr>
</table>

			through Not detected turning right Are falsely detected	• 1a, 1b False Negative: • 1a, 1b, 2a, 2b, 3a, 3b False Positive: • 1a, 1b, 2a, 2b, 3a, 3b
	Drivers	2g	Turn left, right or through	Southbound REL exit green phase
	Signals	2h	Omit phases to westbound Twiggs	When grade crossing preemption is received
Post-conditions	• Notification 1 is terminated when REL is outbound • Notification 2 is terminated when driver exits in the correct direction • Notification 3 is terminated when all drivers travel in the correct direction			
Policies and Business Rules	Florida statute: • Red signal: Do not enter intersection According to MUTCD: • At least one DO NOT ENTER sign shall be conspicuously placed near the downstream end of the exit ramp in positions appropriate for full view of a road user starting to enter wrongly from the crossroad. DO NOT ENTER indicates that traffic is prohibited from entering the restricted roadway, in this case, the REL exit ram Failure procedure explained to participant as part of Informed Consent.			
Traceability	User Needs, CVRIA definitions, HUA			
Inputs Summary	None. Apps function with data input. • Class 1 Driver OBU alert is set at time of manufacture of installation. • Class 2 Driver OBU alert is set by aftermarket supplier • Class 3 Driver OBU alert o is downloaded from app store o device must be on with volume on sufficient to hear the alert with traffic.			
Output Summary	• Alert message sent from RSU to TMC and data repository o Alert message for each activation o Alert message for each termination • Alert message sent to drivers when activated o Notifications 1a and 1b o Notifications 2a and 2b o Notifications 3a and 3b			

Table 18: Wrong-Way Entry Use Case Scenario 4: CV Maintenance Conditions

Use Case	*Wrong Way Entry*
Scenario ID & Title	*UC4-S4: CV* Maintenance Conditions
Scenario	This scenario describes the maintenance conditions that could require temporarily

Objective	"turning off" the CV technology/system/device(s) of the CV apps for the Drivers on Twiggs Street or Meridian Avenue at the Selmon Expressway REL exit during REL operation (6-10 AM weekdays), as well as related RSUs and TMC functions. There are two basic types of maintenance: 1. Single driver app maintenance for device failure 2. Planned system maintenance.
Operational Event(s)	1. Under "app maintenance" conditions: • A driver approaching the intersection fails to receive a notification that drivers are exiting the REL. The driver makes an appointment to receive app maintenance. 2. Under "system maintenance" conditions: • TMC sends an announcement to all app users effected, notifying them of planned maintenance.

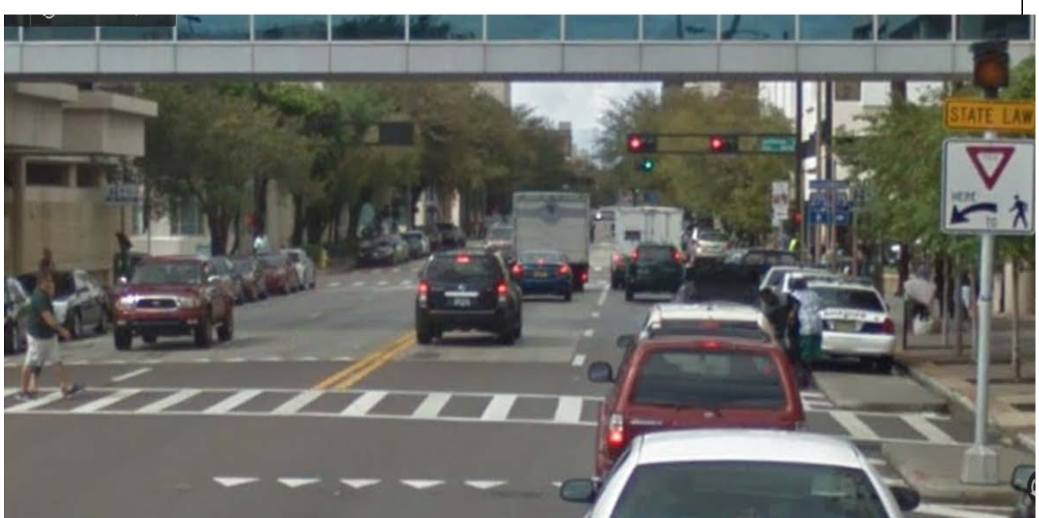
User(s)	User	Role
	Drivers	Has Wrong Way Entry alert app in OBU (IMA) of any of the following OBU classes: • Class 1: Part of vehicle systems • Class 2: Aftermarket device • Class 3: Mobile device mounted temporarily in vehicle cockpit

Key Actions and Flow of Events	Source	Step	Key Action	Comments
	App Maintenance			
	Driver app (Wrong Way)	2a	Notices Wrong Way problem	• Wrong Way inoperable • Received false warning • Didn't receive warning
	Driver app (Wrong Way)	2b	Instructed to update to latest Wrong Way version • Class 1 OBU: OEM • Class 2 OBU: Supplier • Class 3 OBU: App Store	From the device's app store
	Driver app (Wrong Way)	2c	Continuing problem, reports symptoms to office or website	• Received false warning • Didn't receive warning
	Office	2d	Acknowledges problem report	Problem logged
	Office	2e	Correlates time and symptoms with TMC logs from RSU	Investigation
	Office	2f	Initiates problem disposition	• No problem found • Wrong Way rev+1 → OEM • Wrong Way

				rev+1 → Supplier • Wrong Way rev+1 → App store
	System Maintenance			
	TMC	3a	TMC initiates announcement to all app users	• Wrong Way: App store • Class 1 OBU: OEM • Class 2 OBU: Supplier • Class 3 OBU: App Store
	TMC	3b	Wrong Way rev + 1 → app store	• IOS and Android
	TMC	3c	Wrong Way rev+1 → OEM	Class 1 OBU: OEM
	TMC	3d	Wrong Way rev+1 → Supplier	Class 2 OBU: Supplier
	TMC	3e	Wrong Way rev+1 → App store	Class 3 OBU: App Stores
Post-conditions	App is replaced/maintained and is operable.			
Policies and Business Rules	Maintenance procedure explained to participant as part of Informed Consent.			
Traceability	User Needs, CVRIA definitions, HUA			
Inputs Summary	Drivers contact office. No data inputs.			
Output Summary	No data output for maintenance.			

10.3 Pedestrians at Courthouse

Table 19: Pedestrians at Courthouse Use Case Scenario 1: Normal Conditions

Use Case	*Pedestrians at Courthouse*
Scenario ID & Title	*UC3-S1: CV Normal Conditions*
Scenario Objective	This scenario describes the normal conditions where there is a “no problem” or “no issue” with the Pedestrians crossing Twiggs Street at the Courthouse or with Drivers on Twiggs Street proceeding through the site. Although the site is equipped with the proposed technologies, normal events do not initiate the use of the proposed CV technology. Current Situation: At this site, a single primary pedestrian crosswalk connects the Hillsborough County courthouse to a parking garage located on opposite side of Twiggs Street. This crosswalk is identified to pedestrians via 15 foot wide pavement markings and is identified to approaching drivers via a single continuous flashing yellow caution signal installed atop two MUTCD Section 2B.11 Regulatory signs as shown: • MUTCD R1-9 “STATE LAW” • MUTCD R1-5 Yield here to pedestrians • MUTCD R1-5 includes an image of MUTCD R1-2 YIELD sign • MUTCD R1-5 includes an arrow pointing to the yield bar location  Google Streetview, September 2015 The crosswalk is uncontrolled, meaning no sensors or other inputs used to control the flashing signal.
Operational	Under “no issue” conditions:

<table>
<tr><td>Event(s)</td><td colspan="4">• pedestrians cross the street without notification, since no vehicle is approaching the crosswalk
• drivers cautiously pass the crosswalk without notification since no pedestrians are in the crosswalk.</td></tr>
<tr><td rowspan="3">User(s)</td><th colspan="2">User</th><th colspan="2">Role</th></tr>
<tr><td colspan="2">Pedestrians</td><td colspan="2">Jurors, lawyers, and other people use the crosswalk to get to/from the courthouse. Pedestrian Users typically carry a smart mobile device that is not being used while walking.</td></tr>
<tr><td colspan="2">Drivers</td><td colspan="2">Jurors, lawyers, and other people use the Twiggs Street to get to/from the courthouse. Drivers typically may:
• carry a smart mobile device that is not being used while driving
• carry a smart mobile device that is temporarily mounted in the cabin for route guidance to the parking garage
• use the vehicle navigation system for guidance to the parking garage</td></tr>
<tr><td rowspan="9">Key Actions and Flow of Events</td><th>Source</th><th>Step</th><th>Key Action</th><th>Comments</th></tr>
<tr><td>Pedestrian</td><td>1</td><td>Approaches the crosswalk</td><td>Occupies the sidewalk</td></tr>
<tr><td>Pedestrian</td><td>2</td><td>Observes no vehicles approaching</td><td>Not distracted</td></tr>
<tr><td>Pedestrian</td><td>3</td><td>Proceeds across Twiggs Street</td><td>Occupies the crosswalk</td></tr>
<tr><td>Driver</td><td>1</td><td>Approaches the crosswalk</td><td>Occupies Twiggs Street approach to crosswalk</td></tr>
<tr><td>Driver</td><td>2</td><td>Observes the warning signal</td><td>Not distracted</td></tr>
<tr><td>Driver</td><td>3</td><td>Observes the warning signs</td><td>Not distracted</td></tr>
<tr><td>Driver</td><td>3</td><td>Observes no pedestrians</td><td>Not distracted</td></tr>
<tr><td>Driver</td><td>3</td><td>Proceeds through crosswalk</td><td>Occupies the crosswalk</td></tr>
<tr><td>Post-conditions</td><td colspan="4">No actions taken. Pedestrian and driver have uninterrupted experience.</td></tr>
<tr><td>Policies and Business Rules</td><td colspan="4">Florida statute:
• Pedestrian in the crosswalk has right-of-way over driver
• Silent regarding pedestrians occupying the sidewalk who may or may not be waiting to cross
According to MUTCD:
• The YIELD sign assigns right-of-way to traffic approaches
• Vehicles controlled by a YIELD sign need to slow down to a speed that is reasonable for the existing conditions
• Stop when necessary to avoid interfering with conflicting traffic, in this case, pedestrians</td></tr>
</table>

	• Statute is silent regarding pedestrians occupying the sidewalk who may or may not be waiting to cross
Traceability	User Needs: Refer to User Needs for this site
Inputs Summary	None, no data input
Output Summary	None, not data output

Table 20: Pedestrians at Courthouse Use Case Scenario 2: CV Activation Conditions

<table>
<tr><td>Use Case</td><td colspan="4">Pedestrians at Courthouse</td></tr>
<tr><td>Scenario ID & Title</td><td colspan="4">UC3-S2: CV Activation Conditions</td></tr>
<tr><td>Scenario Objective</td><td colspan="4">This scenario describes the activation conditions where conditions will activate or trigger the CV apps for the Pedestrians crossing Twiggs Street at the Courthouse and Drivers on Twiggs Street driving through the crosswalk.</td></tr>
<tr><td>Operational Event(s)</td><td colspan="4">Under “activation” conditions:
• A pedestrian approaching the crosswalk receives a notification that a vehicle is approaching or in the crosswalk
• A pedestrian in the driving lanes outside of the crosswalk receives a notification to use the crosswalk
• A driver approaching the crosswalk receives a notification that
o A pedestrian is approaching or is occupying the crosswalk
o A pedestrian is in the driving lanes outside of the crosswalk
o driver must yield the right-of-way by slowing or stopping behind the yield bar</td></tr>
<tr><td rowspan="3">User(s)</td><td colspan="2">User</td><td colspan="2">Role</td></tr>
<tr><td colspan="2">Pedestrians</td><td colspan="2">Carries vehicle alert app on mobile device such as smart phone (Pedestrian Mobility Ped App)
• Must be on volume high enough to hear with traffic
• Includes haptic alert if device is equipped with vibrate mode
• Includes visual warning display</td></tr>
<tr><td colspan="2">Drivers</td><td colspan="2">Has pedestrian alert app in OBU (PED-SIG) of any of the following OBU classes:
• Class 1: Part of vehicle systems
• Class 2: Aftermarket device
• Class 3: Mobile device mounted temporarily in vehicle cockpit</td></tr>
<tr><td rowspan="2">Key Actions and Flow of Events</td><td>Source</td><td>Step</td><td>Key Action</td><td>Comments</td></tr>
<tr><td>Ped app</td><td>1a</td><td>Securely broadcasts pedestrian location, heading and speed 10 times per</td><td>Basic Safety Message (BSM) compatible with future new vehicles does</td></tr>
</table>

			second from mobile device	not include identification, but includes encryption and authentication as part of this step
	Driver app (PED-SIG)	1b	Securely broadcasts vehicle location, heading and speed 10 times per second from OBU	Basic Safety Message (BSM) compatible with future new vehicles does not include identification, but includes encryption and authentication as part of this step
	RSU	2a	Receives pedestrian BSM using wireless media of mobile device	RSU is compatible with mobile device wireless media, such as WiFi or cellular, depending upon performance required
	RSU	2b	Either validates or corrects the pedestrian location derived from the mobile device	Mobile device may not provide location accuracy required
	RSU	2c	Transmits corrected pedestrian BSM on wireless media to OBU	Proxy message appears to the OBU as if transmitted directly by the pedestrian mobile device
	RSU	3a	Compares Ped location to crosswalk location and to lane placement location	Determine if the pedestrian is in the driving lanes but not the crosswalk
	RSU	3b	If pedestrian is in roadway but not in crosswalk, warns pedestrian to use crosswalk	“Jaywalking” warning issued regardless of whether a vehicle is approaching
	RSU	4a	Receives OBU BSM using wireless media of OBU	RSU is compatible with OBU wireless media, such as DSRC
	RSU	4b	Either validates or corrects the OBU location	Mobile device may not provide location accuracy required
	RSU	4c	Transmits corrected OBU BSM on wireless media of mobile device	Proxy message appears to Ped App as if transmitted directly by the OBU
	Ped app	5a	Receives corrected OBU BSM	Proxy message appears to Ped App as if transmitted directly by the OBU
	Ped app	5b	Calculates the OBU and Ped trajectories	Reuse V2V crash avoidance algorithm

	Ped app	5c	Predicts collisions	Reuse V2V crash avoidance algorithms
	Ped app	5d	Warns pedestrian before collision	Reuse V2V crash avoidance visual, audio & haptic warnings
	OBU	6a	Receives corrected Ped BSM	Proxy message appears to Ped App as if transmitted directly by the OBU
	OBU	6b	Calculates the OBU and Ped trajectories	Reuse V2V crash avoidance algorithms
	OBU	6c	Predicts collisions	Reuse V2V crash avoidance algorithms
	OBU	6d	Warns driver before collision	Reuse V2V crash avoidance visual, audio & haptic warnings
	RSU	7a	Blends proxy and direct BSM	OBUs communicate directly to one another for V2V apps
	RSU	7b	Is removed from service	When mobile devices have the OBU accuracy and wireless media, Ped App becomes V2V without need for redesign
Post-conditions	• Pedestrian with Ped app o Stops "jaywalker" in roadway outside of crosswalk o stops before entering crosswalk or o exits crosswalk away from traffic if already within crosswalk • Driver with app o Slows or stops before yield bar o allows pedestrian to pass • Driver to be aware pedestrians may not have app.			
Policies and Business Rules	Under Florida statute, pedestrian has right of way. Activation procedure explained to participant as part of Informed Consent. • Activation is based on Florida statute and MUTCD • Activation warns of predicted violations before they occur			
Traceability	User Needs, CVRIA definitions, HUA			
Inputs Summary	None. Apps function with data input. • Pedestrian mobile device must be on with volume on sufficient to hear the alert with traffic. • Driver OBU alert is set at time of manufacture of installation.			
Output Summary	• Alert message sent from RSU to TMC and data repository • Alert message sent to drivers on crash trajectory • Alert message sent to pedestrian that are on crash trajectory with OBU o Visual alert on mobile device display overrides running app in case pedestrian is distracted (texting, etc.)			

	o Audible alert on mobile device speaker o Haptic alert via mobile device vibration

Table 21: Pedestrians at Courthouse Use Case Scenario 3: CV Failure/Anomaly/Exception Conditions

<table>
<tr><td>Use Case</td><td colspan="5">Pedestrians at Courthouse</td></tr>
<tr><td>Scenario ID & Title</td><td colspan="5">UC3-S3: CV Failure/Anomaly/Exception Conditions</td></tr>
<tr><td>Scenario Objective</td><td colspan="5">This scenario describes the failure/anomaly/exception conditions that could require temporarily “turning off” the CV technology/system/device(s) of the CV apps for the Pedestrians crossing Twiggs Street at the Courthouse and Drivers on Twiggs Street driving through the crosswalk.</td></tr>
<tr><td>Operational Event(s)</td><td colspan="5">Under “failure/anomaly/exception” conditions:
• A pedestrian approaching the crosswalk fails to receive a notification that a vehicle is approaching or in the crosswalk (False Negative)
• A pedestrian approaching the crosswalk receives a notification when a vehicle is not approaching or not in the crosswalk (False Positive)
• A driver approaching the crosswalk fails to receive a notification that a pedestrian is approaching or in the crosswalk (False Negative)
• A driver approaching the crosswalk receives a notification when a pedestrian is not approaching or is not in the crosswalk (False Positive)</td></tr>
<tr><td rowspan="3">User(s)</td><td colspan="3">User</td><td colspan="2">Role</td></tr>
<tr><td colspan="3">Pedestrians</td><td colspan="2">Carries vehicle alert app on mobile device such as smart phone (Pedestrian Mobility Ped App)
• Must be on volume high enough to hear with traffic
• Includes haptic alert if device is equipped with vibrate mode
• Includes visual warning display</td></tr>
<tr><td colspan="3">Drivers</td><td colspan="2">Has pedestrian alert app in OBU (PED-SIG) of any of the following OBU classes:
• Class 1: Part of vehicle systems
• Class 2: Aftermarket device
• Class 3: Mobile device mounted temporarily in vehicle cockpit</td></tr>
<tr><td rowspan="3">Key Actions and Flow of Events</td><td>Source</td><td>Step</td><td colspan="2">Key Action Failure</td><td>Exceptions</td></tr>
<tr><td>Ped app</td><td>1a</td><td colspan="2">Securely broadcasts pedestrian location, heading and speed 10 times per second from mobile device</td><td>• 3d False Negative
• 6d False Negative</td></tr>
<tr><td>Driver app (PED-SIG)</td><td>1b</td><td colspan="2">Securely broadcasts vehicle location, heading and speed</td><td>• 5d False Negative</td></tr>
</table>

			10 times per second from OBU	
	RSU	2a	Receives pedestrian BSM using wireless media of mobile device	• 3b False Negative • 6d False Negative
	RSU	2b	Either validates or corrects the pedestrian location derived from the mobile device	• 3b False Positive • 6d False Positive
	RSU	2c	Transmits corrected pedestrian BSM on wireless media of OBU	• 3b False Negative • 6d False Negative
	RSU	3a	Compares Ped location to crosswalk location and to lane placement location	• 3b False Negative • 6d False Negative • 3b False Positive • 6d False Positive
	RSU	3b	If pedestrian is in roadway but not in crosswalk, warns pedestrian to use crosswalk	"Jaywalking" warning issued regardless of whether a vehicle is approaching
	RSU	4a	Receives OBU BSM using wireless media of OBU	• 5d False Negative
	RSU	4b	Either validates or corrects the OBU location	• 5d False Positive
	RSU	4c	Transmits corrected OBU BSM on wireless media of mobile device	• 5d False Negative
	Ped app	5a	Receives corrected OBU BSM	• 5d False Negative
	Ped app	5b	Calculates the OBU and Ped trajectories	• 5d False Negative • 5d False Positive
	Ped app	5c	Predicts collisions	• 5d False Negative • 5d False Positive
	Ped app	5d	Warns pedestrian before collision	Reuse V2V crash avoidance visual, audio & haptic warnings
	OBU	6a	Receives corrected Ped BSM	• 6d False Negative
	OBU	6b	Calculates the OBU and Ped trajectories	• 6d False Negative

	OBU	6c	Predicts collisions	• 6d False Negative • 6d False Positive
	OBU	6d	Warns driver before collision	Reuse V2V crash avoidance visual, audio & haptic warnings
	RSU	7a	Blends proxy and direct BSM	• 7b is never achieved
	RSU	7b	Is removed from service	When mobile devices have the OBU accuracy and wireless media, Ped App becomes V2V without need for redesign
Post-conditions	• Pedestrian with Ped app o Stops "jaywalker" in roadway outside of crosswalk o stops before entering crosswalk or o exits crosswalk away from traffic if already within crosswalk • Driver with app o Slows or stops before yield bar o allows pedestrian to pass • Driver to be aware pedestrians may not have app.			
Policies and Business Rules	Under Florida statute, pedestrian has right of way. Failure procedure explained to participant as part of Informed Consent. • Alert is based on Florida statute and MUTCD • Failure alert warns of predicted violations before they occur			
Traceability	User Needs, CVRIA definitions, HUA			
Inputs Summary	None. Apps function with data input. • Pedestrian mobile device must be on with volume on sufficient to hear the alert with traffic. • Driver OBU alert is set at time of manufacture of installation.			
Output Summary	• Alert message sent from RSU to TMC and data repository • Alert message sent to drivers on crash trajectory • Alert message sent to pedestrian that are on crash trajectory with OBU o Visual alert on mobile device display overrides running app in case pedestrian is distracted (texting, etc.) o Audible alert on mobile device speaker o Haptic alert via mobile device vibration			

Table 22: Pedestrians at Courthouse Use Case Scenario 4: CV Maintenance Conditions

Use Case	*Pedestrians at Courthouse*
Scenario ID & Title	*UC3-S4: CV* Maintenance Conditions
Scenario Objective	This scenario describes the maintenance conditions that could require temporarily "turning off" the CV technology/system/device(s) of the CV apps for the Pedestrians

<table>
<tr><td></td><td colspan="5">crossing Twiggs Street at the Courthouse and Drivers on Twiggs Street driving through the crosswalk, as well as related RSUs and TMC functions. There are two basic types of maintenance:
1. Single pedestrian or driver app maintenance for device failure
2. Planned system maintenance.</td></tr>
<tr><td>Operational Event(s)</td><td colspan="5">1. Under “app maintenance” conditions:
• A pedestrian approaching the crosswalk fails to receive a notification that a vehicle is approaching or in the crosswalk. The pedestrian makes an appointment to receive app maintenance.
• A driver approaching the crosswalk fails to receive a notification that a pedestrian is approaching or in the crosswalk. The driver makes an appointment to receive app maintenance.
2. Under “system maintenance” conditions:
• TMC sends an announcement to all app users effected, notifying them of planned maintenance</td></tr>
<tr><td rowspan="3">User(s)</td><td colspan="3">User</td><td colspan="2">Role</td></tr>
<tr><td colspan="3">Pedestrians</td><td colspan="2">Carries vehicle alert app on mobile device such as smart phone (Pedestrian Mobility Ped App)
• Must be on volume high enough to hear with traffic
• Includes haptic alert if device is equipped with vibrate mode
Includes visual warning display</td></tr>
<tr><td colspan="3">Drivers</td><td colspan="2">Has pedestrian alert app in OBU (PED-SIG) of any of the following OBU classes:
• Class 1: Part of vehicle systems
• Class 2: Aftermarket device
• Class 3: Mobile device mounted temporarily in vehicle cockpit</td></tr>
<tr><td rowspan="5">Key Actions and Flow of Events</td><td>Source</td><td>Step</td><td colspan="2">Key Action</td><td>Comments</td></tr>
<tr><td>App Maintenance</td><td></td><td colspan="2"></td><td></td></tr>
<tr><td>Ped app</td><td>1a</td><td colspan="2">Notices app problem</td><td>• Ped app inoperable
• Received false warning
• Didn’t receive warning</td></tr>
<tr><td>Ped app</td><td>1b</td><td colspan="2">Instructed to update to latest Ped app version</td><td>From the device’s app store</td></tr>
<tr><td>Ped app</td><td>1c</td><td colspan="2">Continuing problem, reports symptoms to office or website</td><td>• Received false warning
• Didn’t receive</td></tr>
</table>

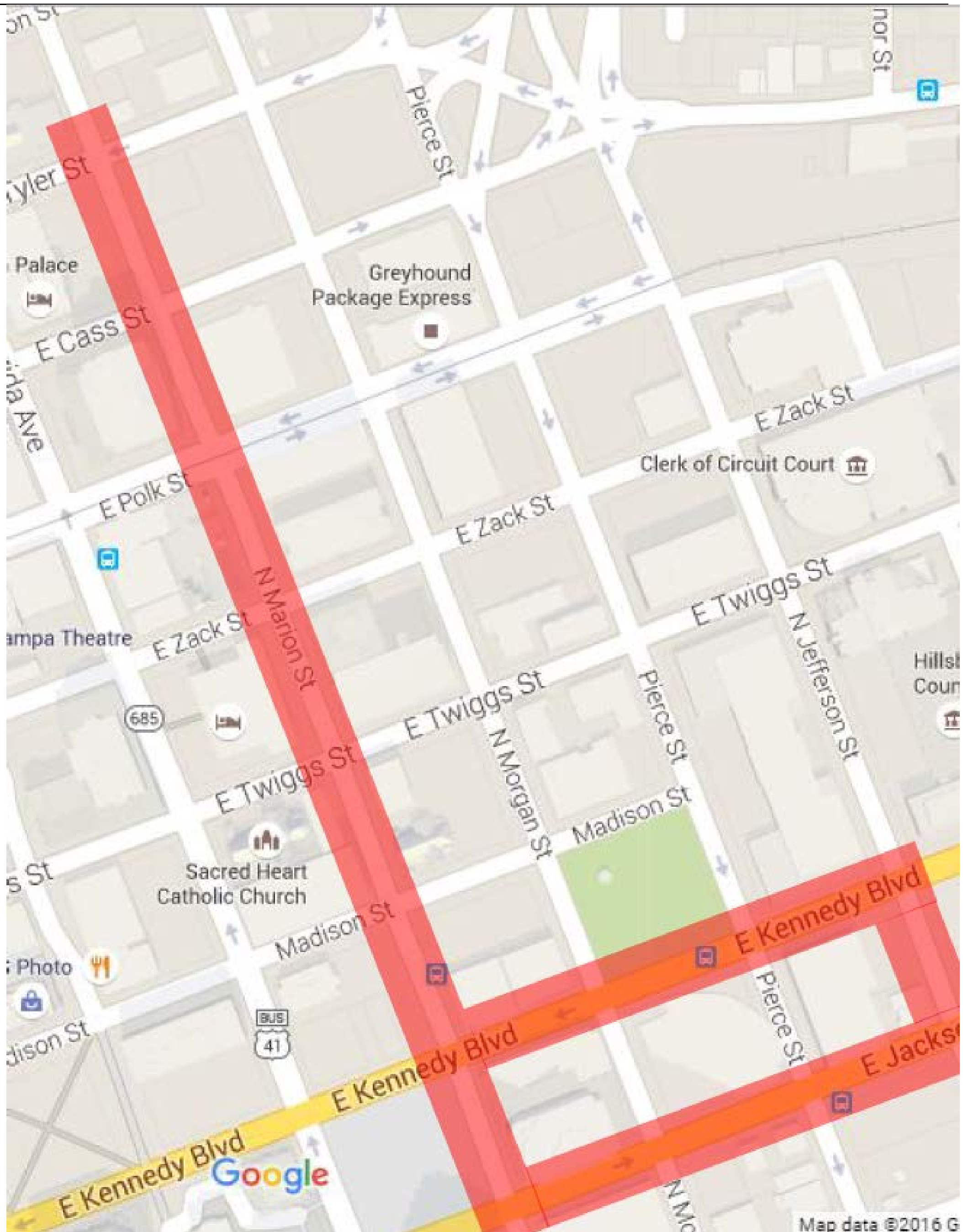
				warning
	Office	1d	Acknowledges problem report	Problem logged
	Office	1e	Correlates time and symptoms with TMC logs from RSU	Investigation
	Office	1f	Initiates problem disposition	• No problem found • Ped App rev+1 → store
	Driver app (PED-SIG)	2a	Notices PED-SIG problem	• PED-SIG inoperable • Received false warning • Didn't receive warning
	Driver app (PED-SIG)	2b	Instructed to update to latest PED-SIG version • Class 1 OBU: OEM • Class 2 OBU: Supplier • Class 3 OBU: App Store	From the device's app store
	Driver app (PED-SIG)	2c	Continuing problem, reports symptoms to office or website	• Received false warning • Didn't receive warning
	Office	2d	Acknowledges problem report	Problem logged
	Office	2e	Correlates time and symptoms with TMC logs from RSU	Investigation
	Office	2f	Initiates problem disposition	• No problem found • PED SIG rev+1 → OEM • PED SIG rev+1 → Supplier • PED SIG rev+1 → App store
	System Maintenance			
	TMC	3a	TMC initiates announcement to all app users	• Ped app: App store • Class 1 OBU: OEM • Class 2 OBU: Supplier • Class 3 OBU: App Store
	TMC	3b	Ped app rev + 1 → app store	• IOS and Android
	TMC	3c	PED SIG rev+1 → OEM	Class 1 OBU: OEM
	TMC	3d	PED SIG rev+1 → Supplier	Class 2 OBU: Supplier

	TMC	3e	PED SIG rev+1 → App store	Class 3 OBU: App Stores
Post-conditions	App is replaced/maintained and is operable.			
Policies and Business Rules	Maintenance procedure explained to participant as part of Informed Consent.			
Traceability	User Needs, CVRIA definitions, HUA			
Inputs Summary	Pedestrians and drivers call office. No data inputs.			
Output Summary	No data output for maintenance.			

10.4 BRT Optimization

Table 23: BRT Optimization Use Case Scenario 1: Normal Conditions

Use Case	*BRT Optimization*
Scenario ID & Title	*UC5-S1: CV Normal Conditions*
Scenario Objective	This scenario describes the normal conditions where there is a “no problem” or “no issue” for the Bus Drivers on the Hillsborough Area Regional Transit Authority (HART) bus express route through signalized intersection on downtown city streets from the Marion Street transit station southward to East Jackson Boulevard and then eastward to North Jefferson Street. The site is to be equipped with the below proposed CV applications: • Transit Signal Priority (TSP) • Intelligent Traffic Signal System (I-SIG) These two applications will work in harmony in that the I-SIG application will operate in normal conditions as an adaptive traffic management system, whereas the TSP will only activate when a bus requires priority. After the bus has cleared the intersection, the I-SIG application will resume and automatically restore the intersection back to adaptive control. Current Situation: The HART bus express route travels through downtown Tampa on restricted access surface streets that are limited to transit buses Monday through Friday from 6 AM to 7 PM. The bus stops include a mixture of far side, near side and midblock transit stops. The HART bus express route along Marion Street travels through signalized intersections at the following cross streets: • East Tyler Street • East Cass Street • East Polk Street • East Zack Street • East Twiggs Street • Madison Street • West Kennedy Boulevard • East Jackson Boulevard From there, the bus express route travels in parallel along East Jackson Boulevard and West Kennedy Boulevard through signalized intersections at the following cross streets: • North Morgan Street • North Pierce Street • North Jefferson Street

<table>
<tr>
<td></td>
<td>


Source: Google Maps

At these intersections, a Bus Driver receives no advanced signal progression.
</td>
</tr>
<tr>
<td>Operational Event(s)</td>
<td>Under “no issue” conditions:
Bus Drivers proceed through the intersections according to what the City of Tampa signal system allows.
</td>
</tr>
</table>

<table>
<tr><td></td><td>

- Cross traffic along the express route does not impede bus progression

</td></tr>
<tr><td>User(s)</td><td>
<table>
<tr><th>User</th><th>Role</th></tr>
<tr><td>Bus Drivers</td><td>Bus drivers typically may:
• carry a smart mobile device that is not being used while driving
• carry a smart mobile device that is temporarily mounted in the cabin for route guidance
• use the vehicle navigation system for guidance in the area
Buses typically may include:
• Mobile computer as part of the bus systems used for bus routes, schedules and others.
• Proprietary communications to the transit station use to track bus location, to offload ridership counts and others.</td></tr>
<tr><td></td><td></td></tr>
<tr><td></td><td></td></tr>
</table>
</td></tr>
<tr><td>Key Actions and Flow of Events</td><td>
<table>
<tr><th>Source</th><th>Step</th><th>Key Action</th><th>Comments</th></tr>
<tr><td>Transit center</td><td>1</td><td>Begins new route shift</td><td>One of several routes</td></tr>
<tr><td>Bus Driver</td><td>1a</td><td>Exits Marion transit station</td><td>Beings new shift</td></tr>
<tr><td>Bus Driver</td><td>1b</td><td>Stop for red traffic signals</td><td>To far side, midblock</td></tr>
<tr><td>Bus Driver</td><td>1c</td><td>Drives to next transit stop</td><td>Arrives on schedule</td></tr>
<tr><td>Passengers</td><td>1d</td><td>Exit bus to transit stop</td><td>Not counted</td></tr>
<tr><td>Passengers</td><td>1e</td><td>Enter bus from transit stop</td><td>New riders</td></tr>
<tr><td>Passengers</td><td>1f</td><td>Validate bus ticket</td><td>Add to ridership count</td></tr>
<tr><td>Bus Driver</td><td>1g</td><td>Proceed if on or behind,
wait if ahead of schedule</td><td>Don’t miss last minute passenger arrivals</td></tr>
<tr><td>Bus Driver</td><td>1h</td><td>If nearside, wait for green</td><td>Clear cross traffic & ped</td></tr>
<tr><td>Bus Driver</td><td>1i</td><td>Repeat 1b to 1h</td><td>Through entire route</td></tr>
<tr><td>Bus Driver</td><td>1j</td><td>Return to transit center</td><td>End of route shift</td></tr>
<tr><td>Transit center</td><td>1k</td><td>Offload ridership, revenue</td><td>Wireless proprietary</td></tr>
</table>
</td></tr>
<tr><td>Post-conditions</td><td>No actions taken. Driver has uninterrupted experience.</td></tr>
<tr><td>Policies and Business Rules</td><td>MUTCD
• R5-1 Regulatory “DO NOT ENTER” sign
• R5-11 Regulatory Selective Inclusion “6 AM to 7 PM” sign
Florida Statute
• Red traffic signal: Do not enter intersection</td></tr>
</table>

Traceability	User Needs: Refer to User Needs for this site
Inputs Summary	Bus schedule input to Bus Driver
Output Summary	• Bus ridership count • Bus revenue

Table 24: BRT Optimization Use Case Scenario 2: CV Activation Conditions

Use Case	*BRT Optimization*	
Scenario ID & Title	*UC5-S2: CV Activation Conditions*	
Scenario Objective	This scenario describes the activation conditions where conditions will activate or trigger the CV app for the Bus Driver.	
Operational Event(s)	Under "activation" conditions: • Cross traffic and pedestrian volumes impede bus progression • Bus progression falls behind published schedule o This condition could occur when the bus ridership is unusually high with lots of riders constantly entering/exiting the bus o This condition could occur when the bus is behind schedule due to traffic causing it traverse the route slower than anticipated o This condition could occur when a bus is at a stop near an intersection and vehicles queue up waiting for the light to turn green preventing the bus from exiting the stop. • A bus driver approaching the intersection o Receives a notification that the bus has transit signal priority o Receives warning when bus is denied transit signal priority ▪ Bus is ahead of schedule ▪ Emergency vehicle with higher intersection service priority is approaching on cross street o Receives visual countdown to signal green phase o Receives red light violation warning if bus location and speed predict the signal will be red at arrival to the stop bar	
User(s)	User	Role
	Bus Drivers	Bus drivers typically may: • carry a smart mobile device that is not being used while driving • carry a smart mobile device that is temporarily mounted in the cabin for route guidance • use the vehicle navigation system for guidance in the area Buses typically may include: • Mobile computer as part of the bus systems used for bus routes, schedules and others.

		• Proprietary communications to the transit station use to track bus location, to offload ridership counts and others.

Key Actions and Flow of Events

Source	Step	Key Action	Comments
Transit center	1	Begins new route shift	One of several routes
Bus Driver	1a	Exits Marion transit station	Beings new shift
Bus OBU	1b	Matches transit zone	To bus location
Bus OBU	1c	Transmits Signal Request Message (SRM) to RSU	SRM = BSM + VIN
RSU	1d	Send SRM to Transit Center	Request for priority
Transit Center	1e	Returns SRM back to RSU Blocks SRM	Behind schedule, (due to delays such as intersection congestion preventing bus from entering/leaving a stop) or high ridership On, ahead, low ridership
RSU	1f	Compares all SRM received	From all vehicles
RSU	1g	Sends Signal Status Message (SSM) to all vehicles	Green: Highest priority Red: All lower priorities
RSU	1h	Sends high priority phase	To signal control
Signal Control	1i	Sends SPaT to RSU	Countdown to change
RSU	1j	Sends SpaT to all vehicles	Countdown to change
Bus OBU	1k	Receives SSM	Green if highest priority Red if lower priority
Bus display	1l	Displays traffic signal	Current signal color
Bus OBU	1m	Receives SpaT	Countdown to change
Bus display	1n	Displays signal countdown	Next signal color
Bus Driver	1o	Red light violation warning	Visual, audible, haptic
Bus Driver	1p	Stop for red traffic signals	To far side, midblock
Bus Driver	1q	Drives to next transit stop	Arrives on schedule
Passengers	1r	Exit bus to transit stop	Subtract from count
Passengers	1s	Enter bus from transit stop	New riders
Passengers	1t	Validate bus ticket	Add to ridership count
Bus OBU	1u	Sends ridership	On service channel
RSU	1v	Receives ridership	On service channel
RSU	1w	Sends ridership to center	On backhaul
Transit Center	1x	Receives ridership	For priority decisions

	Bus Driver	1y	If nearside, wait for green	Clear cross traffic & ped
	Bus Driver	1z	Repeat 1b to 1y	Through entire route
	Bus Driver	1aa	Return to transit center	End of route shift
	Bus OBU	1ab	Offload ridership, miles	On Service Channel
	Transit center	1ac	Upload ridership, revenue	Standard wireless
Post-conditions	• Transit priority terminated when bus progression returns to schedule • Transit priority can run continuously with SRM automatically blocked continuously during normal bus progression without need for transit signal priority			
Policies and Business Rules	MUTCD • R5-1 Regulatory "DO NOT ENTER" sign • R5-11 Regulatory Selective Inclusion "6 AM to 7 PM" sign Florida Statute • Red traffic signal: Do not enter intersection Activation procedure explained to bus driver during Informed Consent or employer briefing.			
Traceability	User Needs, CVRIA definitions, HUA			
Inputs Summary	• Bus schedule • Transit priority zone locations			
Output Summary	Internal cabinet communication network switch • Transit priority to signal control Connected Vehicle Control Channel: • SSM to bus driver • Signal Phase and Timing (SpaT) to bus driver • Red light violation warning to bus driver Connected Vehicle Service Channel • Bus ridership count to Transit Center • Bus revenue to Transit Center Backhaul • Advance signal setting message sent from RSU to TMC • Advance signal setting message sent from RSU data repository			

Table 25: BRT Optimization Use Case Scenario 3: CV Failure/Anomaly/Exception Conditions

Use Case	*BRT Optimization*
Scenario ID & Title	*UC5-S3: CV* Failure/Anomaly/Exception Conditions

Scenario Objective	This scenario describes the failure/anomaly/exception conditions that could require temporarily “turning off” the CV technology/system/device(s) of the CV app for the Bus Drivers, as well as related RSUs and TMC functions.
Operational Event(s)	Under “failure/anomaly/exception” conditions: • A bus driver approaching the intersection fails to receive a notification that the signal will change (False Negative) • A bus driver approaching the intersection receives a notification when traffic is not impeding bus schedule (False Positive) • A bus driver does not receive a red light violation warning when predicted to arrive at red (False Negative) • A bus driver receives a red light violation warning when not predicted to arrive at red (False Positive)

User(s)	User	Role
	Bus Drivers	Bus drivers typically may: • carry a smart mobile device that is not being used while driving • carry a smart mobile device that is temporarily mounted in the cabin for route guidance • use the vehicle navigation system for guidance in the area Buses typically may include: • Mobile computer as part of the bus systems used for bus routes, schedules and others. • Proprietary communications to the transit station use to track bus location, to offload ridership counts and others.

Key Actions and Flow of Events	Source	Step	Key Action Failure	Exceptions
	Transit center	1	Begins new route shift	One of several routes
	Bus Driver	1a	Exits Marion transit station	Beings new shift
	Bus OBU	1b	No transit zone match Mismatch transit zone	False Negative • 1h False Positive • 1h to wrong lane
	Bus OBU	1c	No SRM to RSU	False Negative • 1h
	RSU	1d	Send SRM to Transit Center	False Negative • 1h

	Transit Center	1e	Returns SRM back to RSU Blocks SRM	False Negative • 1h
	RSU	1f	Compares all SRM received	False Negative • 1h False Positive • 1h to wrong lane
	RSU	1g	Sends SSM to all vehicles	False Negative • 1n, 1l, 1o
	RSU	1h	Sends priority phase	Normal safe operation, without bus priority
	Signal Control	1i	Sends SpaT to RSU	False Negative • 1n, 1l, 1o
	RSU	1j	Sends SpaT to all vehicles	False Negative • 1n, 1l, 1o
	Bus OBU	1k	Receives SSM	False Negative • 1n, 1l, 1o
	Bus display	1l	Displays traffic signal	Current signal color
	Bus OBU	1m	Receives SpaT	Countdown to change
	Bus display	1n	Displays signal countdown	Next signal color
	Bus Driver	1o	Red light violation warning	Visual, audible or haptic
	Bus Driver	1p	Stop for red traffic signals	To far side, midblock
	Bus Driver	1q	Drives to next transit stop	Arrives on schedule
	Passengers	1r	Exit bus to transit stop	Not counted
	Passengers	1s	Enter bus from transit stop	New riders
	Passengers	1t	Validate bus ticket	Add to ridership count
	Bus OBU	1u	Sends ridership	On service channel
	RSU	1v	Receives ridership	On service channel
	RSU	1w	Sends ridership to center	On backhaul
	Transit Center	1x	Receives ridership	For priority decisions
	Bus Driver	1y	If nearside, wait for green	Clear cross traffic & ped
	Bus Driver	1z	Repeat 1b to 1h	Through entire route
	Bus Driver	1aa	Return to transit center	End of route shift
	Bus OBU	1ab	Offload ridership, miles	On Service Channel
	Transit center	1ac	Upload ridership, revenue	Standard wireless
Post-conditions	• Transit priority terminated when bus progression returns to schedule • Transit priority can run continuously with SRM automatically blocked continuously with normal bus progression			

Policies and Business Rules	MUTCD • R5-1 Regulatory “DO NOT ENTER” sign • R5-11 Regulatory Selective Inclusion “6 AM to 7 PM” sign Florida Statute • Red traffic signal: Do not enter intersection Failure procedure explained to bus driver during Informed Consent or employer briefing.
Traceability	User Needs, CVRIA definitions, HUA
Inputs Summary	• Bus schedule • Transit priority zone locations
Output Summary	Internal cabinet communication network switch • Transit priority to signal control Connected Vehicle Control Channel: • SRM to Transit Center • Signal Status Message (SSM) to bus display • Signal Phase and Timing (SpaT) to bus display • Red light violation warning to bus driver Connected Vehicle Service Channel • Bus ridership count to Transit Center • Bus revenue to Transit Center Backhaul • SRM from RSU to Transit Center • Advance signal setting message sent from RSU to TMC • Advance signal setting message sent from RSU data repository

Table 26: BRT Optimization Use Case Scenario 4: CV Maintenance Conditions

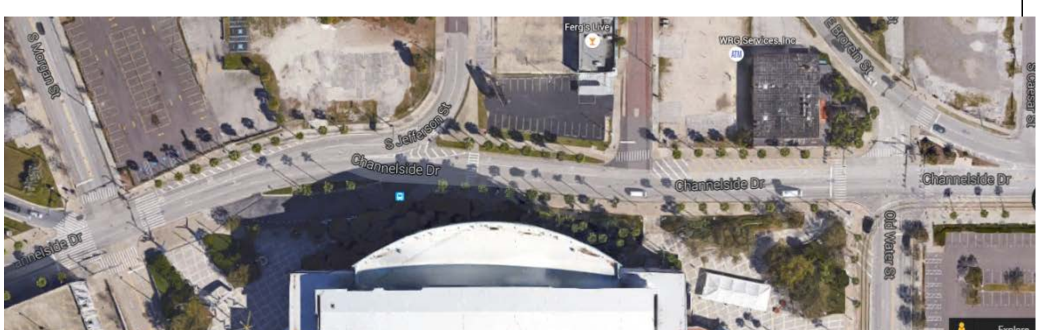
Use Case	*BRT Optimization*
Scenario ID & Title	*UC5-S4: CV* Maintenance Conditions
Scenario Objective	This scenario describes the maintenance conditions that could require temporarily “turning off” the CV technology/system/device(s) of the CV apps for the Bus Drivers, as well as related OBUs, RSUs and TMC functions. There are four basic types of maintenance: 1. Bus display: a. Driver advice app maintenance b. Device failure 2. Bus OBU: a. Wireless software stack updates b. Device failure 3. Intersection RSU:

<table>
<tr><td></td><td colspan="4">a. Wireless software stack updates
b. Device failure
4. Central transit management system
a. Software updates
b. Bus route and schedule updates</td></tr>
<tr><td>Operational Event(s)</td><td colspan="4">1. Under “app maintenance” conditions:
• A driver approaching the intersection fails to receive a notification. The driver makes an appointment to receive app maintenance.
2. Under “system maintenance” conditions:
• HART Dispatcher sends an announcement to all app users effected, notifying them of planned maintenance.</td></tr>
<tr><td rowspan="2">User(s)</td><th colspan="2">User</th><th colspan="2">Role</th></tr>
<tr><td colspan="2">Drivers</td><td colspan="2">Bus drivers typically may:
• carry a smart mobile device that is not being used while driving
• carry a smart mobile device that is temporarily mounted in the cabin for route guidance
• use the vehicle navigation system for guidance in the area
Buses typically may include:
• Mobile computer as part of the bus systems used for bus routes, schedules and others.
• Proprietary communications to the transit station use to track bus location, to offload ridership counts and others.</td></tr>
<tr><td rowspan="5">Key Actions and Flow of Events</td><th>Source</th><th>Step</th><th>Key Action</th><th>Comments</th></tr>
<tr><td>App Maintenance</td><td></td><td></td><td></td></tr>
<tr><td>Bus Driver app (Display)</td><td>2a</td><td>Notices display problem</td><td>• Signal countdown inoperable
• Received false signal priority
• Didn’t receive signal priority</td></tr>
<tr><td>Bus Driver app (Display)</td><td>2b</td><td>Instructed to update to latest Wrong Way version
• Class 2 OBU: Supplier</td><td>From the device’s supplier</td></tr>
<tr><td>Bus Driver app (Display)</td><td>2c</td><td>Continuing problem, reports symptoms to office or website</td><td>• Signal countdown inoperable
• Received false signal priority
• Didn’t receive signal priority</td></tr>
</table>

	Office	2d	Acknowledges problem report	Problem logged
	Office	2e	Correlates time and symptoms with TMC logs from RSU	Investigation
	Office	2f	Initiates problem disposition	• No problem found • Priority rev+1 → Supplier
	System Maintenance			
	TMC	3a	TMC initiates announcement to all app users	• Class 2 OBU: Supplier
	TMC	3d	Transit rev+1 → Supplier	Class 2 OBU: Supplier
Post-conditions	App is replaced/maintained and is operable.			
Policies and Business Rules	Maintenance procedure explained to bus driver during Informed Consent or employer briefing.			
Traceability	User Needs, CVRIA definitions, HUA			
Inputs Summary	Drivers contact office. No data inputs.			
Output Summary	No data output for maintenance.			

10.5 Trolley/Auto/Pedestrian/Bicycle Conflicts

Table 27: Trolley/Auto/Pedestrian/Bicycle Conflicts Use Case Scenario 1: Normal Conditions

Use Case	*Trolley/Auto/Pedestrian/Bicycle Conflict*
Scenario ID & Title	*UC6-S1: CV Normal Conditions*
Scenario Objective	This scenario describes the normal conditions where there is “no problem” or “no issue” with automobiles turning right in front of Trolley Drivers on Channelside Drive and pedestrians/bicyclists crossing in front of the Trolley. Although the site is equipped with the proposed technologies: • Vehicle Turning Right in Front of Transit Vehicle (VTRFTV) • Intelligent Traffic Signal System (I-SIG) normal events do not initiate the use of the proposed CV technology in the vehicle. <u>Current Situation</u>: TECO Line Streetcar System consists of: • Overhead rail electrification gantries • Heritage trolley rolling stock • Rail right-of-way located between the vehicle lanes and sidewalk • Low curbs separating right-of-way from pedestrians/bicyclists and vehicles At cross streets, the trolley line crosses signalized intersections at grade level. The line travels Channelside Drive through six signalized intersections with heavy pedestrian/bicyclist traffic near the waterfront, Amalie Arena, hotels, shopping and the cruise ship dock at cross streets: • South Morgan Street • South Jefferson Street • South Nebraska Street • Old Water Street • East Brorein Street • South Caesar Street  Source: Google Maps

<table>
<tr><td></td><td colspan="4">At these sites, a Trolley Driver receives no advanced signal progression or message of autos turning right in front of Trolley Drivers on Channelside Drive and pedestrians/bicyclists crossing in front of the Trolley.</td></tr>
<tr><td>Operational Event(s)</td><td colspan="4">Under “no issue” conditions:
• Trolley Drivers proceed through the intersections according to what the City of Tampa signal system allows.
• Pedestrians and Bicyclists
o Wait for trolley departure, do not walk/ride in front of trolley
o Wait for vehicle to complete turn in front of trolley, do not enter intersection while vehicle is turning
• Automobile drivers
o Are not distracted
o Obey the appropriate traffic signals
o Obey the applicable traffic laws and signage
o Proactively determine when the trolley is about to depart
o Wait for trolley departure, do not turn in front of trolley</td></tr>
<tr><td rowspan="4">User(s)</td><td colspan="2">User</td><td colspan="2">Role</td></tr>
<tr><td colspan="2">Auto Drivers</td><td colspan="2">Drivers typically may:
• carry a smart mobile device that is not being used while driving
• carry a smart mobile device that is temporarily mounted in the cabin for route guidance
• use the vehicle navigation system for guidance in the area</td></tr>
<tr><td colspan="2">Trolley Drivers</td><td colspan="2">• Typically carry a smart mobile device that is not being used while traveling</td></tr>
<tr><td colspan="2">Tourists, shoppers, bicyclists, sports fans and other people</td><td colspan="2">• Use the trolley, sidewalks and vehicle lanes to and from the nearby attractions.
• Typically carry a smart mobile device that is not being used while traveling</td></tr>
<tr><td rowspan="11">Key Actions and Flow of Events</td><td>Source</td><td>Step</td><td>Key Action</td><td>Comments</td></tr>
<tr><td>Trolley Driver</td><td>1a</td><td>Halts at trolley stop</td><td>Normal service</td></tr>
<tr><td>Passengers</td><td>1b</td><td>Exit trolley</td><td>Normal service</td></tr>
<tr><td>Passengers</td><td>1c</td><td>Board trolley</td><td>Normal service</td></tr>
<tr><td>Trolley Driver</td><td>1d</td><td>Waits for Green signal</td><td>For cross traffic</td></tr>
<tr><td>Traffic Signal</td><td>1e</td><td>Begins Green phase</td><td>Cross traffic clears</td></tr>
<tr><td>Pedestrians</td><td>1f</td><td>Wait during DONT WALK</td><td>While trolley clears</td></tr>
<tr><td>Auto Drivers</td><td>1g</td><td>Wait for trolley to clear</td><td>When turning right</td></tr>
<tr><td>Auto Drivers</td><td>1i</td><td>Turn right</td><td>Behind departing trolley</td></tr>
<tr><td>Bicyclists</td><td>1j</td><td>Turn right</td><td>Behind departing trolley</td></tr>
<tr><td>Pedestrians</td><td>1k</td><td>Proceed to crosswalk</td><td>During WALK phase</td></tr>
</table>

	Traffic Signal	1l	Capacity exceeds volume	Normal traffic progression
Post-conditions	No actions taken. • Driver has uninterrupted experience • Autos obey vehicle signals • Pedestrians/bicyclists obey pedestrian signals			
Policies and Business Rules	Florida Statute • Red signal: do not enter intersection • WALK (or person icon): Pedestrians enter crosswalk • FLASHING HAND: Pedestrian clearance, do not enter crosswalk • SOLID HAND: Cross traffic, crosswalk is clear			
Traceability	User Needs: Refer to User Needs for this site			
Inputs Summary	None, no data input			
Output Summary	None, not data output			

Table 28 Trolley/Auto/Pedestrian/Bicycle Conflicts Use Case Scenario 2: CV Activation Conditions

Use Case	*Trolley/Auto/Pedestrian/Bicycle Conflict*	
Scenario ID & Title	*UC6-S2: CV Activation Conditions*	
Scenario Objective	This scenario describes the activation conditions where conditions will activate or trigger the CV app for the Trolley Driver because of automobiles turning right in front of Trolley Drivers on Channelside Drive and pedestrians/bicyclists crossing in front of the Trolley.	

Operational Event(s)	Under "activation" conditions:
	• Signal about to turn green with autos/pedestrians/bicyclists located
	  o To the left of the trolley
	  o To the right of the trolley
	  o In front of the trolley
	• Channelside Drive progression being impeded by
	  o Signal timing plan
	  o Distracted pedestrians/bicyclists
	  o Pedestrians/Bicyclists not obeying signals and signage	

User(s)	User	Role
	Auto Drivers	Drivers typically may: • carry a smart mobile device that is not being used while driving • carry a smart mobile device that is temporarily mounted in the cabin for route guidance • use the vehicle navigation system for guidance in the area
	Trolley Drivers	• Typically carry a smart mobile device that is not being used while

<table>
<tr><td></td><td colspan="2"></td><td colspan="2">traveling
• Equipped with a Class 2 OBU</td></tr>
<tr><td></td><td colspan="2">Tourists, shoppers, bicyclists, sports fans and other people</td><td colspan="2">• Use the trolley, sidewalks and vehicle lanes to and from the nearby attractions.
• Typically carry a smart mobile device that is not being used while traveling</td></tr>
<tr><td rowspan="27">Key Actions and Flow of Events</td><th>Source</th><th>Step</th><th>Key Action</th><th>Comments</th></tr>
<tr><td>Trolley Driver</td><td>1a</td><td>Halts at trolley stop</td><td>Normal service</td></tr>
<tr><td>Trolley OBU</td><td>1b</td><td>Broadcasts BSM</td><td>Location, heading, speed</td></tr>
<tr><td>Passengers</td><td>1c</td><td>Exit trolley</td><td>Normal service</td></tr>
<tr><td>Passengers</td><td>1d</td><td>Board trolley</td><td>Normal service</td></tr>
<tr><td>Trolley OBU</td><td>1e</td><td>Broadcasts SRM</td><td>Requests Green</td></tr>
<tr><td>RSU</td><td>1f</td><td>Receives SRM</td><td>From all vehicles</td></tr>
<tr><td>RSU</td><td>1g</td><td>Determines Green phase</td><td>Highest priority vehicle</td></tr>
<tr><td>RSU</td><td>1h</td><td>Sends transit priority</td><td>To traffic signal control</td></tr>
<tr><td>RSU</td><td>1i</td><td>Broadcasts SSM</td><td>Phase selected</td></tr>
<tr><td>Private OBUs</td><td>1j</td><td>Receive SSM</td><td>Auto, bicycle, pedestrian</td></tr>
<tr><td>Private OBUs</td><td>1k</td><td>Trolley departure alert</td><td>To nearby private OBUs</td></tr>
<tr><td>RSU</td><td>1l</td><td>Broadcasts SPaT</td><td>Time to next color change</td></tr>
<tr><td>Trolley OBU</td><td>1m</td><td>Receives SSM</td><td>Verify Green priority</td></tr>
<tr><td>Trolley display</td><td>1n</td><td>Displays SSM</td><td>Inform driver to depart</td></tr>
<tr><td>Trolley display</td><td>1o</td><td>Displays SPaT</td><td>Countdown to departure</td></tr>
<tr><td>Traffic Signal</td><td>1p</td><td>Begins Green phase</td><td>Cross traffic is clear</td></tr>
<tr><td>Trolley OBU</td><td>1q</td><td>Receives nearby vehicles' BSM</td><td>Locates nearby threats</td></tr>
<tr><td>Trolley Display</td><td>1r</td><td>Warns driver of threats</td><td>Based on BSM locations</td></tr>
<tr><td>Private OBUs</td><td>1s</td><td>Receive trolley warning</td><td>To nearby OBUs</td></tr>
<tr><td>Trolley OBU</td><td>1t</td><td>Verifies no forward BSM</td><td>Safe to depart</td></tr>
<tr><td>Pedestrians</td><td>1u</td><td>DONT WALK</td><td>While trolley clears</td></tr>
<tr><td>Auto Drivers</td><td>1v</td><td>Wait for trolley to clear</td><td>When turning right</td></tr>
<tr><td>Auto Drivers</td><td>1w</td><td>Turn right</td><td>Behind departing trolley</td></tr>
<tr><td>Bicyclists</td><td>1x</td><td>Turn right or proceed across street</td><td>Behind departing trolley</td></tr>
<tr><td>Pedestrians</td><td>1y</td><td>Proceed to crosswalk</td><td>During WALK phase</td></tr>
<tr><td>Traffic Signal</td><td>1z</td><td>Capacity exceeds volume</td><td>Normal traffic progression</td></tr>
<tr><td>Post-conditions</td><td colspan="4">• Can be terminated during low pedestrian and traffic volumes
• Can run continually without termination</td></tr>
</table>

Policies and Business Rules	Florida Statute • Red signal: do not enter intersection • WALK (or person icon): Pedestrians enter crosswalk • FLASHING HAND: Pedestrian clearance, do not enter crosswalk SOLID HAND: Cross traffic, crosswalk is clear Activation procedure explained to trolley driver during Informed Consent or employer briefing.
Traceability	User Needs, CVRIA definitions, HUA
Inputs Summary	• BSM from private OBUs
Output Summary	• Advance signal setting message sent from RSU to TMC and data repository • Alert message sent to trolley driver • Alert message sent to auto, pedestrian/bicyclists

Table 29: Trolley/Auto/Pedestrian/Bicycle Conflicts Use Case Scenario 3: CV Failure/Anomaly/Exception Conditions

<table>
<tr><td>Use Case</td><td colspan="4">Trolley/Auto/Pedestrian/Bicycle Conflict</td></tr>
<tr><td>Scenario ID & Title</td><td colspan="4">UC6-S3: CV Failure/Anomaly/Exception Conditions</td></tr>
<tr><td>Scenario Objective</td><td colspan="4">This scenario describes the failure/anomaly/exception conditions that could require temporarily “turning off” the CV technology/system/device(s) of the CV app for the Trolley Drivers, as well as related RSUs and TMC functions.</td></tr>
<tr><td>Operational Event(s)</td><td colspan="4">Under “failure/anomaly/exception” conditions:
• A trolley driver approaching the intersection fails to receive a notification that the signal will change (False Negative)
• A trolley driver approaching the intersection receives a notification when traffic is not changing (False Positive)
• A trolley driver approaching the intersection fails to receive a notification that autos are turning right in front of Trolley Drivers (False Negative)
• A trolley driver approaching the intersection receives a notification when autos are turning right in front of Trolley Drivers (False Positive).</td></tr>
<tr><td rowspan="4">User(s)</td><td colspan="2">User</td><td colspan="2">Role</td></tr>
<tr><td colspan="2">Auto Drivers</td><td colspan="2">Drivers typically may:
• carry a smart mobile device that is not being used while driving
• carry a smart mobile device that is temporarily mounted in the cabin for route guidance
• use the vehicle navigation system for guidance in the area</td></tr>
<tr><td colspan="2">Trolley Drivers</td><td colspan="2">• Typically carry a smart mobile device that is not being used while traveling
• Equipped with a Class 2 OBU</td></tr>
<tr><td colspan="2">Tourists, shoppers, bicyclists, sports fans and other people</td><td colspan="2">• Use the trolley, sidewalks and vehicle lanes to and from the nearby attractions.
• Typically carry a smart mobile device that is not being used while traveling</td></tr>
<tr><td rowspan="4">Key Actions and Flow of Events</td><td>Source</td><td>Step</td><td>Key Action Failure</td><td>Exceptions</td></tr>
<tr><td>Trolley Driver</td><td>1a</td><td>Halts at trolley stop</td><td>Normal service</td></tr>
<tr><td>Trolley OBU</td><td>1b</td><td>Broadcasts BSM

Erroneous location</td><td>False Negative
• 1l
False Positive
• 1l</td></tr>
<tr><td>Passengers</td><td>1c</td><td>Exit trolley</td><td>Normal service</td></tr>
</table>

	Passengers	1d	Board trolley	Normal service
	Trolley OBU	1e	Broadcasts SRM	False Negative • 1i
	RSU	1f	Receives SRM Erroneous location	False Negative • 1i False Positive • 1l
	RSU	1g	Determines Green phase	False Negative • 1i
	RSU	1h	Sends transit priority	False Negative • 1i
	Signal Control	1i	Sets priority phase	To highest priority
	RSU	1j	Broadcasts SSM	False Negative • 1l, 1o
	Private OBUs	1k	Receive SSM	False Negative • 1l, 1o
	Private OBUs	1l	Receives Trolley departure alert	To nearby private OBUs
	RSU	1m	Broadcasts SPaT	False Negative • 1p
	Trolley OBU	1n	Receives SSM	False Negative • 1o
	Trolley display	1o	Displays SSM	Inform driver to depart
	Trolley display	1p	Displays SPaT	Countdown to departure
	Traffic Signal	1q	Begins Green phase	Cross traffic is clear
	Trolley OBU	1r	Receives nearby BSM	False Negative • 1s
	Trolley Display	1s	Warns driver of threats	Based on BSM locations
	Private OBUs	1t	Receive trolley warning	To nearby OBUs
	Trolley OBU	1u	Verifies no forward BSM	Safe to depart
	Pedestrians	1v	DONT WALK	While trolley clears
	Auto Drivers	1w	Wait for trolley to clear	When turning right
	Auto Drivers	1x	Turn right	Behind departing trolley
	Bicyclists	1y	Turn right or proceed to cross street	Behind departing trolley
	Pedestrians	1z	Proceed to crosswalk	During WALK phase
	Traffic Signal	1aa	Capacity exceeds volume	Normal traffic progression

Post-conditions	• Can be terminated during low pedestrian and traffic volumes • Can run continually without termination
Policies and Business Rules	Florida Statute • Red signal: do not enter intersection • WALK (or person icon): Pedestrians enter crosswalk • FLASHING HAND: Pedestrian clearance, do not enter crosswalk SOLID HAND: Cross traffic, crosswalk is clear Failure procedure explained to trolley driver during Informed Consent or employer briefing.
Traceability	User Needs, CVRIA definitions, HUA
Inputs Summary	• BSM from private OBUs
Output Summary	• Advance signal setting message sent from RSU to TMC and data repository • Alert message sent to trolley driver • Alert message sent to auto, pedestrian/bicyclists

Table 30 Trolley/Auto/Pedestrian/Bicycle Conflicts Use Case Scenario 4: CV Maintenance Conditions

Use Case	*Trolley/Auto/Pedestrian/Bicycle Conflict*	
Scenario ID & Title	*UC6-S4: CV* Maintenance Conditions	
Scenario Objective	This scenario describes the maintenance conditions that could require temporarily "turning off" the CV technology/system/device(s) of the CV apps for the Trolley Drivers, as well as related RSUs and TMC functions. There are two basic types of maintenance: 1. Single driver app maintenance for device failure 2. Planned system maintenance.	
Operational Event(s)	1. Under "app maintenance" conditions: • A driver approaching the intersection fails to receive a notification. The driver makes an appointment to receive app maintenance. 2. Under "system maintenance" conditions: • HART Dispatcher sends an announcement to all app users effected, notifying them of planned maintenance.	
User(s)	User	Role
	Auto Drivers	Drivers typically may: • carry a smart mobile device that is not being used while driving • carry a smart mobile device that is temporarily mounted in the cabin for route guidance • use the vehicle navigation system for guidance in the area

	Trolley Drivers			• Typically carry a smart mobile device that is not being used while traveling • Equipped with a Class 2 OBU
	Tourists, shoppers, bicyclists, sports fans and other people			• Use the trolley, sidewalks and vehicle lanes to and from the nearby attractions. • Typically carry a smart mobile device that is not being used while traveling
Key Actions and Flow of Events	**Source**	**Step**	**Key Action**	**Comments**
	App Maintenance			
	Trolley Driver app (Display)	2a	Notices display problem	• Signal countdown inoperable • Received false signal priority • Didn't receive signal priority
	Trolley Driver app (Display)	2b	Instructed to update to latest App version • Class 2 OBU: Supplier	From the device's supplier
	Trolley Driver app (Display)	2c	Continuing problem, reports symptoms to office or website	• Signal countdown inoperable • Received false signal priority • Didn't receive signal priority
	Office	2d	Acknowledges problem report	Problem logged
	Office	2e	Correlates time and symptoms with TMC logs from RSU	Investigation
	Office	2f	Initiates problem disposition	• No problem found • VTRFTV rev+1 → Supplier
	System Maintenance			
	TMC	3a	TMC initiates announcement to all app users	• Class 2 OBU: Supplier
	TMC	3d	VTRFTV rev+1 → Supplier	Class 2 OBU: Supplier
Post-conditions	App is replaced/maintained and is operable.			
Policies and Business Rules	Maintenance procedure explained to bus driver during Informed Consent or employer briefing.			

Traceability	User Needs, CVRIA definitions, HUA
Inputs Summary	Drivers contact office. No data inputs.
Output Summary	No data output for maintenance.

10.6 Traffic Progression

Table 31: Traffic Progression Use Case Scenario 1: Normal Conditions

<table>
<tr><td>Use Case</td><td>Traffic Progression</td></tr>
<tr><td>Scenario ID & Title</td><td>UC4-S1: CV Normal Conditions</td></tr>
<tr><td>Scenario Objective</td><td>This scenario describes the normal conditions where there is a “no problem” or “no issue” for the Drivers on Meridian Avenue when progressing through intersections from Twiggs Street to Channelside Drive.

Although the site is equipped with the proposed technologies
• Intelligent Traffic Signal (I-SIG)
• Probe-enabled Data Monitoring (PeDM),
normal events do not initiate the use of the proposed CV technology in the vehicle.

<u>Current Situation</u>:

Site includes Meridian Avenue between the REL and Channelside Drive, including the following intersections:
• Twiggs St: Signalized cross street
• Kennedy Blvd: Signalized cross street
• Jackson St: Signalized tee
• E. Washington St: STOP sign tee, no control on Meridian
• E. Whiting St: STOP sign tee, no control on Meridian
• Cumberland St: Signalized tee
• Channelside Dr.: Signalized cross street

At these sites, a driver receives no advanced signal progression.

REL
Channelside Dr.


←North Source: Google Maps</td></tr>
<tr><td>Operational Event(s)</td><td>Under “no issue” conditions:
• Drivers progress along Meridian according to the City of Tampa signal system timing plan.
• Traffic volumes do not exceed the capacity of the timing plan</td></tr>
</table>

<table>
<tr><td></td><td colspan="4">REL exit queue length at Twiggs is less than the surface lane length
Entire length of the REL exit ramp is free-flowing</td></tr>
<tr><td rowspan="2">User(s)</td><td colspan="2">User</td><td colspan="2">Role</td></tr>
<tr><td colspan="2">Drivers</td><td colspan="2">Drivers typically may:
carry a smart mobile device that is not being used while driving
carry a smart mobile device that is temporarily mounted in the cabin for route guidance
use the vehicle navigation system for guidance in the area</td></tr>
<tr><td rowspan="12">Key Actions and Flow of Events</td><td>Source</td><td>Step</td><td>Key Action</td><td>Comments</td></tr>
<tr><td>Drivers</td><td>1</td><td>Traveling towards Tampa</td><td>Inbound TOD schedule</td></tr>
<tr><td>Drivers</td><td>1a</td><td>Enter the REL westbound</td><td>Tampa and AFB traffic</td></tr>
<tr><td>Drivers</td><td>1b</td><td>Observe lighted MUTCD overhead guide sign “Expressway ENDS ½ MILE”, “SIGNAL AHEAD” mounted beside DMS</td><td>Normal condition of free flowing traffic, no queue on REL</td></tr>
<tr><td>Drivers</td><td>1c</td><td>Begin a sweeping left curve while descending to ground level</td><td>At mile marker 6.2</td></tr>
<tr><td>Drivers</td><td>1d</td><td>Observe an MUTCD roadside guide sign “Twiggs St NEXT SIGNAL”</td><td>At apex of curve</td></tr>
<tr><td>Drivers</td><td>1e</td><td>Continue at ground level below overpass</td><td>At mile marker 6.0</td></tr>
<tr><td>Drivers</td><td>1f</td><td>Observe MUTCD “DO NOT ENTER” above 3 leftmost lanes and MUTCD and “Meridian Ave Aquarium / Seaport / Amalie Arena” over 3 rightmost lanes</td><td>REL ends</td></tr>
<tr><td>Drivers</td><td>1g</td><td>Arrive at normal vehicle queue for signalized intersection at Twiggs</td><td>Signals and queue are visible on straight ground-level lanes, ample time to stop safely for queue</td></tr>
<tr><td>Traffic Signal</td><td>2a</td><td>Allows sufficient GREEN phase to prevent queues from extending to REL</td><td>Normal traffic volume</td></tr>
<tr><td>Drivers</td><td>2a</td><td>Turn or proceed through Twiggs to Meridian</td><td>Most traffic proceeds through</td></tr>
<tr><td>Traffic Signal</td><td>2b</td><td>Progress along Meridian to final designation</td><td>According to signal timing plan</td></tr>
<tr><td>Post-conditions</td><td colspan="4">No actions taken.
Driver has uninterrupted experience.</td></tr>
</table>

	• Queues are confined to straight ground level lanes with good visibility
Policies and Business Rules	MUTCD • "Expressway Ends" guide sign • "Signal Ahead" guide sign Florida Statute • Red signal: do not enter intersection
Traceability	User Needs: Refer to User Needs for this site
Inputs Summary	None, no data input
Output Summary	None, not data output

Table 32: Traffic Progression Use Case Scenario 2: CV Activation Conditions

Use Case	*Traffic Progression*	
Scenario ID & Title	*UC4-S2: CV Activation Conditions*	
Scenario Objective	This scenario describes the activation conditions where conditions will activate or trigger the CV app for the driver. Equipped vehicles (i.e., ones with VADs and OBUs) will be broadcasting their speed, location, and direction of travel. The data will be processed centrally (synchronized) to determine congestion levels. This information will be used to determine the congestion levels and adjust the signal timing accordingly. Note the system should work in either direction.	
Operational Event(s)	Under "activation" conditions: • Queues at REL exit extend to the underpass • Last vehicle in queue becomes visible to overtaking traffic with little safety margin in stopping distance • City of Tampa traffic signals on Meridian Avenue revert from signal timing plan to adaptive control based on approaching traffic from REL	
User(s)	User	Role
	Drivers	Has CV Basic Safety Message (BSM) of any of the following OBU classes: • Class 1: Part of vehicle systems • Class 2: Aftermarket device • Class 3: Mobile device mounted temporarily in vehicle cockpit

	Source	Step	Key Action	Comments
Key Actions and Flow of Events	Drivers	1	Traveling towards Tampa	Inbound TOD schedule
	Drivers	1a	Enter the REL westbound	Tampa and AFB traffic
	Drivers	1b	Observe lighted MUTCD overhead guide sign "Expressway ENDS ½ MILE", "SIGNAL AHEAD" mounted beside DMS	Normal condition of free flowing traffic, no queue on REL

	Drivers	1c	Begin a sweeping left curve while descending to ground level	At mile marker 6.2
	Drivers	1d	Observe an MUTCD roadside guide sign "Twiggs St NEXT SIGNAL"	At apex of curve
	Drivers	1e	Continue at ground level below overpass	At mile marker 6.0
	Drivers	1f	Observe MUTCD "DO NOT ENTER" above 3 leftmost lanes and MUTCD "Meridian Ave Aquarium / Seaport / Amalie Arena" over 3 rightmost lanes	REL ends
	Drivers	1g	Arrive at extended vehicle queue for signalized intersection at Twiggs	Last car in extended queue visible with adequate time to stop safely
	Traffic Signal RSU	2a	• Receives BSM location of extended queue • Activates progression	Heavy traffic volume from REL
	Drivers	2a	Turn or proceed through Twiggs to Meridian	Most traffic proceeds through
	Traffic Signal RSU	2b	• Receives location of arriving BSMs • Activates progression	GREEN phase allocated to accommodate arriving BSMs along Meridian to Channelside Dr.
Post-conditions	• Progression is terminated by REL TOD plan reverse • Progression can run continually through TOD reverse in heavy traffic			
Policies and Business Rules	MUTCD • "Expressway Ends" guide sign • "Signal Ahead" guide sign Florida Statute • Red signal: do not enter intersection Activation procedure explained during Informed Consent.			
Traceability	User Needs, CVRIA definitions, HUA			
Inputs Summary	• Basic Safety Messages from driver OBU			
Output Summary	• Activation alert to TMC			

Table 33: Traffic Progression Use Case Scenario 3: CV Failure/Anomaly/Exception Conditions

Use Case	*Traffic Progression*
Scenario ID &	*UC4-S3: CV* Failure/Anomaly/Exception Conditions

<table>
<tr><th>Title</th><th colspan="4"></th></tr>
<tr><td>Scenario Objective</td><td colspan="4">This scenario describes the failure/anomaly/exception conditions that could require temporarily “turning off” the CV technology/system/device(s) of the CV app for the Drivers, as well as related RSUs and TMC functions.</td></tr>
<tr><td>Operational Event(s)</td><td colspan="4">Under “failure/anomaly/exception” conditions:
• Drivers in queue do not send BSM (False Negative)
• Traffic signal RSUs do not receive BSM (False Negative)
• Inaccurate BSM location
   o False Negative on Meridian
   o False Positive on another phase</td></tr>
<tr><td rowspan="2">User(s)</td><th colspan="2">User</th><th colspan="2">Role</th></tr>
<tr><td colspan="2">Drivers</td><td colspan="2">Has CV Basic Safety Message (BSM) of any of the following OBU classes:
• Class 1: Part of vehicle systems
• Class 2: Aftermarket device
• Class 3: Mobile device mounted temporarily in vehicle cockpit</td></tr>
<tr><td rowspan="9">Key Actions and Flow of Events</td><th>Source</th><th>Step</th><th>Key Action Failure</th><th>Exception</th></tr>
<tr><td>Drivers</td><td>1</td><td>Traveling towards Tampa</td><td>Inbound TOD schedule</td></tr>
<tr><td>Drivers</td><td>1a</td><td>Enter the REL westbound</td><td>Tampa and AFB traffic</td></tr>
<tr><td>Drivers</td><td>1b</td><td>Observe lighted MUTCD overhead guide sign “Expressway ENDS ½ MILE”, “SIGNAL AHEAD” mounted beside DMS</td><td>Normal condition of free flowing traffic, no queue on REL</td></tr>
<tr><td>Drivers</td><td>1c</td><td>Begin a sweeping left curve while descending to ground level</td><td>At mile marker 6.2</td></tr>
<tr><td>Drivers</td><td>1d</td><td>Observe an MUTCD roadside guide sign “Twiggs St NEXT SIGNAL”</td><td>At apex of curve</td></tr>
<tr><td>Drivers</td><td>1e</td><td>Continue at ground level below overpass</td><td>At mile marker 6.0</td></tr>
<tr><td>Drivers</td><td>1f</td><td>Observe MUTCD “DO NOT ENTER” above 3 leftmost lanes and MUTCD “Meridian Ave Aquarium / Seaport / Amalie Arena” over 3 rightmost lanes</td><td>REL ends</td></tr>
<tr><td>Drivers</td><td>1g</td><td>Arrive at extended vehicle queue for signalized intersection at Twiggs</td><td>Last car in extended queue visible with ample time to stop safely</td></tr>
</table>

	Traffic Signal RSU	2a	• No location of extended queue • Inaccurate location of extended queue	2a False Negative 2a False Positive if long 2a False Negative if short
	Drivers	2a	Turn or proceed through Twiggs to Meridian	Most traffic proceeds through
	Traffic Signal RSU	2b	• No location of arriving BSMs • Inaccurate location of arriving BSM	2b False Negative 2b False Negative Meridian 2b False Positive side street
Post-conditions	• Progression is terminated when TOD plan reverses the REL • Progression can remain activated without termination			
Policies and Business Rules	MUTCD • "Expressway Ends" guide sign • "Signal Ahead" guide sign Florida Statute • Red signal: do not enter intersection Failure procedure explained to participant during Informed Consent.			
Traceability	User Needs, CVRIA definitions, HUA			
Inputs Summary	BSM from driver OBUs			
Output Summary	Activation alert to TMC			

Table 34: Traffic Progression Use Case Scenario 4: CV Maintenance Conditions

Use Case	*Traffic Progression*
Scenario ID & Title	*UC4-S4: CV* Maintenance Conditions
Scenario Objective	This scenario describes the maintenance conditions that could require temporarily "turning off" the CV technology/system/device(s) of the CV apps for the Drivers, as well as related RSUs and TMC functions. There are two basic types of maintenance: 1. Single driver app maintenance for device failure 2. Planned system maintenance.
Operational Event(s)	1. Under "app maintenance" conditions: • A driver approaching the intersection fails to send BSM and is not granted GREEN 2. Under "system maintenance" conditions: • TMC sends an announcement to all app users effected, notifying them of

<table>
<tr><td></td><td colspan="4">planned maintenance.</td></tr>
<tr><td rowspan="2">User(s)</td><td colspan="2">User</td><td colspan="2">Role</td></tr>
<tr><td colspan="2">Drivers</td><td colspan="2">Has CV Basic Safety Message (BSM) in any of the following OBU classes:
• Class 1: Part of vehicle systems
• Class 2: Aftermarket device
• Class 3: Mobile device mounted temporarily in vehicle cockpit</td></tr>
<tr><td rowspan="15">Key Actions and Flow of Events</td><td>Source</td><td>Step</td><td>Key Action</td><td>Comments</td></tr>
<tr><td>App Maintenance</td><td></td><td></td><td></td></tr>
<tr><td>Driver app BSM</td><td>1a</td><td>Notices queue extending onto REL ramp or lack of progression on Meridian</td><td>Not transmitting BSM</td></tr>
<tr><td>Driver app BSM</td><td>1b</td><td>Instructed to update to latest BSM version
• Class 1 OBU: OEM
• Class 2 OBU: Supplier
• Class 3 OBU: App Store</td><td>From the device’s app store</td></tr>
<tr><td>Driver app BSM</td><td>1c</td><td>Continuing problem, reports symptoms to office or website</td><td>Not transmitting BSM</td></tr>
<tr><td>Office</td><td>1d</td><td>Acknowledges problem report</td><td>Problem logged</td></tr>
<tr><td>Office</td><td>1e</td><td>Correlates time and symptoms with TMC logs from RSU</td><td>Investigation</td></tr>
<tr><td>Office</td><td>1f</td><td>Initiates problem disposition</td><td>• No problem found
• BSM rev+1 → OEM
• BSM rev+1 → Supplier
• BSM rev+1 → App store</td></tr>
<tr><td>System Maintenance</td><td></td><td></td><td></td></tr>
<tr><td>TMC</td><td>2a</td><td>TMC initiates announcement to all app users</td><td>• Class 1 OBU: OEM
• Class 2 OBU: Supplier
• Class 3 OBU: App Store</td></tr>
<tr><td>TMC</td><td>2b</td><td>BSM rev + 1 → app store</td><td>• IOS and Android</td></tr>
<tr><td>TMC</td><td>2c</td><td>BSM rev+1 → OEM</td><td>Class 1 OBU: OEM</td></tr>
<tr><td>TMC</td><td>2d</td><td>BSM rev+1 → Supplier</td><td>Class 2 OBU: Supplier</td></tr>
<tr><td>TMC</td><td>2e</td><td>BSM rev+1 → App store</td><td>Class 3 OBU: App Stores</td></tr>
</table>

Post-conditions	App is replaced/maintained and is operable.
Policies and Business Rules	Maintenance procedure explained to participant as part of Informed Consent.
Traceability	User Needs, CVRIA definitions, HUA
Inputs Summary	Drivers contact office. No data inputs.
Output Summary	No data output for maintenance.

11 Summary of Impacts

This section discusses impacts of the proposed system on:

- Stakeholders
- Traffic assessed by performance measures
- Security of data integrity and personal information.

11.1Stakeholder Impacts

The ways in which The THEA CV Pilot puts together CV Apps into Use Cases are expected to have desirable impacts for Stakeholders. Impacts for owners and operators of transportation facilities listed in this section positively affect the traveling public as well. The CV system users (i.e., participants) are expected to benefit from the project as discussed in Section 5.6.

However, the Stakeholders who own transportation facilities and operate app equipment also have responsibilities in installing, using and maintaining the CV app equipment. These impacts are important to consider as well.

Besides equipment and operations impacts, Human Use Approval will require some Stakeholders to take into account special considerations in recruiting, training and handling of personnel involved in the project. This will be developed further in Tasks 8, Human Use Approval and 9, Participant Training and Stakeholder Education.

11.1.1 THEA

THEA owns and operates the Selmon Expressway and REL and owns Meridian Avenue as well. The CV Pilot apps aim to improve the use of THEA facilities that will result in:

- Reduced wrong-way entries into REL
- Reduced rear-end incidents exiting REL
- Improved exit flows from REL onto Meridian Avenue
- Improved traffic flows on Meridian Avenue.

In order to realize these benefits THEA will install, monitor, and maintain CV app equipment for the system users (see Section 5.6) and for supporting RSUs on the Selmon Expressway, the REL, and Meridian Avenue. The equipment will be monitored through the TMC and will involve some THEA and City of Tampa TMC staff dedication in its use.

As the CV team Lead Agency, THEA will be responsible for seeing that the Human Use Approval Plan is implemented effectively. This will involve oversight of the efforts made during the recruitment, selection and training of volunteer system users and Stakeholders' staffs. HUA responsibilities will be developed further in Task 8, Human Use Approval.

11.1.2 City of Tampa and Hillsborough County

The City of Tampa owns the city streets (except for Meridian Avenue) and is responsible for operating the city street signal system. The CV Pilot apps aim to improve the use of the city's facilities that will result in:

- Improved traffic flows on city streets on Meridian Avenue, Twiggs Street, Florida Avenue, Marion Street, W. Kennedy Blvd, Jackson Street, N. Nebraska Avenue
- Fewer pedestrian incidents on Twiggs Street at the Courthouse and on Channelside drive
- Improved transit flows and fewer transit incidents which will improve traffic flows on city streets.

The City of Tampa will install, monitor, and maintain supporting CV RSUs on its facilities. The equipment will be monitored through the TMC and will involve some City of Tampa and THEA TMC staff dedication in training, maintenance and use of the equipment.

11.1.3 HART Transit

HART will receive positive impacts from:

- Improved BRT trip times

HART will need to install, monitor and maintain OBUs for TSP and VTRFTV. HART will select and train drivers in the use of the equipment and keep them informed, as needed. There may be changes to staff which could require training new staff. HART's Dispatching Operations Center will require only minimal involvement in noting driver feedback on CV Pilot performance.

11.1.4 TECO Streetcar Line (HART Streetcar Division)

The TECO Streetcar Line will receive positive impacts from:

- Reduced Trolley/Auto/Pedestrian/Bicycle conflicts on Channelside Drive path of the Streetcar Line
- Reduced instances of incidents with vehicles turning right in front of streetcar.

HART's Streetcar Division will need to install, monitor and maintain infrastructure for CV applications. HART will train drivers in the use of the equipment and keep them informed, as needed. HART's Dispatching Operations Center will require only minimal involvement in noting driver feedback on CV Pilot performance.

11.1.5 MAFB

Many MAFB personnel drive to the Base through the study area. MAFB expects to recruit a contingent of volunteers to participate in the CV Pilot as system users. They would receive OBUs and VADs that would aid their trip on the Selmon Expressway and REL, Meridian Avenue and through an app for route selection to the optimal entryway into the Base from four choices. The MAFB will receive positive impacts from:

- Reduced rear-end incidents exiting REL
- Improved exit flows from REL onto Meridian Avenue
- Improved trip times for employees on Meridian Avenue to the Base

MAFB will recruit, select and train personnel as volunteer CV system users. The methods applied to treatment of personnel must be consistent with MAFB regulations and with the Human Use Approval plan approved by the IRB. This will be developed further in Task 8, Human Use Approval.

11.1.6 OEMs

OEMs include BMW/GEWI, General Motors and Honda, among others who may participate in the THEA CV Pilot. Among the benefits attributed to OEMs are:

- Evaluation of OBUs and VADs in a real-world urban environment

- Evaluation of Pedestrian and bike alert software – Pedestrian Mobility App.

OEMs will have impacts with respect to product development to improve their products and may learn lessons with regards to how CV technology affects their liability for equipped vehicles.

11.1.7 Police and Rescue Stakeholders

The Florida Highway Patrol (FHP) and Tampa Police Department (TPD) have police responsibilities in the CV Pilot Deployment area. The Road Ranger Service Patrol (RRSP) operates on the Selmon Expressway and REL along with local towing operators who also cover the street system. The TMC identifies crashes and incidents through CCTV and notifies police dispatch. Medical aid is requested by the TMC, police and the public. The CV Pilot's apps do not have accident notification as part of their repertoire. Benefits to police and rescue include:

- Fewer incidents on city streets and on REL exit onto Meridian Avenue
- Quicker response times of incidents detected and verified by the THEA-Tampa TMC.

There is no new CV app applicable to Police and Rescue Stakeholders and there is no new responsibility to be borne by them.

11.1.8 Amalie Arena, Tampa Bay Port Authority, Tampa Convention Center, Tampa Downtown Partnership, Tampa Bay Lightning Hockey

Amalie Arena, Tampa Bay Port Authority, Tampa Convention Center and Tampa Downtown Partnership, Tampa Bay Lightning Hockey are organizations that support the THEA CV Pilot project. It is expected that they would benefit in the following ways:

- Improved access/egress to/from downtown facilities and special events
- Improved traffic flows on city streets on Meridian Avenue, Florida Avenue, Marion Street, W. Kennedy Blvd, Jackson Street
- Fewer pedestrian incidents on Channelside Drive
- Improved transit flows and fewer transit incidents that improve traffic flows on city streets
- Reduced Trolley/Auto/Pedestrian/Bicycle conflicts on Channelside Drive path of TECO Streetcar Line
- Reduced instances of incidents with vehicles turning right in front of a streetcar.

These organizations do not have responsibility of any costs from the project.

11.2 Performance Metrics

Performance Measures for the THEA CV Pilot will ascertain the effectiveness of the Use Cases regarding Mobility, Safety, Environment, and Agency Efficiency.

Mobility is improved by information transfer between vehicles and traffic signals, which improves signal optimization. Safety is improved by preventative alerts given to car drivers, transit drivers, trolley operators, pedestrians/bicyclists.

Safety and Mobility improvements are intertwined. Improvements to safety improve mobility, due to fewer crashes which reduces delays. Improvements to mobility improve safety as well. Fewer stops, a mobility improvement, mean fewer occasions for rear end crashes (safety improvement). Performance Measurement presents a challenge in the choice of appropriate data-driven techniques to make the best use of the data generated by the Use Cases.

Environmental improvements will not be measured directly, but will be estimated indirectly from mobility improvements that are directly measurable such as travel time savings, queue reduction and braking as impacts on emissions. Assessing environmental impacts will come from computer modeling based on the performance of the traffic system.

Agency efficiency is improved by new automated data collection methods that use new Performance Measures from CV communications (e.g., Basic Safety Message (BSM)). Improvement in data collection can also be measured in hours that staff is relieved from manually performing field collection of data.

Wherever possible, traffic data, safety audits and other historical data will create a baseline for comparison prior to the application of CV apps and Use Cases. The specifics of the baseline data and performance measures will be finalized during Task 5 work.

The USDOT safety and non-safety evaluation needs will be analyzed and the relevant needs will be addressed going forward in the Performance Measurement and Evaluation Support Plan (Task 5) and the System Requirements Specification (Task 6).

11.2.1 Mobility Performance Measures

Mobility Performance Measures include the standard measures traffic engineers and planners collect and use daily: speed, flow, density, link and path travel times, delay at intersections, queuing at intersections, percent arrivals on green, and buffer time, among others. The THEA CV Pilot deployment makes use of several CV Mobility apps:

- Intelligent Traffic Signal System (I-SIG)
- Probe-enabled Data Monitoring (PeDM) (Vehicle Data for Traffic Operations)
- Transit Signal Priority (TSP).

These Mobility apps are used in the two Mobility Use Cases:

- Traffic Progression – I-SIG, PeDM
- BRT Trip Times – I-SIG, TSP.

11.2.2 Safety Performance Measures

Safety performance improvements rely on preventative alerts. To understand their effectiveness requires gathering data on the number of alerts issued and the number of incidents that occur for those that have and do not have the app. It is the aim of the statistical analysis to determine the difference in safety (i.e., risk). The small numbers of incidents at just a few locations over the study time period will, in all likelihood, not yield statistically significant results. Data from participant surveys such as frequency of alerts, user experience and satisfaction with the app, ratings of distraction or helpfulness and how an app might be improved will also be used to gauge the effectiveness of safety performance. Additionally, more active monitoring of safety impacts will provide insight into the safety benefits.

The THEA CV Pilot makes use of several CV Safety apps:

- Curve Speed Warning (CSW)
- Emergency Electronic Brake Light (EEBL) and Forward Collision Warning (FCW)
- Pedestrian in Signalized Crosswalk (PED in Crosswalk)
- Mobile Accessible Pedestrian Signal (PED-SIG) (Pedestrian Mobility)
- Intersection Movement Assist (IMA)
- Vehicle Turning Right in Front of Transit Vehicle (VTRFTV).

These Safety apps are put to use in four the Safety Use Cases:

- Morning Backups – CSW, EEBL, FCW, … and I-SIG
- Pedestrian Conflicts – PED in Crosswalk, PED-SIG, … and I-SIG
- Wrong Way Entries – IMA, … and I-SIG, PeDM
- Trolley/Auto/Pedestrian/Bike Conflicts – VTRFTV, … and I-SIG

Each of the Safety Use Cases has a mobility component in that the I-SIG app will be present. The PeDM Mobility app is also present with the Wrong Way Entries User Case, but this does not affect the primary function of the Use Case for Safety.

11.2.3 Confounding Factors

Performance Measurement is beset with confounding factors that must be mitigated or accounted for in the CV Pilot:

- Weather and seasonal factors
- Combining apps into Use Cases
- Gaming the equipment
- Changes to trip patterns
- Self-selection of participants
- Measurement error.

Among the confounding factors in Mobility and Safety Performance Measurement is inclement weather from storms and seasonal factors which can effect:

- Driver and pedestrian behavior – attention/distraction
- Speeds and trip times in storms
- Trip making due to storms - number of pedestrians and drivers on the road
- Trip making due to the seasonal migrations of “snow birds”.

Weather data will be collected (e.g., rain – heavy, medium, light, clear) to be used with Mobility and Safety data to see how Use Case effectiveness changes with weather. Snow is not a factor in Tampa, though there can be severe thunderstorms on almost a daily basis at certain times of year. These thunderstorms may last for only a few moments to several hours or even for an entire day. The BSM data includes use of windshield wiper data that will indicate the presence and severity of rainfall.

While combining Apps in Use Cases offers advantages to mobility and safety, their combination becomes a confounding factor in measuring and assessing the performance of each app independently. There is considerable overlapping of performance improvement between some of the apps that are used together. When apps are combined in the Use Cases, their performance and effectiveness can only be measured as a unit. Table 35 shows the Performance Measures for the Use Cases with the related apps. Note that I-SIG is present in all the Use Cases.

Another confounding factor is the problem that arises when users game or exploit the limits of the equipment to test it against their everyday allowable risk. For example, pedestrians might push into the crosswalk to assess the Pedestrian Mobility alert’s sensitivity in order to gain some advantage in crossing the street, but increasing the risk of injury. Car drivers may similarly push the limits of their apps and take unnecessary risks. Presumably, people will understand that they are increasing their risk by engaging with the app limits and will not do so recklessly. It is a matter for investigation as to the pervasiveness and danger of such behavior. It is expected that the project will yield survey data that will shed light on risk taking behavior that comes with this new technology. Persons selected for the project will be advised of the limits of the technology and will be required to sign an Informed Consent Form to participate that will explain the limits of the technology and their liability in not using the app as prescribed.

Trip making behavior and trip patterns are subject to change as well and can be another important confounding factor. If more or fewer drivers choose to use the REL, for example, because of some external factor, like construction or a special event, unrelated to the CV Pilot, then that might introduce performance changes. As mentioned earlier, trip patterns can also be affected by seasonal variations in travel from the arrival and departure of Florida's "snow birds."

The participants bias the data through self-selection, since individuals with special interests, motives or responding to incentives choose to participate in the study.

Measurement error might be introduced in the way the study administers information, designs and implements applications.

11.2.4 Performance Measure Targets

It is difficult to set meaningful or useful targets for the parameters of the Use Cases under investigation, since this CV project on city streets is without precedent. The degree of improvement due to Mobility apps will depend on the efficiency of the before, or baseline, state of the traffic network. For users, say, with traffic signal preemption, their improvements in trip time over the signalized network might be as high as 15 percent, though some loss of efficiency on the side street may occur. Target values for traffic improvement can also be highly dependent on local situations and initial conditions. Signal system improvements of 10 percent would be considered quite effective in carefully managed traffic signal systems like Tampa's. The study will assess the extant baseline and determine the project improvements. Generic Mobility improvements in the neighborhood of 10 percent will be considered acceptable. Though no prescribed precise goal is definitive at this stage, improvements are expected.

It is unlikely that Safety will be directly measureable from the small numbers of incidents that will occur within the study limits. The relatively small samples of reported incidents and confounding factors (e.g., weather) will make statistically significant Safety Performance Measures a challenge. Accident avoidance, measured by the number of alerts, may be more important than the number of incidents. In such an experimental environment targets are inappropriate. Other surrogate parameters, such as the frequency of alerts, user experience and satisfaction with the app, ratings of distraction or helpfulness and how an app might be improved will be measured by user surveys.

11.2.5 Performance Measure Matrix for Use Cases

Task 5, Performance Measurement and Evaluation Support Plan will examine more closely the Performance Measures that will be collected and how they will be used. Table 35 presents an early view of what Performance Measures will be collected and applied to the THEA CV Pilot Use Cases. Baseline data will be collected in the near term, where possible, to use in comparisons. Its availability is noted in the table.

Table 35: Performance Measures for Use Cases in THEA CV Pilot Deployment.

Use Case Apps in Use Case	Performance Measure Type	Performance Measure	Current Availability	Target Value Improvement
Morning Backups	Safety			
CSW	Safety	Number of Alerts drivers respond to by reducing speed; this is the speed broadcast by the	Not Available	10 Percent

Use Case Apps in Use Case	Performance Measure Type	Performance Measure	Current Availability	Target Value Improvement
		RSU.		
EEBL and FCW	Safety	Number of Incidents Without App	Available	No Change
		Number of Incidents With App	Not Available	Not Statistically Significant
		Queuing/Position on Curve	Not Available	No Target
		Number of Alerts	Not Available	No Target
		Number of Alerts drivers respond to by reducing speed	Not Available	10 percent
		Traffic Speed	Not Available	No Target
		Crash Rate/Risk	Available	Not Statistically Significant
		BSM Data on vehicle – braking, speed, weather, etc.	Not Available	Not Statistically Significant
I-SIG	Mobility	Queue length	Available	10 percent
		Wait time	Available	10 percent
		Percent on Green	Available	10 percent
		Red Light Running	Available	10 percent
Pedestrian Conflicts	Safety			
Pedestrian in Signalized X-Walk	Safety	Number of Alerts – Drivers and Pedestrians	Not Available	No Target
		Number of Incidents without App - for Drivers and Pedestrians	Available	No Change
		Number of Incidents with App - for Drivers and Pedestrians	Not Available	Not Statistically Significant
		Crash Rate/Risk	Available	Not Statistically Significant
Mobile Accessible Pedestrian Signal (PED-SIG)	Safety/Mobility	Pedestrian Wait Time	Available	10 percent
		Number of Alerts	Not Available	No Target
(Pedestrian Mobility)		Vehicle Wait Time	Available	10 percent
I-SIG	Mobility	Queue length	Available	10 percent
		Percent on Green	Available	10 percent
		BSM Data on vehicle – braking, speed, weather, etc.	Not Available	No Target
Wrong Way Entries	Safety			
IMA	Safety	Number of Alerts	Not Available	No Target
		Number of Incidents without App - for	Available	No Change

Use Case Apps in Use Case	Performance Measure Type	Performance Measure	Current Availability	Target Value Improvement
		Drivers and Pedestrians		
		Number of Incidents with App - for Drivers and Pedestrians	Not Available	Not Statistically Significant
		Crash Rate/Risk	Available	Not Statistically Significant
		BSM Data on vehicle – braking, speed, weather, etc.	Not Available	
I-SIG	Mobility	Queue length	Available	10 percent
PeDM (VDTO)		Wait time	Available	10 percent
		Percent on Green	Available	10 percent
		Path travel time	Not Available	10 percent
		Path delay	Not Available	10 percent
		Buffer time	Not Available	10 percent
Traffic Progression	Mobility			
I-SIG	Mobility	Queue length	Available	10 percent
PeDM (VDTO)		Wait time	Available	10 percent
		Percent on Green	Available	10 percent
		Red Light Running	Available	10 percent
		BSM Data on vehicle – braking, speed, weather, etc.		
		Path travel time	Not Available	10 percent
		Path delay	Not Available	10 percent
		Buffer time	Not Available	10 percent
BRT Trip Optimization	Mobility			
I-SIG	Mobility	Queue length	Available	10 percent
TSP		Wait time	Available	10 percent
		Percent on Green	Available	10 percent
		Red Light Running	Available	10 percent
		BSM Data on vehicle – braking, speed, weather, etc.	Not Available	No Target
Trolley/Auto/Ped/Bike Conflicts	Safety			
I-SIG	Mobility	Queue length	Available	10 percent
		Wait time	Available	10 percent
		Percent on Green	Available	10 percent
		Red Light Running	Available	10 percent
		BSM Data on vehicle – braking, speed, weather, etc.	Not Available	No Target
VTRFTV	Safety	Number of Alerts – Drivers/Pedestrians/ Bikes with Transit	Not Available	No Target

Use Case Apps in Use Case	Performance Measure Type	Performance Measure	Current Availability	Target Value Improvement
		Vehicle		
		Number of Incidents without App - for All Modes	Available	No Change
		Number of Incidents with App - for All Modes	Not Available	Not Statistically Significant
		Crash Rate/Risk	Available	Not Statistically Significant

11.3 Security

11.3.1 Personal Information and Privacy

Personal information collected in the THEA CV pilot will be kept to the minimum necessary for the V2X system to function effectively. The current application assessment does not directly reveal any Personally Identifiable Information (PII) or PII-related information being collected. However, concerns about the overall privacy implications of a system in which vehicles broadcast location and motion information 10 times every second must be addressed. Much of these privacy concerns are addressed in the Security Credentials Management System (SCMS) Proof of Concept (POC) and associated security standards that will be implemented during the CV Pilot.

The SCMS POC being built by the USDOT and Crash Avoidance Metrics Partnership (CAMP) has "privacy by design" as a major tenet of the system development. All V2X system communications will utilize the SCMS POC design along with the IEEE 1609.2 standard to provide communications security and protect user privacy. In order for vehicle OBUs, Personal Information Devices (PIDs), and RSUs to communicate, they must be enrolled with the SCMS which will provide certificates to prove authenticity of their BSMs and other messages. Note that the BSM does not contain personal information. It only contains the location and motion characteristics of the vehicle (e.g., speed, heading, acceleration). To protect privacy, OBEs and PIDs will use pseudonym certificates to sign all messages. Based on information provided by USDOT on the current SCMS POC design, the device will have a pool of 20 certificates that are valid simultaneously for only one week. The device will rotate through certificates every five minutes to limit trackability, which is a commonly voiced concern. Also, any communication to the SCMS through the RSE, for example to replenish certificates, is encrypted and also passes through the Location Obscurer Proxy which strips the request of any device identifying information.

However, the SCMS POC design documentation has not yet been released by USDOT. The POC design is significantly different from the SCMS used for the Safety Pilot. Design documents, which are currently not available, must be reviewed by the THEA team to determine if any additional privacy controls are necessary to address any unique data collection operations performed by pilot-specific applications.

Additional privacy considerations may arise depending on the data that is transmitted and collected by user devices in addition to the standard BSM. The major areas that will further be addressed in the Privacy and Security Management Operating Concept are the PID and vehicle situation/probe data.

While the PID will still use the SCMS POC in much the same way as a vehicle OBU to maintain privacy, the PID will likely have less physical security protection combined with more attack vectors. This presents unique privacy, as well as security, questions. The team needs to better understand how PIDs will be registered along with the general PID data that will be accessed by a PID application. Registering the PID is probably addressed within the SCMS POC design documentation, but needs to be further addressed with the larger THEA team during Privacy and Security Management Operating Concept development.

Even though the privacy by design elements of the SCMS POC should mitigate privacy concerns, the public may be concerned by vehicle situation/probe data depending on the additional data collected outside of the normal BSM and how the data is bundled and stored. The larger THEA team will need to discuss the plans for collection, storage, and use of vehicle situation/probe data to determine if additional privacy controls are necessary. These controls will be outlined in the Privacy and Security Management Operating Concept.

11.3.2 System

In development of the Privacy and Security Management Operating Concept, the THEA CV Pilot team is taking a comprehensive and holistic approach in addressing V2X system security to mitigate threats and vulnerabilities. The THEA team began developing the concept in four phases which combine recommendations from the USDOT guidance documents on privacy considerations and security management with multiple other related projects

1) Gather and Review Existing Analyses and References
2) Categorize Application Information Flows and Systems (i.e., V2X devices) based on FIPS 199
3) Select Security Controls for each System based on FIPS 200 and NIST SP 800-53
4) Conduct Coordination/Reviews and Finalize Concept

In taking this approach, the team started addressing the Security Control Families and specific controls per NIST SP 800-53. However, a current USDOT project is already developing detailed security requirements per this methodology, which should be complete in March. In further discussions during security management coordination meeting, it was decided that the best course of action is to develop a minimum set of security requirements for pilot devices while detailed requirements developed from the other project will be used as guidance for future devices. At a higher level, the concept will cover communications, access, hardware, software, and operating system security to mitigate vulnerabilities in the system to ensure confidentiality, integrity, and availability of information as necessary to support the selected pilot applications.

As stated in the previous section on Personal Information and Privacy, communications security for the THEA CV Pilot is largely ensured through compliance with the SCMS POC design and existing standards and protocols, such as IEEE 1609.2. The team is still analyzing the different considerations for each communication medium (i.e., DSRC, cellular, WiFi direct), but has not yet identified any constraints. As previously stated, the team must review the SCMS POC design documents to determine if there are any communications security gaps. While the SCMS POC design already has established misbehavior reporting and Certificate Revocation List (CRL) distribution processes based on the information provided by the USDOT, misbehavior detection strategies are not complete. The CRL strategy will also have to be tailored to the needs of the pilot. The concept will contain recommendations for local misbehavior detection (i.e., detecting malformed or malicious messages) and CRL distribution based on other projects and pilots.

The concept will address access security, such as the various role based users that can access V2X devices, user name and password policies, and whether remote access is permitted in the THEA CV Pilot. The team will leverage existing THEA access security related policies to reuse as appropriate and modify as necessary for use in the pilot. Access security will also be sufficiently covered in the NIST security controls developed for each device class. There are security control families for Access Control and Program Management.

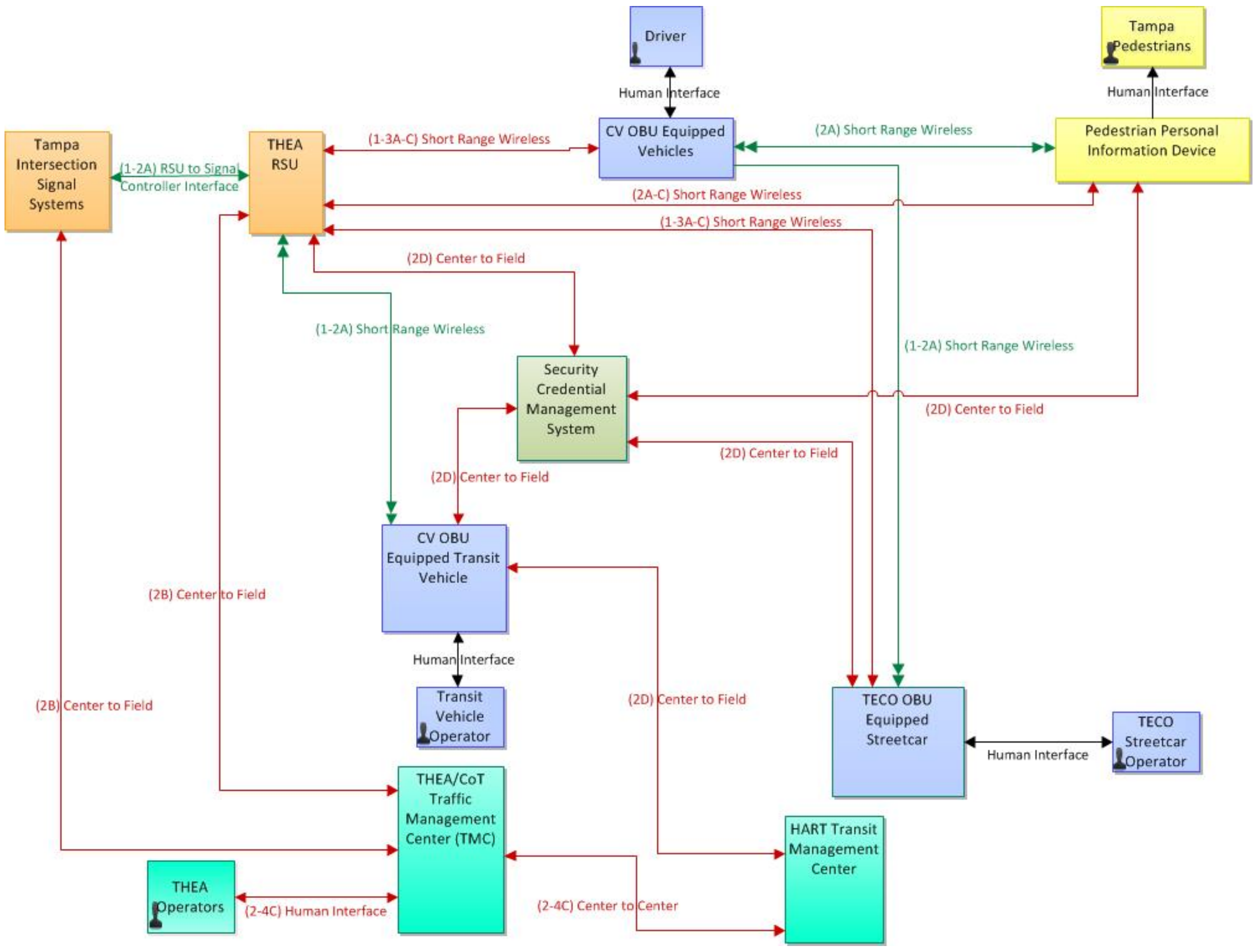
Security requirements for each device classification will specify hardware security control requirements to prevent physical key extraction and similar attacks. These requirements may differ among the PID, OBE, and RSE devices. A widely accepted standard used to specify hardware security requirements is Federal Information Processing Standard (FIPS) 140-2. FIPS 140-2 covers security requirements for cryptographic modules, including protections to prevent device tampering such as tamper evident protections and tamper resistant protections.

While FIPS 140-2 addresses the majority of hardware security requirements, it does not cover all software and operating system requirements, which also need to be addressed. These requirements ensure BSMs cannot be modified and that additional software cannot be installed that would allow an attacker to generate false BSMs using valid BSM keying material, among other threats. Software and operating system security will also be covered in the NIST security controls developed for each device class. Software and operating system controls are addressed in multiple control families including Configuration Management, Maintenance, Systems and Services Acquisition, System and Communications Protection, and System and Information Integrity.

Each device class identified through the FIPS 199 analysis (focusing on the PID, OBE, and RSE) will have security controls aligned per the baseline specified in NIST 800-53. These controls detail the various aspects of the security control families, such as Access Control, Audit and Accountability, and Physical and Environmental Protection. However, there are multiple considerations and constraints in which stakeholders should be aware. Due to these constraints and the concurrent project focusing on detailing these security controls, the concept will focus on a minimum set of requirements to enable an interoperable, secure system while still facilitating realistic device development timelines for device suppliers.

- Recommended security requirements may be cost prohibitive upon further review during the development of the System Requirements Specification document in Task 6
- The concept and requirements may require updates based on the Application Deployment Plan in Task 7 which will not have a complete draft until March 2016
- Device suppliers may not be able to meet all recommended security requirements in time for the planned device deployment

12 APPENDIX: Context Diagram



Context Diagram Source: SET-IT

The context diagram provides an overview of the communication flows and interdependencies of the various system users and system components.

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