Connected Vehicle Pilot Deployment Program System Performance Report – Tampa (THEA)

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Final Report

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Notice

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16. Abstract

The purpose of this document is to report on pre-deployment conditions (pre-Phase 3), to report data being collected for the Performance Measurement and Evaluation and to establish parameters that will be reported to the USDOT monthly. This report and its subsequent updates will serve as the progress updates for data collection and for basic output measures of the deployment as outlined in the next sections. The data and measures provided in this report can be supplemented by the data presented in the Performance Measurement and Evaluation Dashboard, an online tool providing more detailed measures for the overall study area and for each Use Case separately.

For a better understanding of the Performance Measures, methodologies, and data collected, the reader is referred to the Performance Measurement and Evaluation Support Plan Updated April 2019, Publication: FHWA-JPO-16-314. Refer to this document for definitions and details not found in this report.

For the purposes of the Tampa CV Pilot Systems Performance Report, the "System" is defined as the physical infrastructure (i.e., Bluetooth readers and other non-CV equipment), CV Roadside equipment, CV on-board equipment, participants and data.

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List of Acronyms

API	Automated Protocol Interface
BSM	Basic Safety Message
CBD	Central Business District
CUTR	Center for Urban Transportation Research University of South Florida
CV	Connected Vehicle
EEBL	Emergency Electronic Brake Light Warning
ERDW	Exit Ramp Deceleration Warning
FCW	Forward Collision Warning
HART	Hillsborough Area Regional Transit
IE	Independent Evaluator
IMA	Intersection Movement Assist
I-SIG	Intelligent Traffic Signal System
JSON	Java Script Object Notification
OBU	On-Board Unit
PCW	Pedestrian Collision Warning
PED-X	Pedestrian in Signalized Crosswalk
PII	Personally-Identifiable Information
PMED	Performance Measurement Evaluation Dashboard
PMESP	Performance Measurement and Evaluation Support Plan
PSM	Personal Safety Message
REL	Reversible Express Lanes
RSU	Roadside Unit
SDC	Secure Data Commons
SRM	Signal Request Message
SSM	Signal Status Message
TECO	Tampa Electric Company
THEA	Tampa Hillsborough Expressway Authority
TSP	Transit Signal Priority
UC	Use Case
USDOT	United States Department of Transportation
USF	University of South Florida
V2I	Vehicle to Infrastructure
V2V	Vehicle to Vehicle
V2X	Vehicle to Everything
VTRFTV	Vehicle Turning Right in Front of Transit Vehicle

1 Introduction

The THEA Connected Vehicle (CV) Pilot aims to meet the purposes set forth in the USDOT's Broad Agency Announcement and the Cooperative Agreements for Phase 2 and Phase 3 of this Pilot 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 more environmentally friendly. 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.

For a better understanding of the Performance Measures, methodologies, and data collected, the reader is referred to the Performance Measurement and Evaluation Support Plan updated April 2019, Publication: FHWA-JPO-16-314. Refer to this document for definitions and details not found in this report.

1.1 Definition

For the purposes of the Tampa CV Pilot Systems Performance Report, the "System" is defined as the physical infrastructure (i.e., Bluetooth readers and other non-CV equipment), CV Roadside equipment, CV on-board equipment, participants and data.

1.2 Purpose

The purpose of this document is to report on pre-deployment conditions (pre-Phase 3), to report data being collected for the Performance Measurement and Evaluation, and to establish parameters that will be reported to the USDOT monthly. This report and its subsequent updates will serve as the progress updates for data collection and for basic output measures of the deployment as outlined in the next sections. The data and measures provided in this report can be supplemented by the data presented in the Performance Measurement and Evaluation Dashboard, an online tool providing more detailed measures for the overall study area and each Use Case separately.[1]

According to Performance Measurement and Evaluation Support Plan (PMESP Publication: FHWA-JPO-16-314,), the deployment of the connected vehicle technology focuses on six Use Cases. Table 1 summarizes the performance measures to be evaluated for each Use Case.

[1] The Dashboard is under development and will be available at the end of June 2019.

Table 1: Summary of Performance Measures

Pillars	*Performance Measures*	*UC1 Morning Backups*	*UC2 Wrong Way Entries*	*UC3 Pedestrian Safety*	*UC4 Bus Rapid Transit Signal Priority*	*UC5 TECO Line Streetcar Conflicts*	*UC6 Traffic Progression*
Mobility	Travel time	✓	✓	✓			✓
	Travel time reliability	✓		✓			✓
	Queue length	✓		✓			✓
	Vehicle delay	✓	✓	✓			✓
	Percent (%) arrival on green	✓			✓		✓
	Bus travel time				✓		
	Bus route travel time reliability				✓		
	Percent (%) arrival on schedule				✓		
	Excess time spent in idle	✓					✓
Safety	Crash comparison	✓	✓	✓		✓	✓
	Types of crashes	✓	✓	✓		✓	✓
	Severity of crashes	✓	✓	✓		✓	✓
	Type of conflicts	✓	✓	✓		✓	✓
	Severity of conflicts	✓	✓	✓		✓	✓
	Approaching vehicle speed	✓		✓			✓
	No. of alerts from apps	✓	✓	✓		✓	✓
Environmental	Emissions reductions in idle	✓		✓	✓		✓
	Emissions reductions in running	✓		✓	✓		✓
Agency Efficiency	Mobility improvements through the mobility pillar analysis	✓	✓	✓	✓		✓
	Safety improvements through the safety pillar analysis	✓	✓	✓		✓	✓
	Customer satisfaction through opinion survey and/or CV app feedback	✓	✓	✓	✓	✓	✓

1.3 Reporting Period

This report covers the period of pre-Phase 3 from March 2018 to February 2019. During this period, the On-Board Units (OBUs) were installed on participant vehicles and Roadside Units (RSUs) were installed in the study area. In , addition, the collection of several data to control for confounding factors have been collected. These are presented in the last section titled “Data.”

1.4 Data Collection Timeline

The data collection started in March 2018. For the period titled as “Stage 1” in Table 2, all payloads including BSM, SPaT, TIM, MAP, MMITSS, SSM, SRM, and PSM have been collected daily, and their uploads started as shown in Table 25. This report covers this period (Stage 1). Subsequent reports will include data collected during “Stage 2: Silent Period” and “Stage 2: Warnings Visible,” as shown in Table 2.

Table 2: Data Collection Timeline

Month	Mar 2018-Feb 2019	Mar 2019-May 2019	Jun 2019-Apr 2020
Description	Stage 1-CV Technologies On: No Warnings	Stage 2-CV Technologies On: No Visible Warnings (silent period)	Stage 2-Cv Technologies On: Warnings Visible to Treatment Group
Current Status	Period covered in 1st report	Currently in this period	

1.5 Assumptions

The following are assumptions on which the measurement of performance and evaluation support are based:

- Most of the roadside equipment that has been installed remain operational for the duration of Phase 3.
- A sufficient number of participant vehicles will remain equipped for the project duration.
- There are no major changes to the highway and street network within the Study Area (there are several being planned that will be accounted for as confounding factors).
- The Streetcar will maintain operations through the Pilot.
- There are no changes to the bus routes that will be employing CV technologies during the Pilot (as of May 2019).
- All data that are anticipated to be available and that are described in this report remain available for the duration of the Pilot.
- All data connections detailed in this report, the System Design Document, and the Data Management Plan are in place and are uninterrupted.
- The participant identifier described in this report remains constant throughout the end of Phase 3.

1.6 Constraints

The following statements have been identified as constraints to the measurement of performance of the Tampa CV Pilot:

- The number of equipped vehicles and intersections relative to the entire Study Area necessitates the employment of Use Cases that limit measurement and evaluation in space/time. This will make measuring changes associated with the deployment of CV technology more tangible.
- The number of crashes likely to occur with or without the use of CV technologies will be low.
- High participant turnover will negatively impact the evaluation.
- Changes to the operation of the street system within the study area are being planned and must be addressed as a confounding factor.
- Any changes to the schedule or route of any of the three express routes included in the Pilot will be problematic for the evaluation team.
- A high level of equipment failure will compromise the evaluation results.
- The functionality of the TMC Centracs system to route data to the CUTR server.

2 Physical Transportation Infrastructure

2.1 Roadway Use Cases

2.1.1 Use Case 1: Morning Backups

As drivers approach the end of the REL, they enter a curve where the speed limit reduces from 70 to 40 miles per hour (mph). During the morning rush hour, as vehicles exit the REL onto Meridian Street to make a right turn onto East Twiggs Street, the right turn lane backs up. An additional issue is that many of these vehicles then make a right turn onto Nebraska Avenue, which is less than 500 feet after turning onto East Twiggs Street. The combination of these issues causes the queue to back up onto the REL. 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. The following applications will be evaluated for this use case:

- End of Ramp Deceleration Warning (ERDW) - V2I
- Intelligent Signal Control (I-SIG) – V2I
- Emergency Electronic Brake Light Warning (EEBL) – V2V
- Forward Collision Warning (FCW) – V2V

Figure 1 shows the direction of traffic during the morning peak hours. The use case considers traffic on all lanes of the REL, to Twiggs Street and Meridian Avenue Intersection, and to Twiggs Street and Nebraska Avenue intersection. The segments are established as follows:

- Segment 1: REL (beginning of study area) to the beginning of REL right turn lane at Twiggs Street/Meridian Avenue.

- Segment 2: Beginning of REL right-turn lane (end of segment 1) to end of the right-turn lane.
- Segment 3: Beginning of REL right-turn lane (end of segment 1) to the center of the intersection of Twiggs Street/Meridian Avenue.
- Segment 4: End of right-turn lane (end of segment 2) to the center of the intersection of Twiggs Street/Nebraska Avenue.
- Segment 5: Center of the intersection of Twiggs Street/Meridian Avenue (end of segment 4) to the center of the intersection of Nebraska Avenue/Cass Street.
- Segment 6: Center of the intersection of Twiggs Street/Meridian Avenue (end of segment 4) to the center of the intersection of Nebraska Avenue/Kennedy Boulevard.

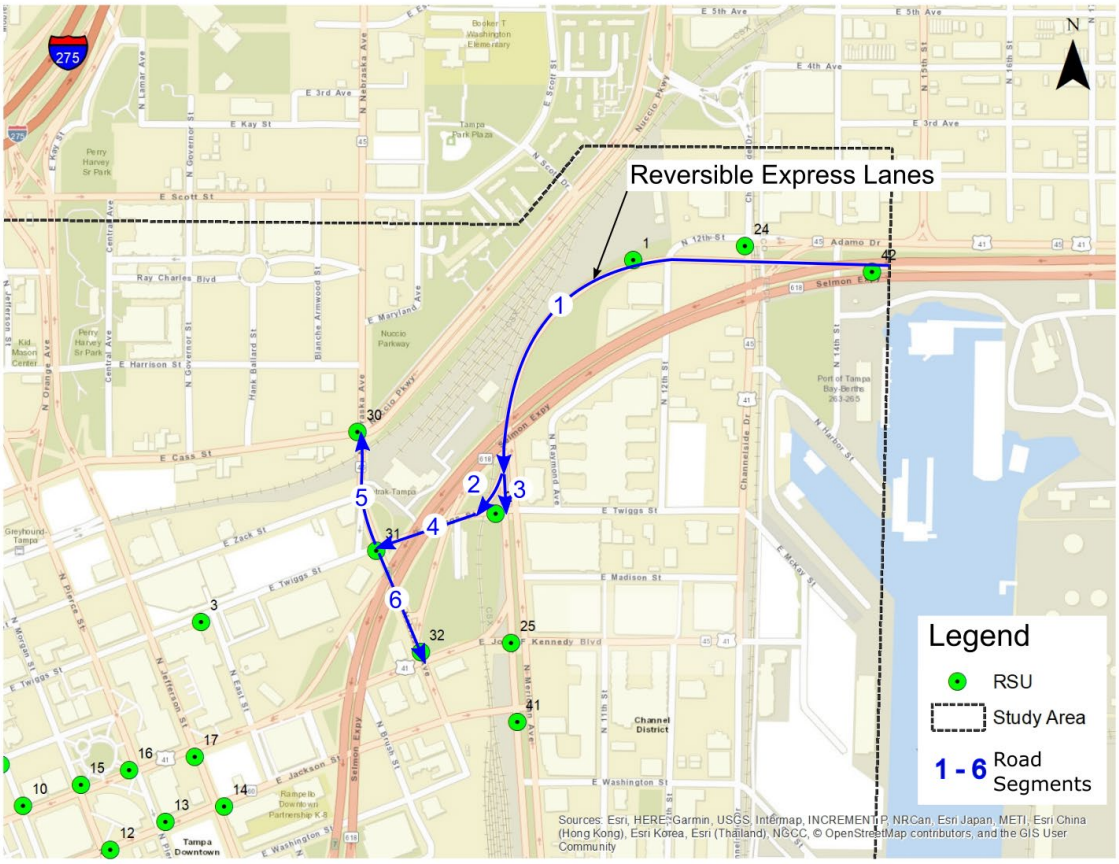


Figure 1: Use Case 1 Road Segments

2.1.1.1 Mobility

Basic Safety Messages (BSM) collected from Roadside Units (RSU) in the area are used to determine the travel time and travel time reliability of the segments shown in Figure 1. Table 3 shows the measures for the REL in the westbound direction, during the weekdays.

Table 3: Mobility Measures for UC1

#	Segment	Direction	Travel time (min)	Travel time reliability
1-3	REL tothe intersection of Twiggs Street/Meridian Avenue	Southbound		
1-2	REL to end of a right-turn lane on Twiggs Street	Southbound		
4-5	End of right-turn lane/Twiggs Street to the intersection of Nebraska/Cass Street	Westbound/Northbound		
4-6	End of right-turn lane/Twiggs Street to the intersection of Nebraska/Kennedy	Westbound/Southbound		

2.1.2 Use Case 2: Wrong-Way Entries

2.1.1.2 Safety

For safety evaluation, the number of warnings from the deployed applications will be reported for each segment shown in Figure 1. These will be presented in the next report as none has been collected for the period this report covers.

During the hours the REL is in Eastbound direction (1 pm-6 am, weekdays) drivers can enter the wrong way causing a safety concern. The CV applications evaluated in this use case are:

- Wrong-Way Entry (WWE) – V2I
- Intersection Movement Assist (IMA) – V2V
- I-SIG – V2I

Figure 2 shows the three possible paths where drivers can enter the REL in the wrong direction. Drivers approaching this intersection coming from downtown and intending to use the REL Westbound can make a left turn onto the REL exit (path 1). Conversely, drivers on East Twiggs Street approaching this intersection going towards downtown can make a right turn onto the REL exit (path 2). Finally, drivers approaching the intersection on Meridian Avenue can potentially veer slightly to the left onto the REL exit (path 3).

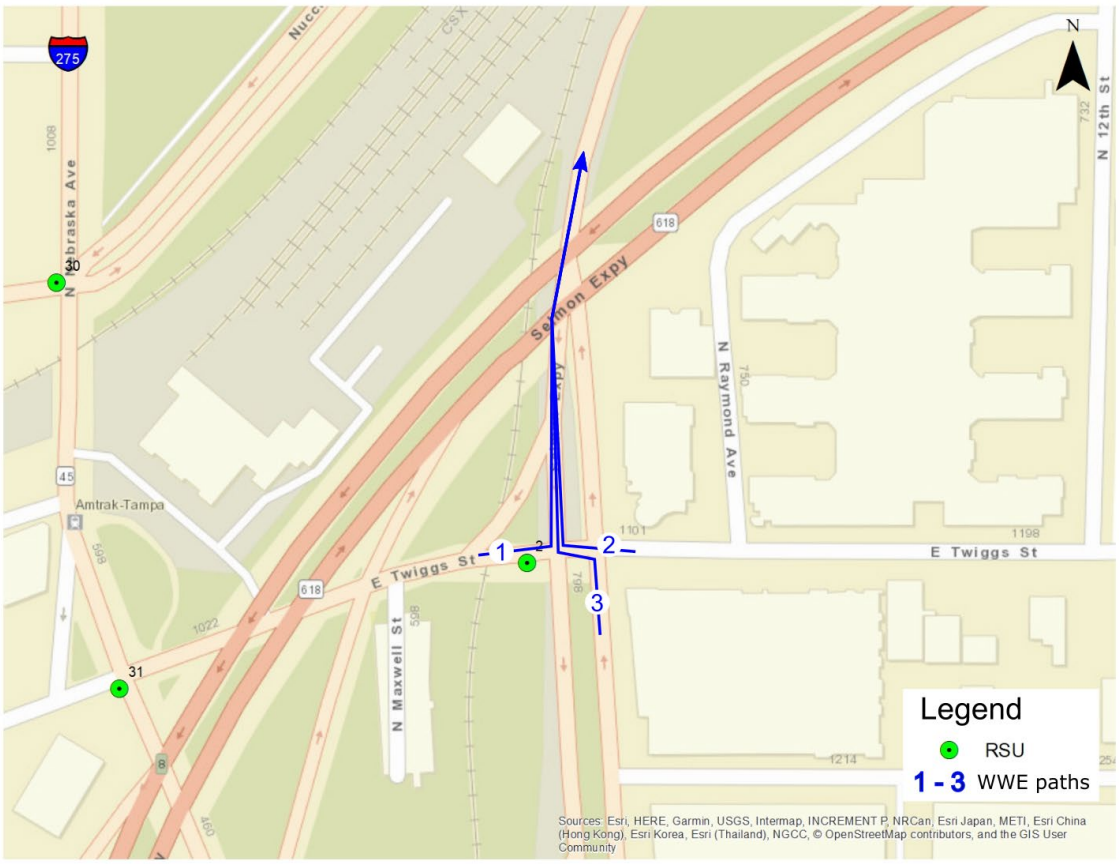


Figure 2: Use Case 2 Wrong Way Paths

2.1.2.1 Mobility

As in Use Case 1, BSMs collected from RSUs are used to determine the travel time for the segment on Twiggs Street from the intersection of Nebraska Avenue to Meridian Avenue. This will be assessed on p.m. peak hours only while the REL is in the westbound direction.

Table 4: Mobility Measures for UC2

#	Segment	Direction	Travel time (min)	Travel time reliability
1	Twiggs/Nebraska to Twiggs/Meridian	Westbound		

2.1.2.2 Safety

For the safety evaluation, the number of warnings from the deployed applications will be assessed for the three paths shown in Figure 2. None has been collected for the period that this report covers.

2.1.3 Use Case 3: Pedestrian Conflicts

At the George E. Edgecombe Hillsborough County Courthouse, there is one primary uncontrolled midblock crosswalk for pedestrian access to the main parking garage. Planned CV deployment at this location includes the following application:

- Pedestrian Collision Warning (PCW) – V2I

Figure 3 shows the road segments considered for mobility and safety evaluation for this use case.

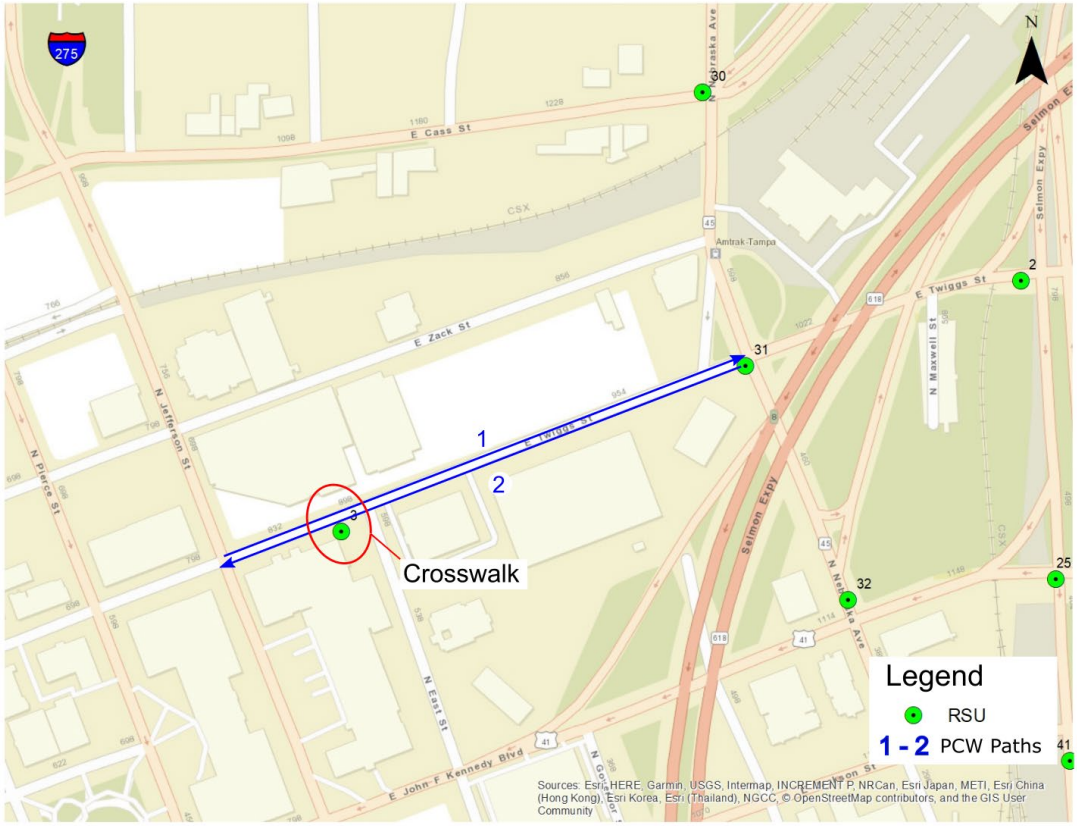


Figure 3: Use Case 3 Road Segments

2.1.3.1 Mobility

For this use case, travel time for the two segments shown in Figure 3 is calculated using BSM data collected by RSUs.

Table 5: Mobility Measures for Use Case 3

#	Segment	Direction	Travel time (min)	Travel time reliability
1	Twiggs/Nebraska to Twiggs/Jefferson	Westbound		
2	Twiggs/Jefferson to Twiggs/Nebraska	Eastbound		

2.1.3.2 Safety

For this use case, the deployment of PCW application will provide alerts to drivers for pedestrians crossing the crosswalk. This will be done via Personal Safety Messages (PSM) that are generated by the RSU#3 and the 2 LIDAR units installed at each side of the road. The PSMs generated to represent the pedestrians walking on the sidewalk or crossing at the crosswalk. The PCW warnings will be presented at subsequent reports. None were recorded for the period that this report covers.

2.1.4 Use Case 6: Traffic Progression

To assess the improvements in traffic progression that can be derived by using the Intelligent Traffic Signal System (I-SIG), this use case considers two segments shown in Figure 4. The segments are along Meridian Avenue and Florida Avenue. The CV applications evaluated for this use case are:

- I-SIG – V2I
- Emergency Electronic Brake Light Warning (EEBL) – V2V
- Forward Collision Warning (FCW) – V2V
- Intersection Movement Assist (IMA) – V2V

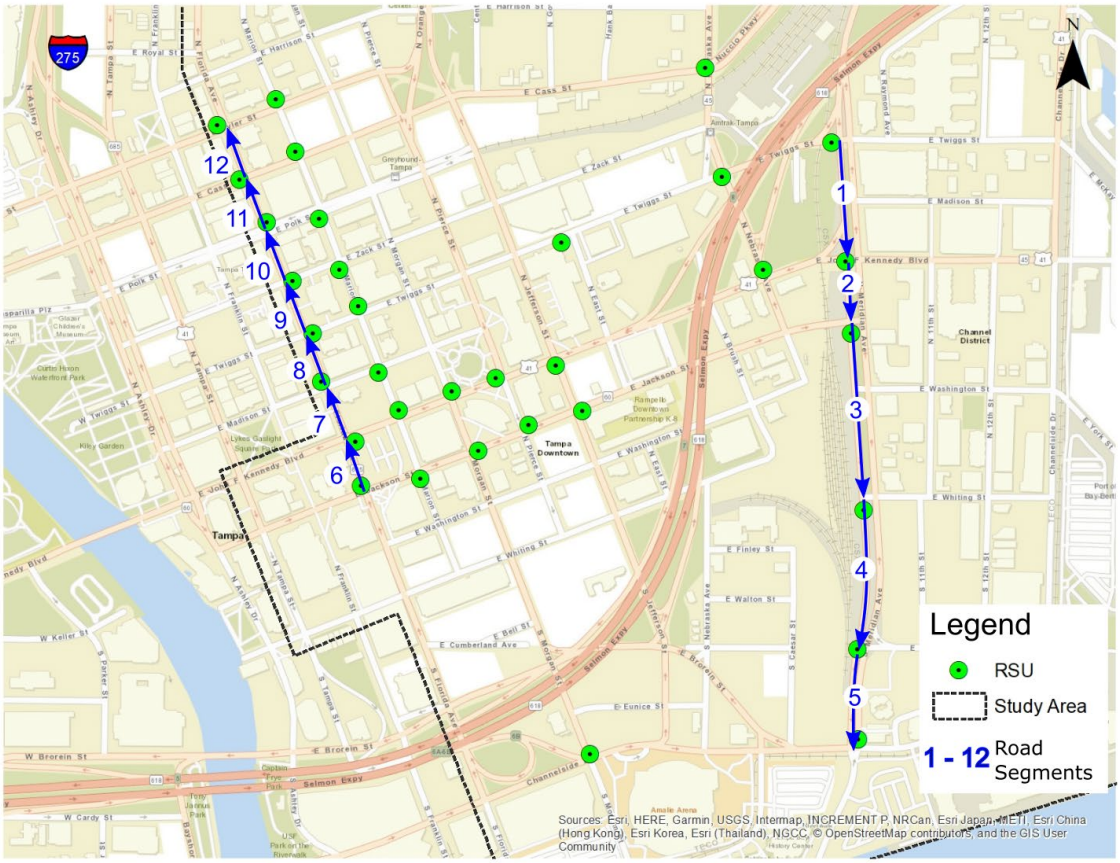


Figure 4: Use Case 6 Road Segments

2.1.4.1 Mobility

Table 6 shows the mobility measures for each segment for this UC. The segments are from signalized intersection to the next, and they can be assessed separately to identify individual segments that present increased delay. Overall, the two routes can also be evaluated in a comprehensive manner considering vehicles that a) start from segment 1 and end on segment 7 for Meridian Avenue corridor and b) start on segment 8 and end on segment 14 for Florida Avenue corridor.

Table 6: Mobility Measures for UC6

#	Segment	Direction	Travel time (min)	Travel time reliability
1	REL/E Twiggs Street to N Meridian Avenue/E Kennedy Boulevard	Southbound		

#	Segment	Direction	Travel time (min)	Travel time reliability
2	Meridian Avenue/E Kennedy Boulevard to N Meridian Avenue/E Jackson Street	Southbound		
3	N Meridian Avenue/E Jackson Street to N Meridian Avenue/E Whiting Street	Southbound		
4	N Meridian Avenue/E Whiting Street to S Meridian Avenue/E Cumberland Avenue	Southbound		
5	N Meridian Avenue/E Cumberland Avenue to S Meridian Avenue/Channelside Drive	Southbound		
6	N Florida Avenue/E Jackson Street to N Florida Avenue/E Kennedy Boulevard	Northbound		
7	N Florida Avenue/E Kennedy Boulevard to N Florida Avenue/E Madison Street	Northbound		
8	N Florida Avenue/E Madison Street to N Florida Avenue/E Twiggs Street	Northbound		
9	N Florida Avenue/E Twiggs Street to N Florida Avenue/E Zack Street	Northbound		
10	N Florida Avenue/E Zack Street to N Florida Avenue/E Polk Street	Northbound		
11	N Florida Avenue/E Polk Street to N Florida Avenue/E Cass Street	Northbound		
12	N Florida Avenue/E Cass Street to N Florida Avenue/E Tyler Street	Northbound		
1-5	REL/E Twiggs Street to S Meridian Avenue/Channelside Drive	Southbound		
6-12	N Florida Avenue/E Jackson Street to N Florida Avenue/E Tyler Street	Northbound		

2.1.4.2 Safety

For this use case, the safety measures outlined in Table 1 are collected, and alerts generated from V2V applications will be reported for the two corridors shown in Figure 4. For the period this report covers, none were collected.

2.2 Transit Use Cases

2.2.1 Use Case 4: Transit Signal Priority

Two express bus routes (24 LX and 25 LX) use the Selmon Expressway to connect the east and west sides of the metropolitan area and exit the Expressway to serve a stop in downtown. These two routes are served weekdays with morning and afternoon routes starting from 5 a.m. to 8 a.m. and from 3 p.m. to 6 p.m.

A third express route (20X) that passes on Marion Transit Parkway is served on weekdays from 6 a.m. to 8 a.m. and from 4 p.m. to 6 p.m. Figure 5 shows the routes inside the study area.

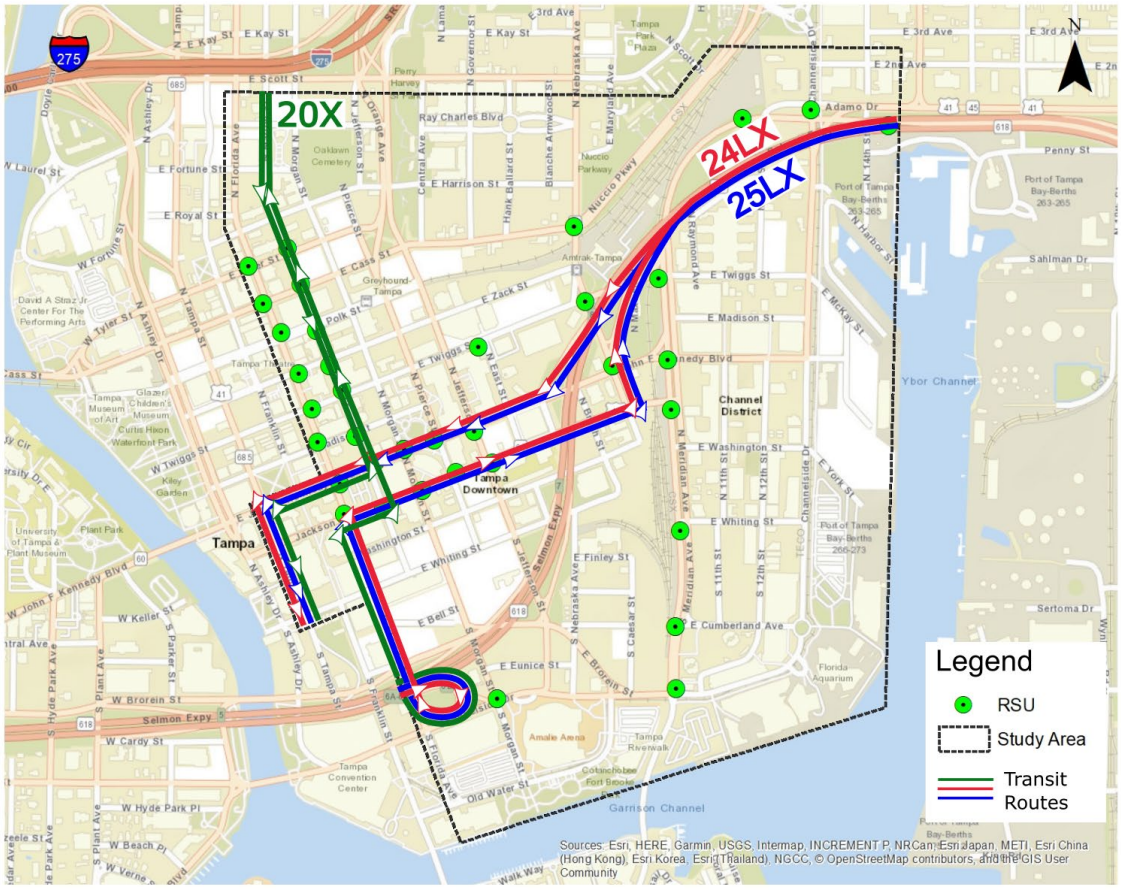


Figure 5: Use Case 4 CV Pilot Transit Routes

A total of 10 HART buses are equipped with OBUs and are assigned to the three express routes for the duration of the Pilot. CV applications planned for deployment of this UC include:

- IMA – V2V
- I-SIG – V2I
- Transit Signal Priority (TSP) – V2I

2.2.1.1 Mobility

The TSP application will be evaluated based on the overall route travel time, the segment inside the study area travel time, and the arrival time at the stops within the study area.
Tables 7-9 show the scheduled time of arrival at the stops inside the study area, and the calculated overall travel time for the segment inside the area and for the overall route with and without TSP. These measures are calculated for every trip, and every day.

Table 7: Route 24LX Evaluation

Route 24LX	Stop Level (Kennedy Blvd @ Pierce St)		Segment Level (inside study area) Travel Time		Route Level Travel Time	
	Scheduled Time of arrival	Actual time of arrival	Without TSP	With TSP	Without TSP	With TSP
Westbound (AM)	5:45 A.M.					
	6:01 A.M.					
	6:21 A.M.					
	6:36 A.M.					
	7:16 A.M.					
Eastbound (PM)	Stop Level (Jackson St @ Pierce St)		Without TSP	With TSP	Without TSP	With TSP
	3:46 P.M.					
	4:01 P.M.					
	4:16 P.M.					
	4:31 P.M.					
	5:11 P.M.					

Table 8: Route 25LX Evaluation

Route 25LX	Stop Level (Kennedy Blvd @ Pierce St)		Segment Level (inside study area) Travel Time		Route Level Travel Time	
	Scheduled Time of arrival	Actual time of arrival	Without TSP	With TSP	Without TSP	With TSP
Westbound (AM)	5:59 A.M.					
	6:34 A.M.					
	7:09 A.M.					
Eastbound (PM)	Stop Level (Jackson St @ Pierce St)		Without TSP	With TSP	Without TSP	With TSP
	3:53 P.M.					
	4:36 P.M.					
	5:21 P.M.					

Table 9: Route 20X Evaluation

Route 20X	Stop Level (Marion Transit Center)		Stop Level (Marion St @ Whiting St)		Segment Level (inside study area) Travel Time		Route Level Travel Time	
	Scheduled Time of arrival	Actual time of arrival	Scheduled Time of arrival	Actual time of arrival	Without TSP	With TSP	Without TSP	With TSP
Southbound (AM)	6:40 A.M.		6:47 A.M.					
	7:28 A.M.		7:35 A.M.					

Northbound (PM)	**Stop Level (Marion St @ Washington St)**		**Stop Level (Marion Transit Center)**		**Without TSP**	**With TSP**	**Without TSP**	**With TSP**
	4:30 P.M.		4:37 P.M.					
	5:15 P.M.		5:23 P.M.					

2.2.1.2 Safety

The IMA application will provide alerts to the bus drivers to avoid a potential collision with cross-traffic. The number of IMA warnings will be provided for each of the three routes. For the period this report covers, no warnings were collected.

2.2.2 Use Case 5: Streetcar Conflicts

The TECO Streetcar runs along Channelside Drive from the Amalie Arena area up Channelside Drive, North, past the Selmon Expressway. The streetcar is a steel wheel on steel rail fixed-guideway system in a dedicated right-of-way and crosses intersections at grade. As a result, at various stops along the streetcar route, vehicles may have to turn right in front of a stopped streetcar. This occurs at signalized and non-signalized intersections, and none have a right turn protected movement. CV technology was deployed to provide information to streetcar operators and drivers to improve safety around these locations. The CV application to be used in this Use Case is:

- Vehicle Turning Right in Front of Transit Vehicle (VTRFTV) – V2V

2.2.2.1 Safety

Figure 6 shows the study area and the route of the streetcar. The VTRFTV application will be evaluated in this use case for the avoidance of conflicts between the streetcar moving north and turning vehicles. The application works between the streetcar and vehicles at any location where turning right in front of the streetcar is permitted. Table 10 lists the intersections where the streetcar is crossing side streets, and a vehicle can make a right turn in front of it, triggering the VTRFTV warning. This can only occur when the streetcar is Northbound as the rail tracks are on the right of Channelside Drive. Figure 7 shows the intersections along Channelside Drive. For the period this report covers, no warnings were collected.

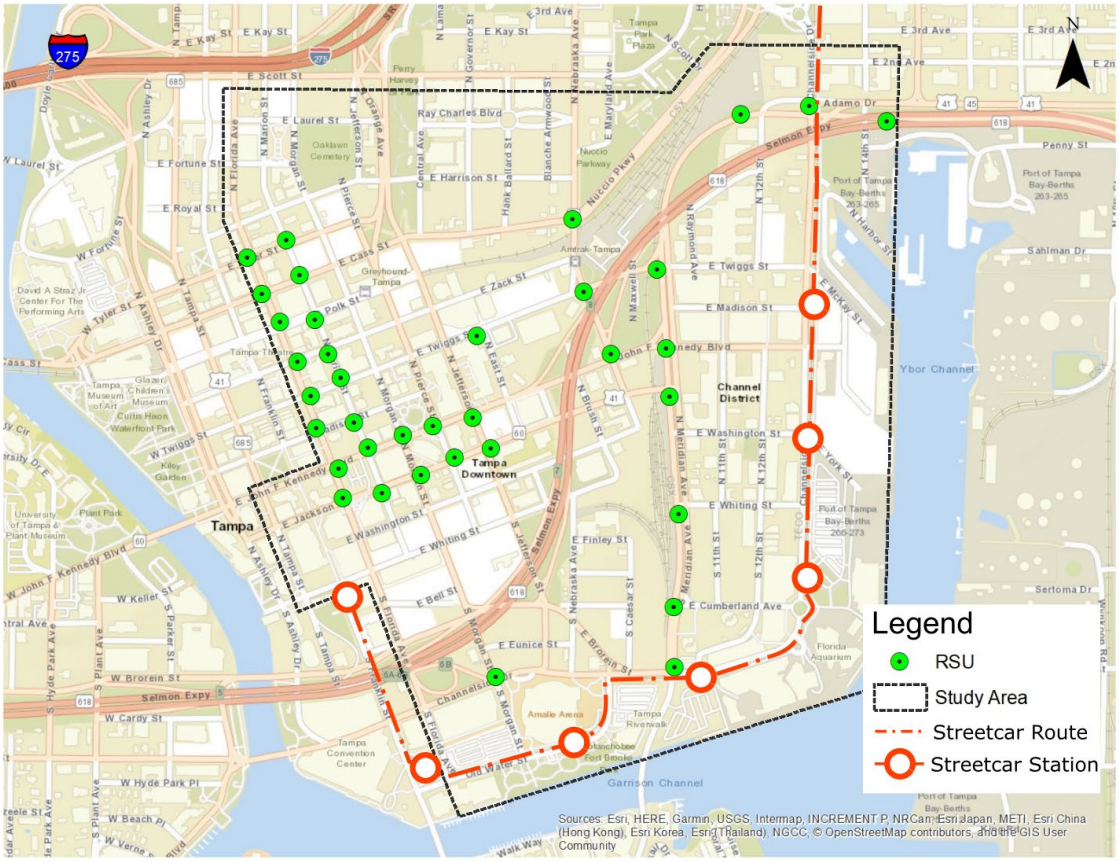


Figure 6: Use Case 5 Streetcar Route

Table 10: VTRFTV Warnings

#	Intersection	No. of VTRFTV Warnings
1	Channelside Drive @ Old Water Street	
2	Channelside Drive @ S Meridian Avenue	
3	Channelside Drive @ Channelside District Entrance	
4	Channelside Drive @ Aquarium Entrance	
5	Channelside Drive @ Port Entrance	
6	Channelside Drive @ E York Street	
7	Channelside Drive @ E Kennedy Boulevard	
8	Channelside Drive @ McKay Street	
9	Channelside Drive @ E Harbor Street	
10	Channelside Drive @ E Adamo Drive	

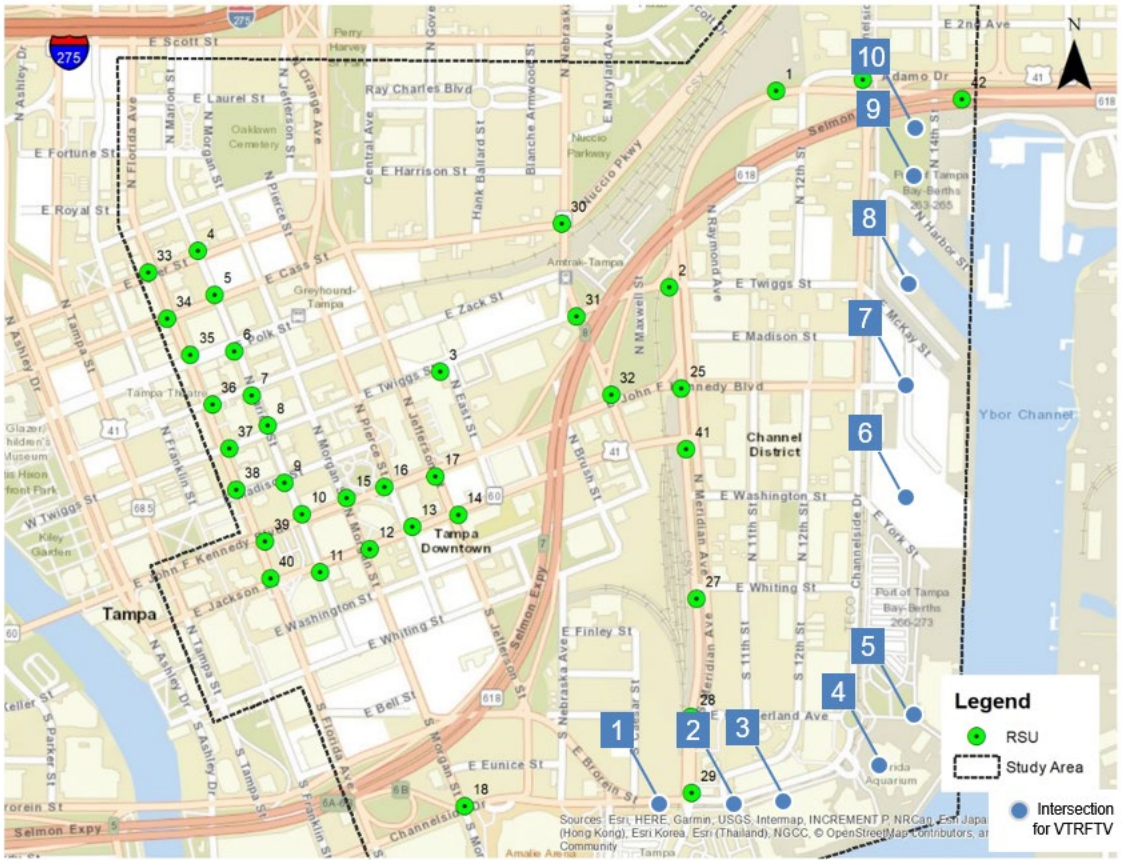


Figure 7: Streetcar Intersections

3 CV Roadside Equipment

3.1 RSU Location and Status

A total of 35 RSUs are installed in the downtown area to accommodate communication between infrastructure and vehicles. Figure 8 shows the location of the RSUs inside the study area. An additional five RSUs are installed at locations on the REL to accommodate over-the-air- (OTA) updates and on-board unit (OBU) data downloads.

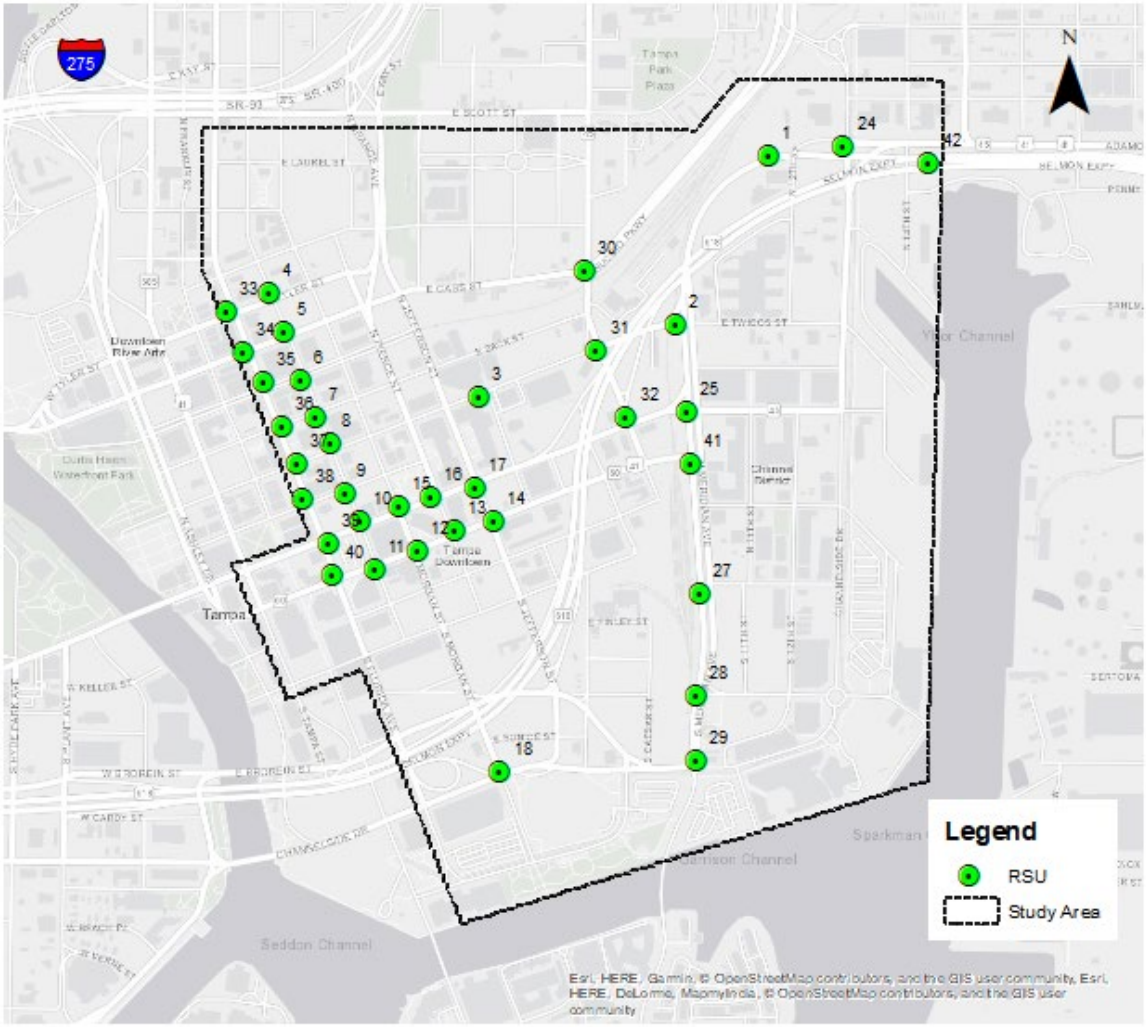
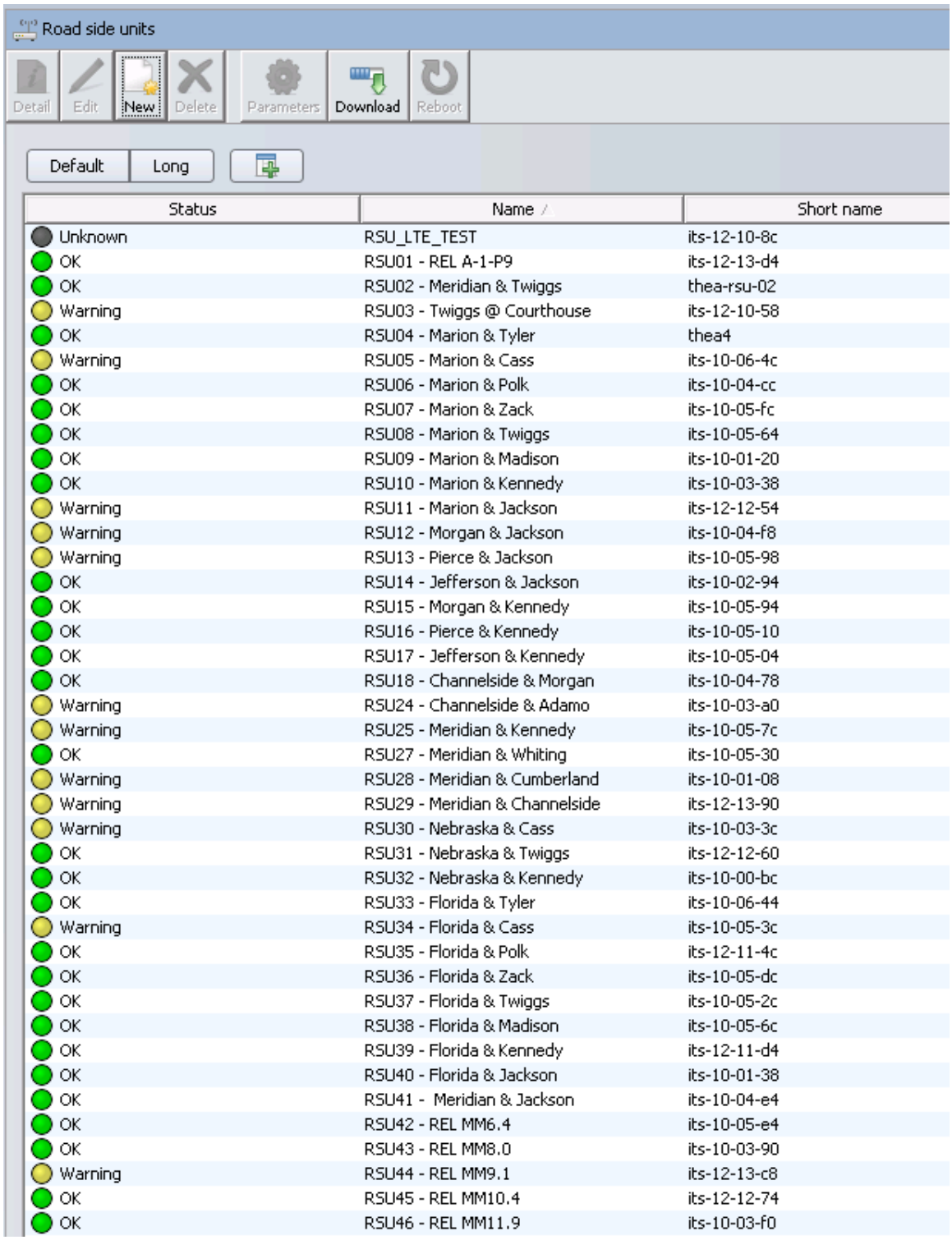


Figure 8: RSU Location Map

Figure 9 shows the operational status of the RSUs as of 2/22/2019 as reported by Siemens.



Status	Name	Short name
Unknown	RSU_LTE_TEST	its-12-10-8c
OK	RSU01 - REL A-1-P9	its-12-13-d4
OK	RSU02 - Meridian & Twiggs	thea-rsu-02
Warning	RSU03 - Twiggs @ Courthouse	its-12-10-58
OK	RSU04 - Marion & Tyler	thea4
Warning	RSU05 - Marion & Cass	its-10-06-4c
OK	RSU06 - Marion & Polk	its-10-04-cc
OK	RSU07 - Marion & Zack	its-10-05-fc
OK	RSU08 - Marion & Twiggs	its-10-05-64
OK	RSU09 - Marion & Madison	its-10-01-20
OK	RSU10 - Marion & Kennedy	its-10-03-38
Warning	RSU11 - Marion & Jackson	its-12-12-54
Warning	RSU12 - Morgan & Jackson	its-10-04-f8
Warning	RSU13 - Pierce & Jackson	its-10-05-98
OK	RSU14 - Jefferson & Jackson	its-10-02-94
OK	RSU15 - Morgan & Kennedy	its-10-05-94
OK	RSU16 - Pierce & Kennedy	its-10-05-10
OK	RSU17 - Jefferson & Kennedy	its-10-05-04
OK	RSU18 - Channelside & Morgan	its-10-04-78
Warning	RSU24 - Channelside & Adamo	its-10-03-a0
Warning	RSU25 - Meridian & Kennedy	its-10-05-7c
OK	RSU27 - Meridian & Whiting	its-10-05-30
Warning	RSU28 - Meridian & Cumberland	its-10-01-08
Warning	RSU29 - Meridian & Channelside	its-12-13-90
Warning	RSU30 - Nebraska & Cass	its-10-03-3c
OK	RSU31 - Nebraska & Twiggs	its-12-12-60
OK	RSU32 - Nebraska & Kennedy	its-10-00-bc
OK	RSU33 - Florida & Tyler	its-10-06-44
Warning	RSU34 - Florida & Cass	its-10-05-3c
OK	RSU35 - Florida & Polk	its-12-11-4c
OK	RSU36 - Florida & Zack	its-10-05-dc
OK	RSU37 - Florida & Twiggs	its-10-05-2c
OK	RSU38 - Florida & Madison	its-10-05-6c
OK	RSU39 - Florida & Kennedy	its-12-11-d4
OK	RSU40 - Florida & Jackson	its-10-01-38
OK	RSU41 - Meridian & Jackson	its-10-04-e4
OK	RSU42 - REL MM6.4	its-10-05-e4
OK	RSU43 - REL MM8.0	its-10-03-90
Warning	RSU44 - REL MM9.1	its-12-13-c8
OK	RSU45 - REL MM10.4	its-12-12-74
OK	RSU46 - REL MM11.9	its-10-03-f0

Figure 9: RSU Operational Status

Source: Siemens

4 CV On-Board Equipment

4.1 Number of Installs

OBUs from three manufacturers have been installed on participant vehicles. The main installation window was from March 2018 to February 2019.

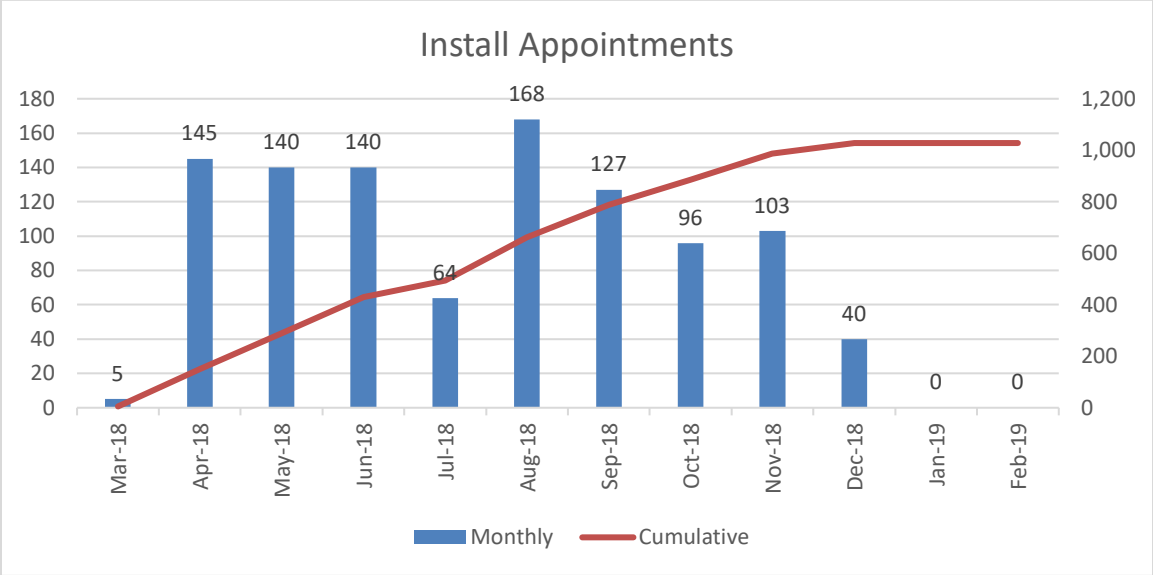


Figure 10: Number of OBU Install Appointments

4.2 Number of Uninstalls

Due to several reasons, participants may choose to uninstall the OBU from the vehicle, and either continue participation with a different vehicle or drop out of the study. According to data provided by Table 11, the data shows the reasons given by participants for the uninstall. These appointments only include participants who did not re-install the equipment. There were an additional seven participants who re-installed the equipment in a new vehicle and continue to participate in the study.

Table 11: Reasons for Uninstall of OBU

Reason Given	No.
Commute route change	2
Concern over aesthetics	3
Lack of incentive	1
Moving out of the area	9
No reason	19
OBU install issue	1
Trade-in/Sold vehicle	27
Vehicle crash	9
Vehicle malfunction (not OBU related)	9
Total	**80**

Figure 11 shows the monthly and cumulative appointments.

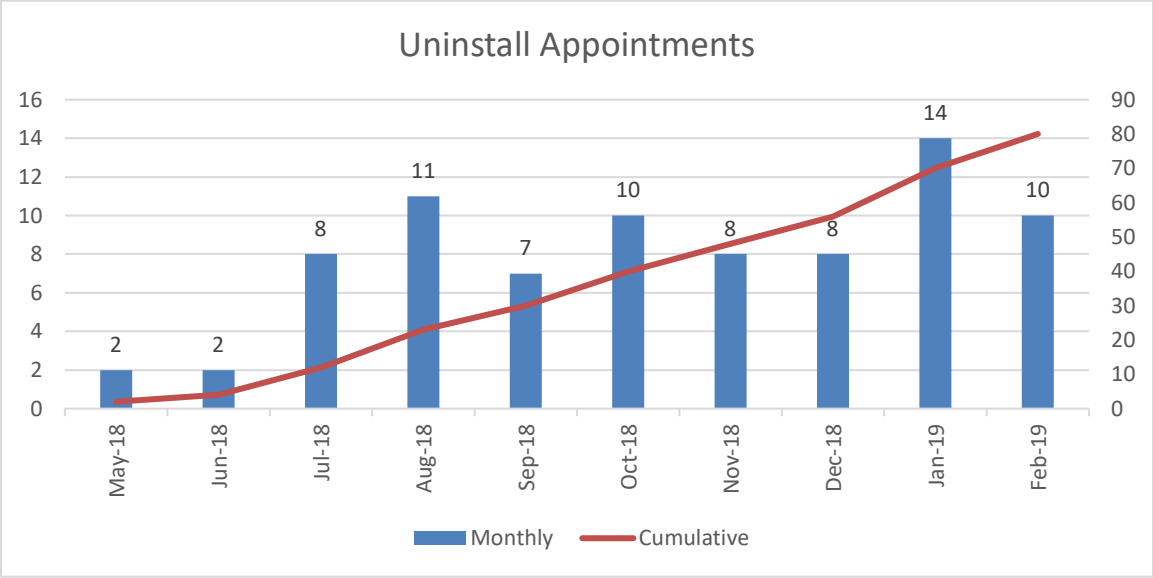


Figure 11: Number of OBU Uninstall Appointments

4.3 Number of Vehicles Equipped with OBUs

During the installation period (section 4.1) OBUs had also to be uninstalled for several different reasons (shown in section 4.2). The number of total vehicles equipped with OBUs for each month is shown in Figure 12. This number is calculated as several installs-number of uninstalls for each month.

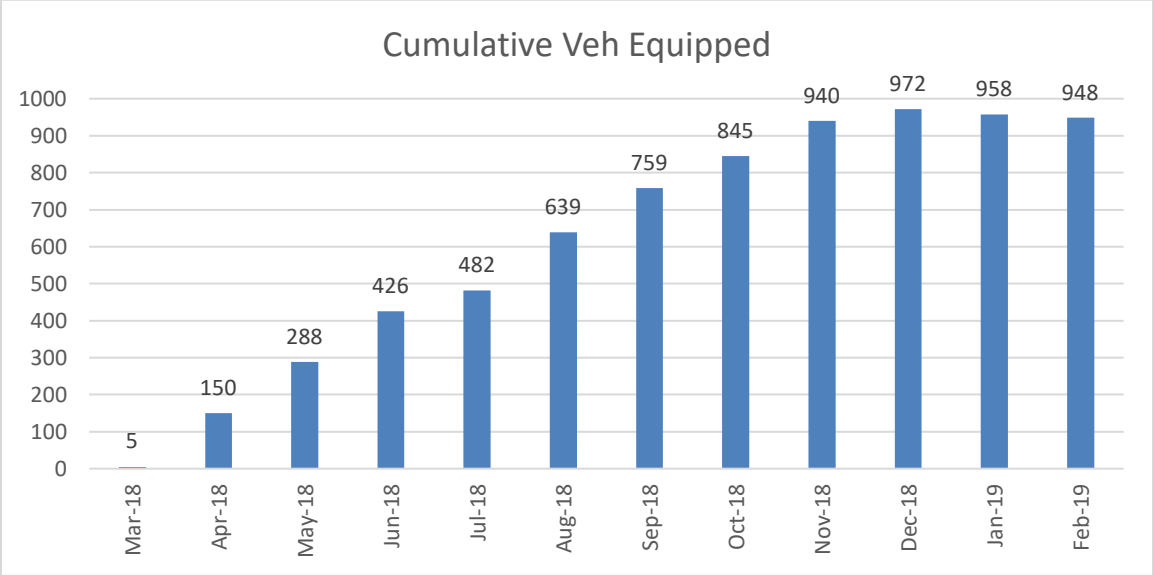


Figure 12: Number of Vehicles Equipped with OBUs

4.4 Number of OBU Repair Issues

Since the beginning of the installation of OBU units in participant vehicles, several issues arose, either with the units themselves or with the installation procedure that had to be remedied via a second appointment to repair the issue. In some cases, calibration, reset or other minor modification worked

in other words, the OBU had to be replaced. Figure 12 shows the number of successfully completed appointments to repair an issue monthly and cumulative.

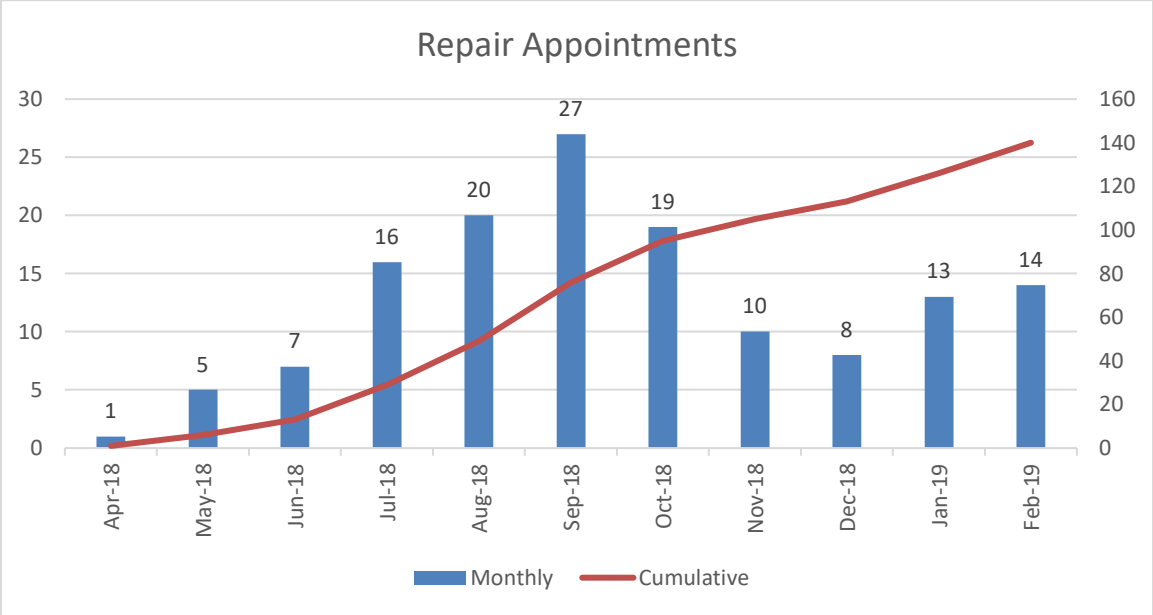


Figure 13: OBU Repair Appointments

4.5 CV Warning Summary

The number of warnings by the application that were triggered for the period this report covers is shown in Table 12.

Table 12: CV Warning Summary

Application Name	Application Type	No of Warnings
Forward Collision Warning (FCW)	V2V	
Wrong-Way Entry (WWE)	V2I	
Wrong-Way Driver (WWD)	V2I	
Vehicle Turning Right in Front of Transit Vehicle (VTRFTV)	V2V	
Pedestrian Collision Warning (PCW)	V2I	
Electronic Emergency Brake Light (EEBL)	V2V	
Intersection Movement Assist (IMA)	V2V	
End of Ramp Deceleration Warning (ERDW)	V2I	
Granted Transit Signal Priority (TSP)	V2I	
	Total	

5 Participants

5.1 Participant Assignment Summary

To support the experimental design outlined in the PMESP, the participants have been assigned to two groups: the control group and treatment group. Analysis of participants' gender, age, income, and education status have been used to assign a 2-1 match for control and treatment. Participants in the control group will not receive the alerts generated by the CV applications for the duration of the study, whereas participants in the treatment group will receive the alerts after a silent period of 90 days. The assignment of the participants has resulted in the following breakdown.

Table 13: Participant Assignment

Group	*25 And Under*	*26-35*	*36-45*	*46-55*	*56 And Over*	*Did Not Answer*	*Total*	
Treatment	20	128	159	182	112	14	615	Frequency
	22	130	151	187	111	15	615	Expected Freq.
	3.3	20.8	25.9	29.6	18.2	2.3	100.0	Row Percentage
Control	16	84	88	123	69	11	391	Frequency
	14	82	96	119	70	10	390.9	Expected Frequency
	4.1	21.5	22.5	31.5	17.7	2.8	100.0	Row Percentage
Total	36	212	247	305	181	25	1006	Frequency
	36	212	247	305	181	25	1006	Expected Frequency
	3.6	21.1	24.6	30.3	18.0	2.5	100.0	Row Percentage

Pearson chi2(5) = 2.2067 Pr = 0.820
Likelihood-ratio chi2(5) = 2.2066 Pr = 0.820

6 Data

6.1 Non-CV Data

To support the work of the Performance Measurement and Evaluation, several non-CV data has been collected to aid in identification and to control of confounding factors or to provide verification of CV data collected by the OBUs.

6.1.1 Bluetooth Data

To collect travel data before the CV Pilot Deployment, the Tampa-Hillsborough Expressway Authority contracted TrafficCast International, Inc. to install Bluetooth readers (i.e., BlueTOADs) in the CV Pilot study area. Bluetooth readers generate travel time data collected from pre-defined road segments and output can be manually downloaded from the secured website. Ten (10) Bluetooth-enabled devices have been installed in the study area. Figure 14 shows the geographical locations of the BlueTOADs.

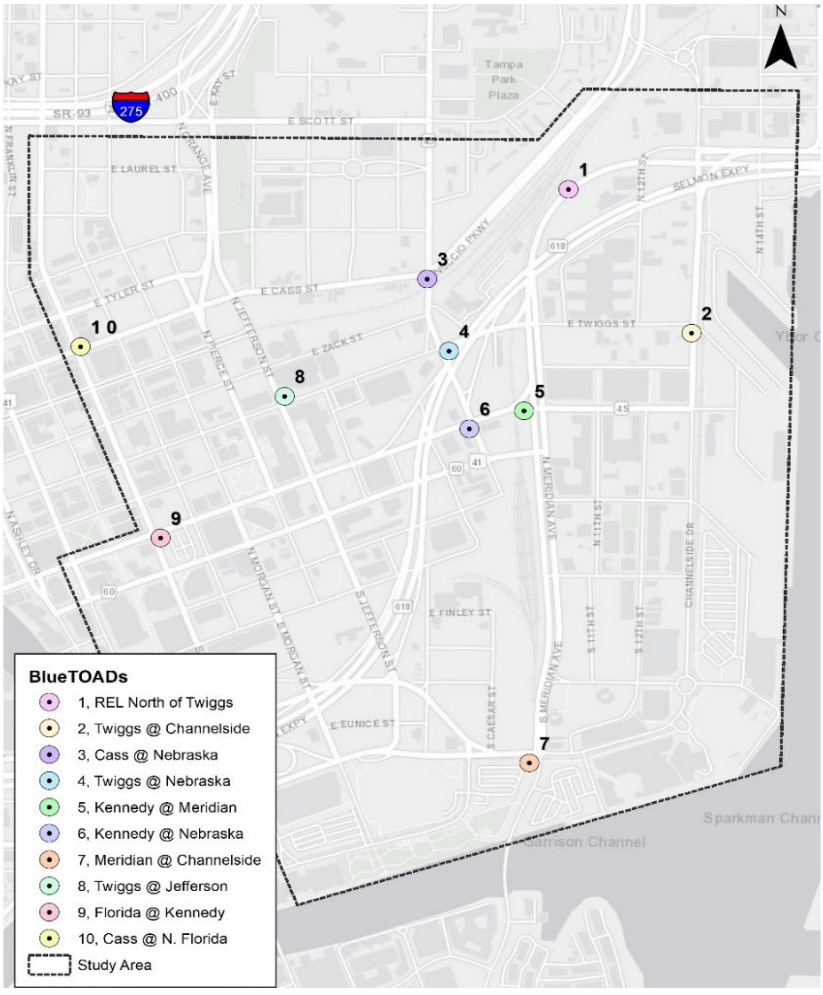


Figure 14: BlueTOAD Readers within THEA CV Pilot Study Area

** BlueTOAD #2 is not used for PM & E for the Pilot.*

1.1.1.1 Bluetooth-enabled Device Location and Pairs

Table 14 shows the pre-defined BlueTOAD pairs that generate baseline travel time data consistent with the mobility performance evaluation detailed in the Performance Measurement Evaluation Support Plan. For example, BlueTOAD pair 1-3 collect data from Bluetooth equipped vehicles passing between BlueTOAD 1 and BlueTOAD 3 (See Figure 13) to estimate travel times between the Reversible Express Lanes (REL) system curve, and the intersection at Cass and Nebraska Avenue.

Table 14: Pre-defined Bluetooth Pairs

Pair ID	*BlueTOAD Pair*	*From*	*To*	*Distance*	*Direction*
TEA-73295	1 - 3	REL North of Twiggs	Cass @ Nebraska	0.42	S/W
TEA-73299	1 - 6	REL North of Twiggs	Kennedy @ Nebraska	0.38	S
TEA-73303	1 - 7	REL North of Twiggs	Meridian @ Channelside	0.80	S
TEA-57887	1 - 5	REL North of Twiggs	Kennedy @ Meridian	0.33	S
TEA-57885	1 - 4	REL North of Twiggs	Twiggs @ Nebraska	0.32	SW
TEA-73306	3 - 1	Cass @ Nebraska	REL North of Twiggs	0.42	E/N
TEA-57875	3 - 4	Cass @ Nebraska	Twiggs @ Nebraska	0.11	S
TEA-57871	4 - 6	Twiggs @ Nebraska	Kennedy @ Nebraska	0.11	S
TEA-57873	4 - 3	Twiggs @ Nebraska	Cass @ Nebraska	0.11	N
TEA-73310	4 - 1	Twiggs @ Nebraska	REL North of Twiggs	0.32	NE
TEA-57865	4 - 8	Twiggs @ Nebraska	Twiggs @ Jefferson	0.26	E
TEA-73313	5 - 9	Kennedy @ Meridian	Florida @ Kennedy	0.49	W
TEA-57863	5 - 7	Kennedy @ Meridian	Meridian @ Channelside	0.47	S
TEA-73315	5 - 1	Kennedy @ Meridian	REL North of Twiggs	0.33	N
TEA-57859	5 - 6	Kennedy @ Meridian	Kennedy @ Nebraska	0.08	W
TEA-57861	7 - 5	Meridian @ Channelside	Kennedy @ Meridian	0.47	N
TEA-73317	7 - 1	Meridian @ Channelside	REL North of Twiggs	0.92	N
TEA-57867	8 - 4	Twiggs @ Jefferson	Twiggs @ Nebraska	0.22	E
TEA-57855	9 - 10	Florida @ Kennedy	Cass @ N. Florida	0.27	N

Data will be uploaded to the SDC in two comma-separated values files reporting travel times (file name: Bluetooth_TravelTime.csv) and travel time reliability measures (Bluetooth-TTR.csv). Table 15 shows the data dictionary for the Bluetooth data.

Table 15: Bluetooth Data Field Description

Field name	Description	Unit
PairID	Pair IDs are the unique IDs of pre-defined route pairs. Pairs are defined in Table 14	
DOW	Names of the days of the week	Day of weeks should be one of the following items: Sunday, Monday, Tuesday, Wednesday, Thursday, Friday, Saturday

Field name	Description	Unit
Timestamp	The timestamp of collected travel time	
Travel time	Travel time collected from pairs	Seconds
Speed	Speed is calculated by travel time divided by route pair length	Mph
Travel Time Reliability	Travel time reliability measures	See Table 17.

6.1.1.1 Bluetooth –based Travel Time

The MAC addresses are used to calculate the travel time of a vehicle between two BlueTOAD units. This time is reported in seconds, as shown in Table 16. The average speed is also shown as the distance between the units is entered into the database. The distance between two BlueTOAD units creating a pair is entered manually at the time the pair is created in the system, and it is the on-the-road distance between the two units.

Table 16: Bluetooth-based Sample Travel Time

PairID	DOW	Timestamp	Travel time (sec)	Speed (mph)
TEA-73295	Wednesday	1/10/2018 8:55:00	32	34.9
TEA-73295	Wednesday	1/10/2018 8:55:00	51	21.9
TEA-73295	Wednesday	1/10/2018 8:55:00	33	33.8
TEA-73295	Wednesday	1/10/2018 8:56:00	16	69.8
TEA-73295	Wednesday	1/10/2018 8:56:00	30	37.2
TEA-73295	Wednesday	1/10/2018 8:57:00	6	186
TEA-73295	Wednesday	1/10/2018 8:57:00	102	10.9
TEA-73295	Wednesday	1/10/2018 8:59:00	122	9.1
TEA-73295	Wednesday	1/10/2018 9:00:00	76	14.7

6.1.1.2 Bluetooth-based Travel Time Reliability

Travel time reliability is generally defined as a function of time of day (TOD), day of the week (DOW) and a segment of interest. TOD can be subdivided into 1-hour, 30-minute, or 15-minute intervals. The default reporting to SDC is at the 30-minute interval (i.e., TimeInterval = 30). The travel time reliability metrics are detailed in Table 17, and a sample of the data is shown in Table 18.

Table 17: Bluetooth TTR Field Description

Field name	Description	Data type	Unit
PairID	Pair IDs are the unique IDs of pre-defined route pairs. Pairs are defined in Table 1	string	
DOW	Names of the day of week	string	Day of the week should be one of the following items: Sunday,

Field name	Description	Data type	Unit
			Monday, Tuesday, Wednesday, Thursday, Friday, Saturday
Time of day		String	In half an hour
Sample size	Travel time data size used for calculating travel time reliability	numeric	
Standard deviation		numeric	minutes
Coefficient of variation	Standard deviation divided by average travel time	numeric	
Buffer time index	The buffer index represents the extra time (or time cushion) that travelers must add to their average travel time when planning trips to ensure on-time arrival	numeric	minutes
Planning time index	The planning time index represents how much total time a traveler should allow to ensure on-time arrival. While the buffer index shows the additional travel time that is necessary, the planning time index shows the total travel time that is necessary	numeric	minutes

Table 18: Travel Time Reliability Sample Data

PairID	DOW	Time of day	Sample size	Standard deviation	Coefficient of variation	Buffer time index	Planning time index
TEA-73295	Sunday	00:00 - 00:30	Low sample size*				
TEA-73295	Sunday	00:30 - 01:00	18	0.25	0.39	0.64	1.82
TEA-73295	Sunday	01:00 - 01:30	16	0.81	0.67	0.56	2.07
TEA-73295	Sunday	01:30 - 02:00	14	3.73	1.00	1.31	2.39
TEA-73295	Sunday	02:00 - 02:30	Low sample size				
TEA-73295	Sunday	02:30 - 03:00	21	0.89	1.22	1.39	4.22
TEA-73295	Sunday	03:00 - 03:30	13	1.07	1.20	0.67	3.00
TEA-73295	Sunday	03:30 - 04:00	12	0.11	0.25	0.28	1.31
TEA-73295	Sunday	04:00 - 04:30	Low sample size				
TEA-73295	Sunday	04:30 - 05:00	Low sample size				

*No matched pairs present in this time period.

6.1.2. Transit Data

The Hillsborough Area Regional Transit Authority (HART) manages regional transit operations and provides transit bus operation data in General Transit Feed Specification (GTFS) format through a dedicated API.[2]

6.1.2.1 Transit Performance - Stop-Level Reliability

Stop level reliability is defined as stop level on-time arrival percentage. Data is provided on selected stops within the CV Pilot Study area identified for CV Pilot Deployment. On-time arrival is defined to be "one minute early and five minutes late" concerning a scheduled stop. The frequency of transit stop-level reliability depends on the transit bus schedule. For example, six trips are scheduled to serve Route 24LX; each direction schedules three trips, then the frequency of stop-level reliability on Route 24LX is three times given any day of the week.

6.1.2.2 Data Collection

Python scripts have been developed to automatically download the GTFS data, including vehicle and trip information. Data consist of route reliability performance measures for select bus routes identified for CV Pilot deployment[3]:

- Route 20X: Pasco/Lutz Express
- Route 24LX: FishHawk/South Tampa Limited Express
- Route 25LX: Bloomingdale/South Tampa Limited Express

The description of the data is shown in Table 19.

Table 19: Transit Data Field Description

Field	Description	Data type	Unit
Route	Bus route ID	numeric	
Trip	Bus trip ID	numeric	
Stop Sequence	Bus stop in sequence, given a route	numeric	
On-time arrival percentage	Percentage of on-time arrival based on historical arriving records. The period starts April 17, 2019.	numeric	%

Table 20 shows a sample of the data collected.

Table 20: Transit Stop Level on Time Performance

Route	Trip	Stop Sequence	On-time arrival percentage
Route24	293361	1	77.14%
Route24	293361	2	94.29%
Route24	293361	3	88.57%
Route24	293361	4	74.29%
Route24	293361	5	80.00%
Route24	293361	6	85.71%
Route24	293361	7	17.14%

[2] http://www.gohart.org/Pages/Travel-HART-AppCenter.aspx

[3] See here for a map of routes serving Downtown Tampa: http://gohart.org/Style%20Library/goHART/pdfs/maps/downtown-network-map-110718.pdf

6.1.3 Weather Data

Dark Sky API is an online service that provides national weather broadcast services.[4] It provides a web service API to allow the public to access weather information for any location by coordinates.

6.1.3.1 Weather Information

Weather data is intended to be used to control for confounding factors affecting travel conditions for participants in the Tampa CV Pilot. This data serves as a proxy for vehicle participant response to weather adverse conditions not recorded by OBUs. Weather data is collected at ten-minute intervals. Weather information is collected by providing the latitude and longitude coordinates to the center of the Tampa CDB to cover the entire CV Pilot Study Area. The *timestamp* is the variable used to add a time-based layer to the BSM datasets. Tables 21-23 show sample weather data collected from Dark Sky API.

Table 21: Weather Sample Data-Part 1

#	timestamp	Datetime	temp_F	humidity	visibility	cloud_cover	dewpoint_F
1	1550689650	2/20/2019 14:07	84.77	0.56	10	0.8	67.53
2	1550693828	2/20/2019 15:17	84.84	0.55	10	0.73	66.91
3	1550694601	2/20/2019 15:30	84.65	0.55	10	0.73	66.85
4	1550695201	2/20/2019 15:40	84.51	0.55	10	0.73	66.8
5	1550695801	2/20/2019 15:50	84.02	0.57	9.36	0.52	67.11
6	1550696401	2/20/2019 16:00	83.86	0.57	9.23	0.52	67.14
7	1550697001	2/20/2019 16:10	83.54	0.58	9.22	0.52	67.17
8	1550697601	2/20/2019 16:20	82.88	0.59	9.21	0.53	67.24
9	1550698201	2/20/2019 16:30	82.53	0.6	9.19	0.53	67.26
10	1550698801	2/20/2019 16:40	82.26	0.6	9.95	0.55	67.2

Table 22: Weather Sample Data-Part 2

#	precip_intensity	wind_bearing	wind_gust	wind_speed	storm_bearing
1	0	191	14.41	12.69	355
2	0	203	15.21	11.64	169
3	0	205	15.47	11.65	168
4	0	206	15.68	11.66	178
5	0	215	14.74	12.27	272
6	0.004	216	15.13	12.38	
7	0	216	15.26	12.25	285
8	0	216	14.82	11.98	214
9	0	217	14.94	11.86	144
10	0.003	224	15.95	12.47	

[4] https://darksky.net/dev

Table 23: Weather Sample Data-Part 3

#	storm_distance	pressure	ozone	uv_index
1	24	1018.33	223.19	5
2	21	1017.54	222.94	4
3	13	1017.55	222.9	3
4	14	1017.55	222.87	3
5	27	1017.31	222.84	3
6	0	1017.4	222.81	3
7	27	1017.34	222.78	2
8	24	1017.25	222.76	2
9	6	1017.19	222.73	2
10	0	1016.99	222.71	1

6.1.3.2 Data Dictionary

Table 24: Weather Data Field Description

Field	Description	Data type	Unit
city	Location (city)	string	
state	Location (state)	string	
zip	Zip code	string	
obs_city	Weather observation location (city)	string	
obs_state	Weather observation location (state)	string	
obs_longitude	Weather observation (longitude)	numeric	
obs_latitude	Weather observation (longitude)	numeric	
obs_elevation	Weather sensor location (elevation)	numeric	
nearest-station	Weather sensor ID	string	
timestamp	Time of weather information collection	datetime	
temp_F	Temperature in F	numeric	F
humidity	Relative humidity between 0 and 1, inclusive	numeric	%
visibility	The average visibility in miles capped at 10 miles	numeric	mi
cloud_cover	The percentage of sky occluded by clouds, between 0 and 1, inclusive	numeric	%
dewpoint_F	The dew point in degrees Fahrenheit	numeric	F
precip_intensity	The intensity (in inches of liquid water per hour) of precipitation occurring at the given time. This value is conditional on probability	numeric	in
wind_bearing	The direction that the wind is coming from in degrees, with true north at 0° and progressing clockwise	numeric	°
wind_gust	Gust speed	numeric	mph
wind_speed	Wind speed	numeric	mph

Field	Description	Data type	Unit
storm_bearing	The approximate direction of the nearest storm in degrees, with true north at 0° and progressing clockwise	numeric	°
storm_distance	The approximate distance to the nearest storm in miles.	numeric	mi
pressure	The sea-level air pressure	numeric	Mb
ozone	The columnar density of total atmospheric ozone at the given time	numeric	Dobson units
uv_index	The UV index	numeric	1-11

6.2 Status and Extent of Data Transmitted to SDC

The data submitted to the SDC include all the payloads used in the study. The upload of the payloads occurs daily. Table 25 shows the start date for each payload, as well as their size and count of files in chronological order to date 3/5/2019. Each file contains multiple payloads (messages), i.e., each file does not correspond to one message.

Table 25: SDC Data Upload Summary

#	Payload	Starting Date	Size	File Count
1	BSM	9/15/18	37GB	148,272
2	SPAT	9/15/18	36GB	128,310
3	TIM	1/31/19	40MB	1,028
4	MAP	1/7/19	305GB	18,229
5	MMITSS	1/31/19	227MB	12,989
6	SSM	2/19/19	333KB	7,792
7	SRM	2/19/19	350KB	8,038
8	PSM	3/1/19	6KB	144

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