Architecture and Design

Transit Bus Stop Pedestrian Warning Application

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16. Abstract

This document describes the Draft System Architecture and Design for the Transit Bus Stop Pedestrian Warning (TSPW) application including the design for the pedestrian detection system and DSRC radio to be deployed at transit stops and includes details on the Enhanced Transit Safety Retrofit Package platform upon which the TSPW application will run on the transit vehicle.

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A	04/15/16	Initial Release	
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Table of Contents

List of Tables

List of Figures

Chapter 1 Scope

This Architecture and Design Specification for the Transit Bus Stop Pedestrian Warning Application (TSPW) captures the architecture and design towards fulfilling the technical objectives as stated in Project No. DTFH61-12-D-0040/5015.

Chapter 2 Applicable Documents

The following documents are referenced within this document. If a specific revision is applicable, that revision is referenced within the text.

Institute of Electrical and Electronics Engineers (IEEE)

IEEE 1609.2	Wireless Access in Vehicular Environments (WAVE) – Security Services for Applications and Management Messages
IEEE 1609.3	IEEE Standard for Wireless Access in Vehicular Environments (WAVE) -- Networking Services
IEEE 802.11p	IEEE Standard for Information technology – Local and metropolitan area networks – Specific requirements – Part 11: Wireless LAN Medium Access Control (MAC) and Physical Layer (PHY) Specifications Amendment 6: Wireless Access in Vehicular Environments

Society of Automotive Engineers (SAE)

SAE J1113	Conducted Immunity, 250 kHz to 400 MHz, Direct Injection of Radio Frequency (RF) Power, SAE International
SAE J1211	Handbook for Robustness Validation of Automotive Electrical/Electronic Modules
SAE J1708	Serial Data Communications Between Microcomputer Systems in Heavy-Duty Vehicle Applications
SAE J1939	Serial Control and Communications Heavy Duty Vehicle Network, SAE International
SAE J2735	Dedicated Short-Range Communications (DSRC) Message Set Dictionary, SAE International
SAE J2945/1	On-Board System Requirements for V2V Safety Communications

International Organization for Standards

ISO 15765-4:2011	Road vehicles – Diagnostic communication over Controller Area Network (DoCAN) – Part 4: Requirements for emissions-related systems

U.S. Department of Transportation

DOT HS 811 492A	Vehicle Safety Communications – Applications (VSC-A), Final Report, September 2011

Battelle Drawings/Documents

FHWA-JPO-16-332	Transit Bus Stop Pedestrian Warning Application Concept of Operations (CONOPS)
FHWA-JPO-16-360	Transit Bus Stop Pedestrian Warning Application Requirements Document
10006445-0021	Enhanced Transit Safety Retrofit Package (E-TRP) Concept of Operations (CONOPS)
100008379-0024	Enhanced Transit Safety Retrofit Package (E-TRP) System Requirements Document

Chapter 3 System Overview

3.1 System Overview and Context

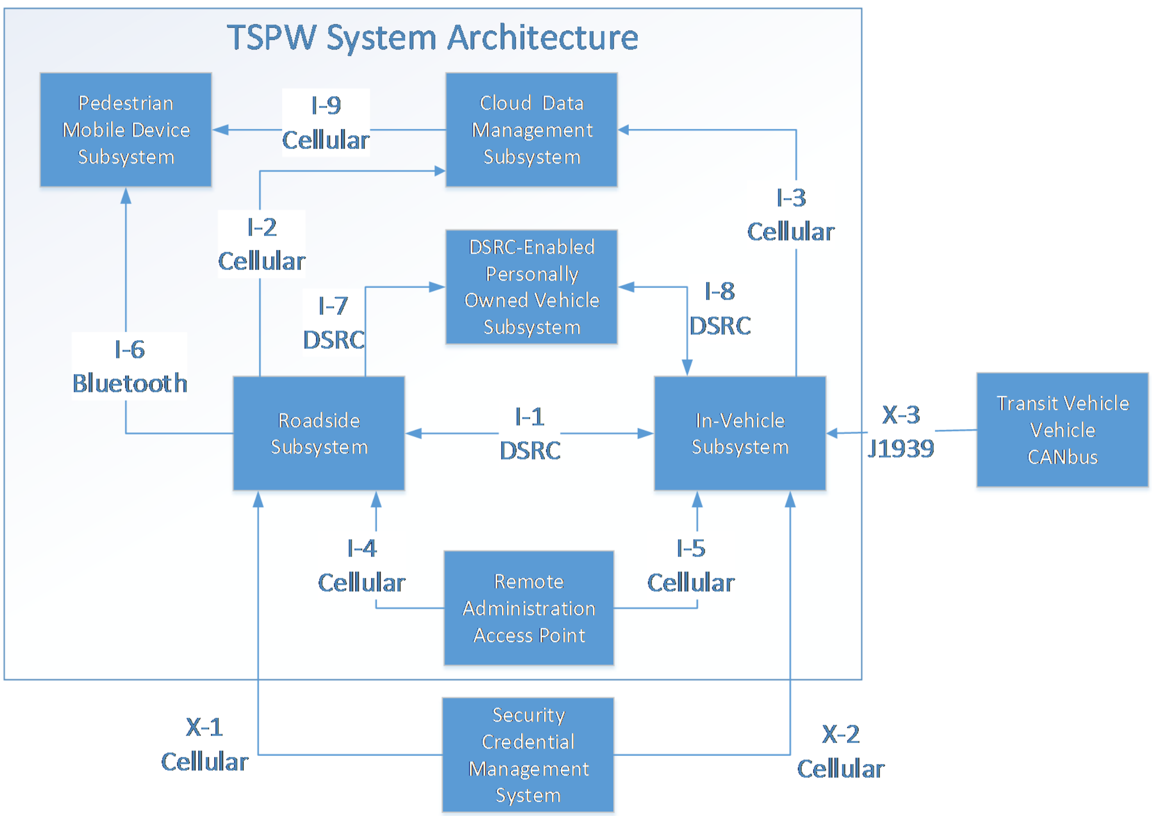
The Transit Bus Stop Pedestrian Warning (TSPW) system is a Connected Vehicle (CV) application sponsored by the United States Department of Transportation (U.S. DOT). The intent of the TSPW system is to utilize Vehicle-to-Infrastructure (V2I) communications to improve the situational awareness and ultimately safety of pedestrians at transit stops. The TSPW system consists of several components and subsystems involving both components within a transit vehicle as well as roadside equipment at transit stops.

The TSPW system will be developed as an application to be combined with and leveraging the components and technologies developed under E-TRP system. It will include additional capabilities to enhance and improve transit vehicle and pedestrian safety in an operational context. The combined E-TRP System + TSPW application (herein known as the TSPW system) will consist of multiple physically separate systems; an on-board, transit vehicle-based system, an infrastructure-based system at each of the selected transit stops, a mobile device application, a personally-owned vehicle integrated application and cloud-computing components. Both the E-TRP and TSPW systems will share some common hardware and software subsystems, as well as having unique subsystem to themselves.

Chapter 4 TSPW Architecture

4.1 Architecture Overview

A high level architectural view of the TSPW system is shown in Figure 4-1.



Source: Battelle

Figure 4-1. TSPW System Architecture

The TSPW system is made up of six main subsystems which work together to fulfill the requirements.

The **TSPW In-Vehicle Subsystem (IVS)** includes the hardware and software components installed within the transit vehicle. Included within the IVS is a Common Computing Platform (CCP), the heart of the IVS. The CCP is the central processor providing the cellular, Global Navigation Satellite System (GNSS) receiver and Dedicated Short-Range Communications (DSRC) Radios serving as the low-latency wireless communications method between the IVS and Roadside Equipment. The IVS also hosts the in-vehicle portion of the software applications. The IVS hosts two Human Interface Subsystems (HIS). The Transit Vehicle Operator HIS is used by both the E-TRP and TSPW projects to alert the Transit Vehicle Operator. The TSPW project adds an additional HIS for pedestrians crossing in front of the transit vehicle. The Transit Vehicle Pedestrian HIS is external to the vehicle and will provide both a visual and aural alert to pedestrians at risk of being struck by either the transit vehicle or an oncoming DSRC equipped Personally-Owned Vehicle.

The **TSPW Roadside Equipment Subsystem (RSE)** also contains a CCP hosting the DSRC and Cellular communication links, and the interface to the Pedestrian Detection System at the locations where the TSPW application is implemented. The **Pedestrian Detection System (PDS)** contains transit stop-based sensors to detect the presence of pedestrians inside a specified detection zone. The PDS contains its own processing and software capability, which would then communicate to the RSE when a pedestrian is detected. Unique to the TSPW project, the RSE also interfaces with a Roadside Pedestrian HIS which alerts pedestrians at a transit stop if they are at risk of being struck by a transit vehicle.

The **Cloud Data Management Subsystem (CDMS)** serves as the remote portal for the IVS and RSE collected data. It also serves as the monitoring point for all deployed fleet system health status (near real-time operational state dashboard).

The **Remote Administration Access Point (RAAP)** is an internet-connected access point into the system that will allow system administrators to perform support and maintenance tasks on the deployed equipment.

The **Pedestrian Mobile Device Subsystem (PMDS**) uses an application which allows communications with the Roadside Subsystem to alert pedestrians of locations where they are at risk of being struck by a transit vehicle.

The **DSRC-Enabled Personally Owned Vehicle Subsystem (POVS)** communicates with the Roadside Subsystem. The on-board Personally Owned Vehicle HIS alerts the POV operator of pedestrians near a transit vehicle at a transit stop that are at risk of being struck by the POV.

External to the TSPW system of interest, but supporting its mission is the Transit Vehicle that is expected to provide power to the IVS and data about the operational situation of the vehicle including telematics data such as speed, gear and brake status. Finally, the U.S. DOT is sponsoring the deployment of a Security Credential Management System (SCMS) which will supply credentialing materials for DSRC communications. Since the latest version of the SCMS will not be available in time for this deployment, the TSPW system will make use of long-term certificates provided by the Safety Pilot SCMS credential manager.

Figure 4-1 also summarizes the logical connectivity between internal and external TSPW subsystems. The software architecture and design described within this document will refer to these logical connections using the enumerators in Figure 4-1. Table 4-1 below lists out each of the logical interfaces connecting the diagramed subsystems as well as the connections made to external systems.

Table 4-1. TSPW System Logical Interfaces with Identifiers

Interface Identifier	Interface Type	Exchanged Information
I-1	DSRC	The Roadside Subsystem will send information to the In-Vehicle Subsystem about the location of pedestrian detection zones with respect to the roadway lanes where the transit vehicle will travel along with the actual status of pedestrian occupation of the pedestrian detection zones. This information will be sent as MAP and Personal Safety Message (PSM) messages via DSRC. The In-Vehicle Subsystem will announce its approach and position by broadcasting Basic Safety Messages (BSM).
I-2, I-3	Cellular	The Roadside and In-Vehicle Subsystems will upload information to the Cloud Data Management Subsystem regarding system health and performance.
I-4, I-5	Cellular	The TSPW System will have a remote administration capability which will be enabled by the Remote Administration Access Point. This remote administration will be performed over the cellular connection and allow both the Roadside and In-Vehicle Subsystems to be updated and configured remotely.
I-6	Bluetooth	The TSPW Roadside Subsystem will communicate with the Pedestrian Mobile Device Subsystem via a wireless Bluetooth communication protocol. This connection will provide the mobile devices information regarding approaching transit vehicles.
I-7	DSRC	The Roadside Subsystem will broadcast messages over DSRC to alert approaching Personally Owned Vehicles enabled with a DSRC radio that there are vulnerable pedestrians in the roadway.
I-8	DSRC	The TSPW Application on both the transit vehicle as well as the Personally Owned Vehicle will use the BSM broadcast from the nearby vehicles to determine the appropriate notification messages to show the driver.
I-9	Cellular	The Cloud Data Management Subsystem will make available the appropriate pedestrian detection zones for each of the instrumented transit stops for use by the Pedestrian Mobile Device Subsystem.
X-1, X-2	Cellular	Both the In-Vehicle and Roadside Subsystems will receive security certificates from the Security Credential Management Service. Long-term credentials will be provisioned to the devices via a secure cellular connection.
X-3	J1939 CAN	The TSPW applications requires information to be acquired from the Transit vehicle. Data such as vehicle speed, gear position and brake status will be read from the vehicle CAN Bus.

Source: Battelle

Chapter 5 TSPW Design

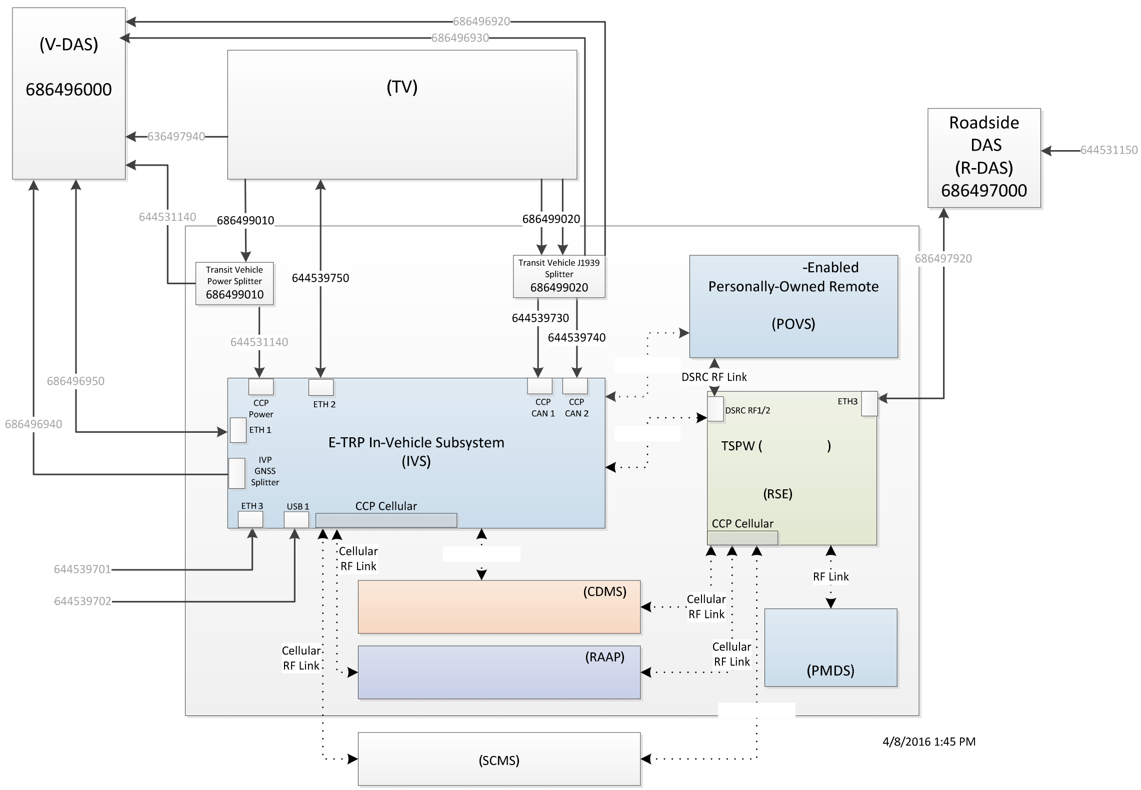
5.1 Design Overview

After performing functional analysis on the TSPW Architecture shown above in Figure 4-1, functional decomposition of the TSPW System was performed to identify appropriate hardware and software boundaries.

The TSPW application will be fulfilled by the RSE, IVS, and the CDMS. The PMDS and the POVS will provide additional human interface platforms to warn pedestrians and non-transit vehicle operators of at risk pedestrians. The RSE will be instrumental in providing information at the transit stop and the state of pedestrians in the enabled safety zones. The IVS is the link to the transit driver, warning them of pedestrians in the enabled safety zones. The CDMS provides a management and data repository function so the transit fleet may be monitored and managed. The PMDS provides a personalized warning on a user's mobile phone, and the POVS provides warnings to the driver of the personal vehicle behind the transit vehicle. The RAAP serves as a secure connection point into the TSPW system so that maintenance activities may be conducted.

5.1.1 Hardware Overview

A hardware block diagram for the TSPW and supporting equipment is shown in Figure 5-1. This figure identifies the main components and the associated interconnections that are required.



Source: Battelle

Figure 5-1. Hardware Block Diagram

A more in depth description of each subsystem and physical connection is described in sections 5.3.1 through 5.3.8.

5.1.2 Software Overview

The software for the TSPW system will be developed for the IVS, RSE, PMDS, POVS and CDMS. Three of the subsystems, the RSE, IVS and POVS subsystems will be built on a common hardware platform. Because of this common hardware, much of the software platform can also be the same across these three subsystems. The CDMS will take advantage of modern advances and efficiencies in service hosting and data storage by leveraging a cloud provider. The PMDS will be constructed on the current mobile operating system for both the Android and Apple smartphones.

At the heart of the RSE, IVS and POVS will be a Common Computing Platform. This platform will run on a Linux operating system which will provide access to the underlying hardware components. All three subsystems will also make use of a common software platform layered on top of the operating system referenced as the Transportation Message Exchange (TMX). TMX, first developed as part of the Integrated V2I Prototype (IVP) project, allows for rapid development of new features and applications while at the same time offering a convenient mechanism for re-using existing capabilities from the E-TRP and other connected vehicle projects

The CDMS will be developed on a different computational platform and therefore be based on a different software stack than that of the RSE, IVS and POVS. The CDMS will be developed using Microsoft Azure Cloud Computing and Services. This platform follows the model where a customer pays for just the amount of computing and data storage services actually used. This is an advantageous model for new projects under development as well as fielded systems expecting to start small and potentially grow over time. Costs can be kept to a minimum and only increased when it is determined that the current capacity is insufficient.

The PMDS will be constructed on a mobile device operating system. In order to provide sufficient coverage of travelers, both major smartphone platforms will be targeted. A TSPW mobile application will be developed and made available to owners of both Android and Apple smartphones.

Additional details for the design of each of these five software systems can be found below in the sections 5.3.1 through 5.3.6 of this document.

5.2 TSPW Input / Output Summary

The data inputs to the TSPW system are varied and each support one or more of the three primary notification areas of the system: Transit Driver, Roadside Pedestrian and Remote Personally Owned Vehicle Drivers. There are three main types of inputs to the system:

1. **Data transmitted via DSRC radio.** This includes messages, such as Basic Safety Messages (BSM) and MAP Messages. These messages provide information about the infrastructure or other vehicles to the TSPW system.
2. ***Data from the Transit Vehicle.*** This information is gathered from the CAN bus to access data such as the vehicle speed and gear position. Needed data is accessed from the vehicle using the J1939 protocol.
3. **Global Navigation Satellite System position and time.** The need to know where the Transit and Personally Operated Vehicles are in relation to the transit stop structures is necessary to the TSPW application's ability to accurately notify the driver and pedestrian of any alert conditions. A detailed list of these inputs is available in Table 5-1 below.

While the TSPW system conceptually has the single output of a notification of a vulnerable pedestrian, there are four different platforms where this notification can occur. Each of these four platforms will have a specific variation of this output. The TSPW application will output Inform (less severe) and Warn (more severe) alerts based on pedestrian and vehicle circumstances. Additionally, each function generates data logs which will be persisted in the Cloud Data Management System. Data is not a tangible output that a user of the system will even be aware of, but it is very useful to administrators and evaluators.

Table 5-1. TSPW Inputs

Inputs	Source	Standard
GNSS Antenna Offset	Config File (Database)	N/A
Transit Vehicle's vehicle length	Config File (Database)	N/A
Vehicle Unique ID (for BSM) (stays with the vehicle, not with the device)	Config File (Database)	N/A
Transit Vehicle Route	Config File (Database)	N/A
Transit Vehicle's current GNSS heading	GNSS	N/A
Transit Vehicle's current GNSS position	GNSS	N/A
Transit Vehicle's current GNSS time	GNSS	N/A
Transit Stop Roadway Geometry MAP	Transit Stop RSE	J2735
Locations of Vulnerable Road Users (Personal Safety Message)	Transit Stop RSE	J2735
Remote Vehicle's Position	Other Vehicle BSM	J2735
Remote Vehicle's Heading	Other Vehicle BSM	J2735
Remote Vehicle's Length	Other Vehicle BSM	J2735
Transit Vehicle's speed	Vehicle CAN Bus	J1939
Transit Vehicle's gear position (PRNDL)	Vehicle CAN Bus	J1939
Transit Vehicle's brake status	Vehicle CAN Bus	J1939

Source: Battelle

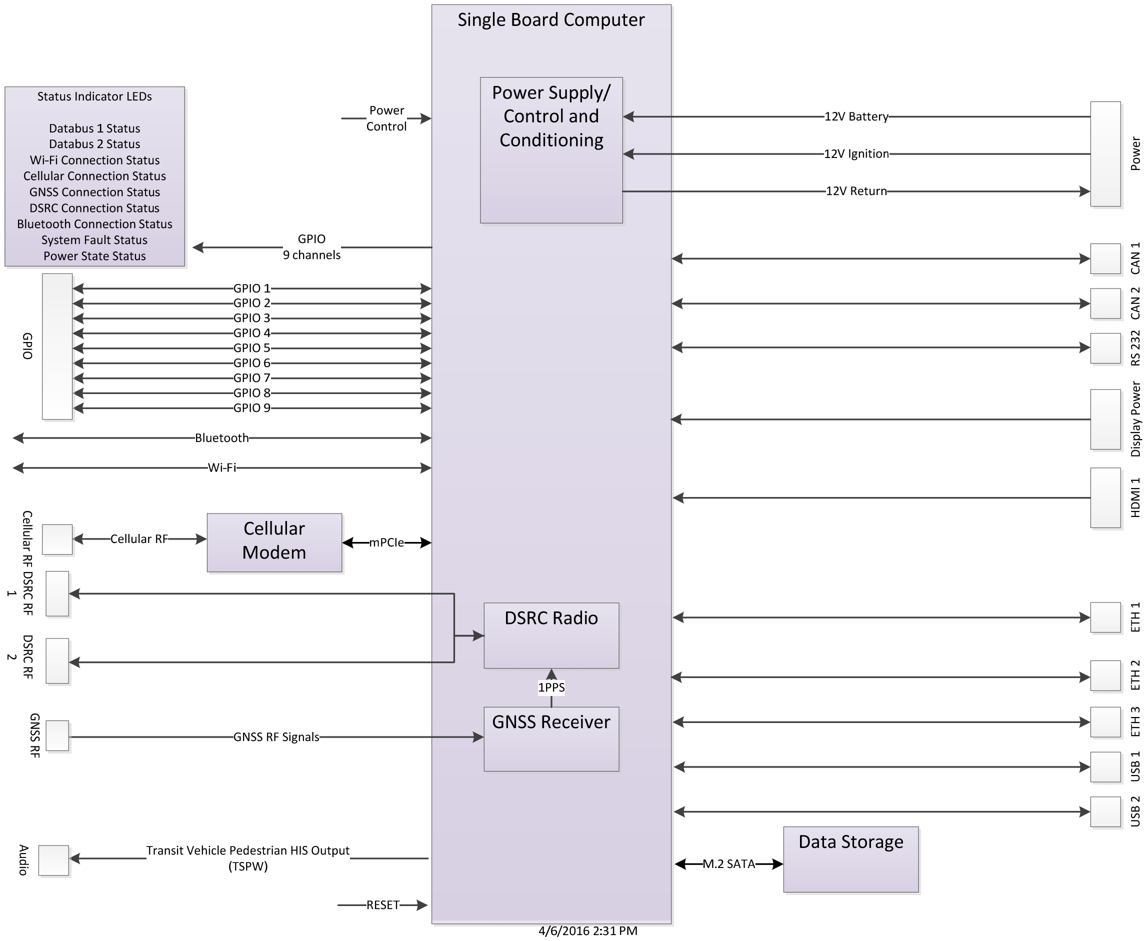
5.3 TSPW System

This section contains a detailed description of each subsystem along with the hardware and software that is either installed or modified to support TSPW in the transit vehicle, at the transit stop, on the traveler's mobile device, in the personally owned vehicle and finally in the cloud.

5.3.1 Common Computing Platform

The CCP forms the heart of the IVS and RSE subsystems. The CCP implements the basic services required by the IVS and RSE including a Single-Board Computer, with Status indicator LEDs, Power Supply/Control and Conditioning circuitry, Cellular Modem, DSRC Radio, GNSS Receiver and local data storage device.

A block diagram of the main CCP subsystem components is shown in Figure 5-2.



Source: Battelle

Figure 5-2. CCP Subsystem Block Diagram

5.3.1.1 Hardware

The components selected to implement the CCP will be critical in fulfilling the requirements for each platform. As such, each component has been selected based on previous experience in both connected vehicle deployments and other non-related industrial applications. Table 5-2 (and the subsections below) describe the components selected for the CCP.

Table 5-2. Key Components of the Common Computing Platform

Function	Integration Point	Implemented Component	Reference Material
Single Board Computer (SBC)		Custom board based on the Quad Core i.mx6 processor	
Power Supply, Control and Conditioning	Integrated on SBC	Custom power supply and conditioning circuit board	
DSRC Radio	Integrated on SBC	Ublox THEO-P1 Host-based V2X transceiver module	https://www.u-blox.com/en/product/theo-p1-series
GNSS Receiver	Integrated on SBC	NEO-7P Ublox 7 precise point positioning GNSS module	https://www.u-blox.com/en/product/neo-7p
Vehicle Interface Circuitry	Integrated on SBC	OBD Solutions STN1170: OBD-II, SW-CAN, MS-CAN Interpreter IC	http://www.obdsol.com/solutions/chips/stn1170/
Data Storage		M.2 Solid State Disk Drive Card	http://www.samsung.com/us/computing/memory-storage/solid-state-drives/ssd-850-evo-m-2-250gb-mz-n5e250bw/
Cellular Modem		uBlox TOBY-L201	https://www.u-blox.com/en/product/toby-l2-series

Source: Battelle

5.3.1.1.1 Single Board Computer (SBC)

The SBC is a custom board, implementing the processor, memory, and input/output (I/O) required to satisfy the needs of the deployment. Not only does the SBC contain the processor and associated circuitry it also implements the power supply, control and conditioning, DSRC radio, GNSS receiver, and vehicle Interface circuitry. This full integration allows for a smaller total package size and tighter coupling of software resources. A data storage medium and cellular modem will be integrated to the SBC via standard connector interfaces so that those components may be easily changed if the deployment requires it. Table 5-3 summarizes the detailed features of the SBC.

Table 5-3. Single Board Computer Features

CPU	
CPU Name	Freescale i.MX6
CPU Type	ARM Cortex™-A9
CPU Cores	4 (Quad-Core or Quad PLUS)
CPU Clock (Max)	1GHz
Memory	
RAM	4GB DDR3
NOR Flash	2MB Serial NOR Flash
eMMC	4GB (expandable to 64GB)
Multimedia	
2D/3D Graphics Acceleration	Vivante™ GC2000 Accelerated 2D and 3D
Video Encode / Decode	1080p60 H.264 Decode, 1080p30 H.264 Encode
Display	
HDMI	v1.4 1920 x 1080 (Type A connector)
Networking	
Ethernet	10/100/1GB (3ea)
WiFi – Internal Antenna	802.11 b/g/n
Bluetooth	Bluetooth 2.1+EDR
	Bluetooth 4.0 (Bluetooth Low Energy)
CAN1	• ISO 15765-4 • J1939
CAN 2	• ISO 15765-4 • ISO 14230-4 (Keyword Protocol 2000) • ISO 9141-2 (Asian, European, Chrysler vehicles) • SAE J1850 VPW (GM Vehicles) • SAE J1850 PWM (Ford Vehicles) • ISO 15765 • ISO 11898 (raw CAN) • GMLAN Single Wire CAN (GMW3089) • Ford Medium Speed CAN (MS CAN) • SAE J1939 bus interface
4G Cellular	4G/LTE Cellular with SIM card
Power	
	• Automotive 12 V (13.6 V) Continuous Input • Additional 12 V input to transition to/from low power mode. • External Power Button. • 0.12 Watts in Low Power Mode • Power circuit needs to be designed to allow for wake on ACC from bus.

Table 5-3. Single Board Computer Features (Continued)

OS Support	
Linux	Ubuntu
Environment Specifications	
SAE J1211	-40 C to 85 C, Shock and Vibe
Electromagnetic	SAE J1113, including procedures -2, -4, -11, -13, -21, -22, -26, -27, 41, 42j.
Dimensions (L x W x H) inches	11 x 8.5 x 5.5 (8 x 4 x 2)
Indicators / LED Drivers	
Isolated Analog/Digital inputs and outputs	• 18 100mA variable drivers (8 bit PWM) • 2 12V Contact closure inputs • 2 analog inputs 0-5V 10 bit • 2 analog outputs 0-5V 10 bit • Header
Storage	
M.2	M.2 connection for SSD
Audio	
Headphone	Yes
Microphone	Analog MIC
Amplifier	2W Audio Amplifier
Connectivity	
I2C	X3
SPI	x1 (via J15)
UART	x2 (RS-232). x1 RS232/RS485. More Available via J15
SD / MMC	x1 microSD
USB	USB 2.0: 3x Host, 1x OTG
RTC	Yes
JTAG	Yes
Other	
GNSS	NEO-7P
DSRC	THEO-P1
Real Time Clock	

Source: Battelle

5.3.1.1.2 Cellular Modem

The cellular modem selected for this fielding will be the UBlox TOBY-L2 series LTE/HSPA+/GPRS module. The cellular modem will plugin to the SBC using a standard Mini-PCI Express connector. Details are provided in Table 5-4.

Table 5-4. Cellular Modem

Source of Supply	Part Number	Link to Datasheet
u-blox	TOBY-L201	https://www.u-blox.com/en/product/toby-l2-series

Source: Battelle

5.3.1.1.3 Data Storage

The data storage solution selected for this fielding will be the Samsung 850 EVO MZ-N5E250BW - solid state drive - 250 GB - SATA 6Gb/s. The drive will plugin to an M.2 connector on the SBC. Details are provided in Table 5-5.

Table 5-5. Data Storage

Source of Supply	Part Number	Link to Datasheet
Amazon.com	Samsung 850 EVO MZ-N5E250BW - solid state drive - 250 GB - SATA 6Gb/s	http://www.samsung.com/us/computing/memory-storage/solid-state-drives/ssd-850-evo-m-2-250gb-mz-n5e250bw/

Source: Battelle

5.3.1.1.4 CCP Connectors and Ports

The CCP will implement a standard set of connector interfaces for communications with peripherals and with the host platform. The CCP connectors are summarized in Table 5-6.

Table 5-6. Common Computing Platform Connector Assignments

Connector Reference Designator	Connector Type	Connector Port Assignment
J4	HEADER 2mm PITCH 20-PIN, RT ANGLE,W/WELD TAB	Connection to SBC CAN ports (OBDII, J1939, J1708)
J5	CONN, 10POS, 2mm PITCH, RT ANGLE	Connection to RS232 port of SBC
J12	HDR, 16 PIN, 100 PITCH, SMT	Connection to Audio port of SBC
J13	HDR, 16 PIN, 100 PITCH, SMT	General purpose I/O
J15	Connector, 4PIN,RT	Power for CCP, Connection to input Power Supply
J16	Connector, 4PIN, SHROUDED HEADER, 2mm PITCH,RT ANGEL	Power for Monitor,
J19	HEADER, WIRE-TO-BOARD, 40 Pin, 2mm PITCH, DUAL ROW, RT ANGLE	Connection to General Purpose LED Input/output signals on SBC
DSRC RF1	Fakra Plug Type Z (5021)	RF Connection to DSRC Radio
DSRC RF2	Fakra Plug Type Z (5021)	RF Connection to DSRC Radio
GNSS RF	Fakra Plug Type C (5005)	RF Connection to GNSS Radio
Cellular RF	Fakra Plug Type D (4004)	RF Connection to Cellular Radio
ETH 1,2	CONN MAGJACK 2PORT 1000 BASE-T	Connection to Ethernet port of SBC
ETH 3	1 Port RJ45 with USB A, Dual Magjack Connector Through Hole “RJMG2310228A0ER“	Connection to Ethernet port of SBC
HDMI	CONNECTOR, RT. ANGLE, MINI HDMI, SMT	Connection to SBC Video Output

Table 5-6. Common Computing Platform Connector Assignments (Continued)

Connector Reference Designator	Connector Type	Connector Port Assignment
USB 1,2	1 Port RJ45 with USB A, Dual Magjack Connector Through Hole “RJMG2310228A0ER“	Connection to USB port of SBC
USB3	USB TYPE A UP-RIGHT CONNECTOR	Connection to USB port to SBC
USB 4	MICRO USB A/B TYPE RT. ANGLE RECEPTACLE	Connection to USB port to SBC
Audio	3.5mm Audio Jack	Connection to Audio port of SBC

Source: Battelle

Additionally, the CCP will employ Bluetooth and Wi-Fi wireless connections.

5.3.1.2 Software

The software provided by the Common Computing Platform will consist primarily of an operating system (OS) and the associated drivers needed to interface with the hardware components. The OS selected for the CCP is Linux due to its open source nature and easy customization to allow a flexible platform for product development.

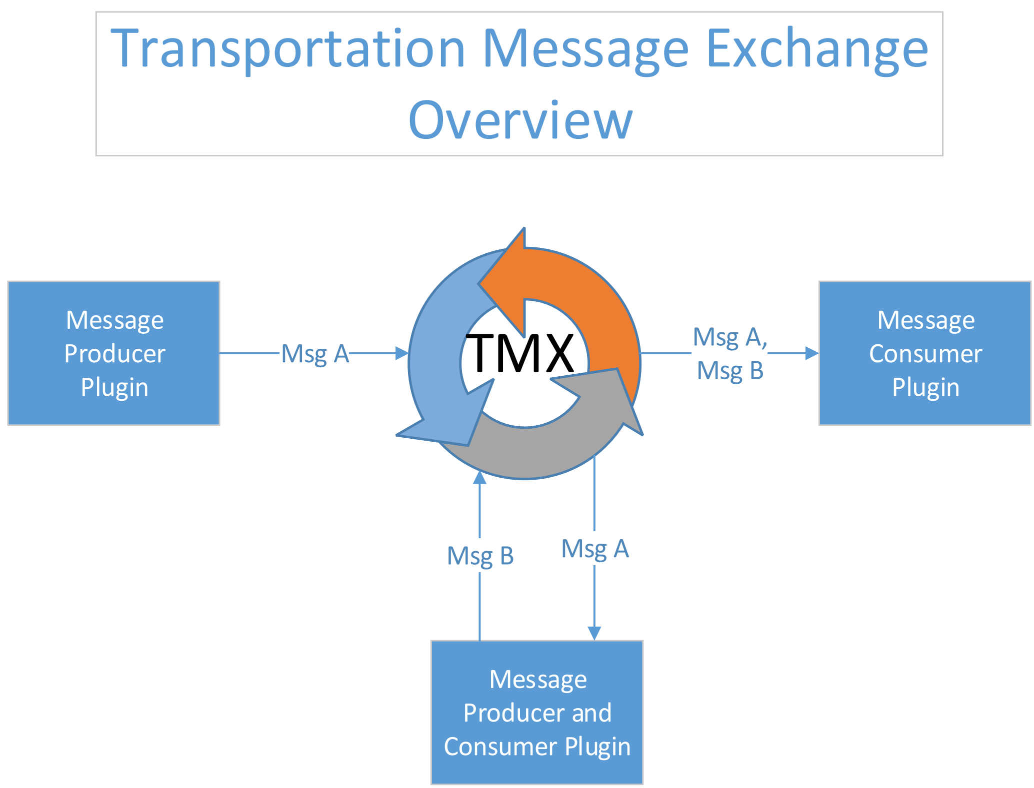
In addition to the OS layer, Battelle has been developing a common messaging framework for use across all connected vehicle projects which allows for code re-use. This common framework (called TMX) is described in greater detail below.

5.3.1.2.1 Linux

The operating system running on the Common Computing Platform will be the most recent version of the Linux Ubuntu distribution with Long Term Support (LTS). At this time, that version is 14.04. This version is built on the 3.14.52 Linux kernel.

5.3.1.2.2 Transportation Message Exchange

A common software platform is planned to be used in each of the TSPW Subsystems. In both the In-Vehicle and Roadside Subsystems, the software developed for this product will be designed around the use of the TMX platform. The TMX platform was originally developed by Battelle for use on the IVP project and has since been refined for use in other projects. TMX is planned to be used in multiple other projects in addition to the planned use in TSPW. A high level overview diagram is provided below in Figure 5-3.



Source: Battelle

Figure 5-3. Transportation Message Exchange Overview

A system developed using the TMX platform is composed of a set of loosely coupled plugins all communicating through the TMX hub. Each plugin is responsible for registering with the TMX hub. As part of this registration, the plugin will notify the hub which messages it will produce and pass to the hub. In addition, the plugin will provide which messages it would like to receive. Plugins can be either message producers, message consumers or both. One key advantage of using the TMX platform as a foundation for building the TSPW system is that as plugins developed by other projects can be leveraged reducing the time of development and testing.

5.3.1.2.3 DSRC Radio Stack

The DSRC Radio transmits and receives messages in accordance to IEEE 802.11p and 1609.2 standards and the J2735 message standards. The TSPW system supports the following messages shown in Table 5-7 and Table 5-8.

Table 5-7. DSRC Received Messages

Common Message Name	PSID	SAE J2735 message	DSRC Channel	DSRCmsgID
Basic Safety Message	0x20	MSG_BasicSafetyMessage	172	
Personal Safety Message (PSM)	0x27	MSG_PersonalSafetyMessage	172	
Probe Vehicle Data	0x84	MSG_ProbeVehicleData	172	0x8D
MAP message (aka GID)	0xBFF0	MSG_MapData	172	0x87

Source: Battelle

Table 5-8. DSRC Transmitted Messages

Common Message Name	PSID	SAE J2735 Message	DSRC Channel
Basic Safety Message	0x20	MSG_BasicSafetyMessage	172
Personal Safety Message	0x27	MSG_PersonalSafetyMessage	172
MAP message	0xBFF0	MSG_MapData	172
Probe Vehicle Data	0x84	MSG_ProbeVehicleData	172

Source: Battelle

The BSM and PSM are transmitted approximately every 100 milliseconds. The MAP and PVD are transmitted approximately every second.

5.3.2 Transit Vehicle In-Vehicle Subsystem

The In-Vehicle Subsystem is a collection of hardware and software with the purpose of providing the transit vehicle driver enhanced safety notifications designed to improve pedestrian and passenger safety.

5.3.2.1 Transit Fleet Summary

Four transit stops and 80 to 100 transit vehicles will be equipped with pedestrian detection equipment in support of the TSPW application. Due to the volume of routes and buses the development team and GCRTA have selected routes with dedicated transit vehicles to ensure the quality and quantity of data collected is sufficient for evaluation purposes. The transit vehicles selected for integration with the TSPW program are summarized in Table 5-9.

Table 5-9. Transit Vehicle Type and Route Serviced

Route (s)	Transit Vehicle Type	Manufacturer	Total #
Cleveland State Line (55)	Diesel Artic Cleveland State Brand	New Flyer	16
22 and 26	Diesel Artic with no branding	New Flyer	23
HealthLine	Hybrid Artic HealthLine Brand	New Flyer	21
HealthLine	Diesel Artic HealthLine Brand	New Flyer	3
B-Line and E-Line	Gillig 35-ft. Trolley (on order)	Gillig	12
General Use	Gillig 40-Ft	Gillig	15
TOTAL			91

Source: GCRTA/Battelle

The Cleveland State Line (also referred to as Route 55) provides service using 16 standard diesel New Flyer 60 foot articulated buses, which are specially branded for Cleveland State University. Both routes 22 and 26 provide service using 23 standard diesel New Flyer 60 foot articulated buses. The HealthLine provides service along Euclid Avenue using 24 New Flyer 60 foot articulated buses; 21 which are hybrid-electric buses and 3 that are standard diesel buses. The B-Line and E-Line provide service using Gillig 45 foot trolleys. Figure 5-4 through Figure 5-6 provide photos of the different bus types that service each route.

Source: [Flickr]

Figure 5-4. New Flyer 60 Foot Articulated Bus Used for Cleveland State Line 55

Source: [GCRTA]

Figure 5-5. New Flyer 60 Foot Articulated Bus Used for HealthLine

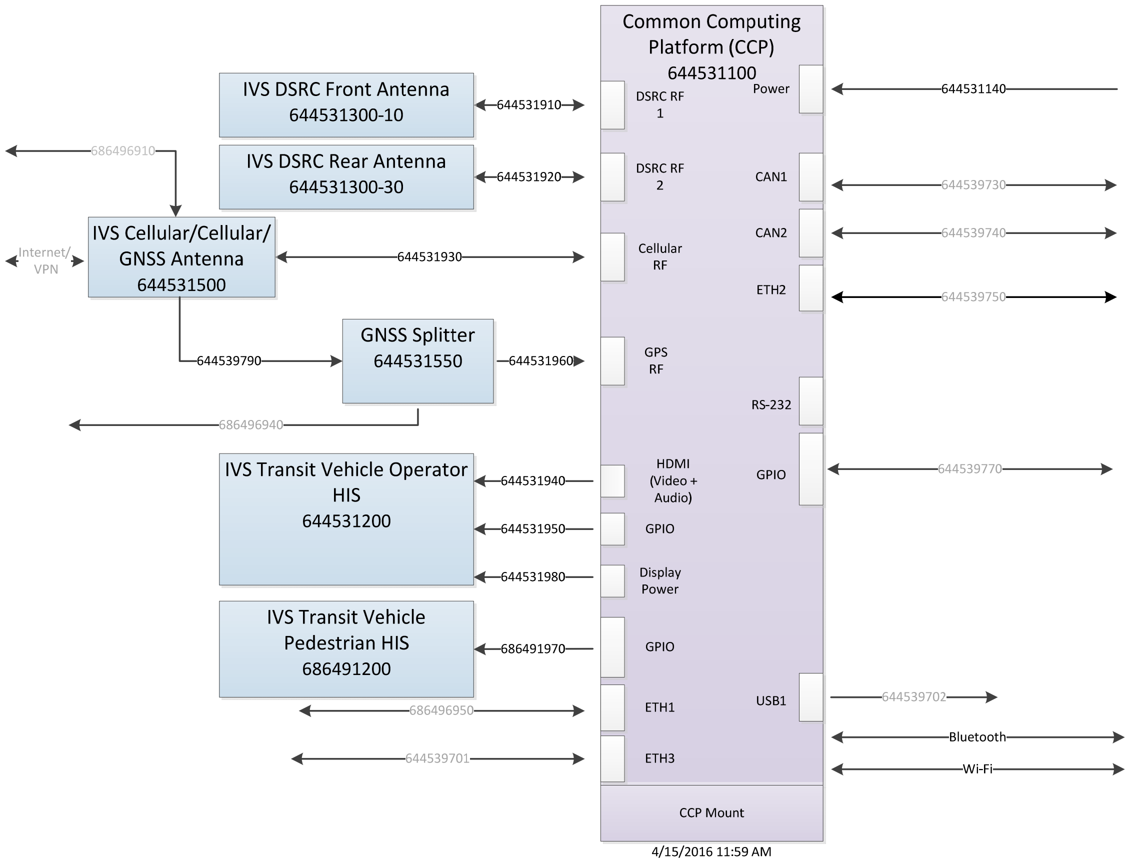
Source: Cleveland Plain Dealer

Figure 5-6. Gillig Trolley Used for B-Line and E-Line

Additional details on the routes and transit stops is provided in section 5.3.3.1 of this document.

5.3.2.2 Hardware

The hardware for the In-Vehicle Subsystem will consist of a CCP, Transit Vehicle Operator Human Interface Subsystem (TVO-HIS), Transit Vehicle Pedestrian HIS (TVP-HIS) and other support peripherals allowing the IVS to communicate with its host platform and other TSPW subsystems. The components used to implement the IVS are shown in Figure 5-7.



Source: Battelle

Figure 5-7. In-Vehicle Subsystem Block Diagram

Each subsystem, assembly and component of the TSPW system will be assigned a part number. These part numbers allow for unique identification during configuration control, assembly and testing activities during the development, testing and fielding lifecycles. The components that make up the TSPW In-Vehicle Subsystem, including the internal part numbers are summarized in Table 5-10 with more details provided in the subsections below.

Table 5-10. In-Vehicle Subsystem Components

Part Number	Item Description
644531100	Common Computing Platform with Mount
644531200	IVS Transit Vehicle Operator HIS
644531300-10	IVS DSRC Front Antenna
644531300-30	IVS DSRC Rear Antenna
644531500	IVS Cellular/Cellular/GNSS Antenna
644531550	GNSS Splitter
644531910	DSRC Front Antenna Coax
644531920	DSRC Rear Antenna Coax
644531930	Cellular Antenna Coax
644531940	IVS Transit Vehicle Operator HIS HDMI Cable
644531950	IVS Transit Vehicle Operator HIS LED Cable
644531960	IVS to GNSS Splitter Coax
644531980	IVS to Transit Vehicle Operator HIS Power Cable
686491200	IVS Transit Vehicle Pedestrian HIS
686491970	IVS to Transit Vehicle Pedestrian HIS Cable

Source: Battelle

Additional Cabling will also be required to interface the IVS with the Transit Vehicle. That cabling is summarized in Table 5-11 and in more detail in the subsections below.

Table 5-11. In Vehicle Subsystem Interface Cables to Host Platform

Part Number	Item Description
644539730	IVS CCP Transit Vehicle J1939 Databus 1 Cable
644539740	IVS CCP Transit Vehicle J1939 Databus 2 Cable
644539750	IVS CCP Apollo Interface Cable
644539790	IVS GNSS Splitter to IVS GNSS Antenna

Source: Battelle

5.3.2.2.1 644531100 Common Computing Platform with Mount

The Common Computing Platform is described in detail in section 5.3.1 of this document

5.3.2.2.2 644531200 IVS Transit Vehicle Operator HIS

The IVS Transit Vehicle Operator HIS (TVO-HIS) provides the Human Interface to the TSPW system. The TVO-HIS provides all alerts intended for the Transit Vehicle Operator. The TSPW system will leverage the TVO-HIS deployed as part of the E-TRP base platform. Details are provided in Table 5-12

Table 5-12. Transit Vehicle Operator HIS

Source of Supply	Part Number	Link to Datasheet
TRU-VU	SRM-10.4	http://www.tru-vumonitors.com/images/10.4_Sunlight_Readable_LCD_Monitor.pdf

Source: Battelle

5.3.2.2.3 644531300-10 and 644531300-30 IVS DSRC Front and Rear Antennas

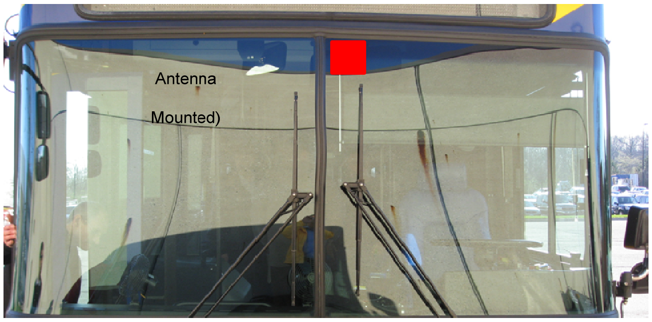
For the TSPW deployment, the transit vehicle must communicate with DSRC enabled transit stops. Based on the experienced gained during the prior TRP project, a DSRC antenna that is mounted on the inside windshield of the transit vehicle will be used. The antenna previously used is summarized in Table 5-13.

Table 5-13. IVS DSRC Front Antenna

Source of Supply	Part Number	Link to Datasheet
Mobilemark.com	IW-5900/1575	http://www.mobilemark.com/product/iw-59001575/

Source: Battelle

A visualization of the installation for the DSRC Antenna is shown in Figure 5-8.



Source: Battelle

Figure 5-8. DSRC Antenna Mounting Location

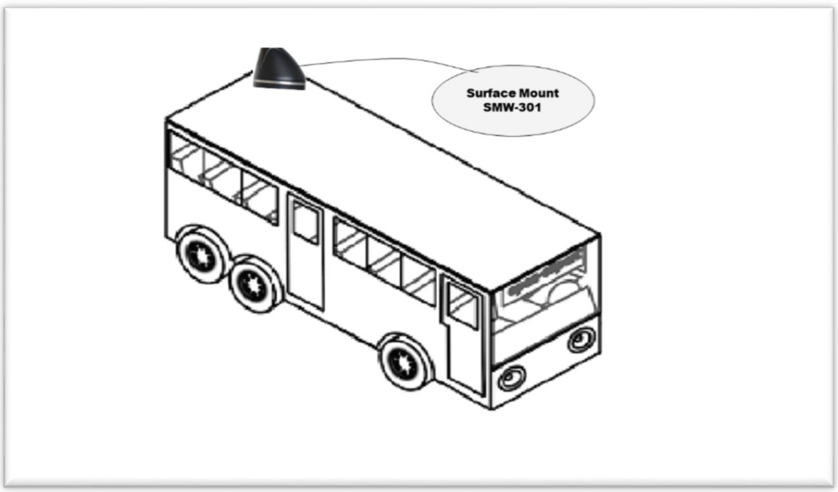
The TSPW application also requires DSRC communication between the transit vehicle and another DSRC-enabled vehicle approaching from behind. Given the expected directionality of that approaching vehicle, an additional antenna will be required on the rear of the transit vehicle. The antenna to be placed at the rear of the transit vehicle is described in Table 5-14.

Table 5-14. IVS DSRC Rear Antenna

Source of Supply	Part Number	Link to Datasheet
Mobilemark.com	SMW-301	http://www.mobilemark.com/product/surface-mount-multiband-800-2700-2400-2500-mhz-wifi-wimax-antenna-for-gps-applications/

Source: Battelle

A visualization of the installation for the DSRC Antenna is shown in Figure 5-9.



Source: Battelle

Figure 5-9. DSRC Rear Antenna Position

5.3.2.2.4 644531500 IVS Cellular/Cellular/ WIFI/ WIFI/GNSS Antenna

The In-Vehicle Subsystem will be regularly communicating with the Cloud Data Management Subsystem and Remote Administration Access Point via cellular communications. A cellular/WIFI antenna will be deployed on the transit vehicle to enable this communications channel. The antenna to be used to receive cellular data also contains two other antenna elements. The In-Vehicle Data Acquisition System (DAS) will use the other cellular connection for this antenna. This antenna package also houses a GNSS antenna which will be shared between the IVS and the In Vehicle DAS. It also has a tow WIFI signal.

The antenna to be used is described in Table 5-15 below.

Table 5-15. IVS Cellular/Cellular/GNSS Antenna

Source of Supply	Part Number	Link to Datasheet
Mobile Mark	LTM502	http://www.mobilemark.com/product/ltm502-2xglobal-cellular-2xwifi-gps/

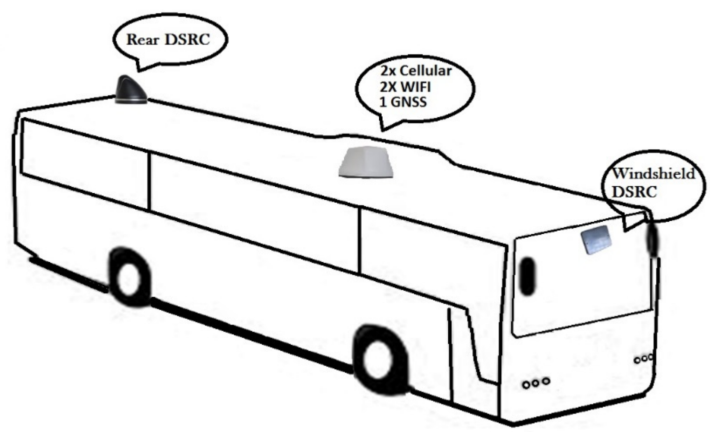
Source: Battelle

A visualization of the installation for the Cellular Antenna is shown in Figure 5-10.

Figure 5-10. IVS Cellular/Cellular/GNSS Antenna

Source: Battelle

A visualization of the installation for the Cellular, GNSS and DSRC antennas on the bus is shown in Figure 5-11.



Source: Battelle

Figure 5-11. Antenna Positions on Bus

5.3.2.2.5 644531550 GNSS Splitter

The IVS Concept of Operation requires the Transit Vehicle to be aware of its position with reference to the transit stop as well as with reference to POVS. The IVS also requires an accurate time source both for logging purposes as well as to enable DSRC communications. There is also a requirement to host a DAS on the transit vehicle which requires an accurate time source. In order to reduce the number of antennas deployed on host vehicle, the TSPW system plans to share a GNSS antenna between the IVS and DAS. In order to share the signal, a GNSS splitter must be used. Table 5-16 shows a GNSS splitter likely to be used.

Table 5-16. GNSS Splitter

Source of Supply	Part Number	Link to Datasheet
In Stock wireless component	GPS200	http://www.instockwireless.com/gps-antenna-signal-splitter-typeN-gps200.htm

Source: Battelle

A visualization of the GPS splitter is shown in Figure 5-12.

Source: instockwireless.com

Figure 5-12. GNSS Splitter

5.3.2.2.6 644531910 DSRC Front Antenna Coax

The intended DSRC Antenna will require an extension cable to reach from its mounting location back to the IVS-CCP. The cable needs an adapter with a Fakra connection, as described in Table 5-17.

Table 5-17. DSRC Front Antenna Extension Cable

Source of Supply	Part Number	Link to Datasheet
Mobile Mark	SMA to Fakra Z Cable 15 ft. Length Using LMR-195Coax	http://www.mobilemark.com/

Source: Battelle

5.3.2.2.7 644531920 DSRC Rear Antenna Coax

The intended DSRC Antenna will require an extension cable to reach from its mounting location back to the IVS-CCP. The cable needs an adapter with a Fakra connection, as described in Table 5-18.

Table 5-18. DSRC Rear Antenna Extension Cable

Source of Supply	Part Number	Link to Datasheet
RSP	NM to SMA Female Cable 80 ft. Length Using LMR-400 Coax	http://www.rspsupply.com/
RSP	NF-Fakra Z Adapter	http://www.rspsupply.com/

Source: Battelle

5.3.2.2.8 644531930 Cellular Antenna Coax

The intended Cellular Antenna will require an extension cable to reach from its mounting location back to the IVS-CCP. The cable needs an adapter with a Fakra connection, as described in Table 5-19.

Table 5-19. Cellular Antenna Extension Cable

Source of Supply	Part Number	Link to Datasheet
Mobile Mark	Fakra to SMA Female Cable 15 ft. Length Using LMR-195 Coax	http://www.mobilemark.com/

Source: Battelle

5.3.2.2.9 644531940 IVS Transit Vehicle Operator HIS HDMI Cable

The Transit Vehicle Operator HIS will require a video display cable to interface with the CCP HDMI Type A connector. Once the final length is determined a cable will be specified to the correct length similar to the item described in Table 5-20.

Table 5-20. Example HDMI Cable

Source of Supply	Part Number	Link to Datasheet
Cables To Go	25FT PRO SERIES HDMI® CABLE – PLENUM CMP-RATED	http://www.cablestogo.com/product/41191/25ft-pro-series-hdmi-cable-plenum-cmp-rated

Source: Battelle

5.3.2.2.10 644531960 IVS to GNSS Splitter Coax

In order to integrate the GNSS Splitter into the IVS a patch cable will be required. The cable will need an adapter with Fakra connection. The cable is described in Table 5-21.

Table 5-21. GNSS Patch Cable to IVS-CCP

Source of Supply	Part Number	Link to Datasheet
RSP	SMA Female to Fakra C adapter	http://www.rspsupply.com/

Source: Battelle

5.3.2.2.11 644531980 IVS to Transit Vehicle Operator HIS Power Cable

The TVO-HIS will require power to operate. In order to manage power usage during both operational and non-operational modes, the power to the TVO-HIS will need to be managed by the IVS. The IVS to Transit Vehicle Operator HIS Power Cable will supply power from the IVS to the TVO-HIS. Once the TVO-HIS design is finalized this cable design will be finalized as well.

5.3.2.2.12 686491200 IVS Transit Vehicle Pedestrian HIS

In addition to providing notifications to the transit vehicle driver, the TSPW system will also provide alerts to pedestrians crossing in front of the transit vehicle under certain circumstances. When the pedestrians are at risk from the approaching DSRC-equipped POV, a warning beacon will signal to pedestrians when it is not safe to cross the street or when they are in imminent danger of an oncoming passenger vehicle. The beacon will be installed externally on the front or left center of the transit bus. It will emit an audible warning through a designated beeping or buzzing sound. The beacon will also emit a visible warning through a high-intensity flashing LED light.

The grey Phannenberg Patrol Series PA 1 sounder will broadcast audible warning to pedestrians in imminent danger in specific circumstances. This sounder has a 100 dB (A) nominal sound pressure level and is capable of producing up to 80 different warning tones at up to 4 different warning stages. The volume is internally controlled in the polycarbonate/ABS blend housing. The PA 1 is UL Type 4/4X and is rated for IP 66 ingress protection and will be surface mounted to the front of the transit vehicle directly beneath the windshield. In parallel with distributing an audible warning, the transit vehicle pedestrian HIS will also emit a visual warning using a strobe light. The VTX609A Whelen Vertex Light has a small 1" circular profile and will be flush mounted on the bottom of the sounder. It will flash rapidly when the right circumstances permit to give a warning to pedestrians in imminent danger. The strobe light and the sounder are both 12VDC and will work in synchronization to create a dual patterned warning. The VTX609A is an amber colored strobe light that has 25 programmable flash patterns. The light is fully enclosed and is built for to withstand moisture and vibration. In addition to warnings given, pedestrians will be informed as to why they were given the warning.

Source: Moflash

Figure 5-13. Transit Vehicle Pedestrian HIS

Source: Battelle/Moflash

Figure 5-14. In situ representation of the Transit Vehicle Pedestrian HIS installation

5.3.2.2.13 686491970 IVS to Transit Vehicle Pedestrian HIS Cable

The IVS-CCP will interface to the Transit Vehicle Pedestrian HIS via an electronic cable to activate the visual and audible warning.

5.3.2.2.14 644539730 IVS CCP Transit Vehicle J1939 Databus 1 Cable

The IVS-CCP will need to interface with the J1939 databus within the transit vehicle. Figure 5-15 show the splitter for the J1939 connector as well as the connector type we will be using. A15ft long cable will be built with this connector.

Source: Pransystems and Vanline

Figure 5-15: J1939 splitter "LEFT". J1939 Connector "RIGHT

5.3.2.2.15 644539740 IVS CCP Transit Vehicle J1939 Databus 2 Cable

While some transit vehicles have multiple databuses, the target vehicles selected from the GCRTA fleet do not, so an additional cable will not be required.

5.3.2.2.16 644539750 IVS CCP Apollo Interface Cable

While not specifically used for the TSPW project, the IVS-CCP will interface with the Apollo camera system integrated on the transit vehicle. The interface to the Apollo system is by RJ45 Ethernet. Once the final length is determined a cable will be specified to the correct length similar to the item described in Table 5-22.

Table 5-22. Example Ethernet Patch Cable to Apollo

Source of Supply	Part Number	Link to Datasheet
Cables To Go	10FT CAT5E SNAGLESS UNSHIELDED (UTP) ETHERNET NETWORK PATCH CABLE	http://www.cablestogo.com/product/15199/10ft-cat5e-snagless-unshielded-utp-ethernet-network-patch-cable-gray

Source: Battelle

5.3.2.2.17 644539790 GNSS Splitter to IVS Cellular/Cellular/GNSS Antenna

The GNSS antenna will need to be connected to the GNSS splitter to be split between the IVS and the In-Vehicle DAS. The cable specified in Table 5-23 will be used.

Table 5-23. GNSS Splitter to IVS GNSS Antenna

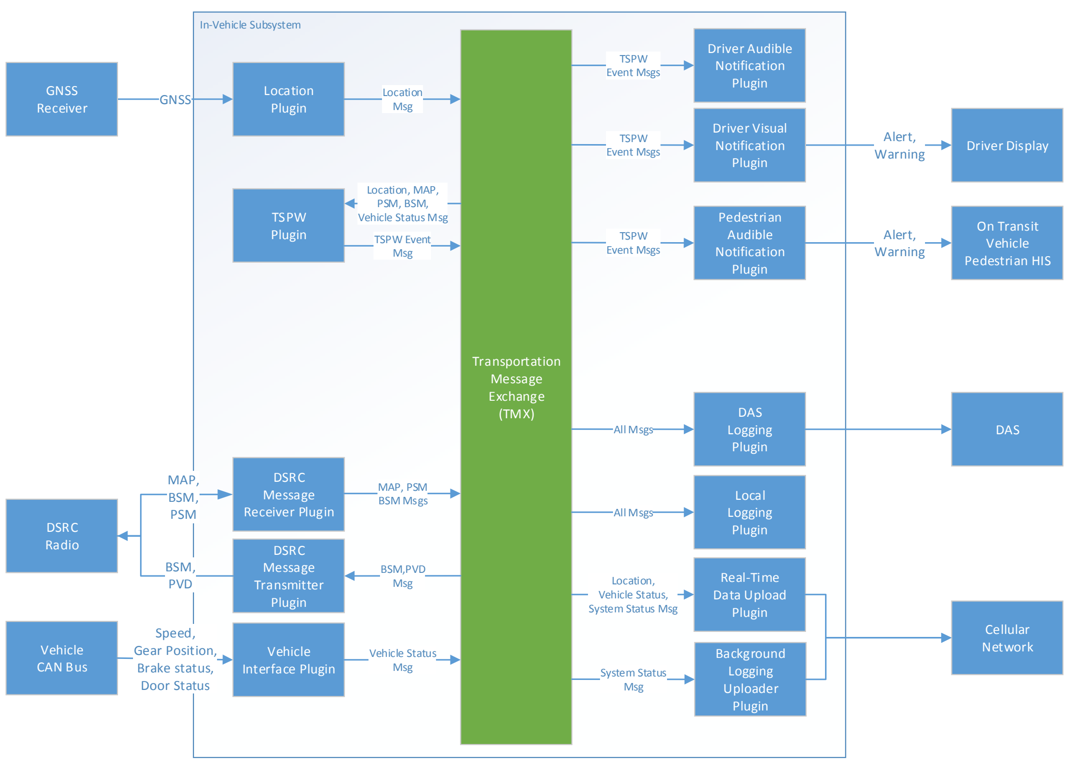
Source of Supply	Part Number	Link to Datasheet
RSP	SMA Female to N-male 15ft Length Using LMR-240 Coax	http://www.rspsupply.com/

Source: Battelle

5.3.2.3 Software

The software for the In-Vehicle Subsystem is designed to implement the two primary functions needed to be performed on the transit vehicle – notifying the transit driver and pedestrians in front of the transit vehicle of TSPW events. Supporting this primary function, will be a set of support features providing the necessary information such as location, vehicle status, roadside information and data logging.

This subsystem software will be designed around the TMX software platform. As a result, the logic required to perform the needed functions will be developed as a set of plugins. Each plugin will perform a discreet function and have a single responsibility. The diagram below in Figure 5-16, illustrates the various plugins and how they interact with the rest of the system.



Source: Battelle

Figure 5-16. In-Vehicle Subsystem Software Design

At the core of the TSPW In-Vehicle software subsystem will be TSPW plugin which will implement the primary functions of the in-vehicle subsystem and generate the TSPW Event messages. A host of support plugins are also included in the subsystem to both act on the TSPW Event messages as well as provide the necessary support data for the TSPW plugin. Table 5-24 below provides a brief description of each plugin and its associated data exchange.

Table 5-24. Plugins with Associated Data Exchange

Plugin	Description	Plugin Input	Plugin Output
Location	This plugin will interact with the GNSS hardware and provide the current location and time information to the rest of the system.	Output stream from GNSS hardware	Location Message
TSPW	The TSPW plugin will monitor the data available and make the determination if an alert should be presented to the transit driver, pedestrian in front of the transit vehicle or both.	Location Message MAP Message BSM Message PSM Message Vehicle Status Message	TSPW Event Message
DSRC Message Receiver	The DSRC Message Receiver plugin is responsible for taking messages received via the DSRC radio and relaying those to the rest of the system.	Messages from DSRC Radio	PSM Message MAP Message BSM Message
DSRC Message Transmitter	The DSRC Message Transmitter plugin is responsible for taking internal messages flagged for transmission and ensuring they are sent out via the DSRC radio.	BSM Message PVD Message	Input to DSRC Radio
Vehicle Interface	The Vehicle Interface plugin will handle the filtering and formatting of the data received from the existing vehicle communications network.	Data from vehicle CAN Bus	Vehicle Status Message
Driver Audible Notification	The Driver Audible Notification plugin will be responsible for alerting the transit driver in an audible fashion through an external speaker.	TSPW Event Message	Suitable audio output through system speakers
Driver Visual Notification	The Driver Visual Notification plugin will control the visual display of alerts to the transit driver.	TSPW Event Message	Events shown on driver display
Pedestrian Audible Notification	The Pedestrian Audible Notification plugin will serve as the interface between the IVS-CCP and Transit Vehicle Pedestrian HIS (TVP-HIS)	TSPW Event Message	Suitable audible output through external TVP-HIS
DAS Logging	The DAS Logging plugin will monitor the system and provide the appropriate information to the DAS.	TSPW Event Message System Status Message	Data logged to DAS

Table 5-24. Plugins with Associated Data Exchange (Continued)

Plugin	Description	Plugin Input	Plugin Output
Local Logging	The Local Logging plugin will monitor the state of the system and record the state information to the local system for later review.	TSPW Event Message Location Message System Status Message	Data logged to local filesystem
Real-Time Data Uploader	The Real-Time Data Uploader plugin will be responsible for the transfer of data from the system to the Cloud Data Management Subsystem during system operation.	Location Message Vehicle Status Message System Status Message	Information sent to Cloud Data Management Subsystem
Background Logging Uploader	The Background Logging Uploader plugin will manage the uploading of collected log data by the system during operation and transfer that content to the Cloud Data Management Subsystem in the background when time and system resources are available.	System Status Message	Log data sent to Cloud Data Management Subsystem
System Monitor	The System Monitor plugin will track the status of the various hardware, firmware and operating system components required for the proper operation of the system.	Input from various hardware and OS level components	System Status Message

Source: Battelle

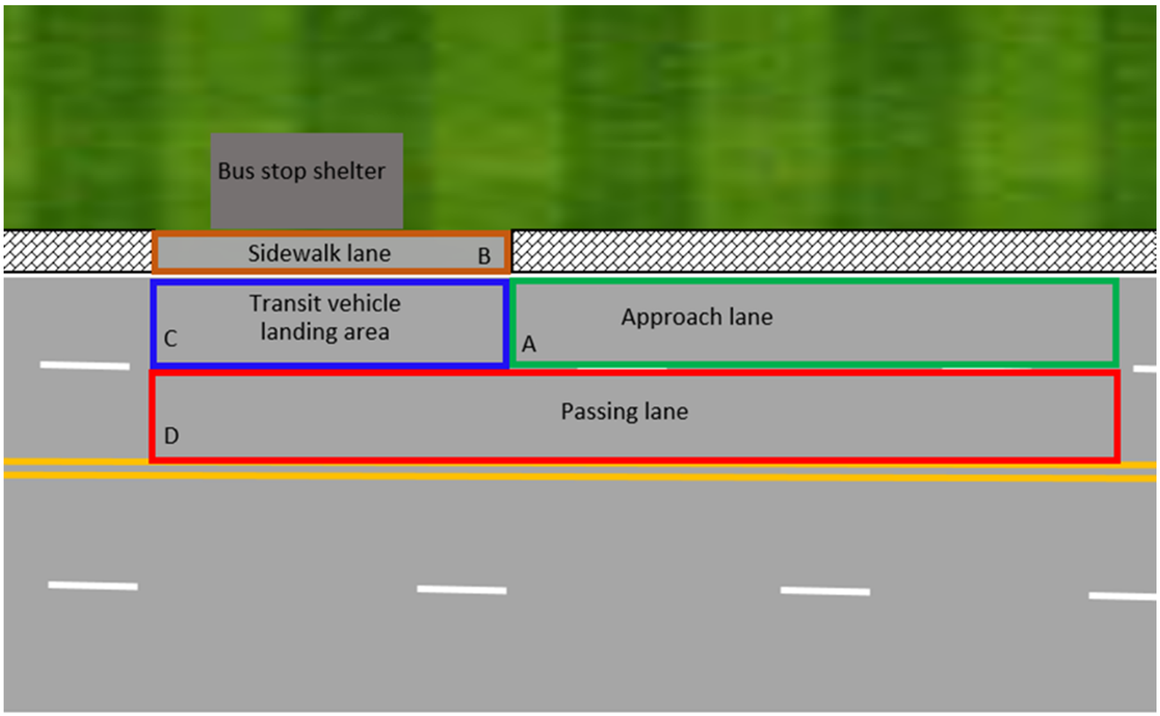
Additional specific details regarding the TSPW application on the In-Vehicle Subsystem are detailed below.

5.3.2.3.1 Transit Bus Stop Pedestrian Warning Application

The TSPW application operating on the In-Vehicle Subsystem is responsible for notifying the transit driver and in special circumstances a pedestrian located in front of the transit vehicle when they are potentially at risk from an approaching POVS passing to the left of the transit vehicle. The TSPW application plugin is supported by a set of plugins designed to provide support in the TMX platform. The Location plugin is required to provide geospatial coordinate information to the system. The DSRC Message Receiver plugin acts as the interface to the DSRC Radio and converts the received PSM and MAP messages into a common format used by the TMX platform. The Vehicle Interface plugin provides the system with the vehicle speed, gear position and brake status as read from the vehicle CAN Bus. There are two plugins responsible for driver notification. One processes any TSPW Event messages and alerts the transit driver using an audible message. The second is responsible for taking the TSPW Event Message and giving the driver a visual notification. Finally, the Pedestrian Audible Notification Plugin will also respond to issued TSPW Event Messages and when appropriate, alert vulnerable pedestrians when they are at risk from a detected POVS behind or beside the transit vehicle.

The TSPW application plugin is always actively monitoring the received DSRC MAP messages. The MAP message defines areas near the transit stop where the transit vehicle is either approaching, passing or within the Transit Vehicle Landing Area (see Areas A, C, and D within Figure 5-17). The

MAP also contains the location of a sidewalk lane (Area B) where pedestrians may be identified by the PDS. Based on the receipt of the MAP message from the transit stop RSE and the current vehicle location provided by the Location plugin, the TSPW application plugin can determine the proximity of the transit vehicle to the transit stop. The application will identify the approach lane, and continue to monitor the transit vehicle, detecting when it has entered the defined lane. The action of entering the approach lane will trigger the application to enter a more active monitoring phase. The first action taken by the application will be to begin announcing its approach to the transit stop by sending a Probe Vehicle Data (PVD) message containing the transit vehicle identification and route number. This message will be sent at a rate of once per second until the transit vehicle has left the Transit Vehicle Landing Area.

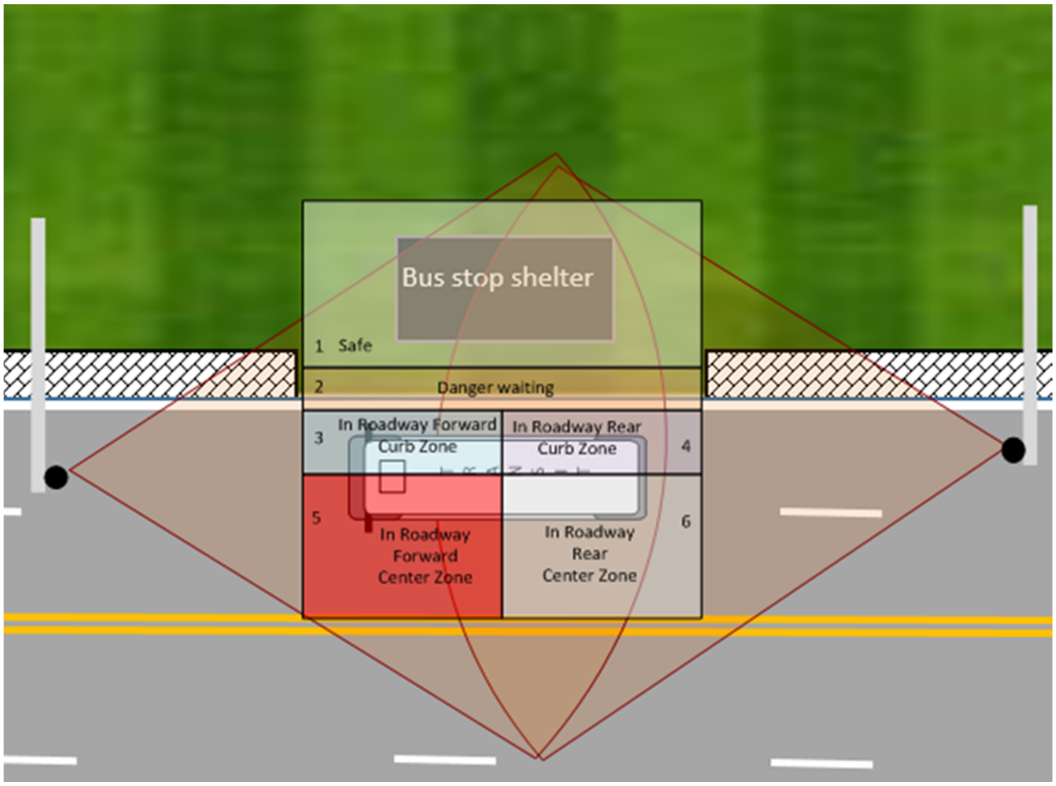


Source: Battelle

Figure 5-17. Illustration of an Example Transit Stop with Identified Vehicle Location Lanes

While the transit vehicle is in the approach lane and the landing area, the TSPW application will be listening for PSM broadcast by the RSE. These PSMs will contain a geographic location which will be used to calculate the pedestrian detection zone (Figure 5-18) indicated as having a pedestrian present. For clarification, the pedestrian detection zones are wholly contained within the Transit Vehicle Landing Area (C) and the Sidewalk Lane (B). Based on the state of these values, the application will make a determination on whether to send a TSPW Event Message and whether to set its value to be an Inform or Warn alert:

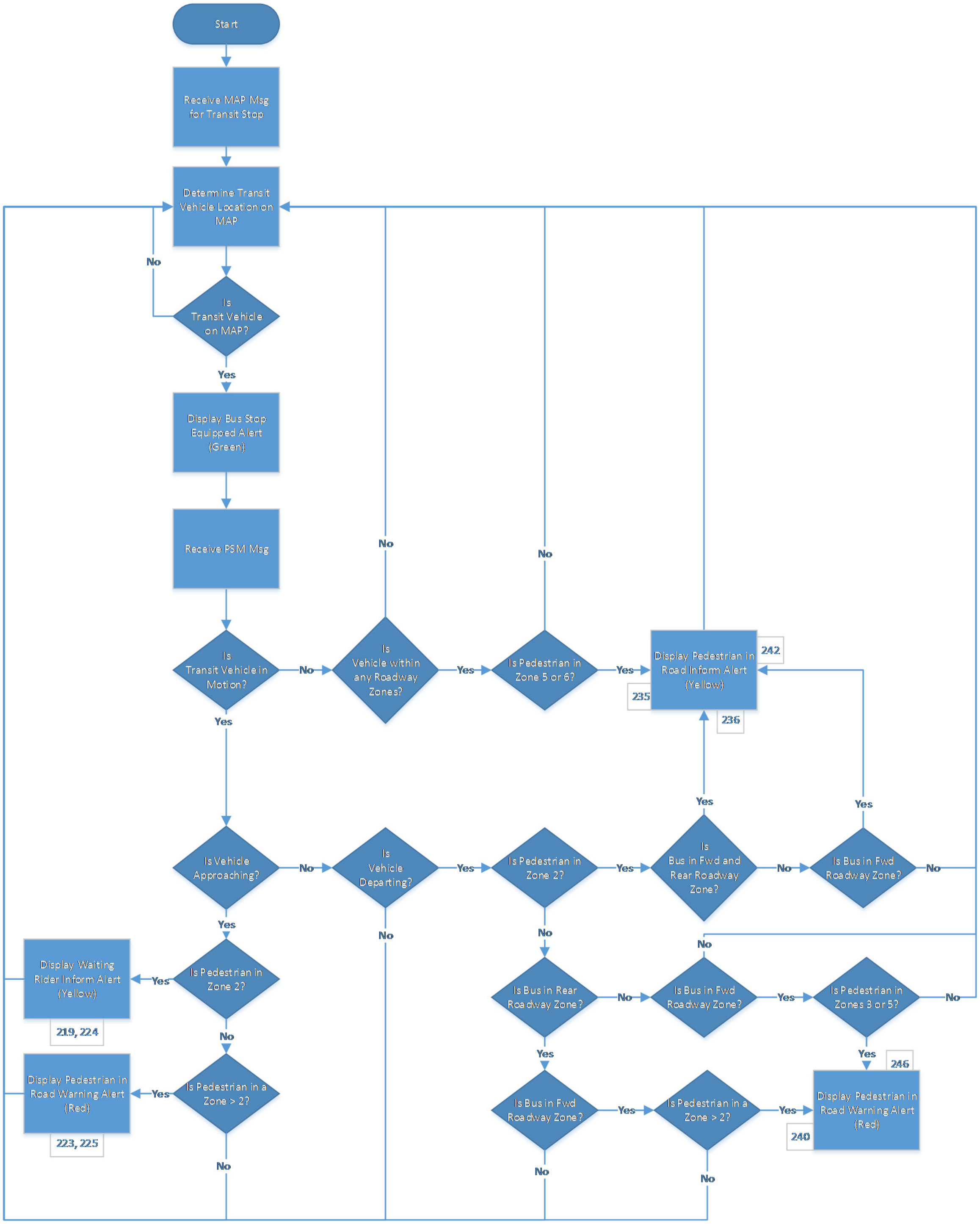
- An "Inform Alert" refers to an indication that a potentially dangerous situation could occur.
- A "Warn Alert" refers to an indication that a dangerous situation is likely to occur.



Source: Battelle

Figure 5-18. Illustration of Example Transit Stop with Pedestrian Detection Zones

The logic flow diagrams below in Figure 5-19 and Figure 5-20 outline in greater detail the decision process regarding whether an alert is issued and if so, at what level. The two diagrams show the logic flow when the vehicle approaches and stops at an instrumented transit stop. These diagrams show the slightly simplified logic flow where an alert from only a single pedestrian detection zone is displayed to the driver. The actual system will support the ability to display alerts for pedestrians detected in any of the five zones simultaneously.

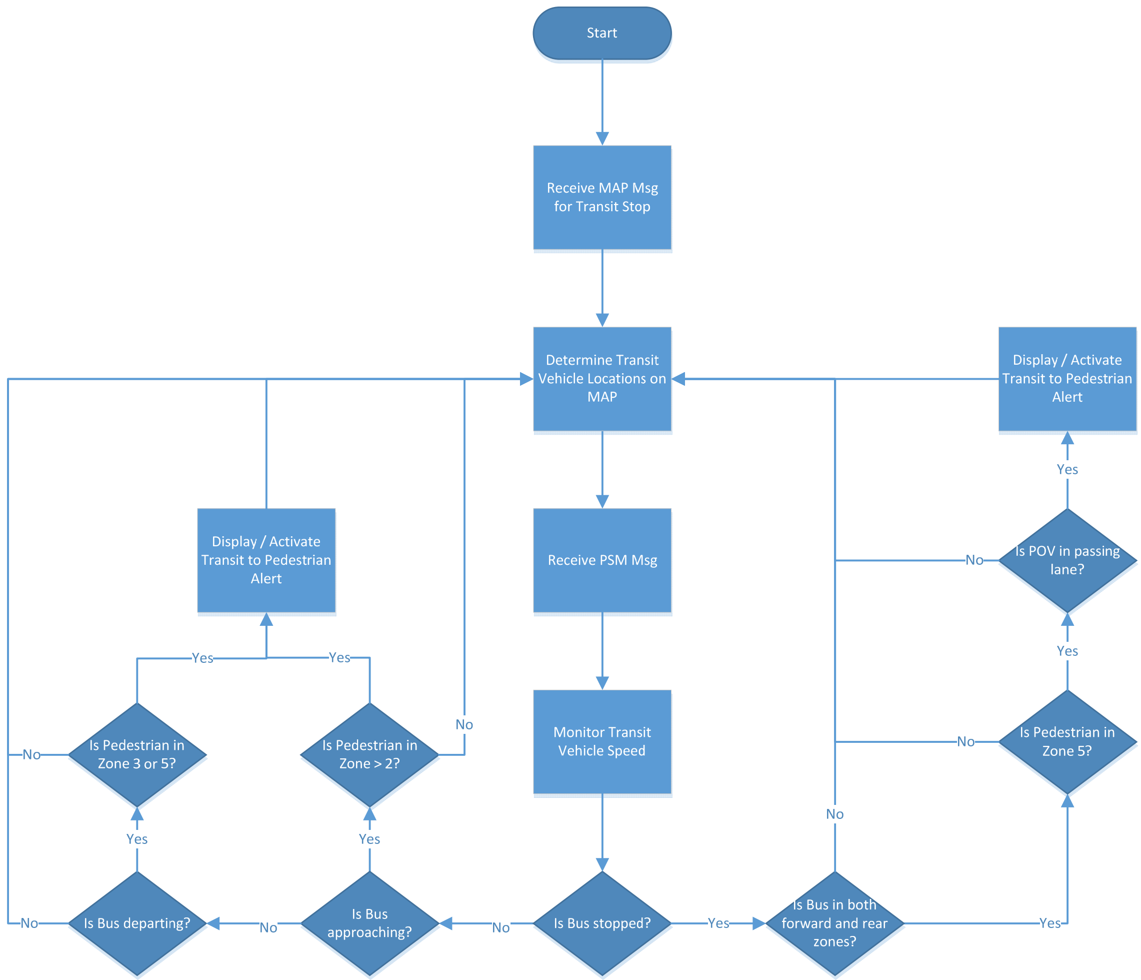


Source: Battelle

Figure 5-19. Logic for Generating the Transit Vehicle Operator TSPW Alerts

In addition to providing notifications to the transit vehicle driver, the TSPW system will also provide alerts to pedestrians crossing in front of the transit vehicle via the Transit Vehicle Pedestrian HIS under certain circumstances. The IVS will monitor the approach of DSRC enabled POVS vehicles.

When the pedestrians are at risk from the approaching vehicle, a notification via equipment mounted on the front of the transit vehicle will be provided.



Source: Battelle

Figure 5-20. Logic for Generating the Pedestrians Alerts from the Transit Vehicle

Finally, to facilitate the notification of pedestrians waiting at the transit stop, the IVS will broadcast messages for the benefit of the transit stop RSE. These messages will contain the position, speed and heading of the transit vehicle as well as provide identifying information about the vehicle and the route it is servicing. This identification information will be used to notify passengers with information about the approaching transit vehicle, providing them information without the need to put themselves at risk at the curbside.

The position information will be provided by broadcasting BSM messages at a rate of 10Hz. Unfortunately for the TSPW application, the BSM does not provide a means of conveying the vehicle identification or route number. To supply this additional information, the IVS will also transmit a PVD message. The PVD has fields available to supply vehicle identification and route number. The PVD messages will be broadcast at a rate of 1 Hz. An example of a PVD message is provided below in Figure 5-21.

```
{
    "timeStamp": "Minute of the Year",
    "probeID": {
        "name": "Route 22;Bus 10092",
        "ownerCode": "GCRTA",
        "id": 1234,
        "vehicleType": "Bus (6)",
        "vehicleClass": "Buses (9228)"
    },
  "startVector": {
      "utcTime": {
          "year": 2016,
          "month": 3,
          "day": 28,
          "hour": 9,
          "minute": 27,
          "second": 35
      },
    "long": -801234,
    "lat": 412345,
    "elevation": 2145,
    "heading": 14400,
    "speed": {
        "transmission": "forwardGears (2)",
        "speed": 50
    }
  },
  "vehicleType": {
      "keyType": "transit-LocalBus (54)"
  }
}
```


Source: Battelle/SAE J2735

Figure 5-21. Example PVD Message

5.3.2.4 External Interfaces

The only external system the TSPW In-Vehicle Subsystem connects to the Transit Vehicle power and data subsystems.

5.3.2.4.1 Vehicle Databus

The Vehicle CAN Bus is based on the SAE J1939 specification. The specific format and payload definitions of the messages are J1939 compliant. The TSPW IVS interfaces to the existing transit vehicle's Vehicle CAN Bus to decode the information listed in Table 5-25.

Table 5-25. J1939 Message Label ID

Inputs	J1939 Label ID
Transit Vehicle’s speed	0xFEF1 or 0xFEBF
Transit Vehicle’s gear position (PRNDL)	0xF005
Transit Vehicle’s brake status	0xFEF1

Source: Battelle/SAE J1939

5.3.3 Roadside Subsystem

The Roadside Subsystem is responsible for monitoring and reporting on the status and condition of the instrumented transit stop. This equipment will wirelessly inform approaching vehicles specific details regarding the physical layout of the stop as well as information about the presence and perceived intent of pedestrians in the area.

5.3.3.1 Bus Stop Selection

The Greater Cleveland Regional Transit Authority (GCRTA) provides transportation services for approximately 50 million riders annually, through a variety of services. In 2015, GCRTA provided more than 13 million vehicle-miles of service, and customers traveled more than 150 million passenger miles on bus, trolley, and bus rapid transit (BRT).

GCRTA’s bus service consists of 60 routes with more than 400 buses that serve more than 39 million annual riders. These buses serve over 6,000 bus stops daily generating over 13 million revenue miles annually.

GCRTA’s two (2) BRT lines provide service to approximately five (5) million riders annually. The HealthLine connects downtown Public Square to the Lois Stokes Station at Windermere in East Cleveland via Euclid Avenue. The Cleveland State Line (Route 55) connects the West Shore communities with Downtown.

GCRTA also provides free downtown trolley service to over 1.5 million annual riders by connecting major downtown venues with one another. The B-Line trolley serves Cleveland’s major business centers from W.6th Street to E.12th Street. The E-Line trolley connects Tower City to the Stephanie Tubbs Jones transit center with stops at premier entertainment destinations along Euclid Avenue. Both the B-Line and E-Line trolley operate Monday through Friday 7am until 7pm. The C-Line trolley operates weekday evenings (7pm-11pm) and weekends (11am-11pm) connecting the Horseshoe Casino, the Convention Center, and Global Center for Health Innovation with stops at Playhouse Square theaters, nightclubs and restaurants on East 4th Street and in the Warehouse District. Finally, the NineTwelve trolley provides weekday AM and PM rush service between the Muny Parking Lot and the area of Huron Avenue and East 6th Street, via East 9th Street.

5.3.3.1.1 Bus Stop Requirements

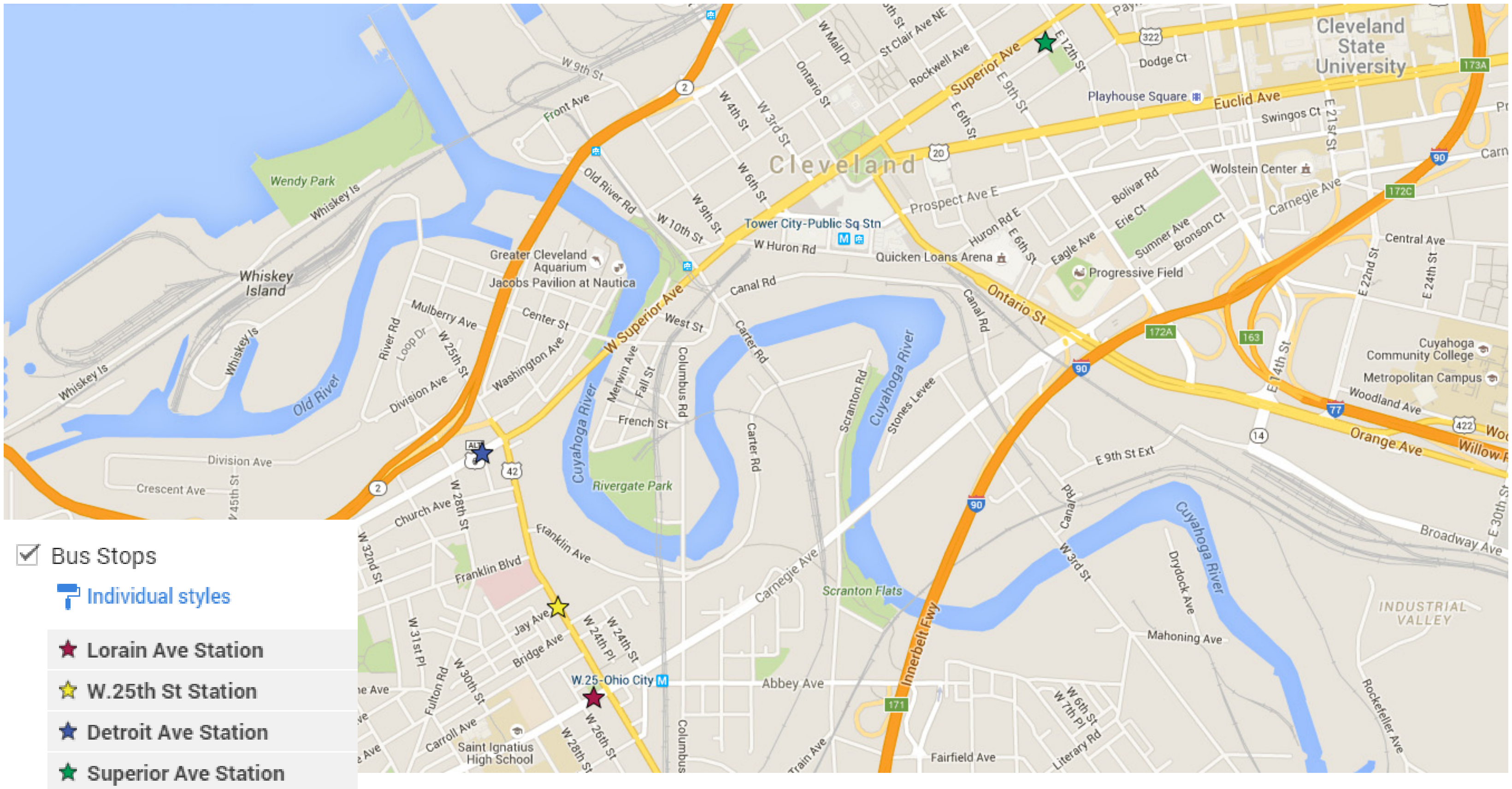
Four (4) distinct bus stop locations will be equipped with the TSPW application. Due to the volume of routes and buses our team has worked with GCRTA to select routes with dedicated buses to ensure the quality and quantity of data collected is sufficient for evaluation purposes. As shown in Table 5-26, the following routes have been selected for this demonstration. Bus stop locations were then selected based on bus and passenger volumes on the selected bus routes.

Table 5-26. Selected Bus Routes

Bus Route	Description
HealthLine	Connects Public Square to the Louis Stokes Station at Windermere in East Cleveland
55/Cleveland State Line	Service between Downtown Cleveland and the Westgate Transit Center.
22	Buses travel from Downtown Cleveland to West 25th Street via the Detroit-Superior bridge.
26	From Downtown Cleveland, the bus travels on Detroit Avenue through Cleveland's West Side, Lakewood and Rocky River.
B-Line	Service between the Warehouse District, Tower City – Public Square, and Central Business District offices
E-Line	Service between the Warehouse District and Stephanie Tubbs Jones Transit Center, via Euclid Avenue

Source: GCRTA/Battelle

From the bus routes indicated in Table 5-26, bus stops were selected based upon the amount of vehicle and pedestrian traffic and the number of interactions between instrumented vehicles and the transit stop. The bus stops selected are mapped in Figure 5-22.



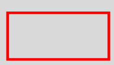
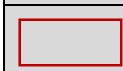
Source: Google Maps / Battelle

Figure 5-22. Selected Bus Stops

5.3.3.1.2 Bus Stop Design

The subsections below provide the details on why each bus stop was selected for the TSPW application and also provides the details for the hardware mounting locations. The mounting locations are shown using the symbols provided in Table 5-27.

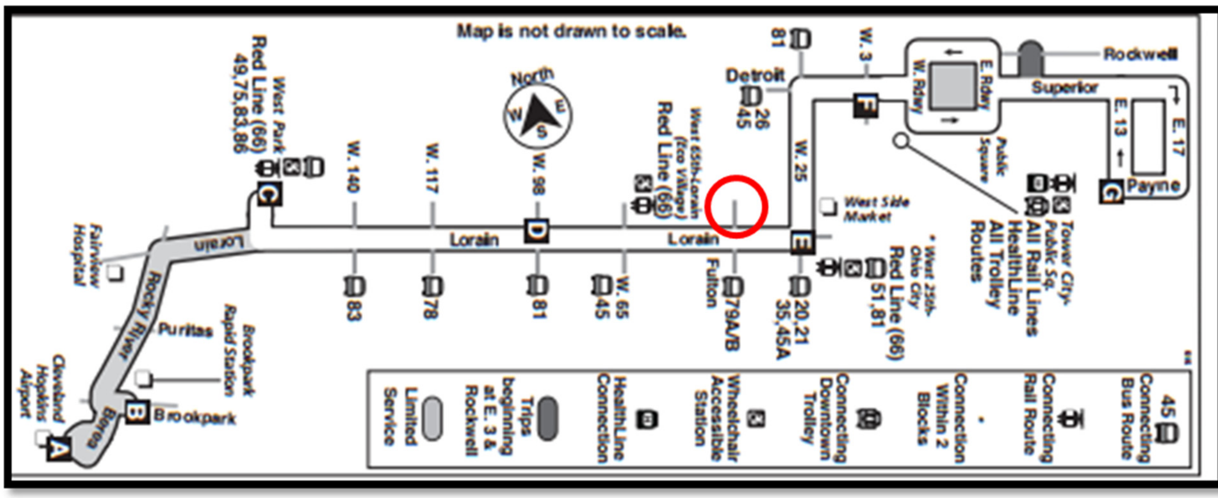
Table 5-27. Legend of Symbols Used in the Bus Stop Measurements and Design

N	Yellow letters indicate compass direction
	Red shaded circle represents the use of a pedestrian detection sensor
	Green right triangle represents the use of a cantilever arm
	Black line represent a proposed new pole
	Light and dark blue boxes represent a DSRC radio
	Blue shaded rectangle with a white and black shaded rectangle represent the pedestrian display
	Red hollow rectangle represents the bus shelter area
Bus Shelter	Red letters indicate bus shelter label
	Yellow hollow rectangles represent in roadway forward curb zone and in roadway forward center zone pedestrian coverage areas
	Orange hollow rectangles represent in roadway rear curb zone and in roadway rear center zone pedestrian coverage areas
	Dark red hollow rectangles represent danger waiting zone pedestrian coverage areas

Source: Battelle

5.3.3.1.3 Lorain Ave. Bus Stop

This bus stop is located on Route 22, on the north side of Lorain Avenue just west of W. 25th Street.[1] This bus stop is surrounded by Market Square Park to the north, the West Side Market to the east, and several restaurants and businesses; it is a bus stop that is heavily used for boarding and alighting. Figure 5-23 provides an overview of route 22 with a red circle to highlight the Lorain Avenue bus stop. Figure 5-24 provides a bird's eye view image of this bus stop, while Figure 5-25 provides a frontal view.



Source: GCRTA www.riderta.com

Figure 5-23. GCRTA Route 22 Highlighting Lorain Avenue Bus Stop

The key attributes for the Lorain Ave. bus stop are summarized in Table 5-28.

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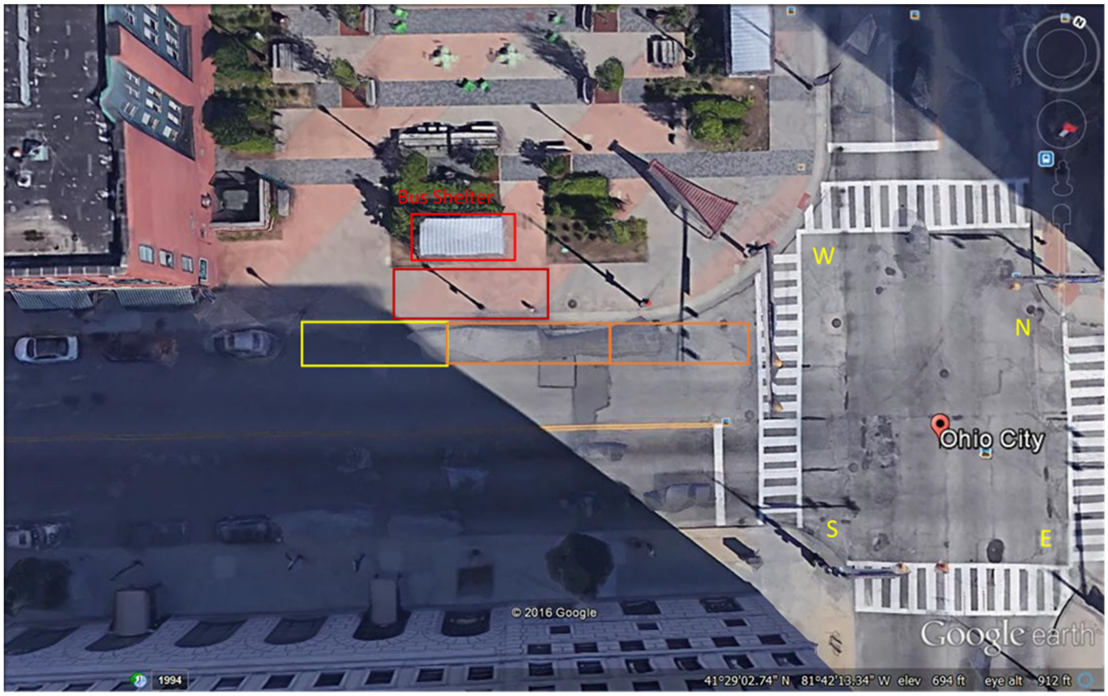
[1] Note: The Lorain Avenue bus stop is also serviced by Routes 20, 21, 35, 45A, 79A and 79B. However, those buses will not be equipped with pedestrian detection equipment.

Table 5-28. This Table Summarizes the Lorain Ave. Bus Stop Design Details

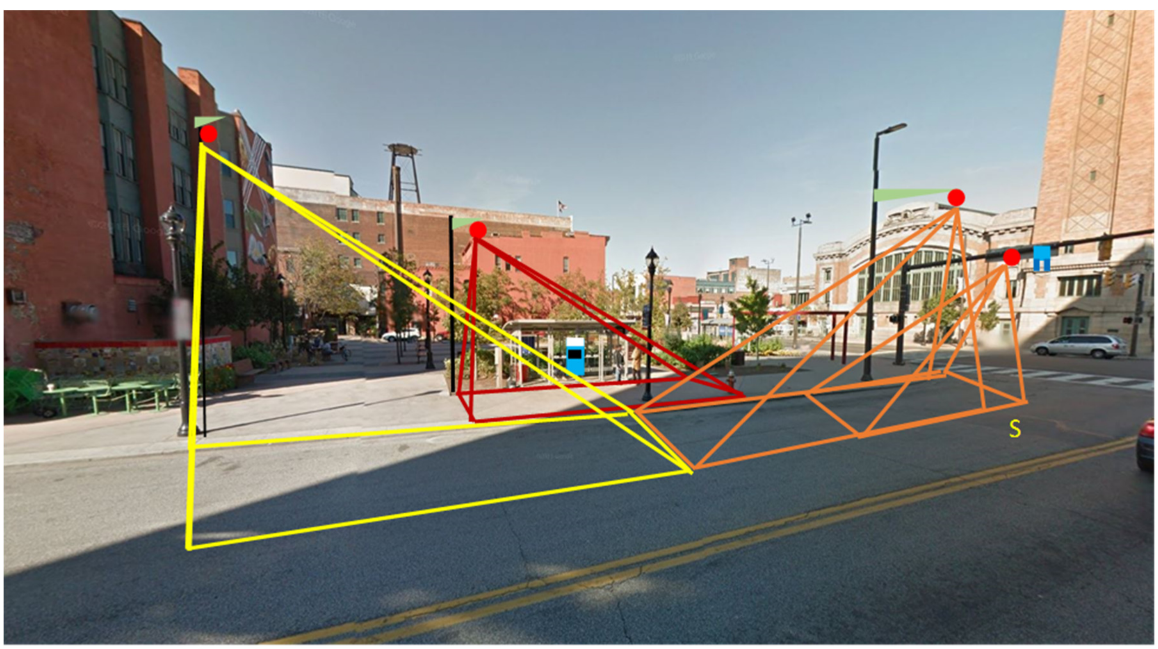
Bus Stop	Lorain Ave. Station
Image	
Nearest Designated Intersection	W. 25th St. & Lorain Ave.
Bus Traversals Per Day	130
Poles being used	Traffic light pole at intersection (1) Light pole with cantilever arm nearest traffic light pole (1) Newly erected pole with cantilever arm in landscaping near bus shelter (1) Newly erected pole with cantilever arm on sidewalk near West Side Market
# of ped. detectors required	4
Mounting height of ped. detector	23'
Where will DSRC Radio be mounted?	Traffic light pole at intersection closest to the designated bus stop

Source: Battelle



Source: Google Earth / Battelle

Figure 5-24. Bird's Eye View Image of the Lorain Avenue Bus Stop



Source: Google Earth / Battelle

Figure 5-25. Frontal View Image of the Lorain Avenue Bus Stop

5.3.3.1.3.1 Danger Waiting Zone Pedestrian Coverage

The danger waiting zone pedestrian coverage is identified by the dark red lines. The pedestrian detector focused on this area will detect pedestrians waiting near the bus shelter where the transit vehicle approaches to pick up riders. One sensor will be mounted on a newly erected pole attached to a 2’ cantilever arm just to the left of the bus shelter in the landscaped area. The sensor will be installed at 23’ high on the pole. The sensor will have a detection range of approximately 37’; however, it will be adjusted to focus on just the area immediately in front of the shelter house.

5.3.3.1.3.2 In Roadway Forward Curb Zone and In Roadway Forward Center Zone Pedestrian Coverage

The in roadway forward curb zone and the in roadway forward center zone pedestrian coverage is identified by the yellow lines. The pedestrian detector focused in this areas will detect pedestrians in the front of the bus when the bus approaches the bus shelter to pick up riders. One sensor will be mounted on a newly erected pole at 23’ high on a 2’ cantilever arm perpendicular to the curb. The sensor has a detection range of 37’.

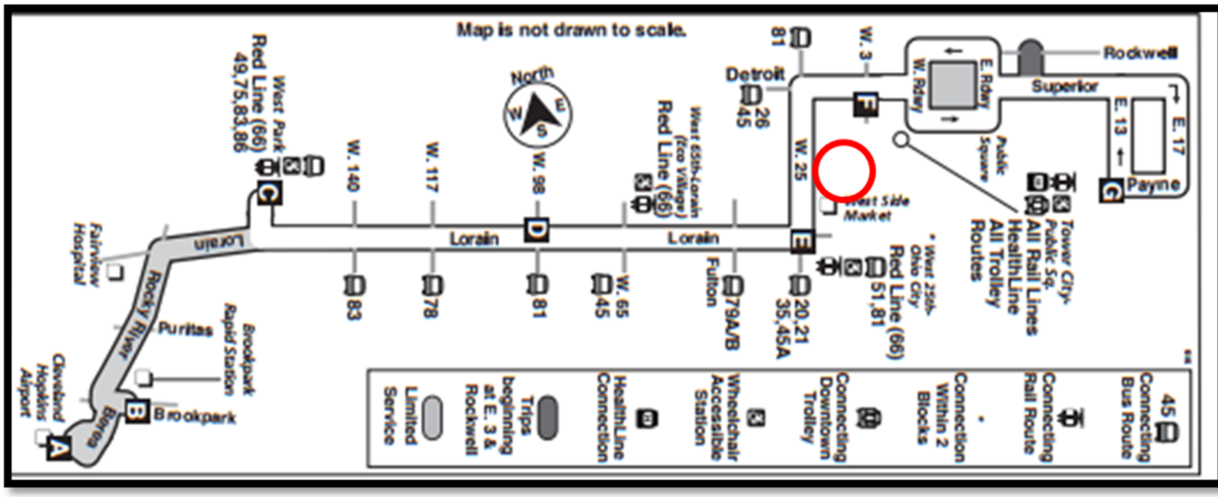
5.3.3.1.3.3 In Roadway Rear Curb Zone and In Roadway Rear Center Zone Pedestrian Coverage

The in roadway rear curb zone and the in roadway rear center zone pedestrian coverage is identified by the orange lines. The pedestrian detection focused in this area will detect pedestrians in the rear of the bus as the transit vehicle approaches the bus shelter to pick up riders. One sensor will be mounted on the existing light pole to the right of the fire hydrant at a height of 23’ with a 10’ cantilever arm extending approximately 4’ into the intersection. The sensor has a detection range of 37’. An additional sensor will be mounted on the traffic light pole. This sensor has a detection range of 37’ and will detect pedestrians behind the transit vehicle.

5.3.3.1.4 W. 25th St. Station

This bus stop is located on the east side of W. 25th Street at the Riverview Apartment complex on Route 22.[2] This bus stop is bordered by the Riverview apartments to the east and the Lutheran Hospital to the west along with several restaurants to the south, making this a well-used bus stop for both boarding and alighting. Figure 5-26 provides an overview of route 22 with a red circle to highlight the W. 25th Street bus stop. Figure 5-27 provides a street view for this bus stop, while Figure 5-28 provide a frontal image view.

[2] Note: W.25th near Jay Street is also serviced by Routes 20, 21, 35, 45A, and 81. However, those buses will not be equipped with pedestrian detection equipment.

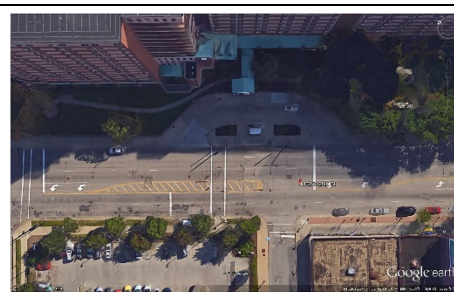


Source: GCRTA www.riderta.com

Figure 5-26. GCRTA Route 22 Highlighting W. 25th Street Bus Stop

The key attributes for the W. 25th St. bus stop are summarized in Table 5-29.

Table 5-29. W. 25th St. Bus Stop Design Details

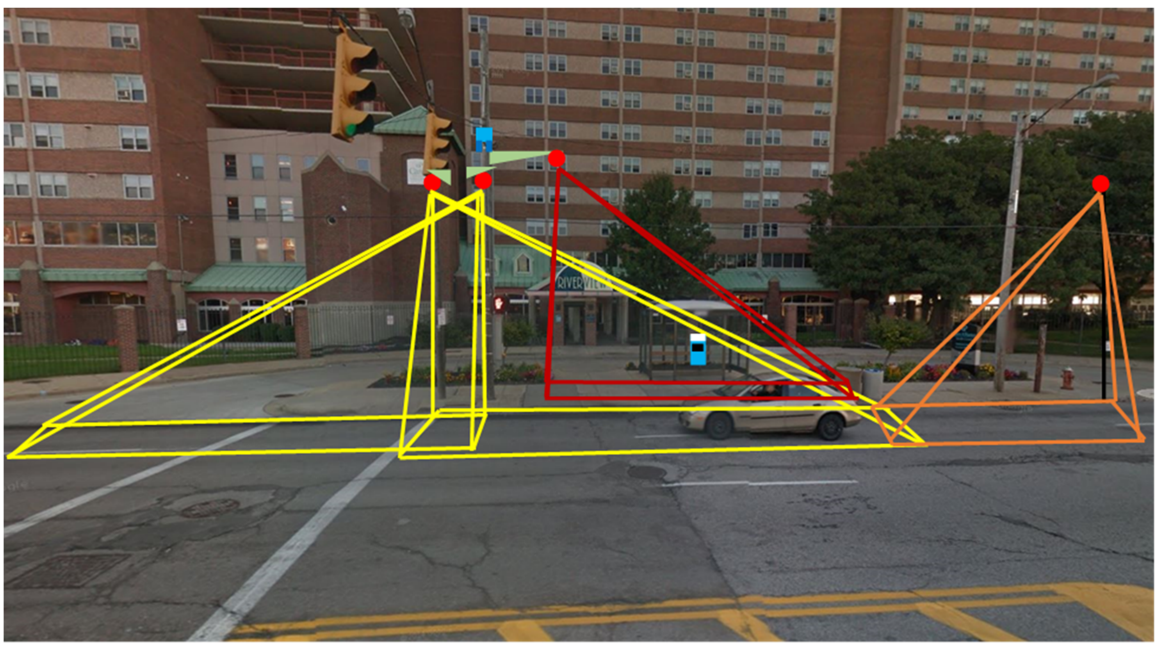
Bus Stop	W. 25th St. Station
Image	
Nearest Designated Intersection	W. 25th St. & Jay Ave.
Bus Traversals per day	130
Poles being used	Light pole with cantilever arm directly in front of stop bar (1) Telephone pole with cantilever arm in front of stop bar (2) Newly erected pole on sidewalk in front of fire hydrant (1) Newly erected pole with cantilever arm across the sidewalk (1)
# of ped. detectors required	5
Mounting height of ped. detector	23'
Where will DSRC Radio be mounted?	Traffic light pole at intersection above traffic cabinet

Source: Battelle

The bus stop measurements and design are shown below in Figure 5-27 and Figure 5-28.

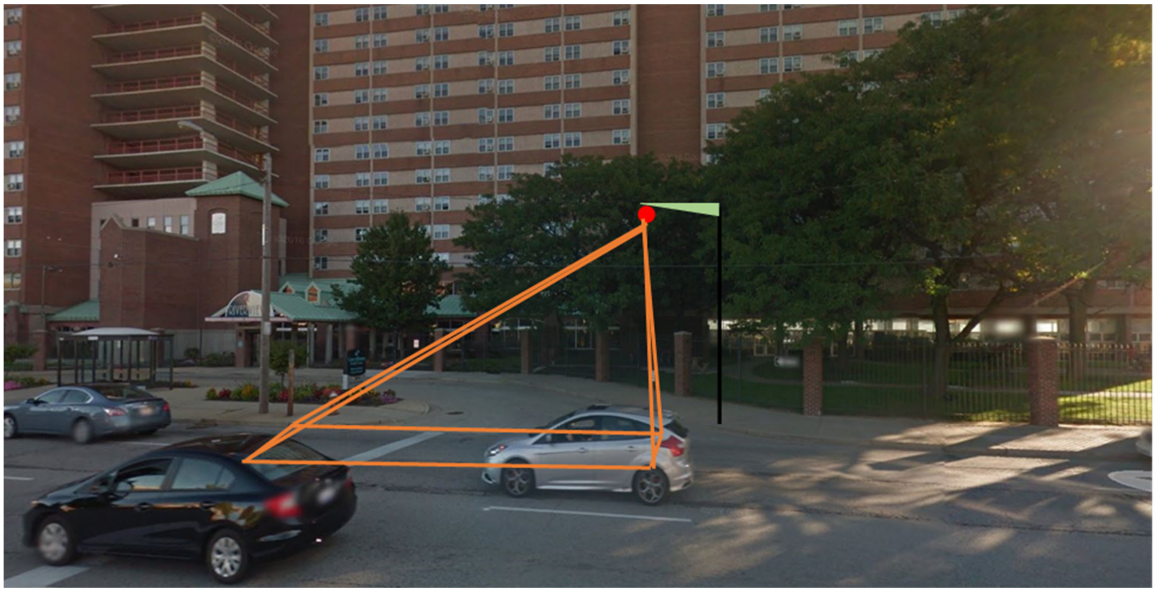
Source: Google Earth/Battelle

Figure 5-27. Bird's Eye View Image of the W. 25th St. Station Bus Stop



Source: Google Earth/Battelle

Figure 5-28. Frontal View Image of the W. 25th St. Bus Stop



Source: Google Earth / Battelle

Figure 5-29. Frontal View Image of the W. 25th St. Bus Stop

5.3.3.1.4.1 Danger Waiting Zone Pedestrian Coverage

The danger waiting zone pedestrian coverage is identified by the dark red lines. The pedestrian detection focused in this area will detect pedestrians waiting near the bus shelter area as the transit vehicle approaches to pick up riders. One sensor will be mounted on the existing power pole that the nearby pedestrian crosswalk traffic cabinet is currently hanging from attached on a 6' cantilever arm. The sensor will be mounted at 23' on the pole. The sensor will have a detection range of 37'; however, it will be adjusted to focus on just the areas where pedestrians and riders are at highest risk of being in danger.

5.3.3.1.4.2 In Roadway Forward Curb Zone and In Roadway Forward Center Zone Pedestrian Coverage

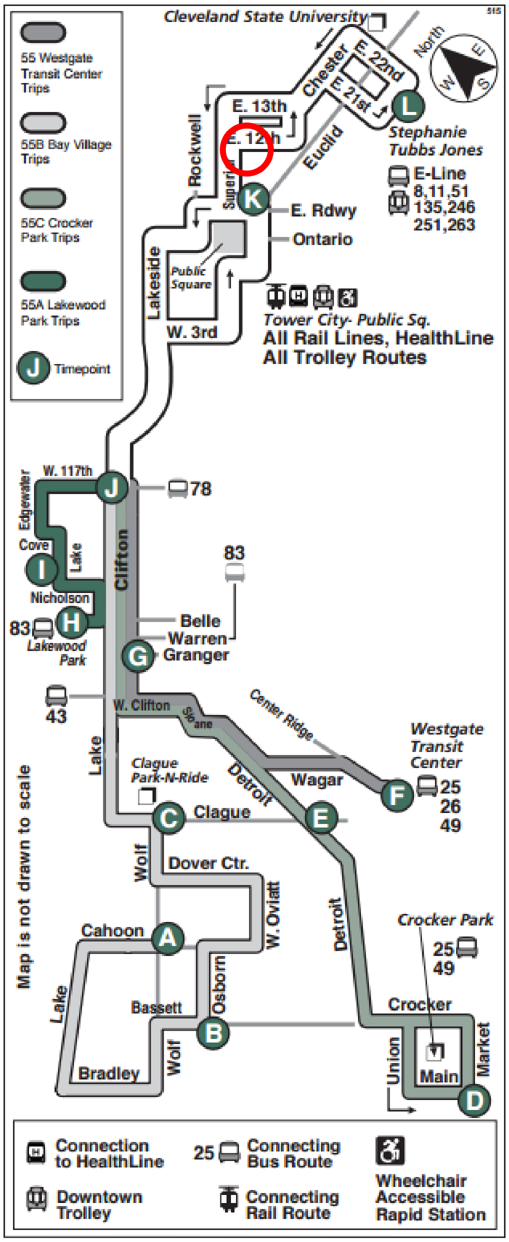
The in roadway forward curb zone and the in roadway forward center zone pedestrian coverage is identified by the yellow lines. The pedestrian detection focused in this area will detect pedestrians in the front of the bus as the transit vehicles approaches the bus shelter to pick up riders. One sensor will be mounted on the light pole facing the front part of the vehicle turnaround in front of Riverview Apartments. This sensor will be mounted at 23' and will have a 4' cantilever arm installed perpendicular to the curb. The sensor has a detection range of 37'. An additional sensor will be mounted on the light pole directly in front of the stop bar painted in the street. This sensor will face towards the bus shelter and will also be mounted at 23' and be extended perpendicular to the curb with a 4' cantilever arm.

5.3.3.1.4.3 In Roadway Rear Curb Zone and In Roadway Rear Center Zone Pedestrian Coverage

The in roadway rear curb zone and the in roadway rear center zone pedestrian coverage is identified by the orange lines. The pedestrian detection focused in this areas will detect pedestrians in the rear of the bus as the transit vehicle approaches the bus shelter to pick up riders. One sensor will be mounted on a newly erected pole directly in front of the fire hydrant. The sensor has a detection range of 37'.'. An additional pole will be installed on the other side of the sidewalk towards the entrance of the Riverview Apartment turnaround. The sensor will be mounted at 23' and will be extended with an 8' cantilever arm.

5.3.3.1.5 Superior Ave. Stop

This bus stop is on the south side of Superior Avenue at E. 12th Street on Routes 22, 26, and 55.[3] This bus stop is surrounded by many large businesses, apartments, and restaurants making it a well-used bus stop for both boarding and alighting. Figure 5-30 provides an overview of route 55 with a red circle to highlight the Superior Avenue bus stop. Figure 5-31 provides a street view for this bus stop, while Figure 5-32 provides a frontal view.



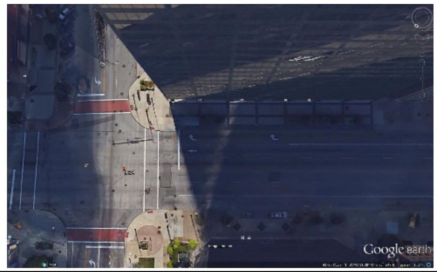
Source: GCRTA www.riderta.com

Figure 5-30. GCRTA Route 55 Highlighting Superior Avenue Bus Stop

[3] Note: The Superior Avenue bus stop is also serviced by buses on routes 3, 38, 135, 251, and 263. However, those buses will not be equipped with pedestrian detection equipment.

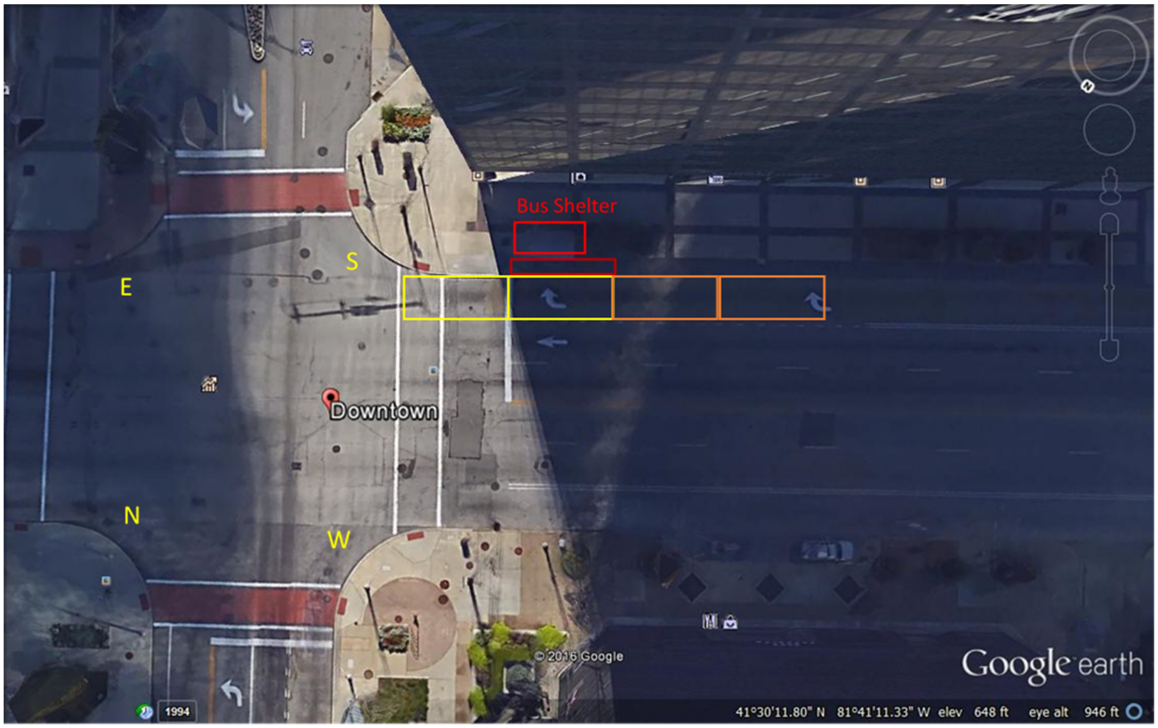
The key attributes for the Superior Ave. bus stop are summarized in Table 5-30.

Table 5-30. Superior Ave. Bus Stop Design Details

Bus Stop	Superior Ave. Stop
Image	
Nearest Designated Intersection	E. 12th St. & Superior Ave.
Bus Traversals per day	416
Poles being used	Light pole nearest to the bus shelter with cantilever arm (3) Light pole with cantilever arm directly in front of Oswald Centre (1) Newly erected pole with a cantilever arm on the curb at the end of the Oswald Centre building (1)
# of ped. detectors required	5
Mounting height of ped. detector	23'
Where will DSRC Radio be mounted?	Traffic light pole at intersection above traffic cabinet

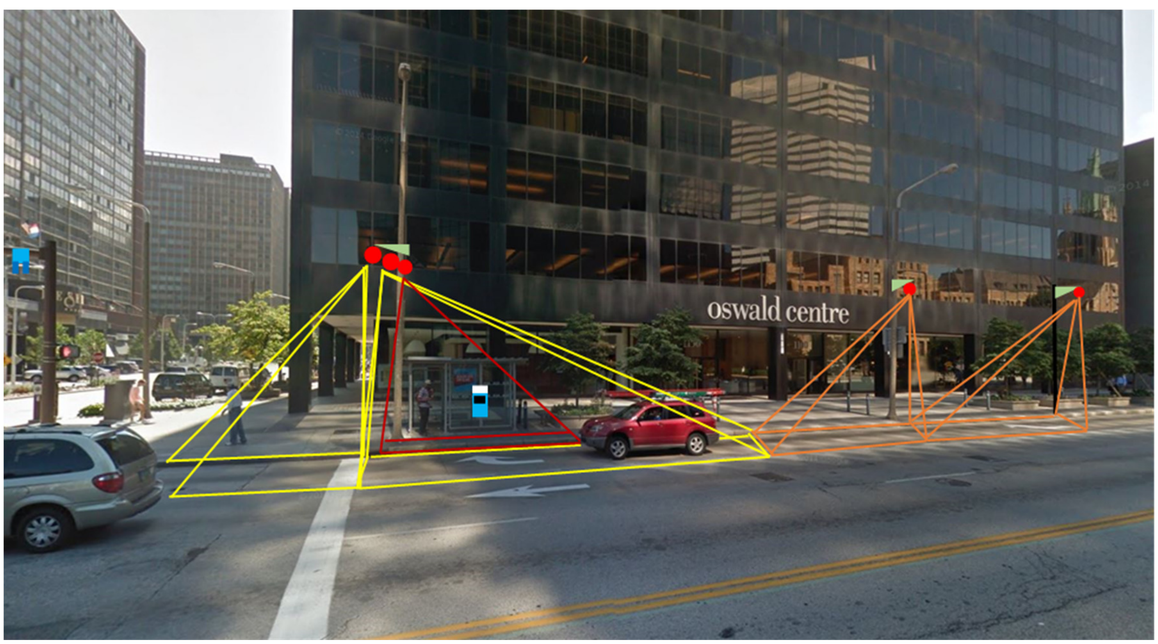
Source: Battelle

The bus stop measurements and design are shown below in Figure 5-31 and Figure 5-32.



Source: Google Earth / Battelle

Figure 5-31. Bird's Eye View Image of the Superior Ave. Bus Stop



Source: Google Earth / Battelle

Figure 5-32. Frontal View Image of the Superior Ave. Bus Stop

5.3.3.1.5.1 Danger Waiting Zone Pedestrian Coverage

The danger waiting zone pedestrian coverage is identified by the dark red lines. The pedestrian detection focused in this area will detect pedestrians waiting near the bus shelter area as the transit vehicle approaches to pick up riders. One sensor will be mounted on the existing light pole nearest to the bus stop. The sensor will be mounted at a height of 23' on a 6' cantilever arm. The sensor will have a detection range of 37'; however, it will be adjusted to focus on just the areas where pedestrians and riders are at highest risk of being in danger.

5.3.3.1.5.2 In Roadway Forward Curb Zone and In Roadway Forward Center Zone Pedestrian Coverage

The in roadway forward curb zone and the in roadway forward center zone pedestrian coverage is identified by the yellow lines. The pedestrian detection focused in this areas will detect pedestrians in the front of the bus when the bus approaches the bus shelter to pick up riders. This sensor will be mounted on the existing light pole next to the bus shelter on the same 6' cantilever arm as previously mentioned in 5.3.3.1.5.3 and will face towards the intersection. An additional sensor will be mounted on the same cantilever arm as well, and will face in the direction of the bus shelter towards the Oswald Centre sign on the building.

5.3.3.1.5.3 In Roadway Rear Curb Zone and In Roadway Rear Center Zone Pedestrian Coverage

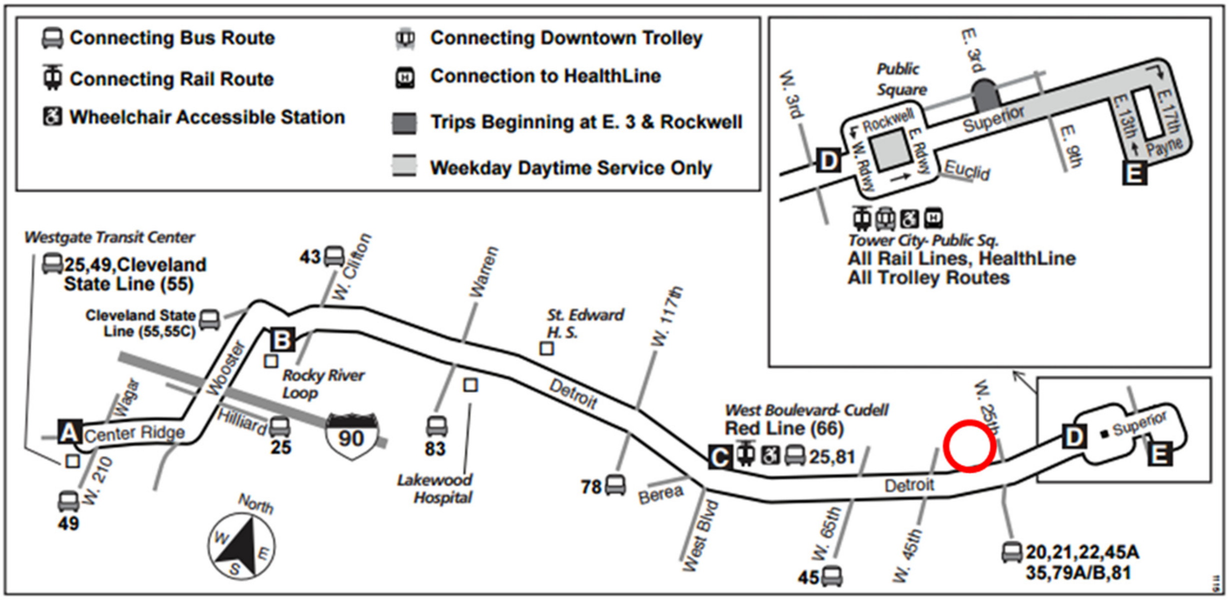
The in roadway rear curb zone and the in roadway rear center zone pedestrian coverage is identified by the orange lines. The pedestrian detection focused in these areas will detect pedestrians in the rear of the bus as the bus approaches the bus shelter to pick up riders. One sensor will be mounted on a newly erected 23' pole with a 6' cantilever arm overhanging the curb directly in front of the Oswald Centre. This sensor has a detection range of 37' and will extend to the rear of the in roadway forward curb and in roadway forward center zones. An additional sensor will be mounted on a newly erected pole approximately 37' further down the street on a 6' cantilever arm. This will ensure all pedestrians are detected behind the transit vehicle.

5.3.3.1.6 Detroit Ave. Bus Stop

This bus stop is located on the north side of Detroit Avenue just west of W. 25th Street on Route 26.[4] This bus stop is located in between intersections to demonstrate that the TSPW application can be equipped at bus stops without equipped intersections nearby. This bus stop has several staffing agencies nearby and is well-used for boarding and alighting.

Figure 5-33 provides an overview of route 26 with a red circle to highlight the Detroit Avenue bus stop. Figure 5-34 provides a street view for this bus stop, while Figure 5-35 provides a frontal view.

[4] Note that the Detroit Avenue station is also serviced by Route 45; however, those buses will not be equipped with pedestrian detection equipment.

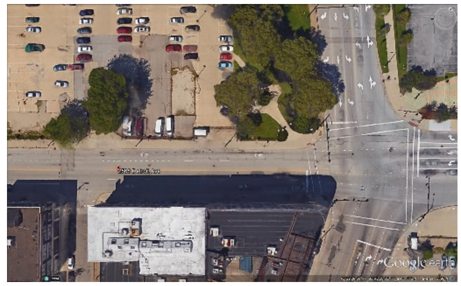


Source: GCRTA www.riderta.com

Figure 5-33. GCRTA Route 26 Highlighting Detroit Avenue Bus Stop

The key attributes for the Detroit Ave. bus stop are summarized in Table 5-31.

Table 5-31. Detroit Ave. Bus Stop Design Details

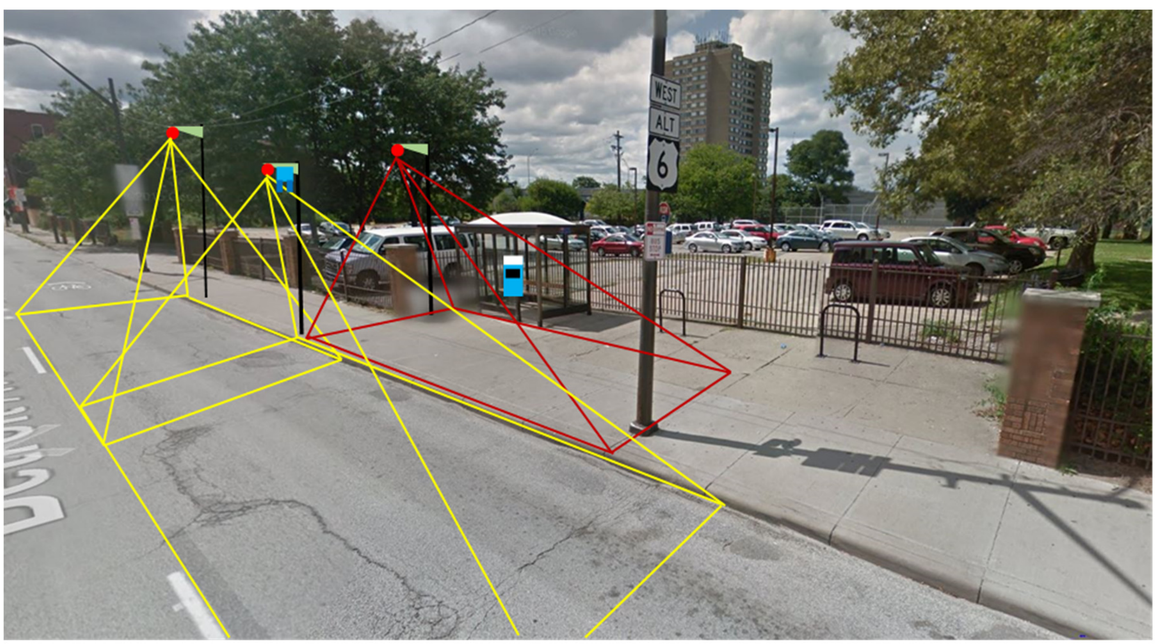
Bus Stop	Detroit Ave.
Image	
Nearest Designated Intersection	None
Bus Traversals per day	139
Poles being used	Newly erected pole on sidewalk in front of brick pillar on cantilever arm (1) Newly erected pole in between bus shelter and brick pillar on cantilever arm (1) Newly erected pole in front of bus shelter near curb on cantilever arm (1) Newly erected pole in front of the signs located near the curb on cantilever arm (1) Newly erected pole near tactile pad closest to intersection on cantilever arm (1)
# of ped. detectors required	5
Mounting height of ped. detector	23'
Where will DSRC Radio be mounted?	Newly erected pole directly in front of bus shelter

Source: Battelle

The bus stop measurements and design are shown below in Figure 5-34, Figure 5-35 and Figure 5-36.

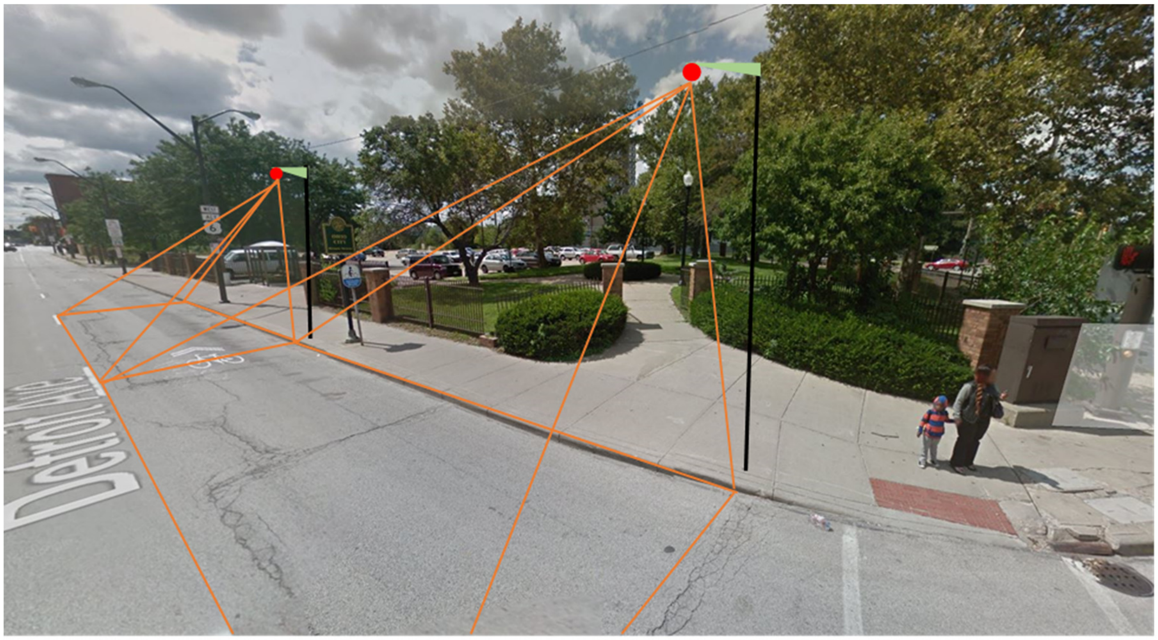
Source: Google Earth / Battelle

Figure 5-34. Bird's Eye View Image of the Detroit Ave. Bus Stop



Source: Google Earth / Battelle

Figure 5-35. Rear View Image of the Detroit Ave. Bus Stop



Source: Google Earth / Battelle

Figure 5-36. Frontal View Image of the Detroit Ave. Bus Stop

5.3.3.1.6.1 Danger Waiting Zone Pedestrian Coverage

The danger waiting zone pedestrian coverage is identified by the dark red lines. The pedestrian detection focused in this area will detect pedestrians waiting near bus shelter area as the transit vehicle approaches to pick up riders. One sensor will be mounted on a newly erected pole at 23’ on a 4’ cantilever arm. This pole will be installed in the landscaped area behind the pillar located directly to the left of the bus shelter. The sensor will have a detection range of 37’ and will extend to the light pole in front of the bus shelter. It will be adjusted to focus on just the areas where pedestrians and riders are at highest risk of being in danger.

5.3.3.1.6.2 In Roadway Forward Curb Zone and In Roadway Forward Center Zone Pedestrian Coverage

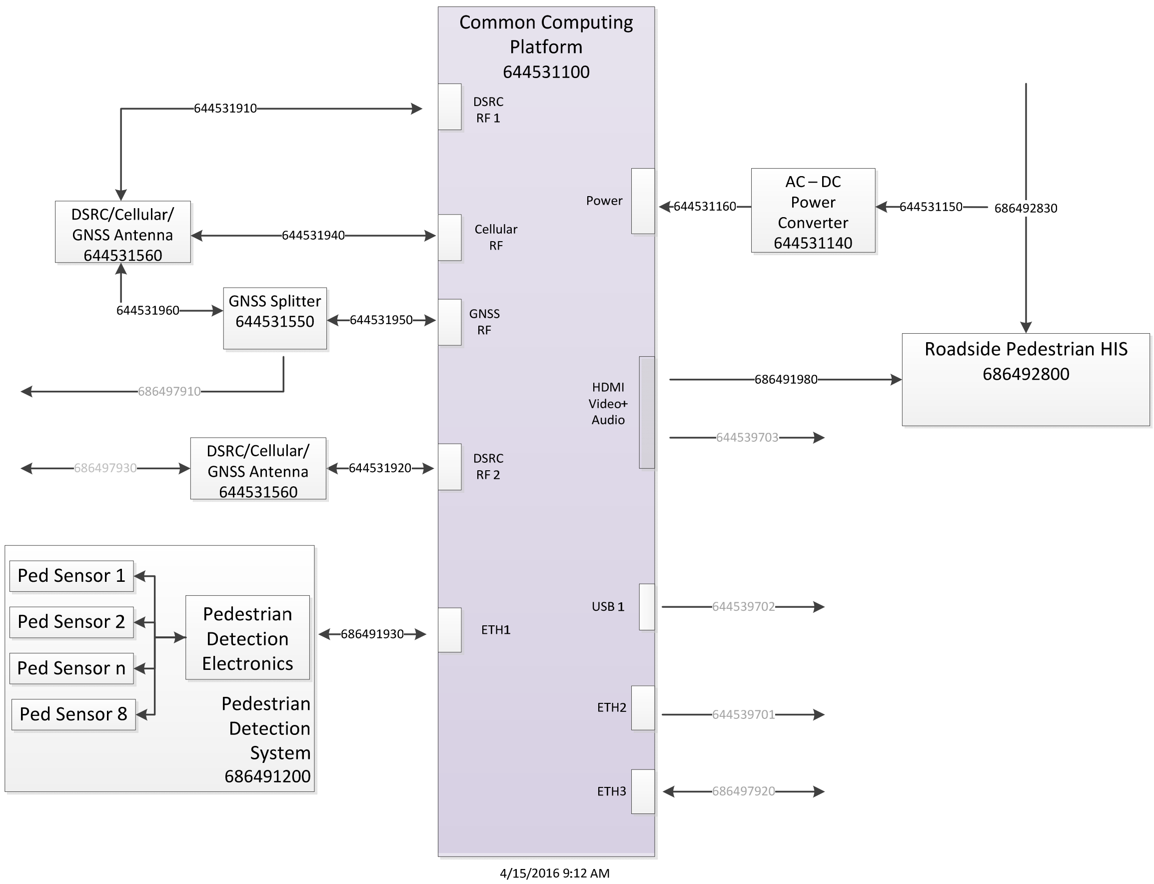
The in roadway forward curb zone and the in roadway forward center zone pedestrian coverage is identified by the yellow lines. The pedestrian detection focused in this area will detect pedestrians in the front of the bus as the transit vehicle approaches the bus shelter to pick up riders. One sensor will be mounted on a newly erected pole in front of the second pillar to the left of the bus shelter. It will be mounted at a 23’ height and will be attached to a 4’ cantilever arm. An additional sensor will be installed to detect pedestrians in the roadway directly in front of the bus shelter. The sensor will be mounted to a newly erected 23’ pole with a 4’ cantilever arm. The detection range of this sensor is 37’ and will extend to the beginning of the in roadway rear curb and in roadway rear center zones mentioned in 5.3.3.1.6.3.

5.3.3.1.6.3 In Roadway Rear Curb Zone and In Roadway Rear Center Zone Pedestrian Coverage

The in roadway rear curb zone and the in roadway rear center zone pedestrian coverage is identified by the orange lines. The pedestrian detection focused in this area will detect pedestrians in the rear of the bus as the transit vehicle approaches the bus shelter to pick up riders. One sensor will be installed on a newly erected 23’ pole extended on a 4’ cantilever arm. This sensor has a detection range of 37’ and will be facing towards the in roadway forward cur and in roadway forward center zones mentioned in 5.3.3.1.6.2. An additional sensor will be installed on a newly erected 23' pole with extended on a 4' cantilever arm directly in front of the tactile pad located at the intersection. The sensor has a detection range of 37' and will be facing the opposite direction of the intersection towards the bus stop.

5.3.3.2 Hardware

The hardware for the RSE will consist of a CCP, Pedestrian Detection Subsystem, and other support peripherals allowing the RSE to communicate with its host platform and other TSPW subsystems. The components used to implement the RSE are shown in Figure 5-37.



Source: Battelle

Figure 5-37. Roadside Subsystem Equipment Components

Each subsystem, assembly and component of the TSPW system will be assigned a part number. These part numbers allow for unique identification during configuration control, assembly and testing activities during the development, testing and fielding lifecycles. The components that make up the TSPW Roadside Subsystem, including the internal part numbers are summarized in Table 5-32.

Table 5-32. Roadside Subsystem Components

Part Number	Item Description
644531100	Common Computing Platform with Mount
644531140	Common Computing Platform AC-DC Power Converter
644531150	Common Computing Platform AC-DC Power Converter Input Cable
644531160	Common Computing Platform AC-DC Power Converter Output Cable
686491200	TSPW RSE Pedestrian Detection System
686491550	GNSS Splitter
686491560	DSRC/Cellular/GNSS Antenna
686491910	TSPW RSE DSRC Antenna 1 Coax
686491920	TSPW RSE DSRC Antenna 2 Coax
686491930	TSPW Pedestrian Detection Interface Cable
686491940	TSPW CCP Cellular RF to Cellular Antenna Coax
686491950	TSPW CCP to GNSS Splitter Coax
686491960	TSPW GNSS Splitter to GNSS Antenna Coax
686491980	TSPW CCP to Roadside Pedestrian HIS HDMI
686492810	Roadside Pedestrian HIS
686492830	Roadside Pedestrian HIS Power Cable

Source: Battelle

5.3.3.2.1 644531100 Common Computing Platform with Mount

The CCP is described in detail in section 5.3.1 of this document

5.3.3.2.2 644531140 Common Computing Platform AC-DC Power Converter

Since the RSE-CCP will require 115VAC to operate at the roadside an AC-DC power converter will be required to convert the available 115VAC found locally at the transit stop to the nominal 12V DC used by the CCP.

5.3.3.2.3 644531150 Common Computing Platform AC-DC Power Converter Input Cable

A cable connecting the existing power interface at the transit stop to the Common Computing Platform AC-DC Power Converter will need to be provided.

5.3.3.2.4 644531160 Common Computing Platform AC-DC Power Converter Output Cable

A cable connecting the Common Computing Platform AC-DC Power Converter to the CCP will need to be provided. This cable will be designed once the power interface to the CCP is defined.

5.3.3.2.5 686491200 TSPW RSE Pedestrian Detection System

FLIR's TrafiSense pedestrian detection cameras will be deployed at each of the designated transit stops. The TrafiSense cameras will detect pedestrian presence within the designated areas near the transit shelter and in the roadway. The pedestrian detection zones will be designed in the TrafiCon Data Tool Software provided by FLIR to be specific to the geometry of the transit stop with respect to the roadway and the infrastructure elements surrounding the transit stop. TrafiSense cameras use thermal vision, which allows for pedestrians to be detected in a variety of weather and lighting conditions. These cameras have the ability to differentiate between vehicles, pedestrians and bicyclists to keep false positive detections to a minimum. In addition to the differentiating ability, the cameras record a data log of all detections and capture a still image of the even triggered. All environmental specifications are met with the housing of the camera being UV-resistant and are IP68 rated. The shock and vibrations standards meet all NEMA specifications and have an operating temperature range from -34℃ to +80℃. They are also FCC part 15 Class A approved. Refer to section 5.3.3.1 for details on sensor mounting locations and pedestrian zone coverage.

Source: FLIR TrafiSense

Figure 5-38. FLIR TrafiSense pedestrian detection camera.

Source: FLIR TrafiSense

Figure 5-39. The TI X-Stream is the Single Board Computer that controls and powers the TrafiSense cameras.

5.3.3.2.6 686491550 GNSS Splitter

In order to reduce part count, the same GNSS splitter will be used on the RSE as is used on the IVS. See section 5.3.2.2.5 for details.

5.3.3.2.7 686491560 DSRC/Cellular/GNSS Antenna

The Roadside Equipment supporting the TSPW application will need to receive DSRC messages from the IVS housed within the transit vehicles. A DSRC/Cellular/GNSS antenna will be mounted at the roadside to enable DSRC communications with the IVS. The antenna described in Table 5-33 will be deployed at the transit stop.

Table 5-33. DSRC/Cellular/GNSS Antenna

Source of Supply	Part Number	Link to Datasheet
Mobilemark.com	SMW-301	http://www.mobilemark.com/product/ surface-mount-multiband-800-2700-2400-2500-mhz-wifi-wimax-antenna-for-gps-applications/

Source: Battelle

5.3.3.2.8 644532410 DSRC Antenna Mount

Each Roadside DSRC Antenna will need to be mounted above the transit stop. The mount we are using is described in Table 5-34.

Table 5-34. Antenna Mount

Source of Supply	Part Number	Link to Datasheet
Mobilemark.com	LTM-PMK	http://www.mobilemark.com

Source: Battelle

5.3.3.2.9 644532700 DSRC Lightning Surge Suppressor

The cable connection coming from the antenna to the cabinet need to be protected from lightning. The lightning surge suppressor to be used is described in Table 5-35.

Table 5-35. DSRC Lightning Surge Suppressor

Source of Supply	Part Number	Link to Datasheet
Mobilemark.com	AL-LSXM-MA Polyphaser	http://www.rspsupply.com/

Source: Battelle

5.3.3.2.10 686491910 TSPW RSE DSRC Antenna 1 Coax

The intended DSRC Antenna will require an extension cable to reach from its mounting location back to the RSE-CCP. Once the final length is determined a cable with its adapter will be specified to the correct length similar to the item described in Table 5-36.

Table 5-36. RSE DSRC Antenna 1 Extension Cable and Lightning protection

Source of Supply	Part Number	Link to Datasheet
RSP	SMA Female to N Female Cable Using LMR-400 Coax	http://www.rspsupply.com/
RSP	NM- Fakra Z	http://www.rspsupply.com/

Source: Battelle

5.3.3.2.11 686491920 TSPW RSE DSRC Antenna 2 Coax

The intended DSRC Antenna will require an extension cable to reach from its mounting location back to the RSE-CCP. Once the final length is determined a cable with its adapter and lightning protection will be specified to the correct length similar to the item described in Table 5-37.

Table 5-37. RSE DSRC Antenna 2 Extension Cable and Lightning protection

Source of Supply	Part Number	Link to Datasheet
RSP	SMA Male to N Male Cable 45 Feet Using LMR-400 Coax	http://www.rspsupply.com/
RSP	NM- Fakra Z	http://www.rspsupply.com/

Source: Battelle

5.3.3.2.12 644532710 Cellular/GNSS Lightning Surge Suppressor

The cable connection coming from the antenna to the cabinet need to be protected from lightning. The lightning surge suppressor to be used is described in Table 5-38.

Table 5-38. Cellular/GNSS lightning Protection

Source of Supply	Part Number	Link to Datasheet
RSP	TSX-NFF Polyphaser lightning protection	http://www.rspsupply.com/

Source: Battelle

5.3.3.2.13 686491940 TSPW RSE-CCP Cellular RF to Cellular Antenna Coax

The intended Cellular Antenna will require an extension cable to reach from its mounting location back to the RSE-CCP. Once the final length is determined a cable with its adapter and lightning protection will be specified to the correct length similar to the item described in Table 5-39.

Table 5-39. Cellular Antenna Extension Cable and Lightning protection

Source of Supply	Part Number	Link to Datasheet
RSP	SMA Female to SMA Female Cable 45 Feet Length Using LMR-240 Coax	http://www.rspsupply.com/
RSP	Adapter NM to Fakra D	http://www.rspsupply.com/

Source: Battelle

5.3.3.2.14 686491930 TSPW Pedestrian Detection Interface Cable

The Pedestrian Detection Subsystem will be interfaced to the RSE-CCP via an Ethernet cable. Once the final length is determined a cable will be specified to the correct length similar to the item described in Table 5-40.

Table 5-40. Example Ethernet Patch Cable to Pedestrian Detection Subsystem

Source of Supply	Part Number	Link to Datasheet
Cables To Go	10FT CAT5E SNAGLESS UNSHIELDED (UTP) ETHERNET NETWORK PATCH CABLE	http://www.cablestogo.com/product/15199/10ft-cat5e-snagless-unshielded-utp-ethernet-network-patch-cable-gray

Source: Battelle

5.3.3.2.15 686491950 TSPW RSE-CCP to GNSS Splitter Coax

In order to connect the RSE-CCP to the GNSS Splitter a patch cable will be required. Once the final length is determined a cable with its adapter and lightning protection will be specified to the correct length similar to the item described in Table 5-41.

Table 5-41. GNSS Patch Cable to RSE-CCP and lightning protection

Source of Supply	Part Number	Link to Datasheet
RSP	SMA Female to N-Male Cable 30 Feet Length Using LMR-200 Coax	http://www.rspsupply.com/
RSP	NM-NM adapter LMR-195 1ft	http://www.rspsupply.com/
RSP	NM-Fakra C 1ft LMR-195	http://www.rspsupply.com/

Source: Battelle

5.3.3.2.16 686491960 TSPW GNSS Splitter to GNSS Antenna Coax

In order to connect the GNSS Splitter to the GNSS Antenna a patch cable will be required. Once the final length is determined a cable will be specified to the correct length similar to the item described in Table 5-42.

Table 5-42. GNSS Patch Cable to RSE-CCP

Source of Supply	Part Number	Link to Datasheet
RSP	SMA Male to Fakra C,5005 Cable 12 Inch Length Using LMR-195 Coax	http://www.rspsupply.com/

Source: Battelle

5.3.3.2.17 686491980 TSPW RSE-CCP to Roadside Pedestrian HIS HDMI

The Roadside Pedestrian HIS display will be implemented to display alerts to pedestrians at the transit stop. This display will be interfaced using a standard HDMI Type A connector. Once the final length is determined a cable will be specified to the correct length similar to the item described in Table 5-43.

Table 5-43. Example HDMI Cable

Source of Supply	Part Number	Link to Datasheet
Cables To Go	25FT PRO SERIES HDMI® CABLE – PLENUM CMP-RATED	http://www.cablestogo.com/product/41191/25ft-pro-series-hdmi-cable-plenum-cmp-rated

Source: Battelle

5.3.3.2.18 686492810 Roadside Pedestrian Human Interface Subsystem (RP-HIS)

The RP-HIS will broadcast visible and audible warnings to pedestrians nearby the bus shelter. These warnings are designed to enhance pedestrian safety, warning them of any imminent danger and to also provide information regarding the approaching buses. The visible warnings will be displayed on a screen enclosed in the system, while the audible warnings will be emitted from a speaker system within.

In order to ensure compliance with the environmental conditions found where the RP-HIS is deployed, a modified Code Blue CB 2-E system was chosen. This system is completely weatherproof and can be customized to any requirement or specification. This system is equipped with an internal speaker and a strobe light and would be customized to house an LCD monitor. The monitor would display warning messages to pedestrians approaching or waiting at the bus shelter. This unit offers little or no incentive for theft making it ideal to install anywhere. They key details and specifications for the Code Blue CB 2-E are summarized in Table 5-44.

Table 5-44. Code Blue CB 2-E Details and Specifications

System Name	Code Blue CB 2-E
Model Number	CB 2-E
Design Rendering	
Power Requirements	24 V AC/ 15W
Brightness	N/A
Resolution	N/A
Size	12.1 x 32.2 x 7.88 inches
Weight	55 lbs.
Expected life	N/A
Temperature Range	N/A
Advantages	Weatherproof, vandal resisted hardware, UV resistant lenses, included speaker system.
Disadvantages	Small area to install LCD display, pedestrians could mistake this unit for emergency use only.

Table 5-44. Code Blue CB 2-E Details and Specifications (Continued)

Connection Options	Cat5e
Software	None
Weatherproofing	IP 56: protected from dust and high pressure water jets from any direction NEMA 4X: protects from extreme environments
Weatherproofing with Case	N/A
Differentiation	Fully customizable, can order without inside components, can choose paint color, light color, graphic lettering, etc.
Website	http://codeblue.com/wp-content/uploads/cps-105_cb02e.pdf

Source: Code Blue/Battelle

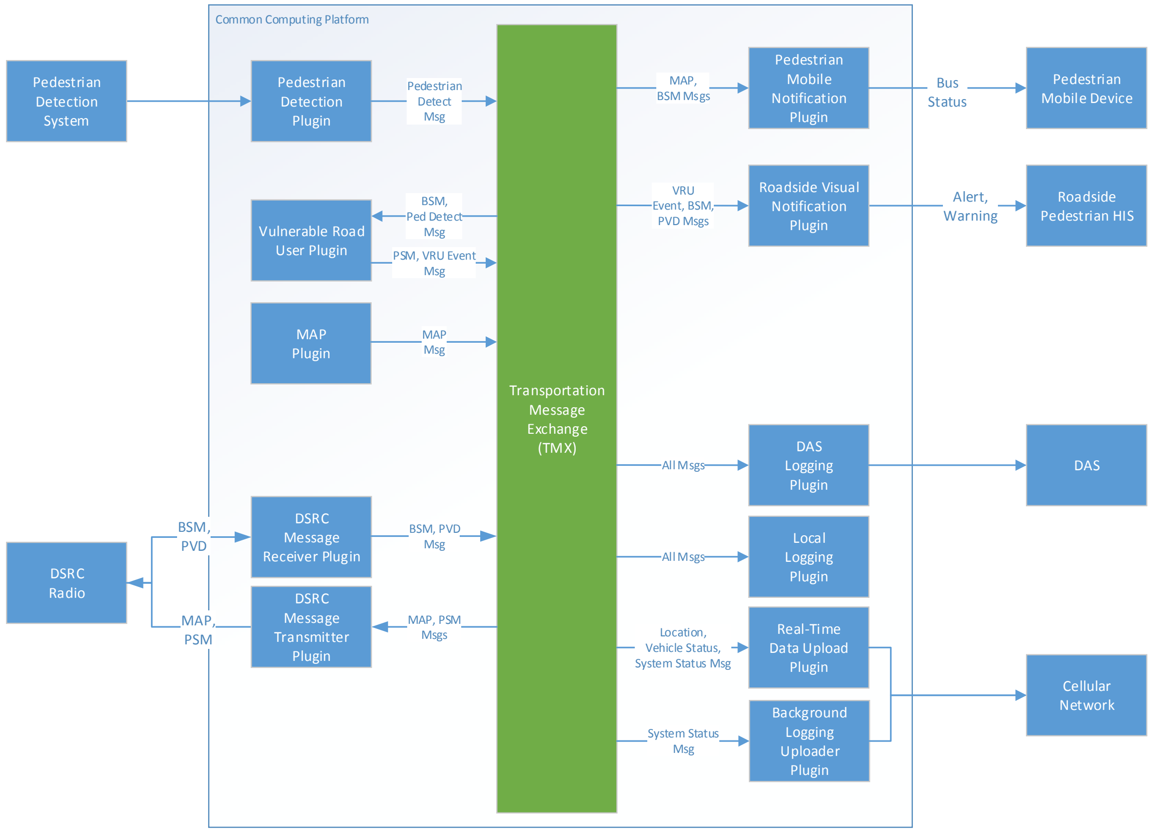
5.3.3.2.19 686492830 Roadside Pedestrian HIS Power Cable

The Roadside Pedestrian HIS will come with an integrated power cable.

5.3.3.3 Software

The Roadside Subsystem software is designed to provide supporting information to the TSPW applications operating on the transit vehicle as well as the Pedestrian Mobile Device and DSRC-Enabled Personally Owned Vehicle. This subsystem will provide detailed information about the transit stop so that the three other subsystems may determine if an alert should be presented to the driver. Key information being provided includes a message containing detailed roadway geometry for the transit stop and another message which provides the output of the Pedestrian Detection Subsystem.

This subsystem software will also be designed around the TMX software platform, just like the In-Vehicle Subsystem. As a result, the logic required to perform the needed functions will be developed as a set of plugins. Each plugin will perform a discreet function and have a single responsibility. Where possible, common functionality between the two subsystems will utilize the same plugins. The diagram below in Figure 5-40 provides a block diagram showing the design on the software.



Source: Battelle

Figure 5-40. Roadside Subsystem Software Design

The core plugins in the Roadside Subsystem are those related to providing the situational information for the transit stop. In particular, the Map, Vulnerable Road User and Pedestrian Detection plugins. The MAP plugin has been developed previously for the IVP project and will be re-used to the extent possible in this project. The remaining plugins are in support of the primary task of providing the transit stop information. Table 5-45 below outlines each plugin designed to be used in the Roadside Subsystem along with the messages produced and consumed by each plugin.

Table 5-45. Roadside Subsystem Plugins with Messages Produced and Consumed

Plugin	Description	Plugin Input	Plugin Output
Pedestrian Detection	The Pedestrian Detection plugin is responsible for interfacing with the detection hardware installed at the transit stop and providing a consistent output suitable for integration into other messages.	Output from Pedestrian Detection Subsystem	Pedestrian Detection Message
Vulnerable Road User	The Vulnerable Road User plugin is responsible for tracking the detected pedestrians at the transit stop and for those within a potentially dangerous zone, broadcasting a Personal Safety Message on their behalf.	BSM Message Pedestrian Detection Message	PSM Message

Table 5-45. Roadside Subsystem Plugins with Messages Produced and Consumed (Continued)

Plugin	Description	Plugin Input	Plugin Output
MAP	The MAP plugin will be responsible for generating the appropriate MAP message for the specific transit stop.	Transit Stop road geometry loaded from filesystem	MAP Message
DSRC Message Receiver	The DSRC Message Receiver plugin is responsible for taking the received DSRC messages from the radio and making them available to the rest of the system.	Output from DSRC radio	BSM Message PVD Message
DSRC Message Transmitter	The DSRC Message Transmitter plugin is responsible for taking internal messages flagged for transmission and ensuring they are sent out via the DSRC radio.	MAP Message PSM Message	Input to DSRC radio to send appropriate message
Pedestrian Mobile Notification Plugin	The Pedestrian Mobile Notification plugin serves as the interface to the pedestrians interacting with the system via their mobile device. This plugin will broadcast the status of approaching transit vehicles.	MAP Message BSM Message	Approaching Transit Vehicle Status
Roadside Visual Notification Plugin	The Roadside Subsystem will include a display used to notify the waiting pedestrians of approaching transit vehicles and alerting those who may be standing in a potentially dangerous zone. This plugin will interface with that display.	VRU Event Message BSM Message	Appropriate signals to Roadside Pedestrian HIS
DAS Logging	The DAS Logging plugin will monitor the system and provide the appropriate information to the DAS.	TSPW Event Message System Status Message	Data logged to DAS
Local Logging	The Local Logging plugin will monitor the state of the system and record the state information to the local system for later review.	TSPW Event Message System Status Message	Data logged to local filesystem
Real-Time Data Uploader	The Real-Time Data Uploader plugin will be responsible for the transfer of data from the system to the Cloud Data Management Subsystem during system operation.	Vehicle Status Message System Status Message	Information sent to Cloud Data Management System
Background Logging Uploader	The Background Logging Uploader plugin will manage the uploading of collected log data by the system during operation and transfer that content to the Cloud Data Management Subsystem in the background when time and system resources are available.	System Status Message	Log data sent to Cloud Data Management System
System Monitor	The System Monitor plugin will track the status of the various hardware, firmware and operating system components required for the proper operation of the system.	Input from various hardware and OS level components	System Status Message

Source: Battelle

5.3.3.3.1 Pedestrian Detection Integration Plugin

The Pedestrian Detection Integration plugin has the responsibility for interfacing with the selected pedestrian detection hardware at the transit stop and converting that data into a form which is useful and in a format expected by the other plugins in the system. At a given transit stop, there will be five zones where pedestrians can be detected. Four of these zones will be in the roadway and the fifth will be a zone adjacent to the roadway along the sidewalk. This plugin will standardize the data output from the Pedestrian Detection Subsystem and translate that information into a message format understood by the other plugins, in particular the Vulnerable Road User plugin.

The specific pedestrian detection technology is still being evaluated and a selection will be made later. The interface to one of the products being tested is via a web socket. In this particular scenario, the Pedestrian Detection plugin would monitor this web socket for the detection of pedestrians into particular zones. These zones would then be mapped over to the appropriate standardized zones. Once the data has been standardized, this plugin would then send out the Pedestrian Detection Message, making this information available to the other plugins operating in the system.

5.3.3.3.2 MAP Plugin

In order to communicate the geographic layout of the various roadway lanes for each transit stop, a MAP message will be broadcast to approaching vehicles. This MAP message will provide the geographic context for which the TSPW application will determine when and what type of notifications to provide to the vehicle operators. Both the IVS and POVS will receive and utilize the MAP messages broadcast from the RSE. An example MAP message as specified in the J2735 R41 specification is provided below in Figure 5-41 with some data from a simulated transit stop.

```
{ "msgID" : 18,
        "msgIssueRevision" : 1,
        "layerType" : "generalMapData",
        "layerID" : 1,
        "roadSegments" : [{
          "name" : "TSPW_TransitStop_1",
          "id" : 1,
          "revision" : 1,
          "refPoint" : {"lat" : "415011090","long" : "-802851800"},
          "laneWidth" : "350",
          "roadLaneSet" : [{
            "laneId" : 1,
            "name" : "CurbDangerZone",
            "laneAttributes" : {
              "directionalUse" : "ingressPath (0) & egressPath (1)",
              "sharedWidth" : "pedestriansTraffic",
              "laneType" : "sidewalk"
            },
            "nodeList" : {
              "nodes" : [{"delta" : {"node-XY4" : {"x" : "-3380","y" : "-180"}}
              }, {"delta" : {"node-XY5" : {"x" : "-5060","y" : "-150"}}}
              ]
            }
          }, {
            "laneId" : 2,
            "name" : "ApproachLane",
            "laneAttributes" : {
              "directionalUse" : "ingressPath (0) ",
              "sharedWidth" : "busVehicleTraffic",
              "laneType" : "vehicle"
            },
            "nodeList" : {
              "nodes" : [{"delta" : {"node-XY4" : {"x" : "-4380","y" : "-280"}}
              }, {"delta" : {"node-XY5" : {"x" : "-5160","y" : "-110"}}}
              ]
            }
          }, {
            "laneId" : 3,
            "name" : "ForwardLandingArea",
            "laneAttributes" : {
              "directionalUse" : "ingressPath (0) ",
              "sharedWidth" : "busVehicleTraffic",
              "laneType" : "vehicle"
            },
            "nodeList" : {
              "nodes" : [{"delta" : {"node-XY4" : {"x" : "-2380","y" : "-80"}}
              }, {"delta" : {"node-XY5" : {"x" : "-1160","y" : "-10"}}}
              ]
            }
          }, {
            "laneId" : 4,
            "name" : "RearLandingArea",
            "laneAttributes" : {
              "directionalUse" : "ingressPath (0) ",
              "sharedWidth" : "busVehicleTraffic",
              "laneType" : "vehicle"
            },
            "nodeList" : {
              "nodes" : [{"delta" : {"node-XY4" : {"x" : "-2380","y" : "-180"}}
              }, {"delta" : {"node-XY5" : {"x" : "-4160","y" : "-210"}}}
              ]
            }
          }
          ]
        }
        ]
}
```


Source: SAE J2735/Battelle

Figure 5-41. Example MAP Message

5.3.3.3.3 Vulnerable Road User Plugin

The TSPW system requires a means of notifying approaching DSRC enabled vehicles of detected pedestrians in potentially unsafe zones. The Vulnerable Road User Plugin will process data from the Pedestrian Detection Plugin and use that information to generate a message suitable for broadcast via DSRC which indicates the zones where pedestrians have been detected. For this the new PSM as defined in SAE J2735 – 2016-03 will be used as an output of the Vulnerable Road Users (VRU) plugin. While the message definition contains a specification for Part I and Part II, the TSPW application will only require the data from Part I. An example PSM message is provided below (Figure 5-42) along with some simulated data.


```
{
    "basicType": "aPEDESTRIAN (1)",
    "secMark": 25000,
    "msgCount": 1,
    "id": 1,
    "position": {
        "lat": 401234567,
        "long": -801234567,
        "elevation": 2560
    },
  "accuracy": {
      "semiMajor": 10,
      "semiMinor": 10,
      "orientation": 32000
  },
  "speed": 8191,
  "heading": 28800,
  "accelSet": {
      "long": 0,
      "lat": 0,
      "vert": 0,
      "yaw": 0
  }
}
```


Source: SAE J2735/Battelle

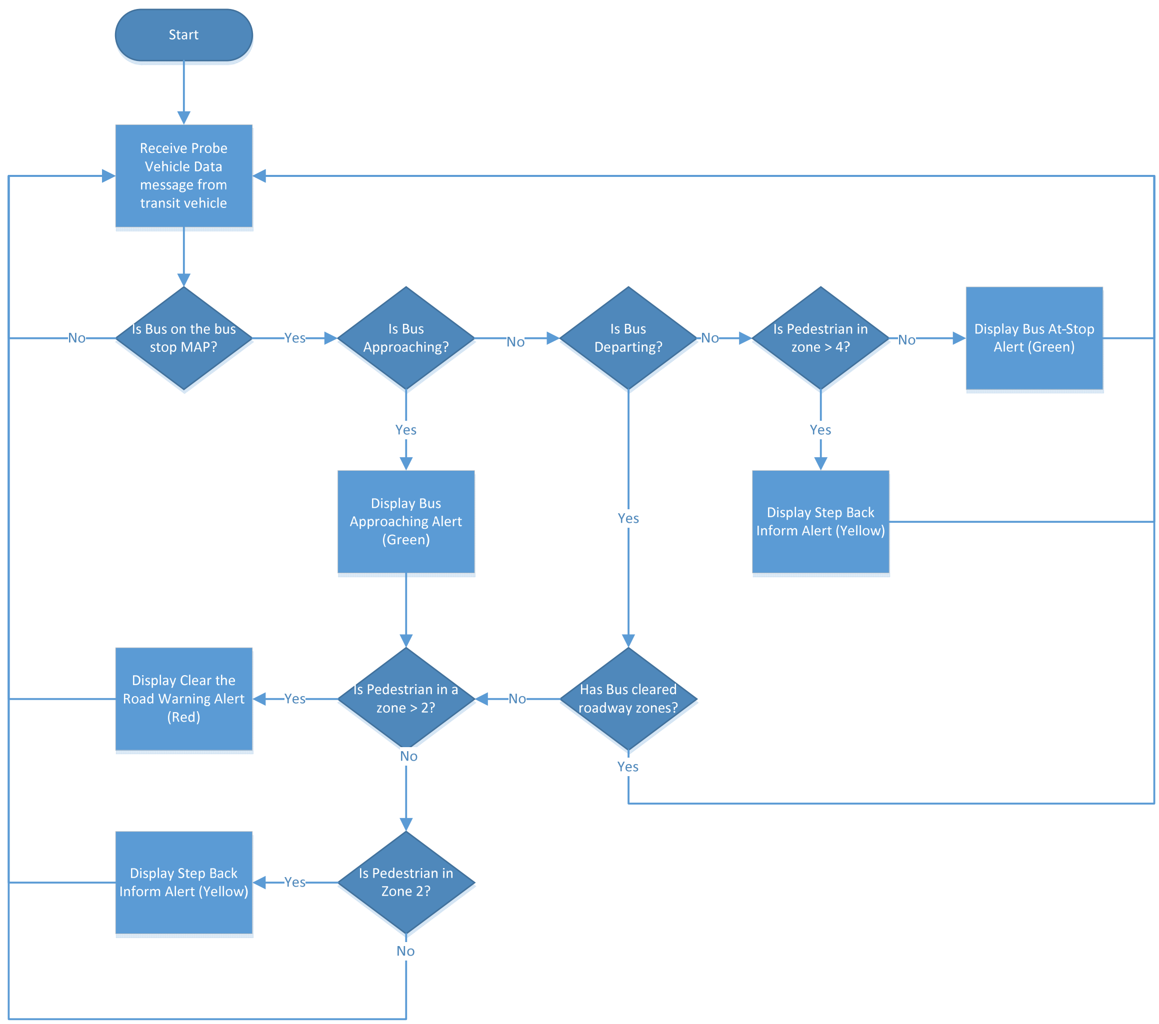
Figure 5-42. Example PSM Message

The position provided in the PSM messages being sent from the RSE will be the center point of the corresponding pedestrian detection zone. A single PSM message will be broadcast from the RSE at a rate of 10 Hz for each zone where a pedestrian is detected. Therefore, under the current design, there can be at most five PSM messages broadcast at a single time. This would occur if all five pedestrian detections zones are occupied simultaneously.

5.3.3.3.4 Roadside Visual Notification

Part of the responsibilities of the RSE is to also provide information and alerts to pedestrians at the transit stop. The RSE will notify waiting pedestrians that a transit vehicle is approaching and provide the route number serviced by the vehicle. In addition, the RSE will also provide a notification to pedestrians detected standing in the potentially dangerous curb zone when a transit vehicle is approaching.

The detection of approaching vehicles is to be accomplished via DSRC messages broadcast by the transit vehicles and received by the RSE. The IVS will already be broadcasting a J2735 Basic Safety Message at a rate of 10 Hz and a PVD message at a rate of 1 Hz. The PVD message will contain the vehicle id, route number and current position. With this information provided by the IVS as well as the pedestrian detection information available locally, the RSE will determine when it is appropriate to notify the waiting pedestrians. The logic diagram below in Figure 5-43 shows the decision process for providing alerts to the waiting passengers at the transit stop.



Source: Battelle

Figure 5-43. Logic Diagram for Generating Roadside Alerts

5.3.4 Pedestrian Mobile Device Subsystem

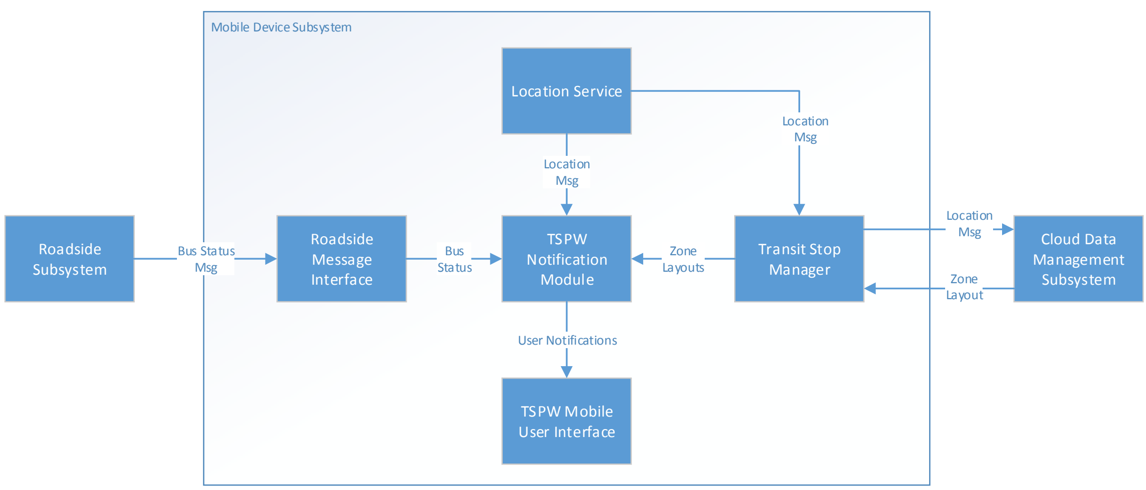
The role of the PMDS is to provide notifications to a pedestrian via their mobile device. There will be two notifications that will be provided to the pedestrian. The first will be to notify the user that a transit vehicle is approaching. The second notification will alert the user to a potentially dangerous situation based on the fact that they are standing too close to the roadway while the transit vehicle is approaching.

5.3.4.1 Hardware

The hardware for the Pedestrian Mobile Device Subsystem utilized for this project will be both the Apple iPhone and Android based smartphones.

5.3.4.2 Software

Unlike the In-Vehicle and Roadside Subsystems, the Pedestrian Mobile Device Subsystem will not be designed around the TMX software platform. Instead this system will conform to a more traditional software architecture used for development of mobile device applications. The TSPW Mobile Application will provide its users with two notifications. The first is a notification of an approaching transit vehicle and the second is an alert when they are in a potentially dangerous area of the sidewalk while a transit vehicle is approaching. The diagram below in Figure 5-44 outlines the major components which are key to this application design.



Source: Battelle

Figure 5-44. Mobile Device Subsystem Component Diagram

The design of the mobile application has important data inputs coming from two directions. The first is information pertaining to the instrumented transit stops provided by the Cloud Data Management Subsystem. This information is detailed zone information for the transit stops. The second is information broadcast to mobile device applications by the RSE via Bluetooth LE. This data received by the mobile device allows the application to determine that transit vehicles have been detected and that they are approaching the transit stop. The TSPW Notification Module will use this information along with the current location of the mobile device to make the determination if an alert should be provided to the mobile device user. Additional details for each of the software modules used in the TSPW Mobile Device Subsystem are provided below in Table 5-46.

Table 5-46. Mobile Device Component Description with Input and Outputs

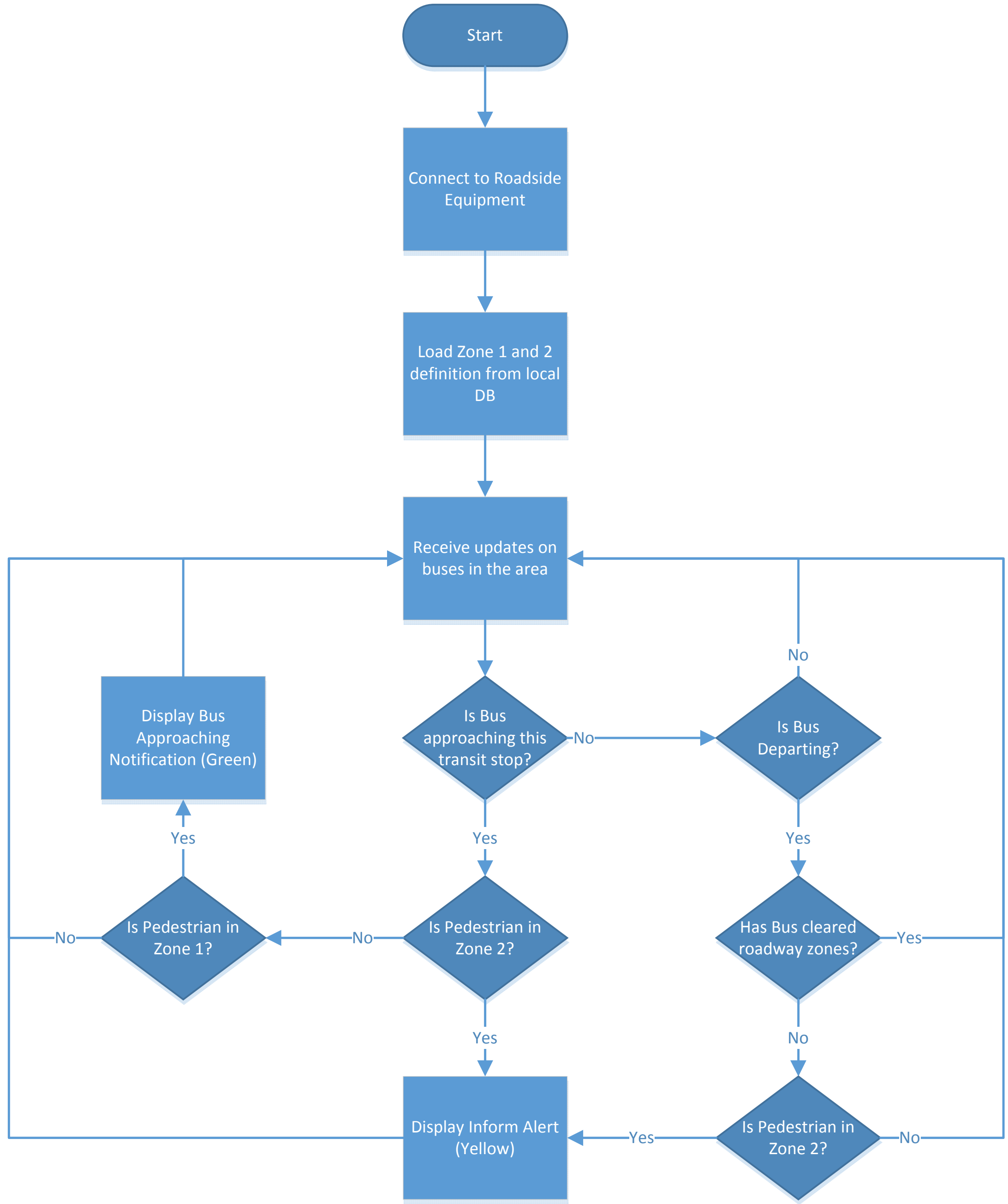
Module	Description	Input	Output
Location Service	This module will interact with the GNSS hardware on the mobile device and provide the current location to the TSPW Notification Module as well as the Transit Stop Manager.	Location data provide by the mobile device OS	Location Message
Roadside Message Interface	The Roadside Message Interface module will listen for and process received Transit Vehicle Status messages transmitted from the Roadside Subsystem	Transit Vehicle Status	Transit Vehicle Status
TSPW Notification Module	The logic of when and which notification to provide to the user is decided in the TSPW Notification Module	Transit Vehicle Status Location Message Zone Layouts	User Notifications
Transit Stop Manager	The Transit Stop Manager module will be responsible for interfacing with the Cloud Data Management Subsystem and ensuring that the local Transit Stop Database is up to date.	Location Message	Updated local Transit Stop database
TSPW Mobile User Interface	The TSPW Mobile User Interface module will provide the interaction with the user and display the appropriate notifications.	User Notification	Displayed information to the user

Source: Battelle

Additional specific details regarding the TSPW Mobile Application on the Mobile Device Subsystem are detailed below.

5.3.4.2.1 Mobile Device TSPW Application

Each time the mobile device is launched or brought to the foreground, an asynchronous task will be initiated with the objective to refresh the local transit stop database. This database will store the GNSS coordinates for each of the instrumented transit stops as well as the polygon definitions for Zone 1 and 2 for each of those transit stops. While the TSPW Mobile app is running, foreground or background, it will periodically check the user's location to determine if they are in the vicinity of an instrumented transit stop. If they are, the application will then begin monitoring their current location with respect to either of the two zones associated with this transit stop. At the same time, the application will begin listening for the Transit Vehicle status information broadcast over Bluetooth LE by the Roadside Subsystem. Based on these inputs to the system, alerts will be presented to the user when the appropriate conditions are met. A more detailed logic diagram for when these alerts are presented to the user are illustrated in Figure 5-45 below.



Source: Battelle

Figure 5-45. Mobile Device Notification Logic Diagram

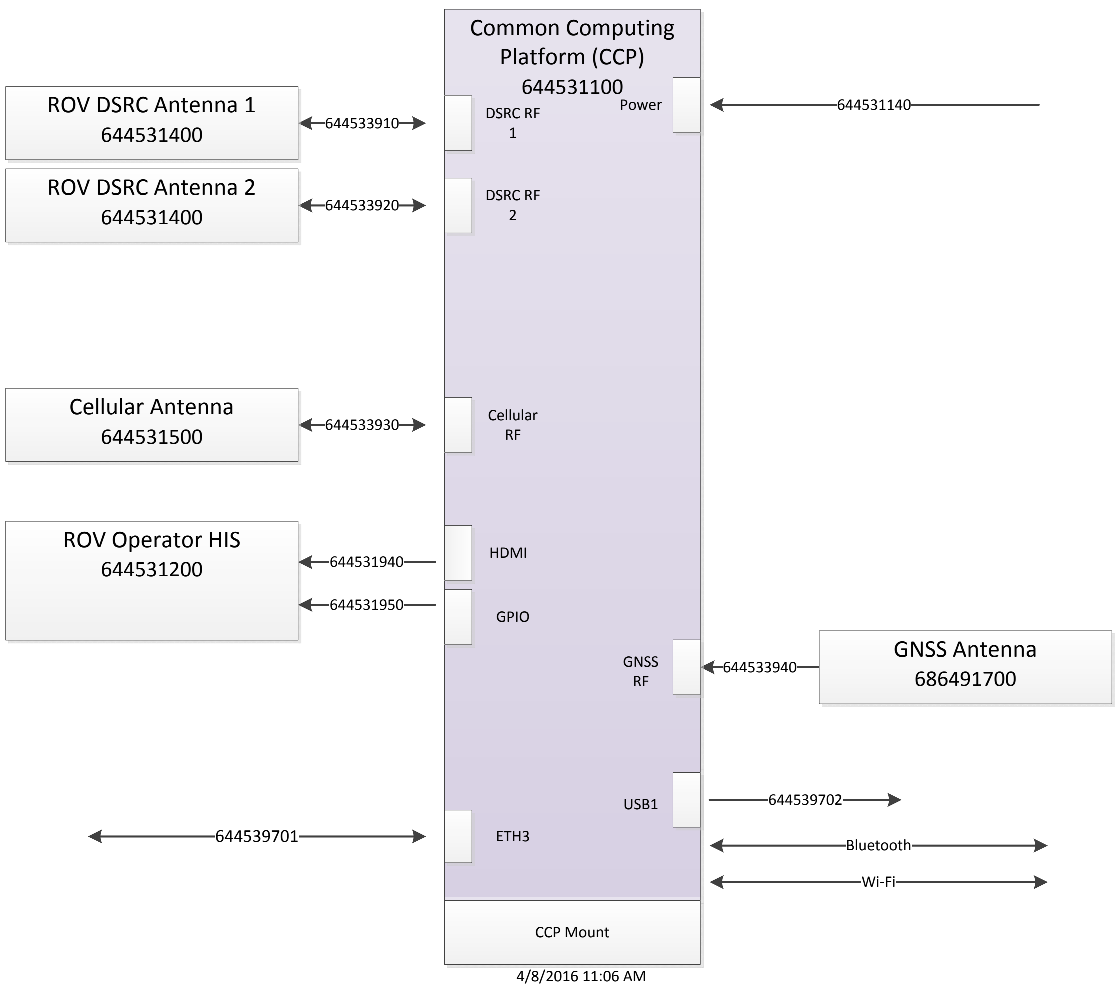
With the desire that this service be made available to as many travelers as possible, this mobile application will target both the Apple iOS and Android smartphone platforms. These platforms are not similar and have historically required that the application be written twice, once for each platform. To mitigate the redundant effort, software development tools have been brought to market in recent years which allow software developers to develop an application in a third party middle ground which allows for the generation of an application suitable for both platforms. One such product is Xamarin (recently purchased by Microsoft). Xamarin is a development environment which allows developers to develop a mobile application using the C# programming language and then target both the iOS and Android platforms. While there are certain capabilities that cannot be accomplished in Xamarin that can be completed in the native development environments, it is expected that all the necessary features required for the TSPW Mobile Device Application will be supported.

5.3.5 DSRC-Enabled Personally Owned Vehicle Subsystem

In addition to protecting passengers from approaching transit vehicles, this system is also exploring new approaches to also protect pedestrians from other POVS while in the vicinity of a transit stop.

5.3.5.1 Hardware

The hardware for the POVS will consist of a CCP, POVS Operator HIS and other support peripherals allowing the POVS to broadcast Basic Safety Messages and receive data from the TSPW RSE. The POVS could be implemented with any DSRC After-Market Safety Device running the TSPW POVS application, but for testing of the TSPW system in Cleveland it will essentially be a much-simplified IVS. The components used to implement the POVS are shown in Figure 5-46.



Source: Battelle

Figure 5-46. POVS Block Diagram

Each subsystem, assembly and component of the TSPW system will be assigned a part number. These part numbers allow for unique identification during configuration control, assembly and testing activities during the development, testing and fielding lifecycles. The components that make up the TSPW POVS, including the internal part numbers, are summarized in Table 5-47 with more details provided in the subsections below.

Table 5-47. POVS Components

Part Number	Item Description
644531100	Common Computing Platform, with Mount
644531400	IVS DSRC Antenna
644531500	Cellular Antenna

Source: Battelle

5.3.5.1.1 644531100 Common Computing Platform, with Mount

The Common Computing Platform is described in detail in section 5.3.1 of this document

5.3.5.1.2 644531400 IVS DSRC Antenna

The DSRC antenna to be used on the POVS will be the same antenna used on the rear of the transit vehicle, only a magnetic mount version. The antenna to be placed at the POVA is described in Table 5-48.

Table 5-48. POVS DSRC Antenna

Source of Supply	Part Number	Link to Datasheet
Mobilemark.com	MGW-301	http://www.mobilemark.com/product/mgw-301-cellular-wifi-gps-2/

5.3.5.1.3 644531500 Cellular Antenna

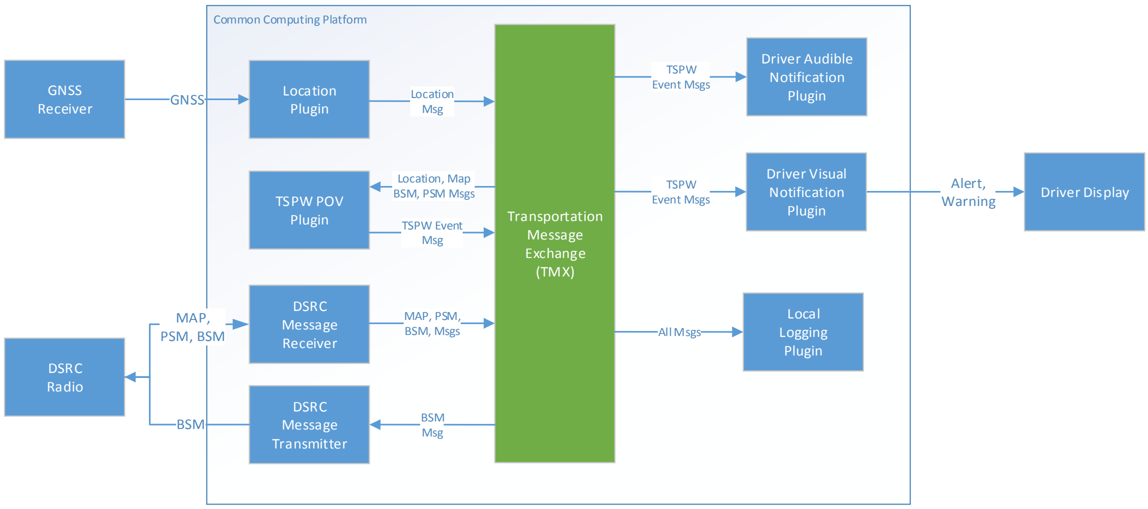
The Cellular Antenna to be used on the POVS will be window mount antenna. The antenna to be placed at the POVS is described in Table 5-49.

Table 5-49. POVS Cellular Antenna

Source of Supply	Part Number	Link to Datasheet
Mobilemark.com	CVL-WLF	http://www.mobilemark.com/product/cvl-wlf/

5.3.5.2 Software

For this prototype, the software deployed in the POVS will be also based on the TMX software platform similar to that of the IVS. By utilizing the same hardware and software platform, much of the software developed for the IVS can be re-used for the POVS. The design of the software is illustrated in the component diagram below in Figure 5-47.



Source: Battelle

Figure 5-47. Personally Owned Vehicle Subsystem Software Design

The logic of when to display an alert to the driver will be implemented inside the TSPW POVS Plugin. This plugin will be responsible from leveraging the services of the other plugins in its determination of when and how an alert is presented to the POVS operator. Table 5-50 outlines all the plugins utilized in this system as well as the inputs and outputs required from each.

Table 5-50. POVS Plugins with Input and Outputs

Plugin	Description	Plugin Input	Plugin Output
Location	This plugin will interact with the GNSS hardware and provide the current location and time information to the rest of the system.	Output stream from GNSS hardware	Location Message
TSPW POVS	The TSPW POVS plugin will monitor the DSRC messages received on the personally owned vehicle and will make the determination if an alert should be presented to the POVS operator.	Location Message MAP Message BSM Message PSM Message	TSPW Event Message
DSRC Message Receiver	The DSRC Message Receiver plugin is responsible for taking messages received via the DSRC radio and relaying those to the rest of the system.	Messages from DSRC Radio	PSM Message MAP Message BSM Message

Table 5-50. POVS Plugins with Input and Outputs (Continued)

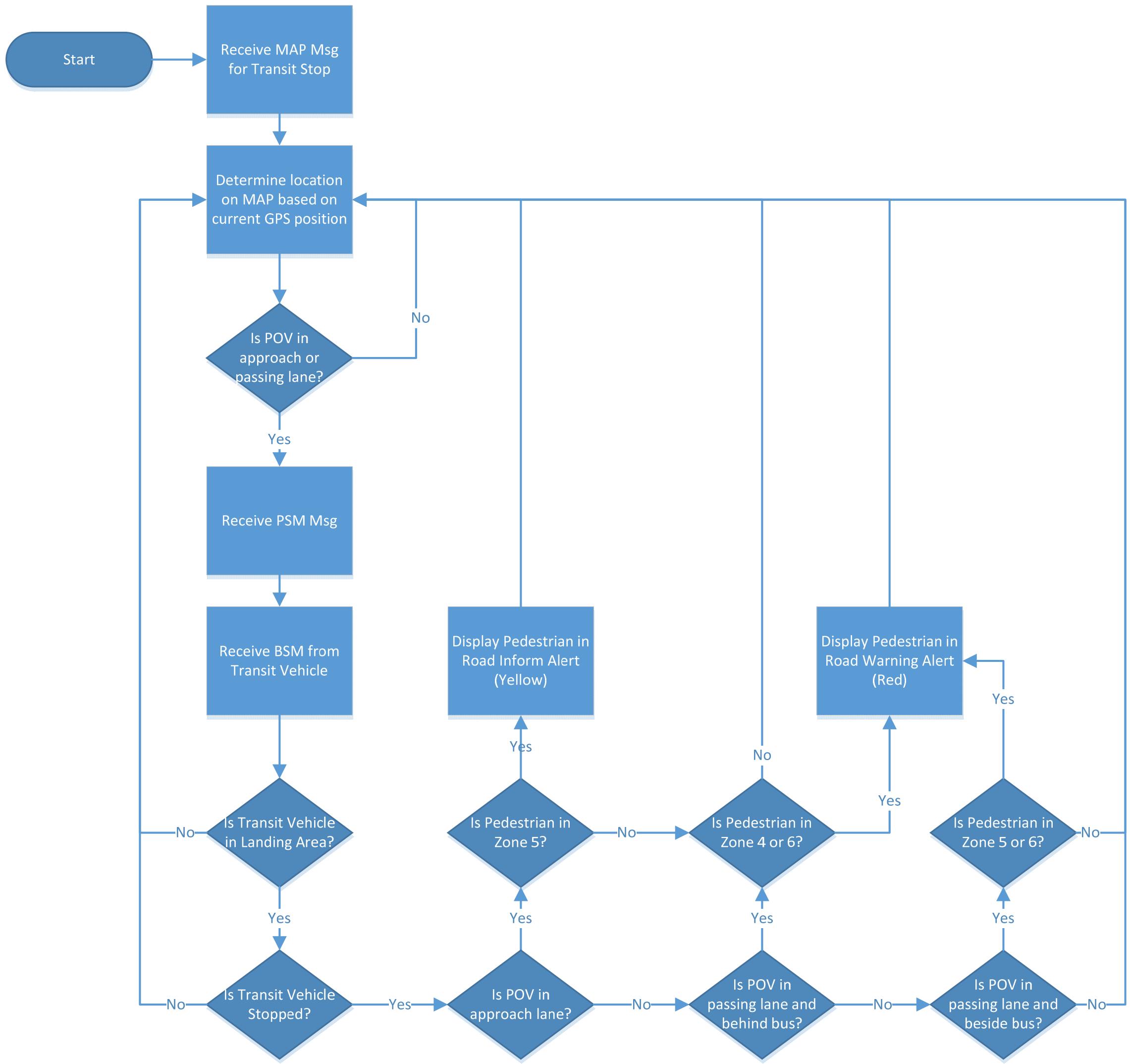
Plugin	Description	Plugin Input	Plugin Output
DSRC Message Transmitter	The DSRC Message Transmitter plugin is responsible for taking internal messages flagged for transmission and ensuring they are sent out via the DSRC radio.	BSM Message	Input to DSRC Radio
Driver Audible Notification	The Driver Audible Notification plugin will be responsible for alerting the transit driver in an audible fashion through an external speaker.	TSPW Event Message	Suitable audio output through system speakers
Driver Visual Notification	The Driver Visual Notification plugin will control the visual display of alerts to the POVS operator.	TSPW Event Message	Events shown on driver display
Local Logging	The Local Logging plugin will monitor the state of the system and record the state information to the local system for later review.	TSPW Event Message Location Message System Status Message	Data logged to local filesystem
System Monitor	The System Monitor plugin will track the status of the various hardware, firmware and operating system components required for the proper operation of the system.	Input from various hardware and OS level components	System Status Message

Source: Battelle

Additional specific details regarding the TSPW application on the In-Vehicle Subsystem are detailed below.

5.3.5.2.1 Transit Bus Stop Pedestrian Warning Application POVS

While the concept of protecting pedestrians at a Transit Vehicle stop is the same for both transit vehicles as well as the personally owned vehicles, the method of implementing the application are slightly different between the two platforms. In the case of the POVS, the logic of when and under which circumstances to notify the POVS driver will differ from that of the transit vehicle. The logic flow diagram below in Figure 5-48 illustrates the process by which the information provided to this system is analyzed and under which conditions an alert is provided to the driver.



Source: Battelle

Figure 5-48. POVS Operator Notification Logic Diagram

As can be seen from the logic diagram above, the key areas of focus for the POVS are protecting pedestrians where they are most vulnerable both while a transit vehicle is stopped at the transit stop. Pedestrians shielded by the transit vehicle are not causes for alert notifications.

The TSPW POVS application will be triggered into an active state by the reception of a Transit Stop MAP message. Once the message has been received and decoded, the application will begin monitoring the current location of the vehicle with relation to the geography described by the MAP. In particular, the application will be looking to see when the POVS has entered with the approach or passing lanes. Once the system has determined that it is in proximity to the transit stop described by this MAP, the application will then begin processing received BSMs from any transit vehicle at the transit stop as well as the PSMs being broadcast by the transit stop RSE. Based on the position reported by the BSM, the application will determine if the transit vehicle is stopped in the Transit Vehicle Landing Area. The locations provided in the PSMs will be analyzed to determine that they are relevant to this transit stop and categorized to determine which pedestrian detection zone they are located in. Based on all these factors, the application will follow the logic outlined above to determine if a Pedestrian in Roadway Inform or Warning Alert should be issued.

5.3.6 Cloud Data Management Subsystem

The Cloud Data Management System will be tasked with two primary objectives: to provide data storage, and to provide management processes to monitor the health and accuracy of the system.

5.3.6.1 User Interface

A web-based portal will be established as the primary user interface for the TSPW system. The website will work in conjunction with data which has been saved to data storage to characterize the activities occurring over all subsystems. Given the number of units being deployed, and their remote nature, it is important to have some visibility into whether the units are reporting data indicating healthy operation. A variety of metrics can be leveraged as indicators to units that may be having issues.

It is important, however, to differentiate vehicles that are simply not in use, and not flag them as being in an errored state. Thus, the first pane will list vehicles that, based on their operation mode and/or gear state, are not actively driving a route. A date will be included that would indicate the date that this mode or state began. This allows an administrator to keep an eye on 'unused' vehicles, and still bring awareness to a possible issue if the state remains for a questionably long period. A possible example of this is illustrated in Figure 5-49.

Vehicles Not In Operational Mode

VehId	Mode	Has been this way since...
Veh1	Standby	2/18/2016 8:00:00
Veh2	Maintenance	2/16/2016 10:34:00
Veh10	Off	2/19/2016 9:00:00

Vehicles Not Driving

VehId	Gear	Has been this way since...
Veh1	Park	2/18/2016 4:02:00
Veh2	Park	2/16/2016 5:45:00

Source: Battelle

Figure 5-49. Inactive Vehicles Web Page

The remaining vehicles, those presumably in active use, would be included in the Activity table that would show the activity of various reported properties about the vehicle. Counts in these property columns would indicate that the respective piece of hardware plus its interface was actively being used and responsive. Brake changes are obtained directly from the vehicle and will report the number of times that the state changes from applied to not applied at a supported stop. The remainder of the columns are outputs from the IVS. Stop Traversals will report the number of total supported stops that the Transit Vehicle has encountered. Transit Vehicle Location Status Changes will report changes in state from entering and exiting the landing zone. Lastly, TSPW Inform and Warning report alerts generated based on those stops. All of these metrics provide quick visibility into properties that are important to proper functioning of the IVS. The page will have a configurable window of time so that a user can see activity over one hour, 8 hours, etc. An example of this is illustrated in Figure 5-50.

Vehicle Activity Over Last X Hours

VehId	Brake Changes	Stop Traversals	Bus Location Status Changes	TSPW Inform	TSPW Warning
Veh3	120	3	12	1	0
Veh4	150	1	3	0	1

Source: Battelle

Figure 5-50. Active Vehicles Web Page

Once counts exist for user review, further automation can be placed on top of those statistics to further assist with highlighting data that may indicate an issue that requires further scrutiny. Experimentally, an expected number of counts per property per hour can be established; for instance, at least 1 Stop Traversal could be expected as a minimum. The counts can then be compared to the statistics to automatically flag any data that does not meet expectation. The counts are tabulated based on the last X hours of forward gear normal operation usage – if the vehicle reported being in Park for 30 minutes of that time, then that 30 minutes would not be counted towards the hours of fulfillment. The benefit of this is illustrated by an example in Figure 5-51. Vehicle 5 (Veh5) did not report any supported stops over the selected duration, which is below the expected threshold. The item can be highlighted to bring this to the attention of the operator so that the issue can be further monitored.

Vehicle Activity Over Last X Hours

VehId	Brake Changes	Stop Traversals	Bus Location Status Changes	TSPW Inform	TSPW Warning
Veh5	120	0	0	0	0
Veh6	150	1	3	0	1

Source: Battelle

Figure 5-51. Active Vehicle Web Page Showing Possible Issues

Additional system health monitoring can be added using the fact that each vehicle is required to report a number of statuses each hour on various hardware modules. These include: power, fault, Bluetooth, DSRC, GNSS, Cellular, Wi-Fi, and operation mode. If any vehicle in normal operation mode has not reported data within the last one and a half hours, then this vehicle can be flagged as an error. Additionally, attention can be brought to any vehicles that report a negative status for any of the modules. Figure 5-52 illustrates that Veh72 may have a hardware issue resulting in a fault, and that Veh45 missed its hourly update message since the time last reported. In both tables, the vehicle Id may be selected to see all the recent updates from that vehicle.

Vehicle Module Health

VehicleId	PowerGood	NoFault	BluetoothGood	DSRCGood	GNSSGood	CellGood	WifiGood	OperationMode
Veh71	1	1	1	1	1	1	1	Normal
Veh72	1	0	1	1	1	1	1	Normal

Non-Reporting Vehicles

VehId	OperationMode	Last Reported
Veh45	Normal	2/19/2016 10:01:00

Source: Battelle

Figure 5-52. Vehicle Monitor Health Web Page

The Roadside Units also report data that can be used to monitor health status. These states include the operational mode and where pedestrians are located in the RSE's zones. Like with the vehicle activity, it can be leveraged that a lack of activity in this table is an indicator that there may be an issue requiring review. Additionally, RSEs are required to store imagery related to a pedestrian trigger event. Counts in these property columns would indicate that the respective piece of hardware plus its interface was actively being used and responsive. Each column would correspond to a zone used for the transit stop. Quotas could be established in a similar fashion to the vehicles data, however they would be daily based, since there would be anticipated vast fluctuations in pedestrians at day vs night. This is illustrated in Figure 5-53, where Zone 2 of RSE 1 may be having an issue. The RSE Id may be selected to see all the recent detail data from that RSE.

RSUs Not In Operational Mode

RsuId	Mode	Has been this way since...
Rsu8	Maintenance	2/16/2016
Rsu9	off	2/19/2016

RSU Activity Over Last Day

RsuId	Zone 1	Zone 2	...	Zone 6
Rsu1	1	0	5	2
Rsu2	3	3	2	4

RSU Video Activity Over Last Day

RsuId	Zone 1	Zone 2	...	Zone 6
Rsu1	1	0	5	2
Rsu2	3	3	2	4

Source: Battelle

Figure 5-53. Roadside Unit Activity Web Page

5.3.6.2 Data Storage

An SQL Azure database will be hosted in Azure to maintain cloud data storage. This database will receive data from the vehicle and roadside units. The Management Portal will utilize the data to assist in monitoring the status of the equipment.

5.3.6.2.1 Data Tables

TspwActivity: Logs states of various properties of each vehicle, new entry made each time a state changes. Includes alerts generated as a result of processing on the In-Vehicle unit.

- Time
- VehicleId
- BrakeState
- GearState
- BusLocationStatus
- TspwEventMessage
- TspwStatus
- MapName
- OperationMode

VehicleHealth: Module status update per vehicle per hour. Also logged upon change in OperationMode.

- Time
- VehicleId
- PowerGood
- NoFault
- BluetoothGood
- DsrcGood
- GnssGood
- CellGood
- WifiGood
- OperationMode

VehicleRoadsideStates: Logs states of roadside pedestrian detection as received and parsed by the vehicle, new entry made each time a state changes.

- Time
- VehicleId
- Zone1: true if pedestrian detected in this zone, false if not.
- Zone …
- Zone 6

RoadsideStates: Logs states of various properties of each RSE, new entry made each time a state changes.

- Time
- RseId
- OperationMode
- Zone1: true if pedestrian detected in this zone, false if not.
- Zone …
- Zone 6

RoadsideImages: Stores an image of pedestrian detection zone when triggered.

- Time
- RoadsideId
- ZoneId
- ImageData

RoadsideVehicleStates: Logs states of vehicle activity as received and parsed by the roadside, new entry made each time a state changes.

- Time
- RoadsideId
- BusLocationStatus
- BusNumber
- RouteNumber

VsuAlerts: Logs alerts generated as a result of processing at the roadside unit, new entry made each time a state changes.

- Time
- RoadsideId
- TspwEventMessage

5.3.6.2.2 Enumeration Tables

Several tables will be required in the database to hold enumerations of types needed throughout the system. These tables are always simple, merely mapping a human-referable name to an integer. The integer can then be used in the other data tables which allows the tables to be smaller, and allows the name to be flexible.

BrakeState

- Applied
- NotApplied

LaneOccupied

- None
- Approach
- Passing

BusLocationStatus

- Out
- Approaching
- EnteredZone
- Stopped
- Departing
- DepartingStillForwardZone

TspwStatus

- None
- Supported: supported stop identified

TspwEventMessage

- None
- Inform
- Warning

GearState

- Forward
- Reverse
- Park
- Other

OperationMode

- Standby: Ignition Off. The IVS-CCP continues to monitor the vehicle CANbus but the other peripherals including DSRC, cellular, and the HID are off. Not applicable to RSE.
- Normal: Ignition On
- Degraded: recovery from fault
- Maintenance: selected by user

SubscriptionType: Lookup table for future expansion to allow for catering of specific subscription emails rather than all of them. These emails are for administrators to be notified of possible issues within the system.

- All

5.3.6.2.3 Management Tables

Subscriptions: Tracks email addresses registered to receive email alerts for various events.

- Id
- SubscriptionType
- Email

5.3.6.3 Web API Interface

The Cloud Data Management Subsystem will host a secure web server over HTTPS protocol (Hypertext Transfer Protocol Secure). This secure web server will implement a simple Representational State Transfer (REST) architecture to service requests directly from the remote devices via a cellular connection. A Mobile Device web client will request a persistent HTTPS connection (Keep-Alive) with the Cloud Web Server to reduce the overhead otherwise required to repeatedly open temporary HTTPS client connections.

The vehicle and roadside units need to report data to the Azure database to have it stored. An Azure Web API will provide this interface. URL endpoints will exist to facilitate saving data to each data table. The vehicle and roadside units will use these URLs to send the JSON data that is to be stored in the database. The Web API software will parse the JSON data and store it.

5.3.6.4 Data Services

5.3.6.4.1 Notifications

A variety of expectations about the data reported to the system was covered in Section User Interface. Each of these expectations can also be verified by software, and if an expectation is not met, an email can be sent to users subscribed to receive them. These routines complete the same logic as the website, but instead generate a once-a-day email rather than web results. The list of metrics that can be automated for notifications are:

- Vehicles Not in Operational Mode
- Vehicles Not Driving
- Vehicle Quotas Not Met
- Vehicle Module Health Failures
- Non-Reported Vehicle Health Updates
- RSE Quotas Not Met

5.3.6.4.2 Monitoring

Automation can also be developed to detect disparities between the RoadsideStates table and the VehicleRoadsideStates table. The RoadsideStates table records when pedestrians are in specific zone. If a vehicle is at the stop during this time, the same zones should be processed and noted in the data tables for the Transit Vehicle and the personally owned vehicle. A background process can monitor this and report discrepancies to another table or be added to the email subscription service.

5.3.7 Subsystem Interface Definition

This section of the design document is focused on the interfaces between the three main TSPW subsystems as well as the communication interfaces between the components within each subsystem.

5.3.7.1 Communication between subsystems

The interaction between the four main TSPW subsystems is limited to just two different interfaces. The Roadside Subsystem will be broadcasting two different DSRC Messages which will be received by the In-Vehicle Subsystem. The second interface is where both the Roadside and In-Vehicle Subsystems communicate via their cellular connections to the Cloud Data Management Subsystem. Additional details about the information exchanged over these interfaces are provided below.

5.3.7.1.1 Roadside Subsystem to In-Vehicle and POVS Interface

The Roadside Subsystem will generate and broadcast two DSRC Messages in support of the TSPW application. The first is a MAP message. This message will define the transit stop geometry allowing an approaching vehicle to determine the layout of roadway lanes and sidewalks. This MAP message will be formatted in accordance with the J2735 R41 specification.

The second DSRC message being used is a PSM message. An example of this message can be seen in Figure 5-42. This message will provide the approaching vehicle information about the status of the pedestrian detection. There are five total zones at each transit stop where pedestrians can be detected. The PSM being sent will contain the GNSS locations of the center of the pedestrian detection zones. These center points will be used by the transit vehicle in the area to determine which corresponding pedestrian zone. The IVS will use the received GNSS location and associate that point on the supplied MAP. This association will allow the IVS to first determine if the pedestrian has been detected in the curb side danger zone or in the roadway. If the pedestrian is detected in the roadway, the IVS will calculate which of the four roadway zones the point represents and proceed through the logic to determine the appropriate TSPW event to generate.

5.3.7.1.2 Roadside Subsystem to Mobile Device Subsystem

A small but critical piece of information will be necessary for the RSE to transmit to the Mobile Device Subsystem. Due to the lack of DSRC radio present on the mobile device, the RSE is needed to relay information regarding the approaching transit vehicle. This relayed information is used by the Mobile Device to both notify the mobile device user of the approaching transit vehicle route number and as a trigger to perform the safety check based on the current pedestrian's position. The amount of data being transmitted is very small. A message is to be transmitted from the RSE to any listening mobile device systems to convey the status of nearby transit vehicles. The message will provide the route number serviced by the transit vehicle as well as the vehicle state. The vehicle state will be either approaching, at stop or departing. Due to the very small amount of data and the desire to minimize the required user interaction to participate the design is to use Bluetooth LE as the connection protocol.

5.3.7.1.3 In-Vehicle Subsystem and POVS Interface

The IVS and DSRC Enabled POVS will communicate via broadcast BSMs. These message will provide both systems the necessary information required to calculate the relative location of the other vehicle with respect to its current location. This information will then be used to determine if TSPW Events should be generated for the given situation.

5.3.7.1.4 Cloud Data Management System Interface

Both the Roadside, In-Vehicle and Mobile Device Subsystems communicate via their cellular connections to the Cloud Data Management Subsystem. The cellular communications interface for both the In-Vehicle Subsystem as well as the Roadside Subsystem will be utilized to provide both outbound and inbound initiated connections. The cellular connection from the Mobile Device will only be initiated by the device and will not allow remote initiated connections. The outbound information will consist of data being uploaded in near real-time as well as batch upload of stored log data. Inbound connections are planned for administrative changes and remote system upgrades.

Table 5-51 provides further details about the information transmitted via the cellular connections.

Table 5-51. Information Transmitted via the Cellular Connections

Information Type	Subsystems	Direction	Frequency	Description
Vehicle Probe Message	In-Vehicle	Outbound	Once per minute	A Vehicle Probe message will be created and sent containing a set GNSS snapshots taken each second over the past minute. GNSS Snapshot will include: • Latitude • Longitude • Elevation • Heading • Speed • Time
System Status Message	In-Vehicle, Roadside	Outbound	Once per minute	This message acts as a bit of a 'Heartbeat' message reporting system status and health. Information included in this message includes: • System Mode • GNSS Status • DSRC Status • Cellular Status • Wi-Fi Status • Bluetooth Status • CAN1 Status • CAN2 Status • Fault Codes

Table 5-51. Information Transmitted via the Cellular Connections (Continued)

Information Type	Subsystems	Direction	Frequency	Description
DSRC Message Logs	In-Vehicle, Roadside	Outbound	Once per day	A PCAP formatted file of all received and transmitted DSRC messages will be uploaded from the In-Vehicle and Roadside Subsystems.
Vehicle Status Logs	In-Vehicle	Outbound	Once per day	This log data will contain a record of the vehicle state capture once every second. Data being recorded will include: • Vehicle Speed • Turn Signal State • Gear Position • Brake Status
Application Logs	In-Vehicle, Roadside, Mobile Device	Outbound	Once per day	In order to evaluate the effective operation of the TSPW application, a detailed log of application status and events will be recorded. This log will provide the details necessary for determining when and under what circumstances the applications alerted the transit vehicle driver.
Debug Logs	In-Vehicle, Roadside	Outbound	Configurable	During the testing and evaluation of the system, additional logged details may be necessary to debug issues. These more in depth log files will be uploaded and analyzed by the system developers.
Transit Stop Data Files	Mobile Device	Inbound	As needed	Detailed information about the layout of the Transit Stops will be available for download from the CDMS by the TSPW Mobile Application.
System Configuration Files	In-Vehicle, Roadside	Inbound	As needed	Throughout the deployment, the configuration of the system may need to be updated. Should that need arise, the ability will exist to remotely update the configuration files.
Application Update Files	In-Vehicle, Roadside	Inbound	As needed	Throughout the deployment, the application executables of the system may need to be updated. Should that need arise, the ability will exist to remotely update those files.

Source: Battelle

5.3.7.2 IVS, POVS and RSE Component Interfaces

As discussed earlier in this design document, both the In-Vehicle and Roadside Subsystem software is built around the TMX platform. As such, the software application is actually composed of a number of loosely coupled components, or plugins, which interact by consuming and producing messages. One key advantage of this approach is that adding in new applications or features can be done by adding new plugins and re-using much of the existing system. There is a significant overlap in the messages used between both subsystems. Therefore, the messages used by both systems will be described in this section. Table 5-52 lists the Message Type, which subsystem uses this message as well as the contents of each message.

Table 5-52. Message Type, Subsystem Use, and Contents

Message Type	Subsystems	Message Definition
Location	In-Vehicle, POVS, Roadside	Latitude Longitude Elevation Speed Heading Date Time
MAP	In-Vehicle, POV, Roadside	Contents as specified in J2735 R41
PSM	In-Vehicle, POVS, Roadside	Contents as specified in J2735 2016-03
BSM	In-Vehicle, Roadside, POVS	Contents as specified in J2735 R41
PVD	In-Vehicle, Roadside	Contents as specified in J2735 R41 with a focus to include the route number of the approaching transit vehicle.
Vehicle Status	In-Vehicle	Speed Gear Status (PRND) Brake Status
TSPW Event	In-Vehicle, POVS	Event Status with the following possible values Entered TSPW Area Exited TSPW Area Inform Pedestrian in Road Warn Pedestrian in Road Clear
Pedestrian Detection	Roadside	Pedestrian In Zone 2 Pedestrian In Zone 3 Pedestrian In Zone 4 Pedestrian In Zone 5 Pedestrian In Zone 6

Table 5-52. Message Type, Subsystem Use, and Contents (Continued)

Message Type	Subsystems	Message Definition
System Status	In-Vehicle, Roadside	System Mode Operational Standby Maintenance Degraded GNSS Status DSRC Status Cellular Status WiFi Status Bluetooth Status CAN1 Status CAN2 Status Fault Codes

Source: Battelle

5.3.8 Remote Administration Access Point

During deployment, it is likely that the CCPs deployed on the transit vehicle and roadside will require maintenance. In order to facilitate this maintenance a RAAP will be deployed. The RAAP consists of a virtual server attached to the internet with a commercial-grade Virtual Private Network (VPN) software solution called OpenVPN (https://openvpn.net/).

OpenVPN Access Server is a full featured secure network tunneling VPN software solution that integrates OpenVPN server capabilities, enterprise management capabilities, simplified OpenVPN Connect UI, and OpenVPN Client software packages that accommodate Windows, MAC, Linux, Android, and iOS environments. OpenVPN Access Server supports a wide range of configurations, including secure and granular remote access to internal network and/ or private cloud network resources and applications with fine-grained access control[5].

The OpenVPN client will automatically be loaded by each CCP deployed in the field, which will setup a secure network connection, over the cellular networking service, back to the OpenVPN server located at Battelle's headquarters in Columbus, OH. Once the connection is established between the client and the server, TSPW system administrators will be able to securely access the deployed devices from Battelle's corporate network. To ensure security, only authorized users on Battelle's network will have access to the VPN tunnel. Additionally, the OpenVPN client running on the CCP will reject any unauthorized incoming connection attempt other than those made through the OpenVPN tunnel.

[5] https://openvpn.net/index.php/access-server/overview.html

APPENDIX A. Terms, Definitions, and Acronyms

BRT	Bus Rapid Transit
BSM	Basic Safety Message
CAN	Controller Area Network
CCP	Common Computing Platform
CDMS	Cloud Data Management Subsystem
CONOPS	Concept of Operations
CPU	Central Processing Unit
DAS	Data Acquisition System
DSRC	Dedicated Short-Range Communication
E-PCW	Enhanced Pedestrian at Crosswalk Warning
ESP	External Sensor for Phase
GCRTA	Greater Cleveland Regional Transit Authority
GID	Geometric Intersection Description
GNSS	Global Navigation Satellite System
GPIO	General Purpose Input/Output
HDMI	High-Definition Multimedia Interface
HIS	Human Interface Subsystem
HTTPS	Hypertext Transfer Protocol Secure
IEEE	Institute of Electrical and Electronics Engineers
ISO	International Organization for Standardization
IVP	Integrated V2I Prototype
IVS	In-Vehicle Subsystem
LED	Light Emitting Diode
NOACA	Northeast Ohio Areawide Coordinating Agency
OS	Operating System
PDS	Pedestrian Detection System
PMDS	Pedestrian Mobile Device Subsystem
PSM	Personal Safety Message
POVS	DSRC-Enabled Personally Owned Vehicle Subsystem
PVD	Prove Vehicle Data Message

RAAP	Remote Administration Access Point
RCI	Rear Camera Integration
REST	Representational State Transfer
RSE	Roadside Subsystem Equipment
RSU	Roadside Unit
SAE	Society of Automotive Engineers
SBC	Single Board Computer
SCMS	Security Credential Management System
SMA	SubMiniature version A
SNMP	Simple Network Management Protocol
SPaT	Signal Phase and Timing
TCP/IP	Transmission Control Protocol/Internet Protocol
TMX	Transportation Message Exchange
TSPW	Transit Bus Stop Pedestrian Warning Application
TV	Transit Vehicle
TVO-HIS	Transit Vehicle Operator Human Interface Subsystem
USB	Universal Serial Bus
U.S. DOT	United States Department of Transportation
VPN	Virtual Private Network
VRU	Vulnerable Road User

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