Phase 2 System Design Document (SDD)

GDOT ITS4US Deployment Project

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ITS4US

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U.S. Department of Transportation

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16. Abstract

The Georgia Department of Transportation ITS4US Deployment project, Safe Trips in a Connected Transportation Network (ST-CTN), is leveraging innovative solutions, existing deployments, and collaboration to make a positive impact using transportation technology to support safety, mobility, and reliability. The ST-CTN concept is comprised of an integrated set of advanced transportation technology solutions (connected vehicle, transit signal priority, machine learning, predictive analytics) to support safe and complete trips, with a focus on efficient and cost-effective transportation options for all.

This System Design Document (SDD) details the design of all sub-systems and system components, describing the full scope of the proposed ST-CTN System. The SDD provides complete traceability from requirements to system design, with each requirement tracing to at least one design element, with some requirements tracing back to multiple design elements.

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1 Introduction

The System Design Document (SDD) details the design of all sub-systems and system components, describing the full scope of the proposed Safe Trips in a Connected Transportation Network (ST-CTN) System. The SDD provides complete traceability from requirements to system design, with each requirement tracing to at least one design element, with some requirements tracing back to multiple design elements. This document is supported by the System Architecture Document [SAD] which describes the system framework and the Interface Control Document [ICD] which describes the data exchange between the source and destination of each interface and further details the relationship between interfaces and system requirements. The SDD was developed following the guidelines provided in the IEEE Standard 1016-2009 (IEEE Recommended Practice for Software Design Descriptions).

1.1 Intended Audience

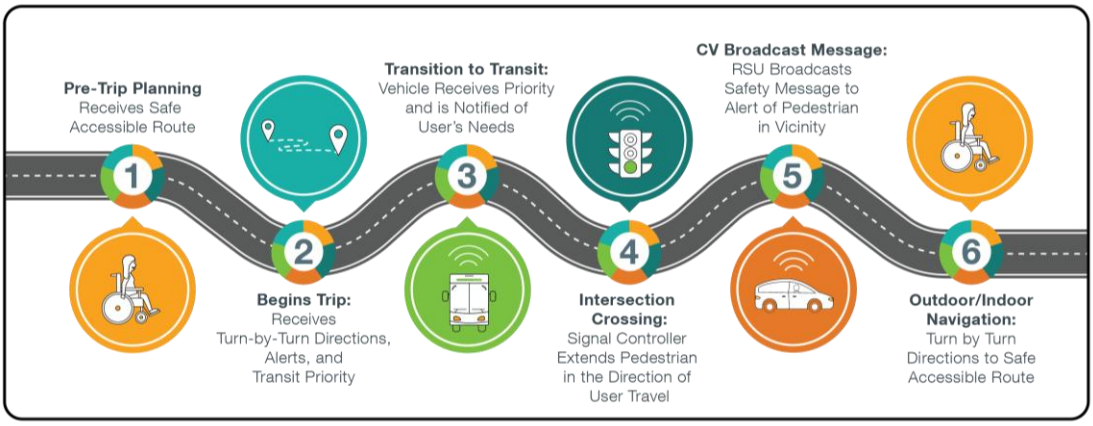
The ST-CTN project is being led by the Georgia Department of Transportation (GDOT). The intended audience for this SDD is the United States Department of Transportation (USDOT) and the ST-CTN project team, which includes GDOT and the following partners:

- Atlanta Regional Commission (ARC)
- Gwinnett County
- Statewide Independent Living Council of Georgia (SILCGA)
- GO Systems and Solutions (GOSystems)
- Georgia Institute of Technology (GA Tech)
- Arcadis Group (Arcadis)
- ICF International, Inc. (ICF)
- Kimley-Horn and Associates, Inc. (KHA)
- Georgia Tech Research Institute (GTRI)
- Avail Technologies (Avail)

This document provides the detailed design of all sub-systems and system components of the ST-CTN deployment and is intended to be utilized as a reference by agencies and industry professionals that are interested in deploying a system similar to the ITS4US ST-CTN Deployment.

1.2 Project Background

The ST-CTN project aims to upgrade and integrate existing technologies and services so that all travelers can accomplish their complete trip successfully, safely, and reliably. The vision of the project is to provide users with directions, conditions, and status on the links between trip legs that are personalized based on the user's profile, while connecting the user to Connected Vehicle (CV) infrastructure to provide safer trips and more transportation network awareness. As an illustration of how the ST-CTN system will be used, transit-based trips were delineated into six segments (as depicted in Figure 1) to allow for easier understanding and a greater breakdown of priorities and goals.



Source: ARC, 2020

Figure 1. Traveler's Complete Trip

The delineated trip segments include the following steps and project components:

- **Step 1 Pre-Trip Planning.** The traveler plans for and receives a safe accessible route.
  - The ability to customize trip preferences based on the user's needs.
- **Step 2 Begins Trip.** The traveler begins their trip and receives turn by turn directions, alerts, remote pedestrian activation, and can trigger transit signal priority (TSP).
  - Turn by turn, shortest path, directions along pathways that meet user defined preferences.
  - Provides support services for users if they become disoriented or have issues accessing defined paths.
  - Activates TSP if the user's trip includes fixed route transit service that is behind schedule.
- **Step 3 Transition to Transit.** The traveler transitions to transit and the transit vehicle receives priority and is notified of users' needs. TSP can be triggered if the bus is running behind schedule due to a longer boarding time needed by a user.
  - Provides users with transit trips that meet user defined preferences.
  - Sends alerts to transit vehicles when users need additional time to board, navigate internally, or alight the transit vehicle.

  - Remotely requests service from transit vehicles while waiting to board or alight.
  - Triggers TSP if the bus is running behind schedule greater than one minute.

- **Step 4 Intersection Crossing.** When crossing a signalized intersection, the traveler indirectly interacts with the signal controller in that an authorized system call is made to the controller which extends the pedestrian phase in the direction of user travel.
  - Allows the user to communicate with connected intersections if they are unable to reach or press the crosswalk button.
  - Provides the user with information about the intersection crossing and adds time to the crossing if needed.
- **Step 5 CV Broadcast Message.** Roadside units (RSUs) broadcast safety message to alert CVs of pedestrians in the intersection.
  - Provides communications to enabled CVs from pedestrian crossing signal systems (via RSUs) to make them aware of pedestrians crossing a roadway.
- **Step 6 Outdoor/Indoor Navigation.** The traveler is provided with turn by turn directions to a safe accessible route.
  - Hands-free navigation via mobile apps and/or wearables and multiple channels (haptic, voice, text).
  - Alerts and dynamic rerouting in response to changes in path conditions.
  - Provides the user with efficient routes into and through two facilities within the project area.
  - Provides users with updates on the operating status of indoor infrastructure such as elevators and escalators.

There is an additional **Step 7** that is not part of the traveler's complete trip but is part of the ST-CTN system: **Reporting**. This step provides summaries of the data collected during the Complete Trip process.

System development and system integrations completed within the scope of this project enable travelers to program and safely complete single mode or multimodal trips that are based on their needs; improve the transition between modes by providing additional details to users and transit service operators; suggest dynamic routing changes based on infrastructure condition and calculated delay.

The existing initiatives that are being leveraged to support the proposed ST-CTN system are defined in more detail below as well as those components that were developed specifically to support ST-CTN project evaluation. The icons and colors depicted below are used throughout the SDD to clearly identify the critical components of ST-CTN. In some cases, partner agencies are upgrading the services within their current systems to create a more robust data set or toolset for the ST-CTN program.



OTP for G-MAP. Atlanta Rider Information and Data Evaluation System (ATL RIDES) includes an Open Source Software (OSS) multi-modal trip planning and mobile application, integrated mobile fare payment options, and a Connected Data Platform (CDP) using regional General Transit Feed Specification (GTFS) transit service data. The tool supports multi-agency context, multilingual support, and mobile app turn-by-turn directions. The

OpenTripPlanner (OTP) architecture facilitates integration with additional OSS tools including a data analytics engine, call center module with application programming interfaces (APIs), and account management system. The existing ATL RIDES application was modified and enhanced based on ST-CTN project needs and leveraged to create a new, independent application which is differentiated as the *OTP for G-MAP* subsystem (hereafter referred to as G-MAP).



SIDEWALKSIM. SidewalkSim is an asset management system and shortest path (lowest impedance) routing tool for pedestrian pathways. Site inspections provide more detailed design and condition data for use in pathway efficiency analysis. SidewalkSim identifies the best path between any two points in the pedestrian network, given the set of pathway characteristics and any user-specified needs and route penalties.



CV1K. The Atlanta region is home to one of the largest CV deployments in the United States – Regional Connected Vehicle Infrastructure Deployment Program (CV1K). CV1K is deploying interoperable CV technologies at signalized intersections throughout the Atlanta region using both Dedicated Short-Range Communications (DSRC) and Cellular Vehicle to Everything (C-V2X) technologies to deliver safety and mobility-based applications. The program provides support to configure, operate, and maintain CV infrastructure and applications, including TSP. Gwinnett County is one of the largest recipients of the first phase of this deployment.



CVTMP. Gwinnett County's Connected Vehicle Technology Master Plan (CVTMP) sets out to develop and improve economic viability and quality of life, address the needs and challenges to motorized and non-motorized modes, establish guidelines for deploying technology, and have broad applicability to Gwinnett, other local jurisdictions, and across the state—to set the standard for implementing CVs. Among the high priorities is establishing a mobile safety program and alternative strategies for TSP in Gwinnett County.



STM. The Space Time Memory (STM) platform processes traffic volume and speed data from multiple monitoring and modeling sources, tracks network performance measures, and predicts evolving route conditions using traditional and machine learning techniques. The STM projects trip trajectories through the transportation network, as network conditions change in space and time. This tool will be applied to analyze and predict performance through the multi-modal transportation network. The shortest path analysis will be applied to the combined roadway, transit, sidewalk, and shared-use path networks, allowing routing decisions to incorporate travel time, safety, and other impedances into path selection.

In addition, the ST-CTN system includes the development of a Performance Measurement Dashboard (PMD) that was not previously in use.



PMD. The PMD is a data storage and distribution tool that archives operational, survey and performance metrics of the system. The PMD intends to ingest, quality check, and curate all types of data – static and dynamic, structured and unstructured, open and private datasets. The PMD stores the datasets so that they can be viewed and accessed based on user roles. And the PMD includes a public PMD for the public to access open data presented on an interactive dashboard to the public.

1.3 Purpose of the Plan

The SDD provides the detailed design of the sub-systems and system components comprised in the ITS4US ST-CTN Deployment. The document also establishes traceability from requirements to one or more system elements.

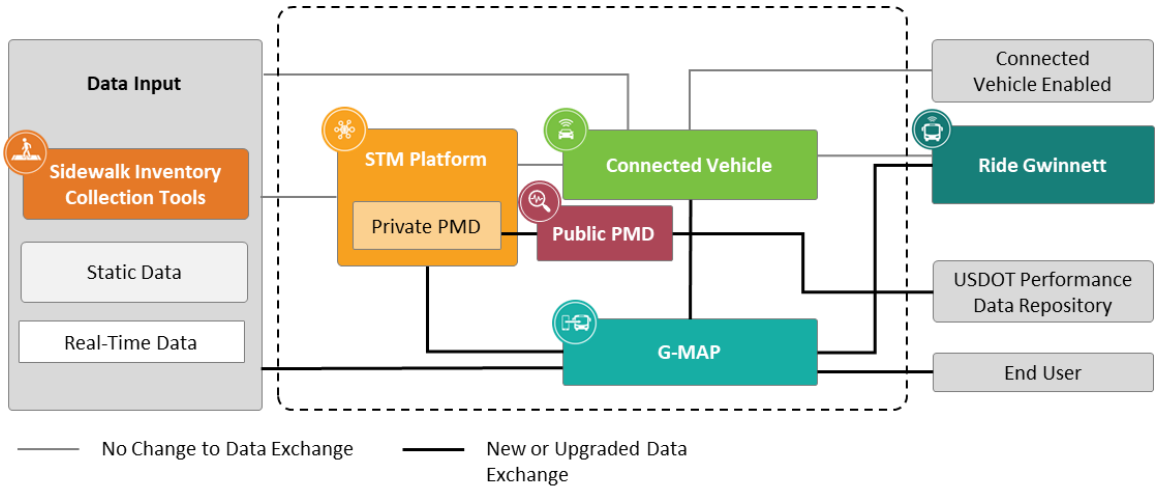
This document details how the design of the proposed ST-CTN system addresses the needs and desired capabilities identified in the Concept of Operations [ConOps], meets the requirements stated in the System Requirements Specification [SyRS], and complies with the structure, behavior, and viewpoints of the system architecture defined in the SAD.

2 System Description

The following subsections provide a high-level overview of the ITS4US ST-CTN system and the four major subsystems in accordance with the SAD.

2.1 Physical System Overview

This section provides a high-level description of the proposed System of Interest (SOI). The context diagram presented in Figure 2 illustrates the concept developed in Phase 1 and shows the interactions among the end user and subsystems. The subsystems, users, flows, and their relationships are explored further in the four major functional views presented in the following sections.



Source: GDOT, 2023

Figure 2. ST-CTN High-Level Context Diagram

The scope of the project expands and enhances capabilities of the existing programs deployed in the project area. The programs are described as follows:

Georgia Mobility and Accessible Planner (G-MAP) Subsystem. Based on ATL RIDES which was developed with the support of Federal Transit Administration's (FTA) Integrated Mobility Innovation (IMI) Grant program. The existing program provides more reliable and easier to access journey planning to all travelers making it easier to utilize the region's transit services. The ST-CTN extends the ATL-RIDES functionality to provide additional user interaction to plan and safely complete single mode or multimodal trips that are based on their abilities; improve the transition between modes by providing additional details to users and transit service operators; suggest dynamic routing changes based on infrastructure condition and calculated delay. The extended capabilities are branded as G-MAP. It should be noted that during

Phase 1, 'ATL RIDES' was used to describe the trip planning and user interface (UI) subsystem. However, the subsystem naming convention has been refined to be described as G-MAP herein to clarify the distinct systems.

The G-MAP includes several additional functions to aid travelers in their journey. These include:

- **Ride Request.** The Ride Request application allows a transit passenger to send a stop request to an approaching transit vehicle. This application allows a transit vehicle to know that a passenger has requested a transit stop from a mobile device. The application uses the Ride Request (GCT) Ride Request application integrated in their Computer Aided Dispatch / Automatic Vehicle Location (CAD/AVL) system as the core functionality that G-MAP uses to alert a transit operator to a traveler's presence and stop request at a transit stop.

- **Mobile Accessible Pedestrian Signal System (PED-SIG).** PED-SIG is an application that allows for an automated request via a center to center (C2C) information flow from G-MAP to the central traffic signal system (part of the CV Subsystem) to request the pedestrian signal (PED-X) at a specific intersection crossing. The PED-X signal at the intersection provides confirmation of the request.

- **Indoor Navigation.** The indoor navigation function is enabled by the installation of waypoint and aiding transceivers to support the wayfinding and routing functions in the G-MAP mobile app. The indoor navigation beacons are installed in the Gwinnett Voter Registration and Health Services Building and Gwinnett Justice Administration Center.



Connected Vehicle (CV) Subsystem. The CV Subsystem is composed of the systems included as a part of the Gwinnett County and GDOT CV programs. Gwinnett County and GDOT are leaders in the deployment of CV infrastructure. The subsystem leverages the current CV components deployed in the Gwinnett County Connected Corridor and the GDOT CV1K projects including all the center, roadside, and vehicle components. As described in the current system, the center components consist of components located at the GDOT Traffic Management Center (TMC) and Gwinnett County Transportation Control Center (TCC) – Navigator TMC, central system signal operations, Security Credential Management System (SCMS), MAP Server and Intelligent Transportation System (ITS) Hub connected through GDOT communications network. The roadside components consist of traffic signal systems owned and operated by GDOT and Gwinnett County. The equipment and operations of the subsystems did not change in the ST-CTN project.



Space Time Memory (STM) Subsystem. The STM Platform predicts trajectories through the multimodal network based on network characteristics as congestion evolves in time and space and to provide users with more realistic estimates of commute duration, impedance value, and energy use across alternative departure times, routes, and transportation modes. The impedance-based network calculations are prepared in the STM subsystem and include all-path networks (APN). The APN includes sidewalks and all local roads and corresponds to an updated OpenStreetMap (OSM) network employed after modifications are made to add missing pathways and remove non-pathway links to improve speed.



Performance Measurement Dashboard (PMD) Subsystem. The PMD Subsystem is a data storage and distribution tool that archives operational, survey and performance metrics of the system. The PMD intends to ingest, quality check, and curate all types of

data – static and dynamic, structure and unstructured, open and private datasets, store the datasets so that they can be viewed and accessed based on user roles, and provide access to and present open-based data on an interactive dashboard to the public.

2.2 List of Subsystems and Components

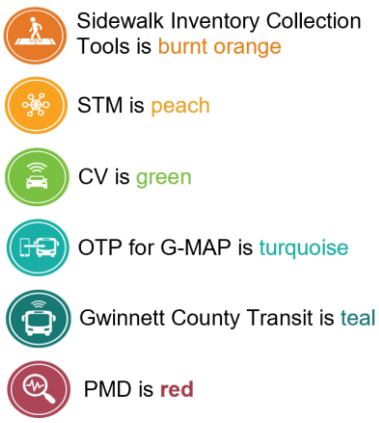
As highlighted in **Section 2.1**, the SOI includes four major subsystems (G-MAP, STM, CV, and PMD). In addition, system interfaces between SOI subsystems and with external system interfaces are described.

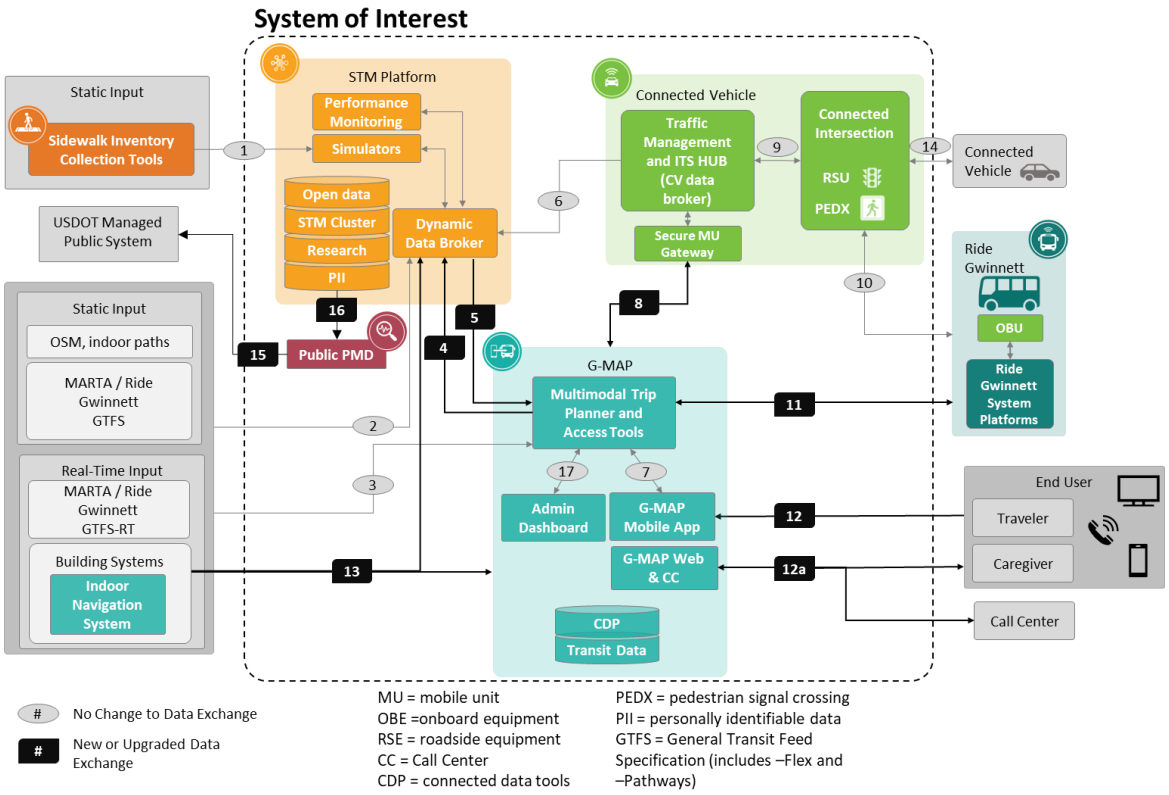
Critical ST-CTN data exchanges are identified by number and color in the context diagram and correspond to the exchanges described in Table 1. These descriptions are focused only on the scope of work required to implement the new system and information that is necessary to provide context to that work. As described in the SAD, there are a number of existing and on-going efforts that are being performed outside the scope of this project that are critical to the success of ST-CTN.

Figure 3 provides the ST-CTN high-level functional and information flow diagram in more detail and corresponds with the flows described in Table 1. These flows are shown throughout the subsystem Functional View diagrams and are consistent with the definitions provided in Table 1. The flows are further described in the SAD.

The following five diagrams in this section present the Functional View for the ST-CTN System and each subsystem within the system. The legend below describes the objects displayed in the diagrams.

- Bold dashed boxes outline the system/subsystem of interest,
- Major subsystem components presented by the ST-CTN project are depicted by rectangular boxes with black bold outlines,
- Major subsystem components that are existing are depicted by rectangular boxes with transparent outlines,
- External system components are depicted by light grey rectangular boxes,
- People are designated with a silhouette inside of a rectangular box,
- Each subsystem is indicated by color and icon, as shown on the right.





Source: GDOT, 2024

Figure 3. Functional Architecture for ST-CTN System

The system information flows are identified by number in the functional diagram above and described in Table 1. The grey oval labels indicate existing data exchanges that are utilized with no change to the current data exchange. Black rectangular labels indicate data exchanges that are new or upgraded to support the ST-CTN system. The information flow identifiers (column 1) in the table are used in every functional diagram in this section.

Table 1. Critical ST-CTN Information Flow Descriptions

Information Flow ID	Description	Source	Destination
1	Sidewalk inventory data, including accessibility features to the STM Platform simulators	External	STM
2	Static data from various existing sources to the STM Platform dynamic data broker	External	STM
3	Static and dynamic data from various existing sources to the G-MAP multimodal trip planner	External	G-MAP
4	G-MAP Mobile App logs and trip feedback	G-MAP	STM
5	STM Network Impedance API	STM	G-MAP

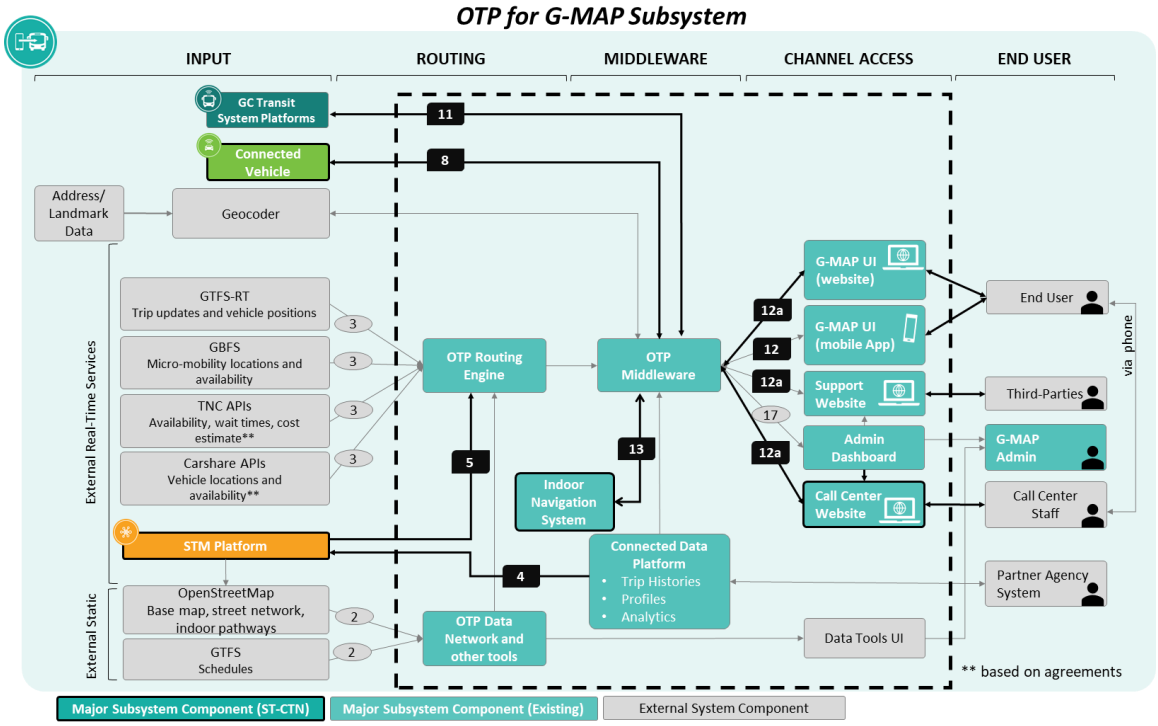
Information Flow ID	Description	Source	Destination
6	CV and Traffic Operations Messages: signal phasing and timing NaviGAtor ITS, road characteristics, traffic data	CV	STM
7	OTP APIs and G-MAP APIs	G-MAP (trip planner)	G-MAP (channel access)
8	Mobile Accessible Pedestrian Signal System (PED-SIG)	G-MAP	CV (Secure Mobile Unit (MU) gateway)
9	CV messages	CV (CV data broker)	CV (Connected Intersection)
10	TSP and other CV application messages	GCT On-board Unit (OBU)	CV (Connected Intersection)
11	Ride Request messages	G-MAP Mobile App via G-MAP	Ride Gwinnett
12	G-MAP Mobile App APIs and Traveler exchange – profile, trip plan, settings, notifications, feedback, etc.	End user G-MAP mobile app	G-MAP Mobile App
12a	Similar data flows to Data Exchange ID 12 with restrictions on viewing and changing certain data.	End user G-MAP mobile app	Website, Call Center, Caregiver device
13	Dynamic information from building facilities, (including beacon signals to the G-MAP Mobile App) and INS vendor cloud SDK	Building System (external)	G-MAP
14	CV data	CV OBU	CV RSU
15	Project data for USDOT-managed Public System	Public PMD	USDOT Managed Public System
16	Public facing data and visualizations for reporting on system operations and performance	Private PMD (STM)	Public PMD
17	G-MAP Web Services and Traveler exchange – profile, trip plan, settings, notifications, feedback, etc. Access to functions and information depends on user role. Interface available to traveler (registered person), trusted companion, or call taker in call center.	G-MAP (trip planner)	G-MAP Admin Dashboard

2.2.1 OTP for G-MAP Multimodal Trip Planner Subsystem

ATL RIDES was developed with the support of FTA's IMI Grant program and is a journey planning application to provide more reliable and easier-to-access transit data to all travelers, making it easier to utilize the region's transit services. The OTP code developed for ATL RIDES served as the base code for G-MAP with enhancements for the ST-CTN program.

As described in the SAD, the G-MAP is augmented to support infrastructure features, user routing and accessibility preferences and notifications, and ingest dynamic information from the STM platform and output performance metrics (stripped of traveler account information) to the STM which connects with the PMD for evaluation purposes.

Figure 4 shows the functional view of G-MAP subsystem with associated existing and extensions proposed for the ST-CTN. The G-MAP UI exists but is enhanced as part of the ST-CTN deployment project.



Source: GDOT, 2024

Figure 4. Functional View of the G-MAP Subsystem

G-MAP is architected as a three-tier solution with input data, processing including routing and middleware functions, and channel access (see headers on the top of the diagram). Specific functions identified as the major subsystem components embedded in the G-MAP subsystem (identified boxes in the dotted enclosure) and located under the architecture tiers are the functional elements of the subsystem. Table 2 provides a summary of functional elements for the G-MAP Trip Planner.

Table 2. Functional Elements for G-MAP Trip Planner

Function Name	Function and Feature Descriptions
Channel Access	The channel access provides web services and APIs to a responsive web application, native mobile app, and call center module. Channel access involves multiple methods for travelers to access notifications and information and are cross-referenced throughout the SDD. Features include the following: • User preference settings such as through path dimension, features, and condition of shared use paths (sidewalk and intersections), indoor navigation needs (elevators/escalators), assistive device types (wheelchair type) and support aides (service dog, trusted companion), sensory delivery of event triggers and notifications (for hands-off operation), third-party user support (e.g., dial trusted companion), and turn by turn direction support will be added to the existing profile description and routing engine. (see **Section 4.3.5**). • Notifications to additional recipient(s) such as trusted companions (e.g., arrived at destination). (see **Section 4.4.4**). • Synchronizing with user device(s). (see **Section 4.3.2**). • Notifications to users based on their preferences (e.g., voice, text, haptic). (see **Section 4.3.5**). • Triggering settings to connect to infrastructure and transit assets (PED-X request, bus stop request) as well as sending notifications to a specified asset when approach / arrive at transition point. (see **Section 4.3.5**). • Call Center access (see **Section 4.4.6**). The channel access functions include information flows and UI to: • G-MAP UI mobile app • G-MAP UI for web application • Support Website for third party app access • Admin Dashboard for G-MAP configuration and management • Call Center application **Server UIs:** Current web-based UIs include access for travelers to register, add their profiles and travel preferences, plan a trip, review a trip, download their trip to their mobile app, review trips taken, take surveys, and report trip obstacles. **Mobile UIs:** The Mobile app provides UIs that support similar functionality as the web-based version for registration, profiling, trip planning and report summaries as the web UI. In addition, the mobile app tracks and monitors traveler trip plans, receives notifications related to their preferences, triggers events based on geolocation (including Ride Request and Pedestrian Signal Actuation requests), and interacts with the indoor environment and incorporates an API or service to provide navigation instructions to travelers of indoor facilities. Specifically for the indoor

Function Name	Function and Feature Descriptions
	navigation function, the mobile handset interface monitors the environment for indoor beacon signals and uses those signals as waypoints to navigate through an indoor facility and locate their destinations.
Middleware	The Middleware provides data brokering functionality which ingests external system web services and directs them to the appropriate destination. Additionally, it manages internal data flows and channels them to appropriate external UIs. Among the new information flow management activities include: • Interface with the STM Platform and STM Network Impedance API for real-time condition information on user trip itineraries. • Interface with CV Subsystem to interface with Gwinnett County traffic control center (TCC) and the SMUG for PED-X actuation. • Interface with the Gwinnett Transit – Transit Management System (e.g., their CAD system) to exchange messages with the Ride Request module. The following new data information flows is ingested and managed: • **Static Data Input.** GTFS-Pathways (indoor station graphs). • **Real-time Data Input.** STM Network Impedance API. • **Output APIs and Services.** Performance data output to the STM / Private PMD.
Routing	Existing OTP software provides trip planning functionality for multiple modes (walking, transit, etc.). Enhancements to the routing services includes incorporating the OSM graph for sidewalks and roadways using updated impedances from STM network. This new feature incorporates information from the STM Network Impedance API and uses that network for routing in the OTP routing module. Minimal updates to the software design were implemented. The storage of the graph impedances and additional impedances selected were implemented.
CDP and Administration Tools	The data and administration tools provide data management and curation services for specific data such as GTFS and GTFS-Flex, as well as generate performance metrics and business to business communications with agency partners. These functions are not augmented as part of this project except for generating and accessing new performance measures which are shared with the STM Platform to generate evaluation measures. Performance measures are derived through the data collected and stored in the CDP, including trip histories, profiles, and analytics.

Operating Environment

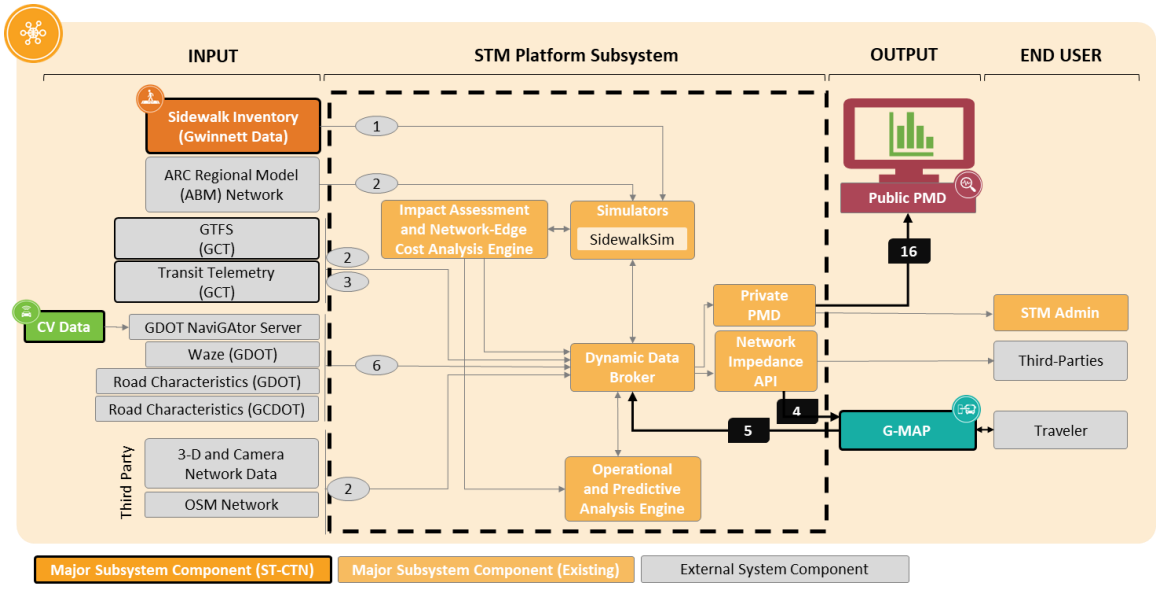
Given the production needs of the G-MAP, the infrastructure was hardened to ensure subsystem reliability, scalability, and availability. The G-MAP routing engine and middleware are cloud hosted on Amazon Web Services and sit behind a load balancer, allowing for scaling of resources to match level of use of the system.

The G-MAP mobile app is available for users to download via the Apple AppStore and Google Play stores. These App Stores also manage upgrade distribution for G-MAP to help ensure users are running the most recent version of the app available.

2.2.2 Space Time Memory Platform Subsystem

As mentioned in the SAD, the STM Platform is a prediction engine that predicts trajectories through the multimodal network. The prediction is based on network characteristics and integrates real time information such as congestion as it evolves in time and space. The predictions provide users with more realistic estimates of commute duration, impedance value (access to travel), and energy use across alternative departure times, routes, and transportation modes.

The STM Platform subsystem has been deployed to work in conjunction with the CV ITS Hub and work in collaboration with the G-MAP subsystem to generate walking and traffic graphs personalized for traveler preferences and abilities. The subsystem was updated to increase the origin-destination shortest path query response speed and has been integrated with new real-time data streams (e.g., information flow ID “5”, Table 1). Figure 5 provides the STM Platform Functional View diagram with functions and information.



Source: GDOT, 2024

Figure 5. Functional View of the STM Platform Subsystem

Table 3 provides a summary of the functional elements for the STM Platform subsystem.

Table 3. Functional Elements for the STM Platform Subsystem

Function Name	Function and Feature Descriptions
Dynamic Data Broker	The dynamic data broker is extended to ingest additional data sources. The expanded data sources include the following: • GTFS and General Transit Feed Specification Real Time (GTFS-RT) data from GCT • CV data from the GDOT CV ITS Hub • Augmented static sidewalk data from the sidewalk inventory tools • Feedback from G-MAP on traveler trips (and travel pathways) • Traffic, wayfinding and safety assets located in pathways • Indoor pathways and obstacles including vertical conveyances (elevators, escalators, and stairs) including GTFS Pathways In addition, the broker manages generation and publication of two new information flows including: **OSM Updates.** The STM transforms the continuously updated simulations (transit, traffic and sidewalk Sim models) to an OSM network model that can be ingested into the G-MAP OTP (routing) engine. The updated SIM graphs includes awareness of current impedance penalties by integrating real-time information about disruptions, obstacles, and traffic on roads and pathways. The frequency of the update and shared storage of the OSM model is at a rate and location available for G-MAP to consume. **STM Network Impedance API.** The STM Network Impedance API communicates changes in network impedance values in OSM/OTP data structures that can be used by the G-MAP app and provided to the public through the Public PMD.

Function Name	Function and Feature Descriptions
Simulators	After creating an inventory of the infrastructure in the study area, the SidewalkSim simulator processes generate routing graphs (navigable maps) customized for various underserved groups identified among the user classes. These graphs are capable of including indoor navigation features such as locating the most appropriate accessible entrance, navigating to operating elevators, and more. The graphs depend on the information available to generate the graphs. To ensure compatibility with the G-MAP app, the OSM network is regularly updated to reflect changes in static network elements identified via SidewalkSim inventory and inspection tools and as machine-learning processes identify network refinements that can increase route efficiency. Additional functionality includes: • The simulator updates sidewalk network changes using construction permit final inspection reports generated by Gwinnett County, regular Sidewalk Inventory tools, and agency field inspections. • The simulator associates and updates Sidewalk infrastructure conditions with sidewalk links, ramps, curb cuts, and other elements that are explicitly tracked. These elements are updated regularly via regular Sidewalk inventory tools, inspection, and via agency field inspection.
Impact Assessment and Network-Edge Cost Computing Engine	The Network-Edge Cost Computing Engine calculates the customized impedance values for traveling on a segment of the trip. Different penalties are associated with sidewalk features based on different user class vulnerabilities. For example, rough sidewalks, crosswalks without curb cuts (or narrow curb cuts), debris or potholes in pathways score high impedances for people with mobility challenges. Permanent protrusions (i.e., architectural features) and temporary protrusions (i.e., low hanging branches) narrow the walking path and score high impedance values for people with vision loss. Permanent protrusions are documented during the sidewalk inventory. The algorithms assign impedance values to different features based on an enumerated set of preferences that are consistent with the G-MAP user created profiles. The functionality of the proposed system is worked out in the design phase of this project and is highly adaptive, allowing GA Tech to specify any set of impedance functions for various disabilities and ranges, mode, or sub-mode.
Operational and Prediction Analysis Engine	The Operational and Prediction Analysis Engine serves as the ML function of the STM. This module consumes feedback from traveler's execution of their trip plans and updates the Cost Analysis Engine edge costs based on changes made by users of the tools. The processes interpret planned versus actual travel of various user classes.

Function Name	Function and Feature Descriptions
Performance Management Dashboard (Private PMD)	The performance management dashboard is used to monitor performance for evaluation of the pilot as well as computing and tracking performance and safety measures. The performance measurement engine track performance characteristics, such as volume and frequency of requests, response speeds, and data throughput. Comprehensive performance measurement metrics are developed and included in the PMESP.

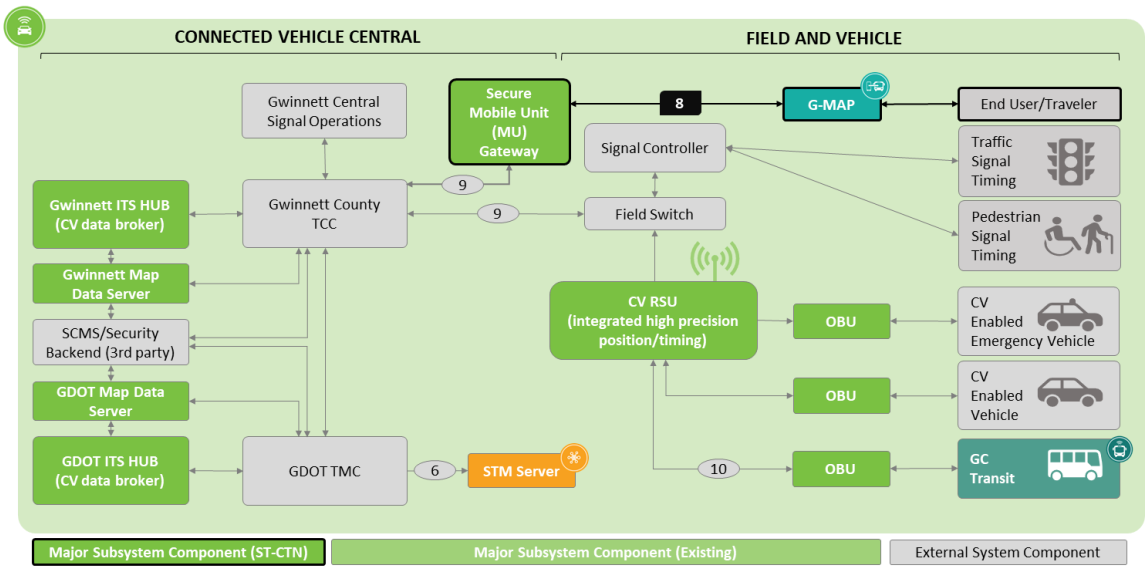
Operating Environment

The system requires a dedicated server environment in a cloud-based infrastructure. This ensures scalability and redundancy to meet reliability and expansion needs.

2.2.3 Connected Vehicle Subsystem

The CV subsystem, shown in Figure 6, is composed of the systems included as a part of the Gwinnett County and GDOT CV programs. Gwinnett County and GDOT are leaders in the deployment of CV infrastructure. The CV subsystem leverages the current CV components deployed in the Gwinnett County Connected Corridor and the GDOT CV1K projects including all the center, roadside, and vehicle components. Additional roadside equipment (RSE) was purchased to accommodate the full ST-CTN project area or if transit routes are changed. Gwinnett County CV devices leverage C-V2X communication and are operating under experimental licenses.

The current system, which did not change for this project, is composed of components located at the GDOT TMC and Gwinnett County TCC – NaviGator TMC, the central system signal operations, SCMS, MAP Server and ITS Hub connected through GDOT communications network. The roadside components consist of traffic signal systems owned and operated by GDOT and Gwinnett County. In addition, the equipment includes OBEs installed on GCT vehicles to support TSP. To mitigate security considerations, request signal control messages (e.g., for the Pedestrian Signal Crossing) to the CV Subsystem are channeled through the G-MAP (server). A secure, firewalled network connection was established to enable signal control requests through a Secure Mobile Unit Gateway (SMUG). Any data feeds from the CV to other subsystems (e.g., STM Platform) are unidirectional from the ITS Hub or GDOT TMC to the destination platform. Note that this service does not interfere with existing operations of the pedestrian requests actuated by travelers pressing the physical pedestrian push button.



Source: GDOT, 2024

Figure 6. Functional View of the CV Subsystem

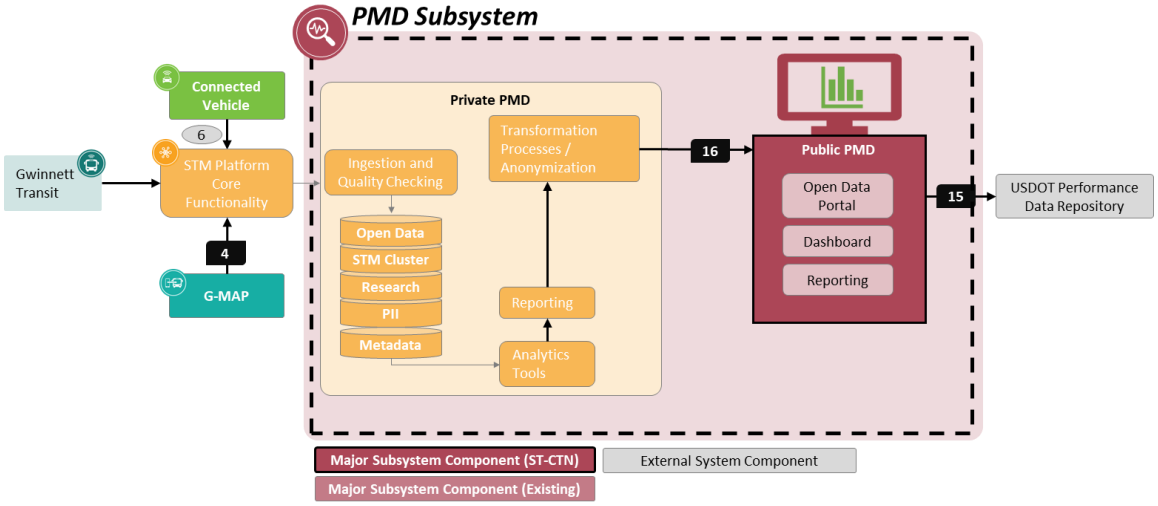
The existing system only requires minor configuration updates to accommodate the Pedestrian Signal Request (information flow from Interface #8 to pedestrian signal via Interface #9) and to update the frequency of information from the GDOT TMC (including CV data from the GDOT ITS HUB).

In addition, the existing security equipment is configured to enable the G-MAP to transmit pre-defined PED-X messages to the Gwinnett County TCC.

2.2.4 Performance Measurement Dashboard Subsystem

The PMD is a data storage and distribution subsystem that archives operational, survey, and performance metrics of the ST-CTN system. The PMD ingests, quality checks, and curates the data. The PMD performs data analytics to support the evaluation of performance measures, consistent with the Performance Measurement and Evaluation Support Plan [PMESP].

The Functional View of the PMD subsystem is shown in Figure 7. The PMD subsystem is comprised of private and public components where the private PMD manages and performs analytics on private data, including Personal Identifiable Information (PII) and then provides anonymized data to the public PMD. The public PMD displays the performance measures within a public facing dashboard and provides anonymized data to the USDOT Performance Data Repository.



Source: GDOT, 2022

Figure 7. Functional Architectural View – PMD Subsystem

Table 4 provides a summary of functional elements of the Private PMD. The Private PMD is an existing component within the STM Platform and will be enhanced and connected to the Public PMD.

Table 4. Functional Element of the Private PMD

Function Name	Function Description
Ingestion and Quality Checking	Ingest static and dynamic performance measures data within the STM Platform. Refer to the PMESP for specific datasets included. Quality of data is reviewed and verified prior to storing the data and making it accessible for analysis. Data that does not meet quality standards will trigger an alert within the monitoring system.
Data Storage	The descriptions for each of the data servers, their content and operating systems are described below.
Open Data Server	STM; Operational Open data are stored and made available through an open data server. The server will be an open data portal where the public may access the data (dependent on a project user agreement). The design, structure, and UIs for the open data portal were undertaken during design. Note: although most of the datasets originate in the GDOT/Gwinnett County Department of Transportation (GCDOT) ITS Data Hub, they are not archived.

Function Name	Function Description
PII Server	STM; Operational Separate resources are maintained for handling PII data at GA Tech. The PII servers reside on a separate secure network that restricts access to other networks even within the GA Tech Civil Engineering network. The access to the server requires physical presence in the secure access lab (badge access controlled) in the GA Tech Civil Engineering building. Note: Processed data are stored on the research server.
Research Server	STM (subset on STM Cluster); Operational Multiple high-resource computers (e.g., 96 cores, 512 gigabytes RAM) are used for the development, training and execution of the ML processes. Processed data will be stored on the research server. The research server will be located with the PII server and access will be limited.
STM Server Cluster	STM; Operational A cluster of computer and storage servers that store and preprocess historic operation and mobility information and translates them into information. The STM ties in with the Partnership for an Advanced Computing Environment (PACE) cluster at GA Tech to leverage high-performance computing for processing the archival data while it uses the STM cluster resources for integrating real-time information with the historical conditions. The STM Server Cluster stores and processes STM network and Network Impedance data.
Metadata	Information about the datasets stored on the data storage systems.
Analytic Tools	Performance metrics data are processed and analyzed.
Reporting	Performance metrics data are reported in a manner that is capable of being transformed.
Transformation Process/ Anonymization	Reported data are transformed and anonymized and made available for public consumption. Additional transformation and aggregation is applied to meet performance measurement and analytic requirements.
Interfaces	See Section 5.1.5 in the SAD.

Operating Environment

The operating environment is defined for each of the data servers in the Table. Reporting and analytical tools are external systems applied to private data stores.

Table 5 provides a summary of functional elements of the Public PMD. The Public PMD was developed and provides a public facing dashboard to display the evaluation of the ST-CTN performance measures.

Table 5. Functional Element of the Public PMD

Function Name	Function Description
Open Data Portal	Replication of the open data server formatted for access by the public or by a registered key.
Dashboard	Visualization of performance measures anonymized and aggregated by the Private PMD.
Reporting	Replication of reports generated in the Private PMD.
Interfaces	See Section 5.1.5 in the SAD.

The operating environment uses a web server.

3 Subsystems and Components

The subsystems and components are divided into two types of development methodologies:

- Systems developed using the Agile development method (**Section 3.1**).
- Systems configured from procured commercial off-the-shelf (COTS) (**Section 3.2**).

Section 3.1 describes the method for developing and integrating the COTS using the Agile techniques while **Section 3.2** describes the equipment and tools used to configure the COTS or existing systems. Additional information on equipment configuration is described in the Comprehensive Installation Plan [CIP] for the Indoor Navigation System (INS), and ICD for interface specifications related to other external system (e.g., Ride Request).

3.1 Agile Process

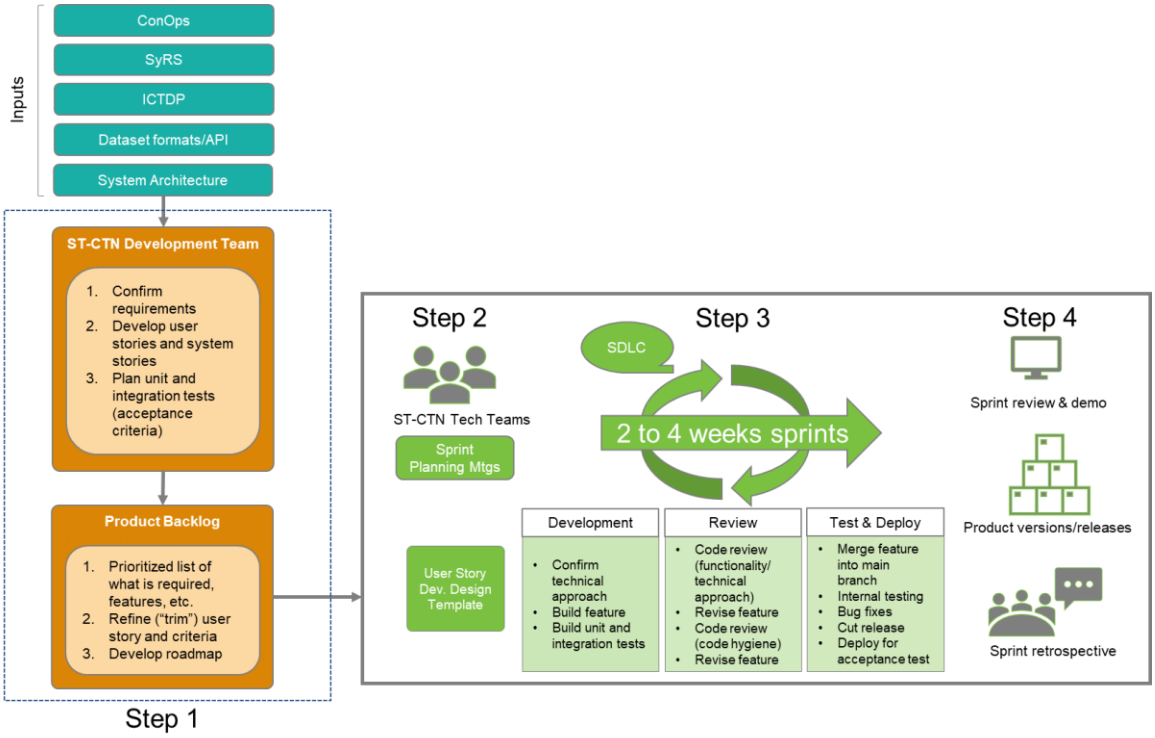
The Agile development process is regularly used by software developers and advocates adaptive planning, evolutionary development, early delivery, and continual improvement, and it encourages rapid and flexible response to change. Requirements and solutions evolve through the collaborative effort of self-organizing and cross-functional technical teams who regularly engage with their product owner and end users.

3.1.1 Overview

The nature of agile process allows for iterative and incremental development during the design and implementation stage, enabling the team to make smaller strides and achieve immediate progress as they focus on delivering a subset of features in each iteration. For this reason, the SDD remains as a living document that is updated as development continues.

Scrum is an Agile methodology in which the basic unit of development is called a Sprint. Every Sprint begins with a Sprint Planning meeting in which tasks for the Sprint are defined. This is also the part where the estimated commitment for the Sprint Goal is made. The Agile Process involves a team working through a complete Software Development Life Cycle (SDLC) process. Products are developed incrementally through several iterations throughout a Sprint process. A Sprint concludes with a Sprint Review meeting and a Sprint Retrospective where progress is evaluated, and the lessons learned are shared.

An overview of the Agile Process is depicted in Figure 8 and defined by the following steps.



Source: ARC, 2021

Figure 8. Agile (Scrum) Process

Step 1: Software Product and Release Planning. Content from deliverables such as the ConOps, SyRS, Integrated Complete Trip Deployment Plan [ICTDP], and SAD serve as inputs to the Agile Process. Using these documents as inputs, the ST-CTN Development Teams worked with ST-CTN Stakeholder Groups to perform Software Release Planning. During Software Release Planning, user needs and requirements are broken down into Epics and Agile User Stories. Epics are large user stories, typically one that is too big to fit in a single Sprint. Epics are broken down into smaller user and system stories before implementation as part of a Sprint. User Stories include a statement (or a group of statements) that expresses the desired end user functionality. User Stories are simple, short, and easy to implement. User stories are expressed in a simple sentence, structured as follows:

"As a [persona], I [want to], [so that]."

User Stories are captured in the Product Backlog which is kept in the ST-CTN Agile Development Process Tool (e.g., Jira). The Backlog is organized as a roadmap, an ordered list of the work to be done in order to create, maintain and sustain the ST-CTN products. It is managed by the Scrum Master with direction from the Product Owner and input from stakeholders and is visible to all team members depicting a real-time picture of the work that the Development Team plans to accomplish during the Sprint.

Step 2: Sprint Planning. Sprint Planning consists of processes related to planning and estimating tasks for an upcoming Sprint. Prior to beginning a Sprint, user stories and their related acceptance criteria are created and incorporated into the Prioritized Product Roadmap. The

Product Owner, with support from the Scrum Master and the rest of the development team is responsible for prioritization of the Roadmap.

Once all stories are ready, a Sprint Planning meeting is held with the team to create a Sprint Backlog containing all tasks to be completed in the Sprint. The team consists of the Product Owner, Scrum Master, and Development Team, and other team members relevant to the Sprint. Other relevant team members may include USDOT, Infrastructure owner-operators (IOOs), end users, etc., as is necessary based on the focus of the development. The purpose of the Sprint Planning is to reach agreement with the team members that they have time to complete the tasks assigned to them for the sprint. The Scrum Master and ST-CTN Development Teams estimate the effort required to develop the functionality described in each user story, and the ST-CTN Development Team commits to delivering the tasks during the Sprint period.

Step 3: Implementation. Implementation includes the execution of the tasks and activities in a Sprint to iteratively create the ST-CTN product. In this step, the ST-CTN Development Teams work on the tasks in the Sprint Backlog to create deliverables, features, or products. The ST-CTN Agile Development Process Tool, such as Jira, is used to track the work and activities being carried out. A time-boxed meeting is conducted on an established sprint cycle. These meetings serve as the forum for the team to update each other on their progress and any impediments they may be facing.

Key activities included in this step include:

- **Development.** Development includes confirmation of the technical approach, building features, and/or conducting unit and/or integration tests. The Development Team works to deliver an MVP in accordance with the Product Backlog. The team then incrementally develops additional features to deliver the full product.
- **Code Review.** Review includes conducting two types of code review (functional and technical) and code hygiene (style and documentation).
- **Documentation.** Documentation includes developing appropriate documentation as described in the Systems Engineering Management Plan (SEMP) and uploading materials within the appropriate Agile development tools.
- **Test and Deploy.** This activity includes merging features back into the main branch, conducting internal testing, identifying and fixing bugs (if required), and conducting acceptance testing. Acceptance tests are used to check the requested and implemented feature and determine whether these deliverables, features, or products meet the requirements. Rather than taking a big-bang approach to testing, testing occurs incrementally as part of the Agile Process. All user stories are mapped to user needs and requirements – and include acceptance criteria and test cases.

Step 4: Review and Retrospective. This step includes reviewing the deliverables, features, and products and the work that has been done and determining ways to improve the practices and methods used to do project work. The ST-CTN Development Team demonstrates the Sprint deliverables to the Product Owner and stakeholders in a Sprint Review meeting. Where appropriate, proxy users – or representatives from stakeholder groups – may be included in Sprint reviews to provide feedback. Discussions, actions, action items, and agreements are documented in meeting notes and stored on the project document site. The purpose of Sprint Review meetings is to secure approval and acceptance from the Product Owner and/or

stakeholder group for the deliverables created in the Sprint. The Scrum Master and Development Team also conducted a Sprint Retrospective to discuss the lessons learned throughout the Sprint. This information is documented as lessons learned which can be applied to future Sprints. A feature may be sent back for refinement if the reviewers agree on an update, change or fix a perceived flaw in the implementation.

3.1.2 Agile Process Traceability

The requirements met by the agile process are provided in Table 6. The table provides the requirement ID, requirement title, statement describing the requirement and the section of this document that addresses this requirement.

Table 6. Agile Process Requirements Traceability

Requirement ID	Requirement Title	Requirement Statement	Section
1.2.0-019	Agile Backlog	The Agile Development Process shall define how software developers will develop, publish and schedule epics and user stories that will be used as part of their Agile process, in coordination with the stakeholder review team (SRT). The Agile Development Process will be defined in the Systems Engineering Management Plan (SEMP).	3.1.1
1.2.0-020	Agile Sprint Tracking	The Agile Development Process shall define how software developers will provide access for stakeholders to view sprint assignments and performance statistics including but not limited to sprint schedules, progress, and bug tracking.	3.1.1
1.2.0-021	Agile Stakeholder Engagement	The Agile Development Process shall define a process to assign end-users to a Stakeholder Review Team which will review user stories and drive priority development.	3.1.1

3.2 Existing and Commercial off the Shelf (COTS) Systems

The ST-CTN system leverages existing systems and integrated COTS systems to achieve the goals of the system. The following subsections provide a high-level overview of the leveraged systems. Specific integration design elements are described in **Section 4** and **Section 5.** References to sections that describe the system design elements (e.g., hardware, software, tools) are included in each subsection below.

3.2.1 Connected Vehicle Subsystem

The CV subsystem is composed of the existing systems included within the Gwinnett County and GDOT CV programs. The CV subsystem leverages the current CV components deployed in the Gwinnett County Connected Corridor and the GDOT CV1K projects including all the center, roadside, and vehicle components. Additional RSEs were purchased to accommodate key intersections of the ST-CTN project area.

The current system is composed of components located at the GDOT TMC and Gwinnett County TCC – NaviGator TMC, the central system signal operations, SCMS, MAP Server and ITS Hub connected through GDOT communications network. The roadside components consist of traffic signal systems owned and operated by GDOT and Gwinnett County. In addition, the equipment includes OBEs installed on Ride Gwinnet vehicles to support TSP.

The CV Subsystem provides dynamic traffic operations data for impedance calculations and performance metrics including Pedestrian Prescence Alert (PPA).

The CV design elements are integrated into the G-MAP, STM and private PMD subsystems. Updates to and current operations of the CV subsystem are discussed in **Section 6.1**.

3.2.1.1 Enhanced TSP

The TSP functionality is deployed using the OBE on board the buses and the RSE. The enhanced TSP use case begins when the Ride Request function is initiated by the traveler when nearing a bus stop. The enhanced TSP logic detects the need to expedite the transit vehicle to the stop by lowering the threshold granted to vehicles behind schedule. The design specifics are described in **Section 6.1.2**.

3.2.1.2 Pedestrian Crossing Actuation Request

An interim solution to the PED-X function was developed to implement PED-X while the current traffic signal operations software is being replaced. The solution provides a means to request pedestrian actuation via a secure gateway between the G-MAP request (request generator) and the traffic signal operations (MaxTime) (request server). The design component is described in **Section 6.4**.

3.2.2 Indoor Navigation System

The INS design aims to assist users in navigating complex indoor environments. The design leverages mobile applications, Bluetooth Low Emitting (BLE) beacons, and supporting Software as a Service (SaaS) to provide real-time navigation, location-based information, and optimal routes to users within a specified environment. The system, procured from CXApp, is composed of hardware, Software Development Kit (SDK) for mobile platforms (iPhone Operating System (iOS) and Android), and CXApp software SaaS tools.

The design component is described in **Section 6.2**. Additional information on configuration and installation procedures may be found in the CIP.

3.2.3 Ride Request

The Ride Request functionality enables a person who needs extra time boarding a transit vehicle to alert the driver that a passenger is waiting at a future stop. The trip plan includes an event that triggers the G-MAP server to send an alert to the driver when the rider is near the stop. The functionality is built on the Avail *Enterprise Transit Management Suite* of software that are currently deployed at Ride Gwinnett.

The design component is described in **Section 6.3**.

3.2.4 Public PMD Design Element

The PMD is a data storage and distribution subsystem that provides operational, survey, and performance metrics of the ST-CTN system. The PMD subsystem is comprised of private and public components where the public PMD provides an online interface that displays information and statistics regarding the performance measures developed for the ST-CTN system. The data provided on each performance measure is based on data collected from the G-MAP application and feedback reports completed by users.

Datasets from the G-MAP application and feedback reports are imported, curated and anonymized by the private PMD and then deposited into the Public PMD to be curated within Power BI before presenting on the public PMD web server.

3.3 Requirements Traceability Approach

The system requirements are the basis of this system. They were first developed in Phase 1 based on the system needs that were generated from user needs. Each system requirement is assigned a subsystem (listed in **Section 2.2**), where applicable. Throughout the project, the system requirements have been refined as the system concept has been adjusted and the system design has been developed.

Through the system design development process, the requirements were first traced to their relevant systems engineering documents, which include the Systems Engineering Management Plan (SEMP), Data Management Plan (DMP), Data Privacy Plan (DPP), Comprehensive Maintenance and Operations Plan (CMOP), and this document, the SDD. The requirements that are related to the functionality and its source design descriptions are traced to the Agile epic or design element. For documentation purposes, these requirements are assigned a design section or subsection in which it appears in this system design document. At the end of each major design element section, the traceability from requirement to design element is documented.

The Master Requirements Traceability Matrix (MRTM) references the comprehensive trace to related documents including this SDD. The MRTM is available upon request from the project manager.

4 G-MAP Design Elements

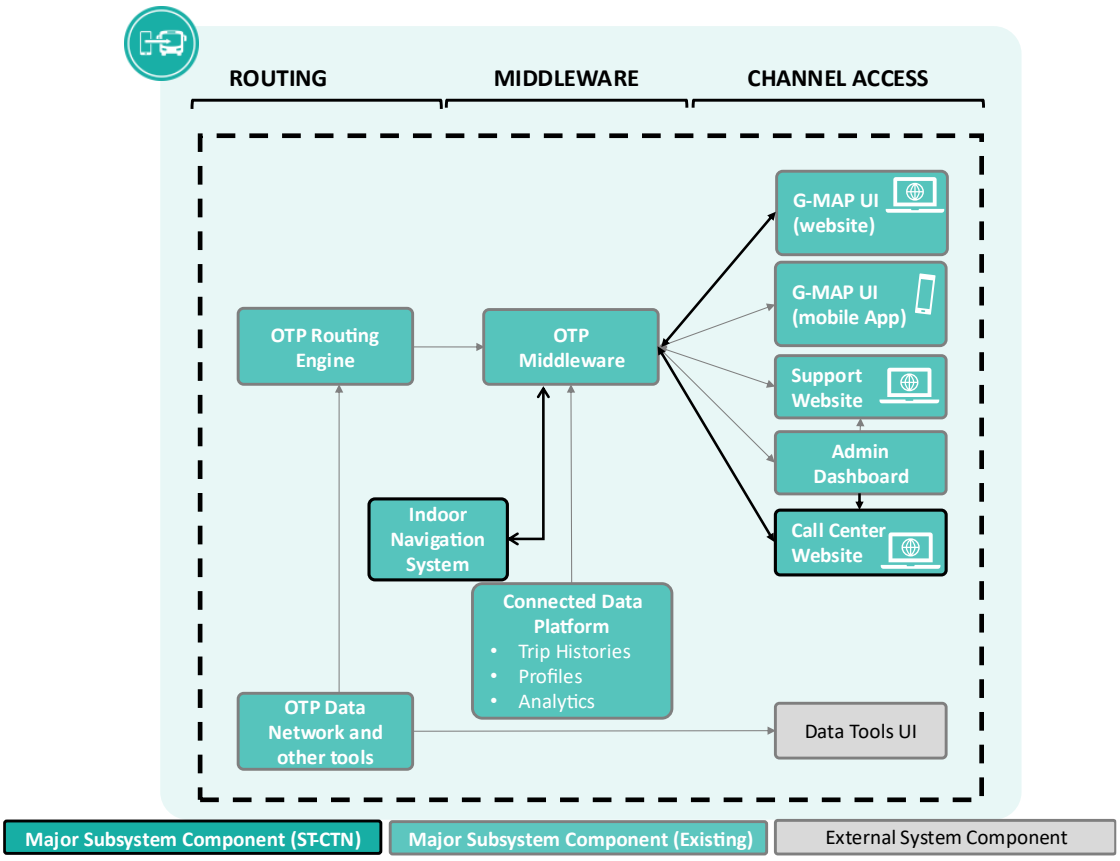
This section describes the design elements of OTP for G-MAP Multimodal Trip Planner. The functional architecture for G-MAP and its information flows are shown in **Section 2.2.1**. As mentioned above, G-MAP leverages the OTP ATL RIDES OSS code as the core instance of development. This section includes an overview and Agile epics backlog for the application development (**Section 4.1**) as well as an overview of the types of design for feature enhancement and augmentation of the ATL RIDES app (mobile and web applications). The setup and configuration of existing OTP OSS is included. Its design description can be reviewed from the OTP GitHub and Arcadis GitHub sites.

4.1 G-MAP Design Overview

G-MAP is composed of three major design components as shown in Figure 9**:**

- **Routing** which includes the OTP Routing Engine and the OTP Data Network.
- **Middleware** which includes the OTP Middleware and connected Data Platform (CDP) (secure storage related to OTP-personas).
- **Channel Access** methods for accessing G-MAP information including G-MAP web and mobile app UIs, call center module, and other administrative and support tools. The access is through native platform communications channels such as WiFi, cellular and bluetooth.

In addition, the G-MAP app includes the Indoor Navigation System (INS) software design kit (SDK) from CXApp. These components are described in the SAD and in **Section 2.2.1,** Table 2.



Source: GDOT, 2023

Figure 9. G-MAP Design Components

Note that all G-MAP components exist and were deployed in Epic 0; the design elements contained in this section include enhancements as follows:

Enhanced Trip Registration and Planning. Includes support for additional privacy provisions (Epic 2), registration for a mobility mode (Epic 3a), selection of additional preferences related to notifications (Epic 3b and 3c).

Enhanced Trip Functionality. Includes in-trip support while traveling (Epic 4 and 8) and exchange of information between mobile apps and back office (OTP Middleware), and support for group / trusted party access (Epic 6), practice mode (Epic 7), call center (Epic 16), and presentation and collection of user experience survey link (Epic 1), and summary user experience and feedback reports (Epic 9).

G-MAP Summary Statistics. Collection and aggregation of trip histories (Epic 11), trip logging (Epic 12), travel summary statistics (Epic 13), and delivery of the data for the private PMD analysis engine (Epic 15).

Integration Elements. Description of integration design with the external systems – PED-X (Epic 5), Ride Request and Enhanced TSP (Epic 17), and Indoor Navigation (Epic 14).

UI. UI icons and navigation action graphics used throughout the browser and mobile platforms (**Section 4.7**) and are developed as part of each Epic. In addition, this section includes a description of the differences between the mobile and web browser platforms.

G-MAP Requirements to Design Traceability. Table tracing design paragraphs to requirements.

The Epics are primarily focused on the functional enhancements to the G-MAP components. Each epic description and related component are listed in Table 7. Note that the Epics are associated with different components and different types of enhancements. The development of the epics did not follow a sequential path to implementation or a sequential association with the functional improvements categorized by **Sections 4.3** to **4.6**. Table 7 associates the related component and the epic name and description with the section in which it is located in this document.

Table 7. G-MAP Epic Descriptions and Location in SDD

Epic Name	Epic Description	Related Component	Section #
Epic 0 – Setup and Configure G-MAP	Setup and configure unique instance of OTP routing engine for G-MAP.	All	4.2
Epic 1 - Survey and Feedback	Set up an in-app link to an outsourced long-form survey. Configure questions into survey module and define survey trigger.	CDP	4.4.7.1
Epic 2 - PII Management	Develop option for users to opt-in to storing and using PII enabling G-MAP account management and mobile app to register, select preferences and track users. Develop option to opt-out after opting in and set up feature to provide users with information regarding opt-in/opt-out options.	CDP	4.3.1
Epic 3 - Support Service Options	The Support Service Options functionality support traveler mobility preferences. This consists of recording and matching user preferences to travel networks generated by the STM impedances (impediments and accessibility features) for trip paths.	OTP, CDP, Middleware	4.3.2
Epic 3a - User Mobility and Accessibility Profiles	Develop user mobility/ accessibility /assistance needs profiles with defined mobility profile types and criteria. Configure web app for detailed	CDP, Middleware	4.3.3

Epic Name	Epic Description	Related Component	Section #
	mobility profiles and mobile app UI for setting up mobility profiles.		
Epic 3b - Routing Enhancements	Update and enhance routing to support users' mobility profiles based on impedance time/cost penalties from STM Network Impedance API.	Middleware	4.3.4
Epic 3c - Notifications	Update notifications to reflect updated routing and live tracking. Detailed design of notifications includes update of preferences, methods, and triggers based on mobility profiles, routing, and live tracking.	Middleware	4.3.5
Epic 4 - Live Tracking and In-Trip Support	Develop a detailed technical design for live tracking and in-trip support functionality.	Middleware, G-MAP Mobile UI	4.4.2
Epic 5 – PED-X	Develop PED-X request functionality.	Middleware	4.6.1
Epic 6 - Third Party Access/Group Travel	Define mobilities for group travel and configure role-based access for travel companion. Detailed technical design for features to allow users to plan trips with a travel companion.	Middleware, CDP	4.4.44
Epic 7 - Practice Mode	Develop practice mode functionality that allows users to simulate their turn-by-turn directions before starting their trip.	Middleware, G-MAP Mobile UI	4.4.5
Epic 8 - Dynamic Trip Planning	Develop design that uses live trace data and user location to make routing decisions in real-time and provide routing updates.	Middleware, G-MAP Mobile UI	4.4.2
Epic 9 - Misc Mobile App Updates	Miscellaneous mobile app updates such as sending traveler comments to PMD and Gwinnett County Accessibility group.	Middleware	4.4.7.2
Epic 10	Note: there is no Epic 10.	n/a	n/a
Epic 11 - Trip Histories	Develop functionality for logging trip histories for planned trips as well as flagging and logging trips that were taken.	CDP	4.5
Epic 12 - Completed Trips Logging	Log route traces of completed trips.	CDP	4.5

Epic Name	Epic Description	Related Component	Section #
Epic 13 - Travel Statistics	Develop functionality to provide account holders with general statistics on their trips and calculate summary statistics about travel patterns.	CDP	4.5
Epic 14 - Indoor Navigation Integration	Integrate OTP for G-MAP with the indoor navigation system.	Middleware, Indoor Navigation	4.6.3
Epic 15 - G-MAP – PMD Integration	Integration of OTP for G-MAP with the PMD.	Middleware	4.5
Epic 16 - Call Center Web App	Set up a variation of OTP Web App to be used by call center staff which has a different UI, but receives the same updates as the app.	Middleware (includes CDP and OTP)	4.4.6
Epic 17 - Ride Request and Enhanced TSP Integration	Develop functionality to trigger a ride request to bus operator. Enhance TSP functionality to provide priority to ST-CTN users when onboard.	Middleware	4.6.2

4.2 Setup and Configure G-MAP (OpenTripPlanner) Development Environment (Epic 0)

Epic 0 Description: Setup and configure unique instance of OTP routing engine for OTP for G-MAP.

The details of the OTP Development environment and existing code are available from Arcadis GitHub.

The initial epic includes set up and configuration of the existing code base including the major internal and external components for the project area (Gwinnett County). The components, shown in Figure 4, include:

- **OTP Routing Engine**. This module uses the OTP version 2.x OSS. This module performs the trip optimization functionality.
- **OTP-personas Middleware.** The OTP-personas provides storage and access to unique user profiles for each registered user including saved trip planning and places, and other settings.
- **OTP-Places Geocoding Module**. This module provides geocoding services within the project area.

- **OTP Web App**. The UIs and template configured for functions and UIs specifically for web browser application. This UI provides access to users to plan and schedule trips.

- **OTP Native Mobile Apps Dev Environment**. The development environment and reuseable code to deploy Android and iOS mobile apps.

The basic setup of the G-MAP instance includes configuring the following:

- Enabling guest and account holder modes.

- Ingesting Gwinnett project and adjacent area external data files including:

    - Ride Gwinnett GTFS / GTFS-realtime

    - MARTA GTFS / GTFS-realtime

    - OSM for region

The OSM data ingestion synchronizes with the same model ingested by the STM to ensure each subsystem ingests the same model network for the region.

4.3 Enhanced G-MAP Trip Registration and Planning

4.3.1 PII Management (Epic 2)

Epic 2 Description: Develop option for users to opt-in to storing and using PII enabling G-MAP account management and mobile app to register, select preferences and track users. Develop option to opt-out after opting in and set up feature to provide users with information regarding opt-in/opt-out options.

The PII management currently applies Amazon Web Services (AWS) security to all PII. User permissions are managed through the AWS Identity and Access Management (IAM) features and policies. All access to PII and trip information is subject to an authentication token and whitelisting all Internet Protocol (IP) addresses to limit access to only known and trusted end points.

Additional enhancements include requiring users to consent to tracking their movement while they are using their app. Consent is acquired through the following methods:

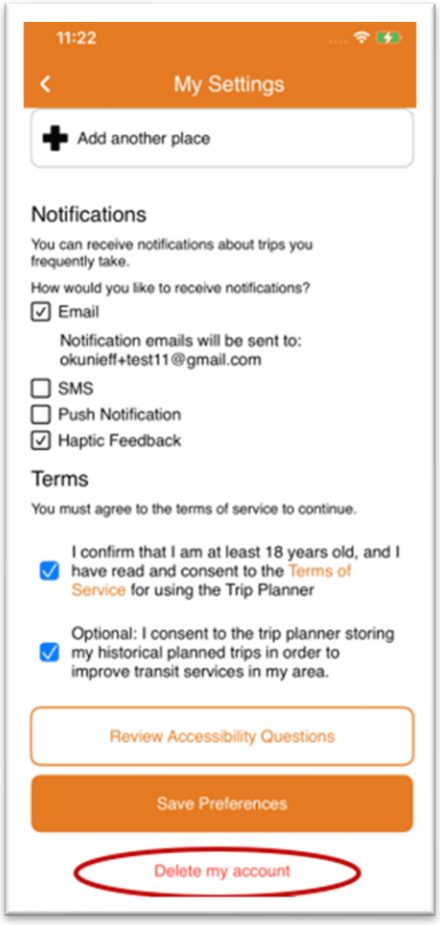
- Native mobile platforms request permission for app to follow you at time of download. This setting can be updated at any time through the platform settings features.
- App (mobile and web) consent form which describes how the data will be used, and who can access the data. A user will not become a registered user unless the consent form is signed.

The account holder may stop tracking if they do the following:

- Delete the app from their phone.
- Set their mobile settings so that they are not tracked by the app.
- Turn off their data.

The account holder may opt out of the app from collecting and storing their PII if they do the following:

- Delete their account (in the settings section). When an account holder deletes their account, all the data stored in their account (in the CDP) will be wiped from the application. Figure 10 shows the location in My Settings for deleting my account.



Source: GDOT, 2024

Figure 10. My Settings with "Delete my account" selection

The process for deleting my account is as follows in both the web and mobile platforms.

1. Select “Delete my account” button from the bottom of the settings page.

2. A pop-up message appears in the web browser that asks – “Are you sure you would like to delete your user account?” User is prompted to select OK or Cancel.

3. When the user selects OK, another pop-up message appears that reads – “Your user account (user account email) has been deleted.” User is prompted to select OK. The account and all the data are deleted.

4. Screen transitions to Landing page in Guest mode.

After removal, the user can set up a new account using the same email address, however, none of the previous history saves. The user needs to reset their consent form, saved trips, places, mobility modes, and all other settings.

4.3.2 Support Service Options (Epic 3)

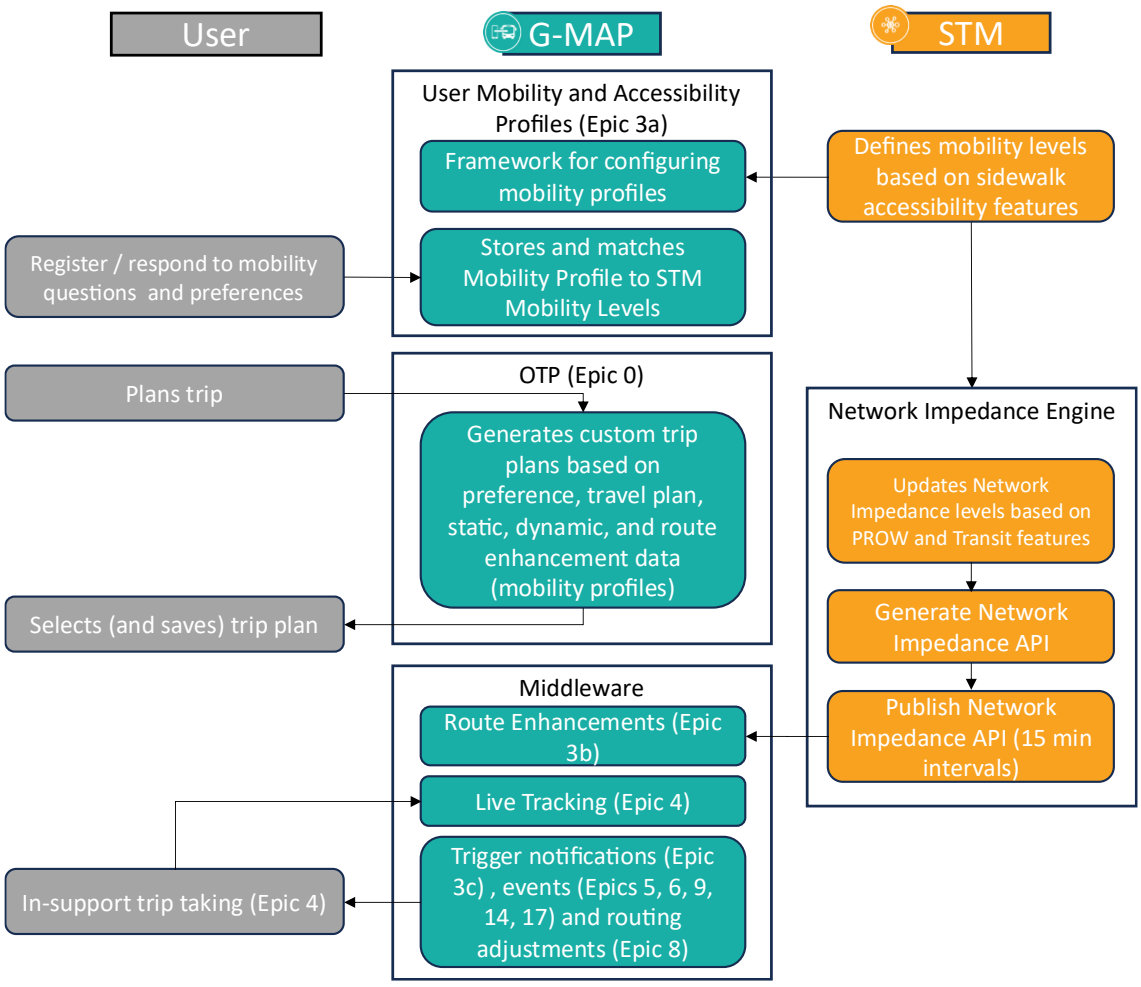
Epic 3 Description: The Support Service Options functionality supports traveler mobility preferences. This consists of users selecting their preferences. The enhancement features consist of the following (related to the three epics):

- **Epic 3a**. Enhance User Accounts and Mobility Preferences.
- **Epic 3b**. Enhance Routing Features by uploading and integrating STM Impedance values into OSM network impedances.
- **Epic 3c.** Enhance and configure standard notifications, turn-by-turn directions, and live tracking triggered notifications.

Although all enhanced features are for both web and mobile applications, Epics 3b Route Enhancements and 3c Notifications use triggers set by live location tracking which are only available in mobile applications.

Figure 11 shows the interaction between the user/traveler and G-MAP functions, as well as the feed generated and provisioned by the STM to the traveler application. In particular, when the user registers, they are asked to set their preferences for mobility options. Once registered and stored in G-MAP, the application stores and matches their preferences to a Mobility Profile established by the STM Mobility Categories. G-MAP designed a framework so that the mobility levels are configurable, since the levels may change as traveler behavior is better understood.

Once the mobility profile is determined, whenever the traveler plans a trip, G-MAP tailors the trip based on their profile and preferences, and match those to the static, dynamic and enhanced routing data (STM impedance values as described in **Section 5**). The enhanced routing data is updated by the STM Impedance Engine on a frequent basis to support the traveler en-route.



Source: GDOT, 2023

Figure 11. Support Service Options and interactions with User, STM and other G-MAP Epics

While the traveler is taking their trip, the Live Location Tracking (Epic 4), provides them with updated accessibility options including events (Epics 5, 6, 9, 14, 17) such as indoor navigation, PED-X, and Ride Request. Notifications are triggered based on their preferences, information about accessibility of modes / services, and route impacts.

4.3.3 User Account/Mobility Preference Extensions (Epic 3a)

Epic 3a Description. Develop user mobility/assistance needs profiles with defined mobility profile types and criteria. Configure web app for detailed mobility profiles and mobile app UI for setting up mobility profiles.

The core OTP functionality includes sign-up, registration, and trip preference processes. This epic extends the core functionality to provide trip customization based on user's accessibility preferences including types of assistive devices, mobility challenges, and additional notification channel preferences. Additionally, the mobility mode selections replace some typical preferences

like wheelchair, walking speed, maximum walking distance, and number of transfers. These features are typically accommodated by mobility mode impedance levels.

Following the initial sign-up, the user is asked a series of questions to determine their mobility profile and preferred notification channels.

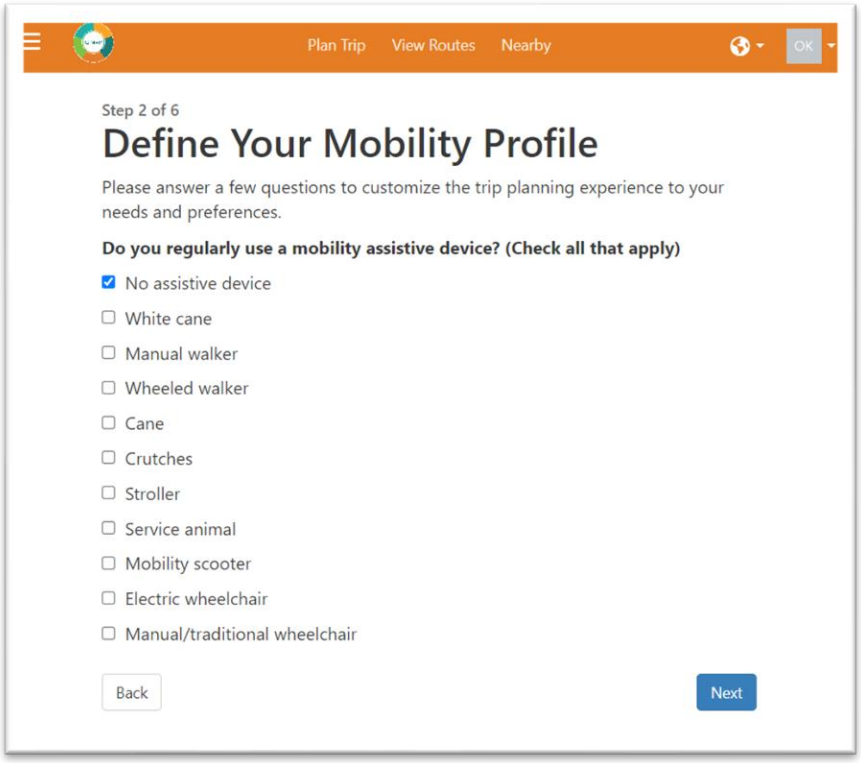
4.3.3.1 Sign-Up Process

The sign-up process is as follows:

- Select person icon from screen (web – top right side; mobile – bottom right side).
- Select “Sign-Up” tab
    - The user is prompted to enter email address
        - Email is validated for proper syntax
    - The user is prompted to enter password
        - Password requires capitalized letters, uncapitalized letters, numbers and special characters greater than 8 fields.
        - The password is hidden but the user can reveal entry.
        - A separate pop-up window shows the password features that the user incorporates into their password.
        - User selects Set-up account
- The user is requested to verify their account
    - An email is sent to the registration email with a link to verify their account
    - When user clicks the email link, they can go back to the trip plan page and click on the “Verified Account”
        - If they did not click the email link, then the G-MAP page refreshes with the Verify Account page.
        - Screen transitions to Create a New Account page
- Step 1 of 6 Create a New Account page includes the following:
    - A note that you must agree to the terms of service to continue with a check box and a link to the Terms of Service.
    - At the bottom of the page, a red button to “Delete my account” is present if user needs to delete the account or restart the account sign up process.
    - Next button.

- If pushed without the terms and conditions selected, a pop-up warning is shown that directs the user to select the check box.
- When the check is selected, the Next button transitions the page to Step 2 of 6 Define Your Mobility Profile.

- Step 2 of 6 Define Your Mobility Profile page includes the following:
  - As shown in Figure 12, the first of three mobility profile questions is asked. The default – No assistive device, is selected upon the initial display. Any number of the other check boxes may be selected. Although multiple assistive devices may be checked, once one device is selected the No assistive device field is unchecked.



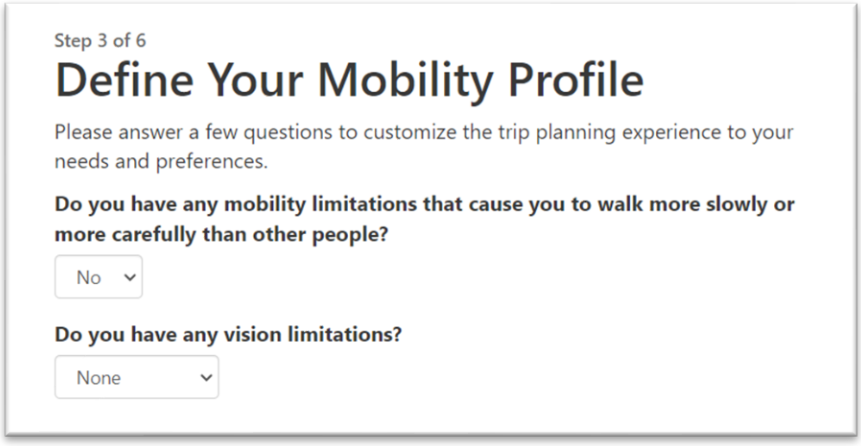
Source: GDOT, 2024

Figure 12. Sign-Up Step 2 of 6 Define Your Mobility Profile Page (web)

  - User selects Next to move to Step 3 of 6.

- Step 3 of 6 Define Your Mobility Profile page includes the following:
  - Two questions are asked on this page, as shown in Figure 13:
    - The first asks about mobility limitations with a dropdown list that includes No (default) or Yes.

- The second asks about vision limitations with a dropdown list that includes None (default), Low-vision, or Legally-blind. These are all exclusive selections.

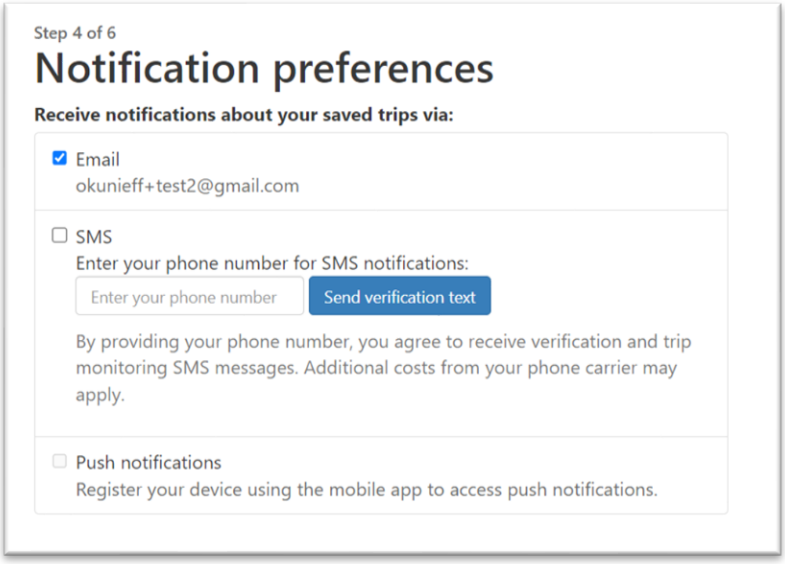


Source: GDOT, 2024

Figure 13. Sign-Up Step 3 of 6 Define Your Mobility Profile Page (web)

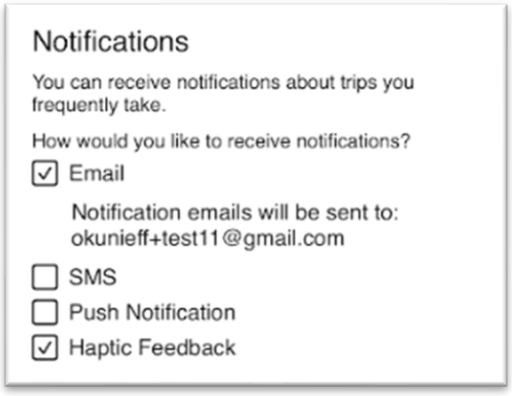
- User selects Next to move to Step 4 of 6.

- Step 4 of 6 Notification Preferences page is shown below. Figure 14 provides the web view and Figure 15 provides the mobile view.



Source: GDOT, 2024

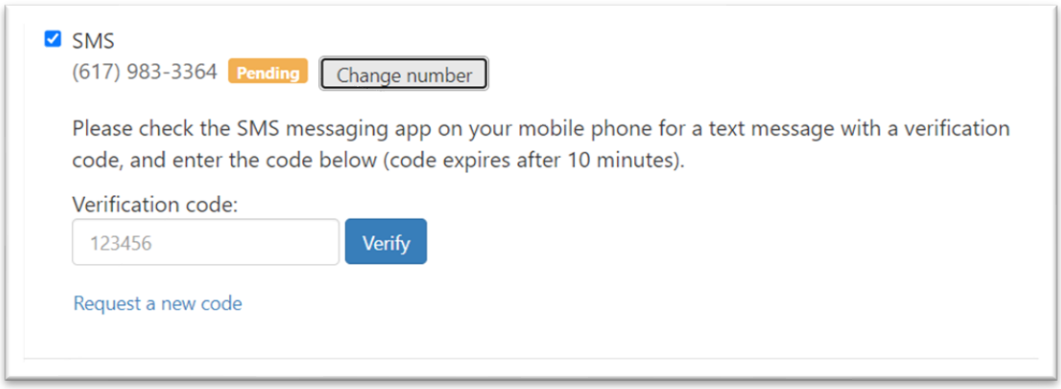
Figure 14. Sign-up Step 4 of 6 Notification Preferences (web)



Source: GDOT, 2024

Figure 15. Sign-up Step 4 of 6 Notification Preference (mobile)

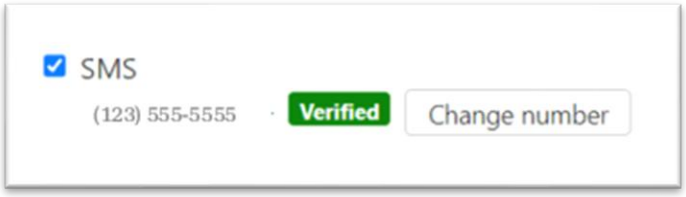
- Preferences for notifications include email (default), Short Message Service (SMS), Push (only for mobile) and Haptic (only for mobile)
  - The email address is the one used for the sign-up. The email address is included below the selection.
  - The SMS requires verification that the message was received. The user must enter the phone number into the field (the field is automatically masked). Then the user selects the Send verification button.
  - Once selected, a verification code is sent to the SMS. The field shows the SMS as pending and opens a field to enter the verification code (Figure 16).



Source: GDOT, 2024

Figure 16. SMS Pending (web)

- When entered, the user selects Verify and the app changes the field to Verified. The user is then provided with an option to change the number, as shown in Figure 17.



Source: GDOT, 2024

Figure 17. SMS Verified (web)

- If the user unselects SMS after verifying the number, the number is still verified, but the notification is not forwarded to the user's SMS.

- Push and Haptic are only available to select via the mobile app. The Haptic does not even appear on the web version page.

- User selects Next to move to Step 5 of 6.

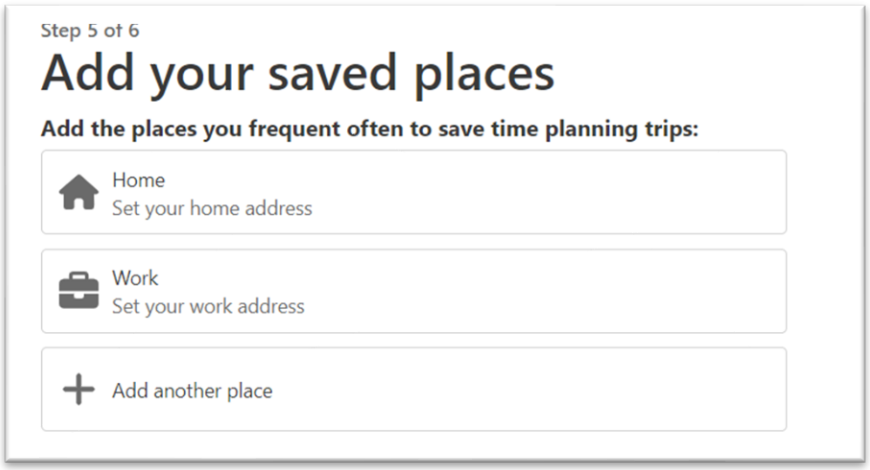
- Step 5 of 6 Add your saved places page includes the following:

  - The saved places function has not been enhanced. The user is prompted to add a home or work address or another place, as shown in Figure 18.

  - User selects Next to move to Step 6 of 6 which indicates that the user's account setup complete. The user is prompted to select Finish.

  - Selecting Finish transitions the user to the Plan Trip Splash page.

  - The user's initials should appear in the top left hand corner in place of the person icon.



Source: GDOT, 2024

Figure 18. Step 5 of 6 Add your saved places (web)

4.3.3.2 Mobility Profile Assignment

G-MAP uses the mobility profile questions to assign the standardized cost to travel that matches the mobility mode category generated by the STM. Specifically, sidewalk assets and conditions are used to calculate each category based on traveler's abilities and assistive devices as described in more detail in **Section 5.6.** Mobility profiles are used to select the impedance layer (time cost to traverse a path) submitted to the OTP routing engine (in the core OTP code) instead of one that is generated from the native OSM data.

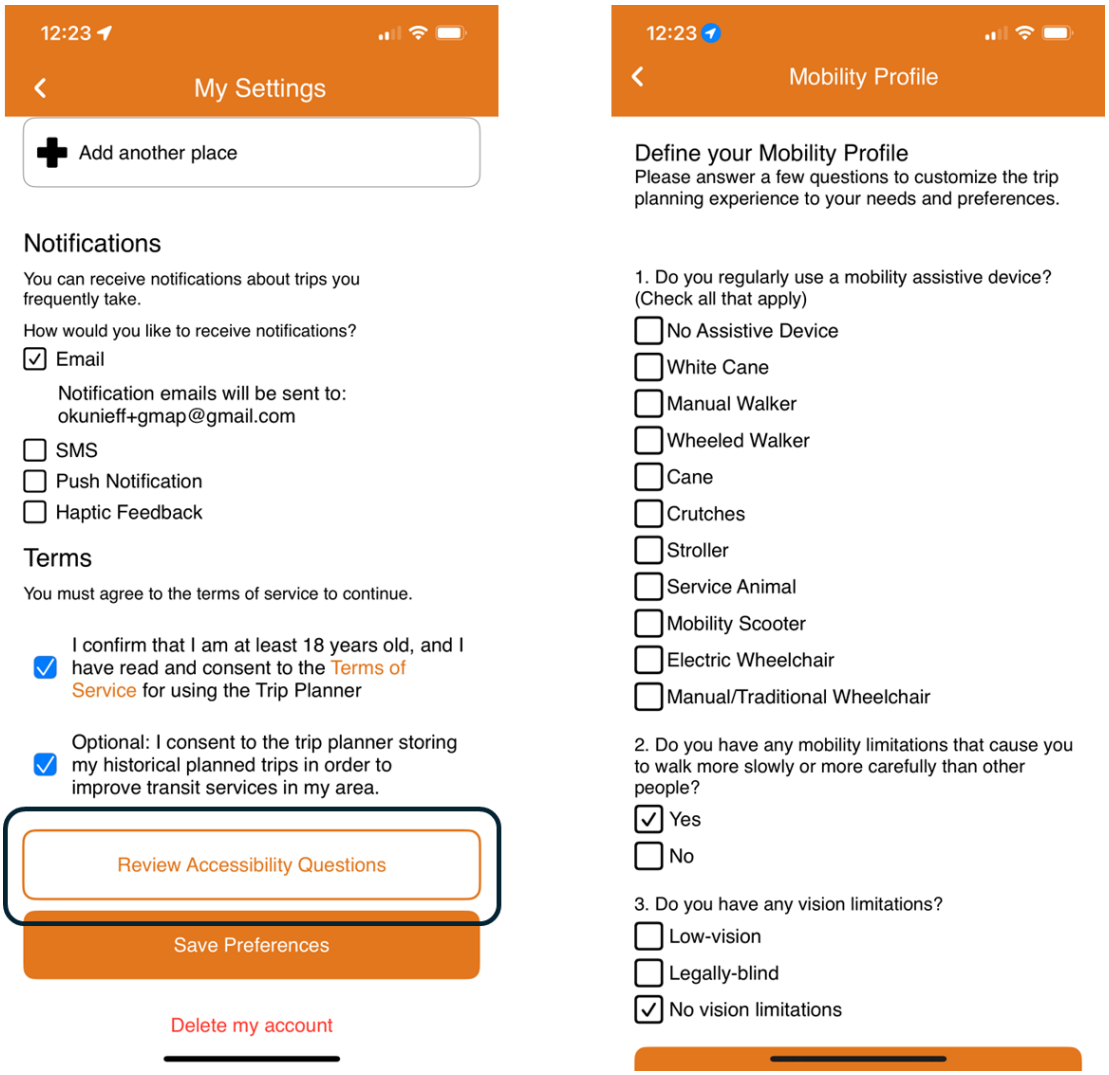
The specific assignment based on the responses to the three questions are mapped to one of eighteen (18) mobility profiles listed in Table 57**.**

The Mobility Categories are described in more detail in **Section 5.3.3** and Appendix B. Logical Flow for Mobility Mode and Vision Combinations

4.3.3.3 My Settings Processes

Access to the registration information is available from the user profile icon and settings tab. The My Settings page, shown in Figure 19**,** enables the traveler to edit or remove the settings from their account, allowing the user to update the following preferences:

- Saved Places
- Notifications
- Agreement Accessibility Questions (which changes their mobility profile)
    - Selection of the Review Accessibility Questions opens the Mobility Profile page
- Delete my account



Source: GDOT, 2024

Figure 19. UI (iOS) Mobility Profile Accessibility Questions

4.3.4 Routing Enhancements (Epic 3b)

Epic 3b Description: Update and enhance routing to support users' mobility profiles based on impedance time/cost penalties from STM Network Impedance API.

The routing enhancements consist of several additional functions or configuration adjustments. Two were implemented in the G-MAP app. They include the following:

STM Impedance Based on Mobility Profiles. The first enhancement provides a function where the G-MAP ingests the STM Impedance API at periodic intervals (currently every 15 minutes) and applies the impedances to the OSM graph object (currently applied in the native OTP routing engine). The STM provides 18 levels that are used by the OTP routing engine when generating a trip plan for each traveler / account holder.

There are several steps associated with this process. G-MAP:

1. Calls STM Network Impedance API (see ICD, Int-6) at every configurable period, currently set at every 15 minutes.

2. Associates each link (in each direction) with the OSM graph object.

3. Makes the OSM graph object available for trip planning (i.e., generates a trip plan).

Adjust Slack Time to Meet Transit. The second enhancement is an adjustment to lower the estimated time to arrive at the bus stop to catch transit, also called slack time. The typical slack time is 15 minutes, but because Ride Request provides a more reliable connection, the slack time was reduced to 5 minutes.

4.3.5 Notification and Event Framework (Epic 3c)

Epic 3c Description: Update notifications to reflect updated routing and live tracking. Detailed design of notifications includes update of preferences, methods, and triggers based on mobility profiles, routing and live tracking.

In this set of functions, the G-MAP design provides a framework to add “methods” (or triggers) to send or push time or spatial events messages to travelers.

The list of notifications and their triggers are be based on their major elements:

- Mobility Profiles and user preferences.

- In-trip support while live tracking is on (Epic 4) including walking directions and indoor navigation via in-app push and haptic notifications.

- Mode notifications such as start trip and transit trips.

The framework is based on a real-time event loader to manage pending notifications and event alert when a trigger is encountered. Each event uses a java method that includes the:

- **Notification Type**. The type of message or notification.

- **Event Trigger**. The trigger based on time or proximity, e.g., within 15-minute walk of a bus stop.

- **Content**. API with parameters to complete, e.g., Ride Request API.

- **Method**. What is the means that the message is sent, e.g., Representational State Transfer (REST) API and JavaScript Object Notation (JSON) payload.

- **Recipient**. Who and where to send the API, e.g., to TSP Proxy Server and Gwinnett’s Enterprise Transit Management System. Note that this element also provides in-app support using haptic, push messages, SMS and email.

A notification service (Java methods) is triggered when a trip is scheduled and active. The methods are pushed to the appropriate channel and recipient as needed. Table 8 provides a list of notification types and their associated characteristics.

Table 8. List of Notification Types and Characteristics

Notification Type	Event Trigger	Content	Method	Recipient
Pre-Trip Departure	Trip monitoring is defined by user preference. Default monitoring begins 30 minutes before a trip starts.	"Your trip has the following notifications: Reminder for (trip name) at (saved trip time). We will let you know if anything changes."	Push Notification, SMS or email	User
Pre-Trip Disruption	Trip monitoring is defined by user preference. Default monitoring begins 30 minutes before a trip starts. User can set amount of disruption time; default is 5 minutes	"Your trip has the following notifications: Your itinerary was not found in trip planner results for today! Please check realtime conditions and plan a new trip."	Push Notification, SMS or email	User
Service Alert	Trip monitoring is defined by user preference. Default monitoring begins 30 minutes before a trip starts.	*(Content dependent on saved itinerary)* "Your trip has the following notifications: Reminder for (trip name) at (saved trip time). (#) new alerts found"	Push Notification, SMS or email	User

Notification Type	Event Trigger	Content	Method	Recipient
Location updates	User navigates route via walk or transit	API Call to G-MAP endpoint	REST API, JSON object	Middleware
Turn-by-Turn Direction	User loads and starts a saved route with Bluetooth enabled. Location updates mapping to the route with user's location.	*(Content dependent on saved itinerary)* Next instruction in trip itinerary, i.e., walking directions or upcoming connections	Push Notification or Haptic	User, Middleware
In-Trip Disruption	Vehicle status updates	Delays, Missed transfers	Push Notification	User
Live Tracking Termination	User navigates away from route	Termination messaging, REST API, JSON object	Push Notification	User, Avail Mobile Data Terminal (MDT)
Route Completion	User arrives at destination/ destination inside facility	API Call to G-MAP endpoint	REST API, JSON object	User, Middleware
Indoor Navigation	Geofence trigger at facility entrance	CXApp UI	Audio, Push Notification or Haptic	User
Ride Request	Geofence trigger around bus stop	API call to Avail endpoint	REST API, JSON object	Avail MDT
Ped-X Request	Geofence trigger at enabled intersection	API call to PEDX endpoint	REST API, JSON object	Ped-X Controller
TSP Request	See Ride Request	API call to TSP endpoint	REST API, JSON object	Signal Controller

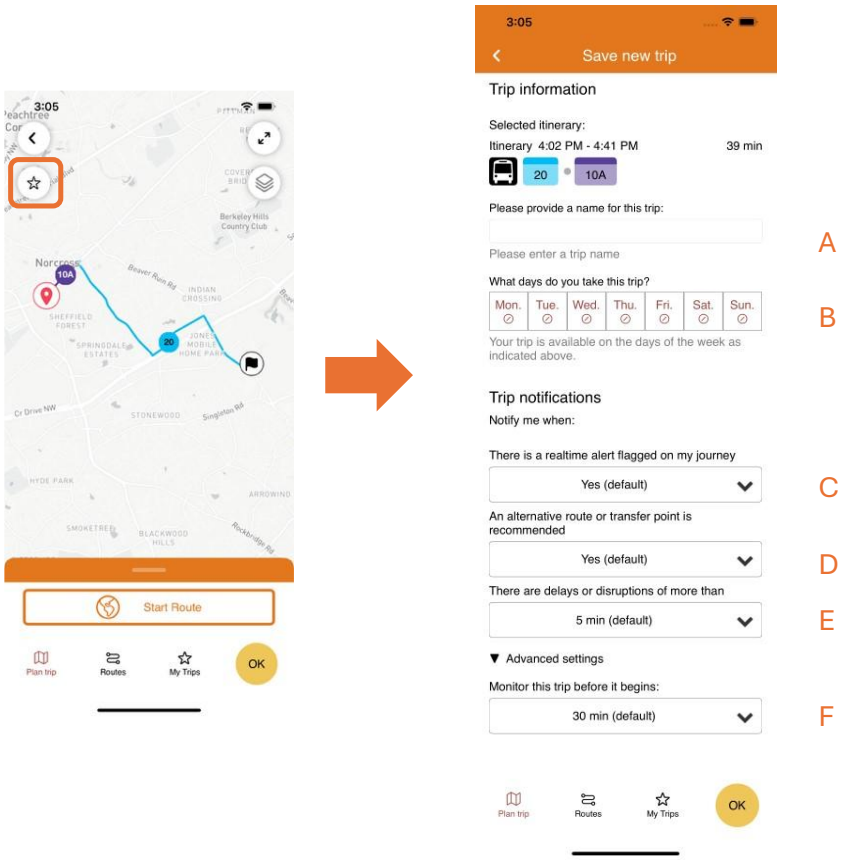
4.3.5.1 Notification Settings

As noted in Table 8, there are several types of notifications that are sent to travelers/users. These include:

- Alerts associated with transit (routes/stops).

- Time to depart for journey or arrive at destination.
- Changes to journey (in-transit).

Notifications are set up when a trip is planned or scheduled. After a trip is scheduled or saved, the traveler can set notifications for the trip. For walking, car, or biking trips, a traveler can set a start of trip notification.



Source: GDOT, 2024

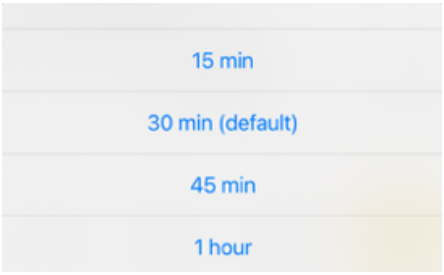
Figure 20. Settings for Trip Notifications

The traveler can set notifications for each trip or saved trip as shown in Figure 20. From the map page, the traveler selects the star icon to show the Save new trip page. Each trip can be named (line A) and the days of the week when the trip is taken (line B). If this is a one-time trip, then the days are not active. Trip notifications use pull down fields that provide Boolean or configurable time alerts. The notifications include:

- **Line C**. Alert flag for realtime delays. These are for delays to transit service based on GTFS-realtime messages. (Default – yes).
- **Line D**. Alert for an alternate route or transfer point. An example of this alert may occur when a bus is late to a transfer or when a traveler detours from their walking path. (Default – yes).

- **Line E**. Alert for a transit trip disruption. This line is associated with the realtime alert flag (line C). The alert can be configured to send a notification for delays of more than 5, 10 or 15 minutes.

- **Line D**. Alert to begin trip. The traveler must open the Advanced settings to see the notification type. The alert can be configured to send a notification 15 min, 30 min (default), 45 min or 1 hour in advance. An example of the pull-down menu is shown in Figure 21.



Source: GDOT, 2024

Figure 21. Example of a pull-down menu

4.3.5.2 Trip Monitoring States

When monitoring a trip, the trip monitor logic checks for the next possible itinerary and calculate the status. If the resulting itinerary has a start time before the current time and an end time after the current time, then the trip status is set to TRIP_ACTIVE. If the following possible itinerary has a start time after the current time, then the trip status is set to TRIP_UPCOMING. If there is no matching itinerary occurring on the next possible day that trip monitoring is supposed to happen, then the status is set to NEXT_TRIP_NOT_POSSIBLE.

A notification is sent when a trip is detected as not being possible, and all further trip monitoring calculations for that day cease. That day of the week is flagged as impossible when last checked. Once the trip monitor has reached a point where it has calculated a trip as not being possible on any day of the week after checking each day and marking it as not possible according to the NEXT_TRIP_NOT_POSSIBLE logic, it performs one final check on the original day marked as NEXT_TRIP_NOT_POSSIBLE. If the trip is still not possible, then the status of the trip is permanently marked NO_LONGER_POSSIBLE, and the trip is no longer monitored. The user needs to delete the trip.

A list of these notifications is included in Table 9. The table includes the following columns:

- **Trip Monitoring States.** Name of the notification and the label shown to the traveler.

- **State Description.** The description of the notification.

Table 9. Trip Monitoring States

Trip Monitoring States	State Description
NO_LONGER_POSSIBLE	The trip is no longer possible on any of the days of the week that the user selected for monitoring the trip.
NEXT_TRIP_NOT_POSSIBLE	The trip might still be possible on other days of the week but isn't possible on the next possible time that it would've otherwise been possible.
TRIP_UPCOMING	The next possible trip is possible, but the start time of the itinerary is in the future.
TRIP_ACTIVE	The next possible trip is possible, and the current time is between the itinerary's start and end times.

4.4 Enhanced Trip Functionality

4.4.1 OTP Middleware

The OTP Middleware manages and orchestrates messaging between the OTP server and the traveler mobile app as well as between the OTP server and external services such as PED-X, Ride Request, Enhanced TSP, Private PMD, and indoor navigation. The notifications framework manages the event triggers and messages that time and spatial management processes monitor.

The OTP Middleware existing interfaces were slightly updated to accommodate the exchange of information between the OTP server / CDP and web browser.

Note that the ingestion of the STM Impedance API occurs in a different module (see Epic 3b, **Section 4.3.4**) since it is part of the OTP routing engine realtime updaters functionality that manages the routing engine network data structure.

In addition, the OTP Middleware includes a submodule called the OTP-personas which provides storage and access to unique user profiles for each registered user including saved trip planning and places, and other settings. The OTP-personas Middleware (designated in Figure 9 as the CDP) archives transaction history (all input and output messages) that are handled by the middleware. This function enables the trip histories (see Epic 11, **Section 4.5**) to be logged and analyzed (where trip plans are compared against actual trips taken).

The interfaces supported by the OTP Middleware are described in the ICD (ICD, 2025).

4.4.2 Live Tracking and In-Trip Support (Epic 4)

Epic 4 Description. Track traveler and support their trip while they journey on their trip. This epic is called live tracking and in-trip support.

Live Tracking and In-Trip Support includes the following high-level assumptions:

- User has the ability to opt in / opt out of live tracking (see Epic 2).
- After planning a trip, the traveler has the ability to start tracking function.
- The user initiates the route from a saved trip to begin live tracking (See Epic 4).
- While on the journey, the user is provided alerts and “live” turn-by-turn instructions.

The Live Tracking and In-Trip Support functionality is implemented in the customer-facing mobile app and the middleware processing component. The functionality for each flow is described in Table 10.

Table 10. Live Tracking and In-Trip Support Process Flow

Live Tracking Process Flow	Description / Assumptions

User logs in and initiates saved route	The user logs in with the web / mobile G-MAP app. The app sends authentication requests and user data to web services which handle authentication processes. Users save trip itineraries for immediate or future travel, initiating dynamic routing including turn-by-turn directions. The app transmits route, user, and location information to web services. Web services begin to provide direction messages to the user to guide them along the selected route
	• Logs in
	  ○ Mobile App: sends Auth requests / user data.
	  ○ Web services: handle Authentication and save / maintains user data.
	• Initiates Saved Route
	  ○ User loads & starts a saved route.
	  ○ Mobile App sends Route, User, and Location Information.
	  ○ Mobile app starts collecting at current location / start of trip.
	  ○ When user is traveling on a transit vehicle, use traveler’s location as the bus/train location.
	Web Services return direction messages.

Live Tracking Process Flow	Description / Assumptions
Navigating a route	Trip itineraries incorporate mobility profile selections and impedance calculations to routing users on accessible paths. When traversing each trip leg, the app: • Identifies when the user starts and transitions to a mode (e.g., walk, transit, indoor facility). • Provides continuous directions as the user proceeds along their leg (including turn-by-turn directions -- forward, turn left, turn right, cross intersection, or board, continue or alight a transit vehicle). • Alerts the user as they approach the end of the leg (i.e., last stop, room destination). • Presents a termination message and will exit from Navigation when the user confirms termination.

Middleware processes trip progression (location) information	• Middleware receives location at a configurable frequency (based on trip stage).
	
	• Middleware uses location data, planned trip, and RT data to calculate initial status (Is trip running on time? Is the user at a transition point? Is the user following the trip? Is the user going to miss a transfer?)
	
	  ○ Generate updates (Epic 8) and notifications (Epic 3c) as appropriate within 1 second of the trigger.
	
	• Middleware sends status back to mobile app with appropriate triggers within a second and progress on trip path
	
	  ○ Middleware logs events including location, matching status, triggers, etc. (Epic 11 and 12).
	
	• When approaching an intersection, the mobile app sends location updates and presents direction message. Web service triggers PED-X and returns direction messages.
	
	• When approaching a transit leg, the mobile app sends location updates and presents direction message. Web service triggers Ride Request and enhanced TSP APIs and returns direction messages.

Live Tracking Process Flow	Description / Assumptions

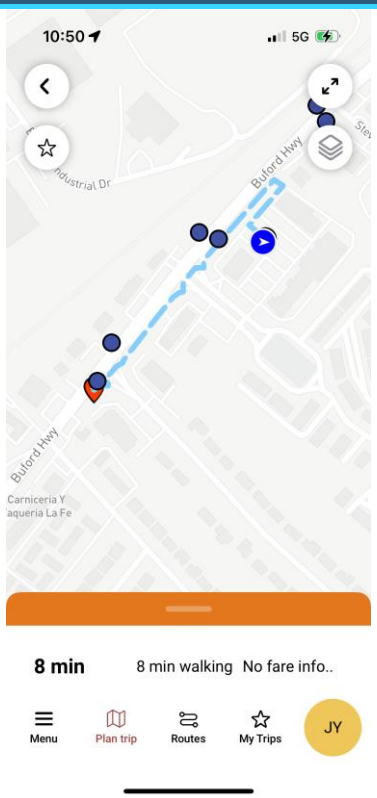
End of trip	• When arriving at a destination (address or facility):
	  ○ Mobile app sends location updates and geofence confirmation, and presents direction message.
	  ○ If entering facility with indoor navigation, Mobile app transitions to CXApp UI, presents user with facility room list (Epic 14, **Section 4.6.3**).
	  ○ Web service returns direction message (pathway)
	• When approaching a final transit (or connection) stop:
	  ○ Mobile app sends location updates and presents stop/connection message.
	  ○ Web service returns direction stop/connection message.

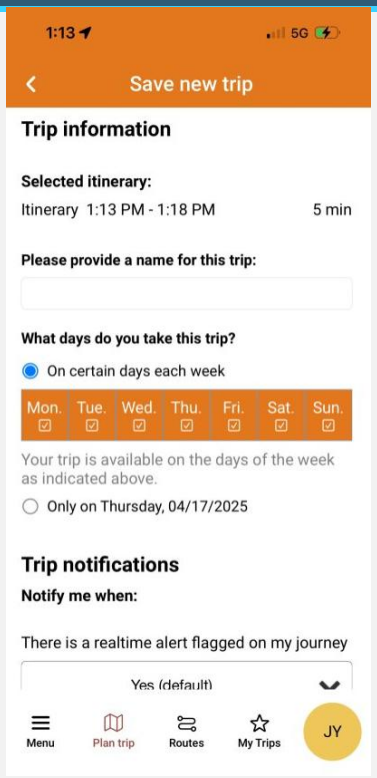
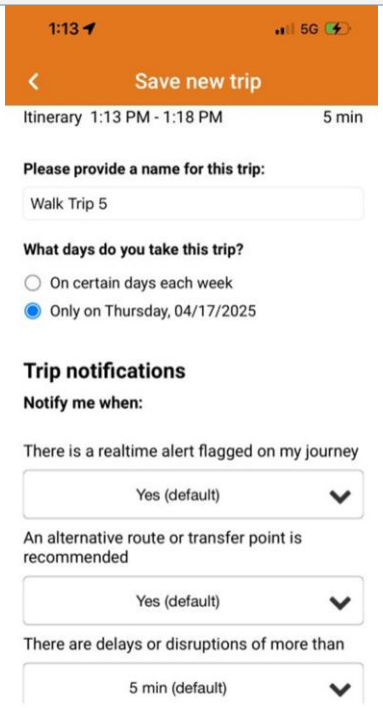
Core functionality includes:

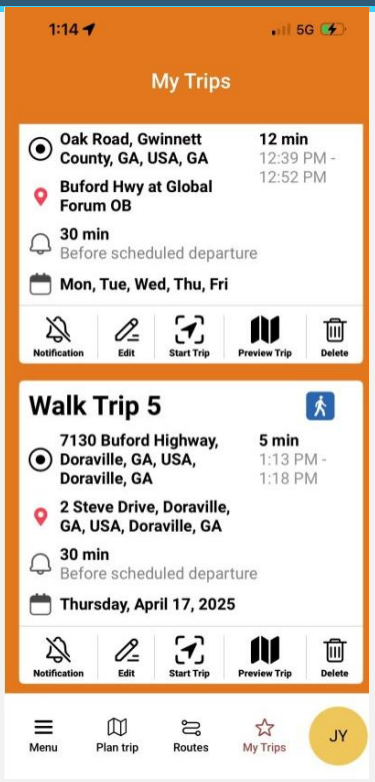
- Log route trace data including test accuracy by
  - Collecting user location data when in active trip scenario at a configurable interval.
  - Applying location smoothing to avoid jumping/messy location data.
  - Bundling location data and account info / device ID.
- Pass live track data from mobile app to OTP-personas
  - The OTP mobile apps use the mobile device location services to geolocate a user at a regular interval and track them through their trip process. This location information is used by the OTP-personas middleware to track the user through their trip, trigger updates/notifications, and provide other in-trip support.
  - The mobile apps pass location information to the OTP middleware tied to a user's account and mobile device ID for that location info to be used for route tracking and in-trip support.
- Real time loader – used to accept traveler locations (tracked by mobile app) that also enables processes to instantiate trigger events for receipt of notifications and turn-by-turn direction by travelers.

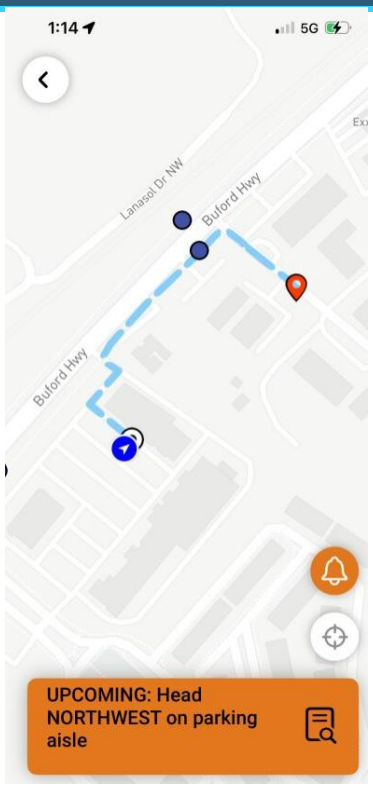
In addition, the UI for turn-by-turn directions and transit notifications were designed as part of this epic. Table 11 walks through the confirmation, trip preference selections, saving, starting, and executing the trip processes.

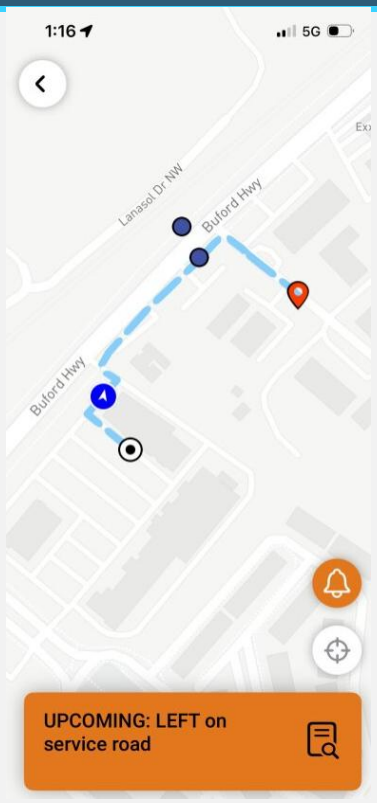
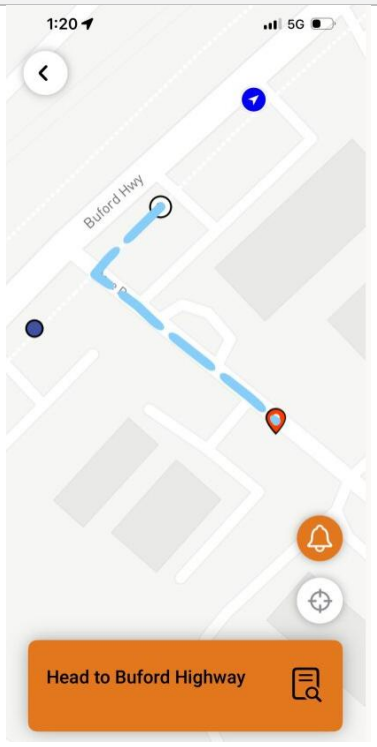
Table 11. Screenshots of Live Tracking Process

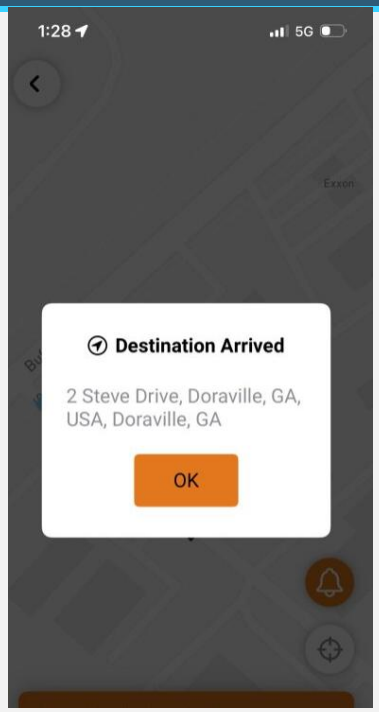
Description	Screenshot
Following Planning Trip, the map page is shown. User location indicated on screen at the origin of the trip plan, walking path to destination and destination (red drop icon).	

Description	Screenshot
Save new trip page includes preferences for: • Naming trip • Scheduling trip • Selection notifications	
Edit saved trip includes Trip Notification Preferences (1) Trip Notifications Select notifications for • Real time alerts • Alternative route or transfer point • Delays or disruptions Note: additional preferences shown in **Section 4.3.5.1**	

Description	Screenshot
My Trips Use to start the trip (see circled button on bottom of Walk Trip 5). • Walk Trip 1 is the trip name. • Dot in circle is the beginning of trip location with a duration of 8 minutes; starting from 10:50am to 10:58 am • Red tear drop is destination • Notification set for 30 minutes prior to scheduled departure • Trip is schedule for daily (Mon-Sun)	

Description	Screenshot
While walking, turn-by-turn instructions include *upcoming* turns and crossing information. Instructions are provided on an orange notification on the bottom of the page.	

Description	Screenshot
Map display is active while the user's live location is indicated on the map and turn-by-turn directions are displayed in an orange notification on the bottom of the page.	
When the traveler deviates from their trip plan path outside of the configurable distance (see blue dot for location of traveler), the app will trigger a pop-up screen asking if the traveler would like a reroute. Note: the notification will continue to direct the traveler based on the original direction until the pop-up is triggered.	

Description	Screenshot
Upon arrival at the destination, a pop-up message displays that the traveler has arrived at their destination	

4.4.3 Dynamic Trip Planning (Epic 8)

Epic 8 Description: Develop design that uses live trace data and user location to make routing decisions in real-time and provide routing updates.

Dynamic Trip Planning includes the following high-level assumptions:

- The user initiates the route from a saved trip to begin live tracking (See Epic 4) and dynamic routing.
- While on the journey, the user is prompted to reroute if they have deviated from the saved trip itinerary.
- A deviation from a saved trip itinerary is defined as deviating from the route for more than 10 meters and longer than 1 minute.

If a user triggers a deviation (deviating from the route for more than 10 meters and longer than 1 minute), the app provides an alternative route for them to reach their original destination. This includes the following use cases:

- User travels outside of planned route from saved trip.
- User takes the incorrect bus from saved trip.

The functionality for each design process is described in Table 12.

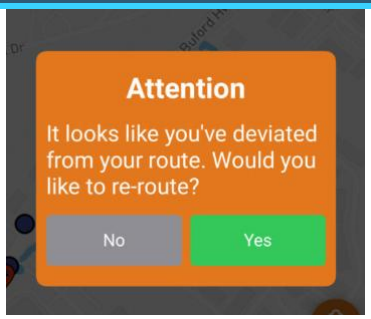
Table 12. Dynamic Trip Planning

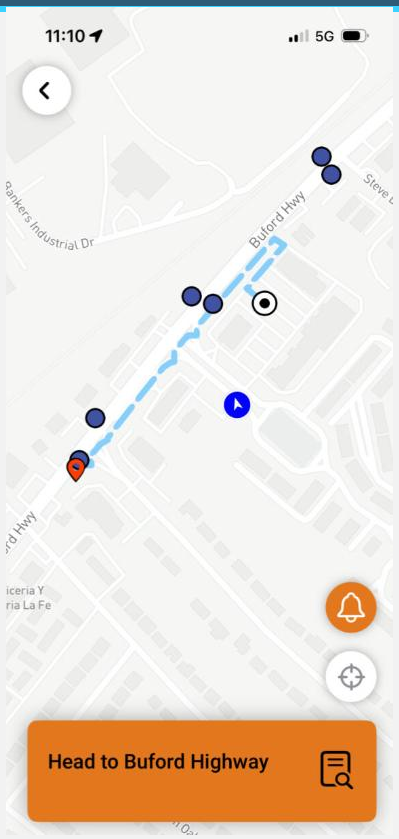
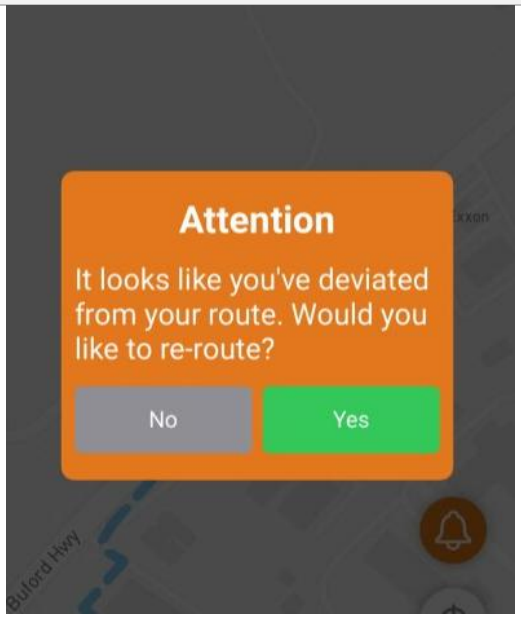
Step	Processes	User, Mobile App and Backend Design
1	Route Deviation – trigger deviation	If a user meets the deviation criteria (*deviating from the route for more than 10 meters and longer than 1 minute*), they trigger and receive a rerouting prompt and post-travel survey notification. See **Section 4.4.7** for more details regarding the post-travel survey.
2	Route Deviation – receiving rerouting prompt	Once the user receives the rerouting prompt, the rerouting prompt asks the user if they would like to be rerouted, and the user has the option to accept or decline the prompt. The rerouting prompt is triggered every minute, if the user is still deviating from the route.
3A	Route Deviation – accepting rerouting prompt	If the user accepts the prompt, then a new route is generated from OTP still using the user's original destination. Live tracking and turn-by-turn instructions continue from the user's current location. Note that if the user initiated the original trip itinerary from a saved trip plan, the new route is recorded as a rerouted variation on routing, not a distinct saved trip.
3B	Route Deviation – declining rerouting prompt	If the user declines the prompt, live tracking continues to display the user's location on the app but discontinues after more than 10 minutes of continued deviation.

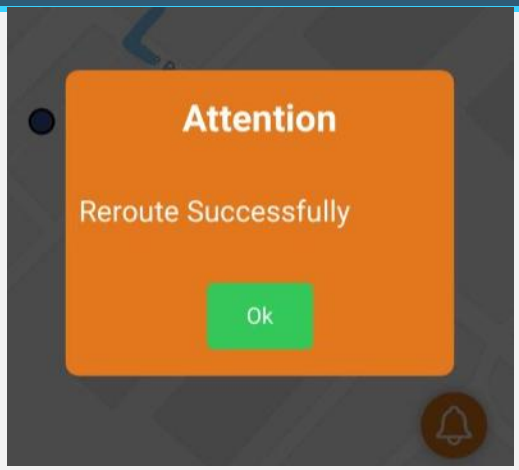
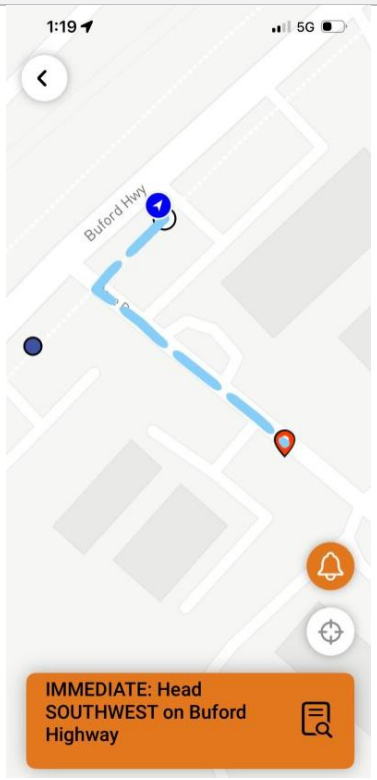
Once the user initiates a saved trip plan, the app automatically begins live tracking and provides the user with turn-by-turn directions. The app is designed to support the user through dynamic events that can occur during a trip plan. These events are dynamic in nature because they depend on the user's live location and trip plan.

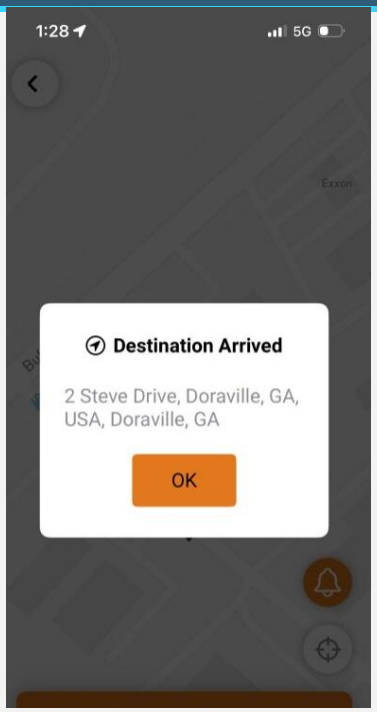
The UIs for dynamic trip planning, including the initiation of a saved trip and route deviations, are a part of this epic (see Table 13).

Table 13. Dynamic Trip Panning -- Rerouting Notifications User Interfaces

Description	Screenshot
While traveling if traveler deviates from their trip plan beyond the threshold, the app asks traveler if they would like to re-route their tip. If they agree, then a new route will appear with turn-by-turn directions.	

Description	Screenshot
Traveler deviating from trip (see blue dot). This is the same map and trip path that is shown if the traveler declines re-route.	
When a traveler deviates from the path, the app detects the deviation and asks if the traveler wants to be re-routed.	

Description	Screenshot
When the traveler selects “yes” then the app lets them know that the reroute has been updated. Note: if the traveler indicates “no” then the notifications continue to reflect the original trip plan.	
All future walking paths follow rerouted path.	

Description	Screenshot
Upon arrival at the destination, a pop-up message displays that the traveler has arrived at their destination.	

4.4.4 Third Party Access/Group Travel (Epic 6)

Epic 6 Description. Define mobilities for group travel and configure role-based access for trusted companion.

The system provides the third party access functionality in which travelers are able to assign a designated person to assist with their trip planning and execution. This third party is noted as a trusted companion and can be given access while traveling with the traveler (called a "companion") or can remotely view traveler trip details (called an "observer"). Roles and responsibilities are detailed in Table 14.

Table 14. Third Party Access Roles and Responsibilities

Role	Responsibility
Traveler	• Register (add, remove, pause) a trusted companion • Enable functionality for trusted companion to view trip, plan trip, and/or remotely observe trip execution • Configure notifications trusted companions can receive

Role	Responsibility
Trusted Companion	• Agree (remove) as a trusted companion • View planned trips • Plan trip for traveler • Progress through trip alongside G-MAP traveler • Remotely observe trip execution by viewing traveler location • Receive enabled notifications as traveler progresses through the trip

Detailed technical design for features to allow users to plan trips with a trusted companion include the following major components:

- Register a trusted companion through a secure method that enables role-based access to traveler's trip plans and journey.
- Allow a trusted companion to schedule trips for either themselves, the traveler, or both; mobility profile defaults to the capabilities of the impedance of the highest impedance level (person with assistive devices requiring the most challenges, e.g., child in stroller, person in manual wheelchair). Note: a companion cannot set the mobility preferences for a traveler; they can only set their own mobility preferences as shown in **Section 4.3.3.2**).
- View all planned trips (overlap with Epic 0 – Core Functionality).
- View traveler's locations while traveling (overlap with Epic 4 – Live Tracking and In-Trip Support).
- Receive a subset of notifications when traveling separately such as arrival time to transit, departure and arrival times from the trip's origin or destination, arrival time at next leg of trip plan, and transit delays (overlap with Epic 3c - Notifications).

Functions associated with the design are described in Table 15.

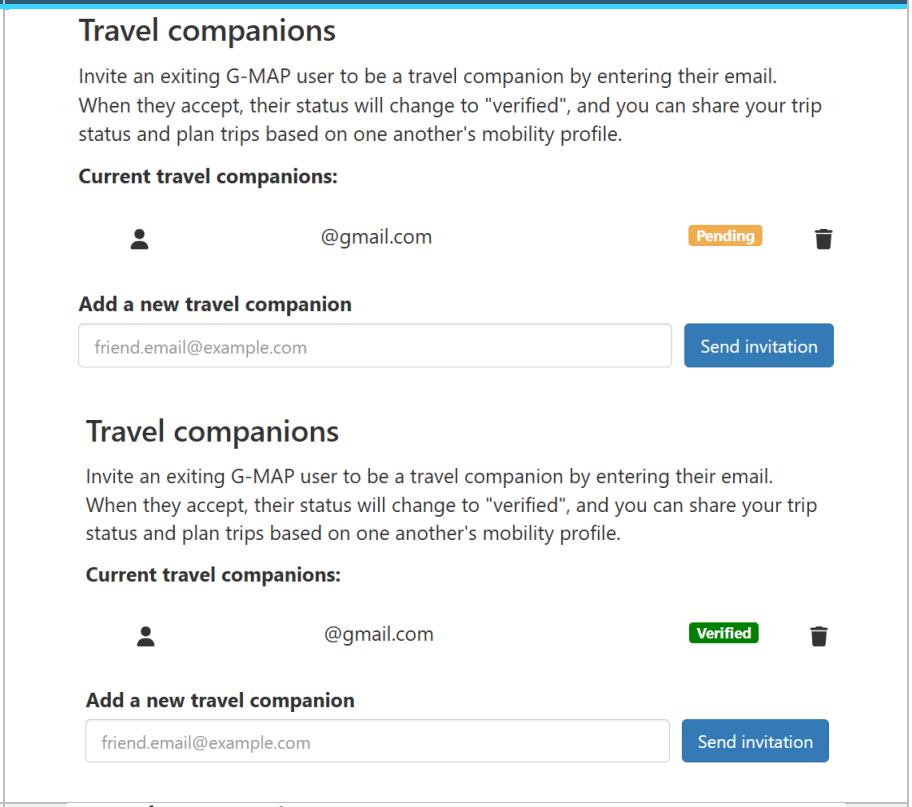
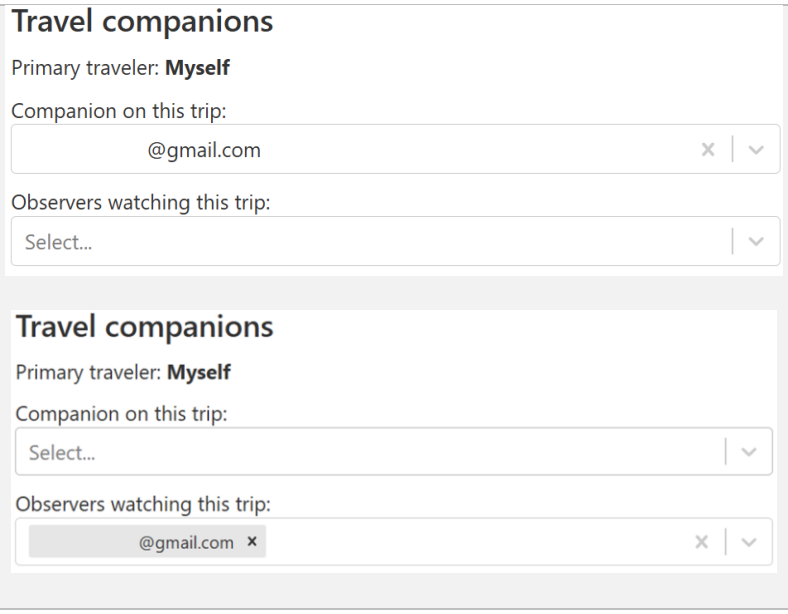
Table 15. Third Party Access and Group Travel Functions

Function	Traveler	Trusted Companion
Register Trusted Companion	Add, remove, pause, apply notifications	Agree, disagree (ignore), remove Configure notifications

Function	Traveler	Trusted Companion
Schedule trips	Plan trip (now, saved) Manage trips (share with trusted companion, change settings, add a new trusted companions)	Schedule for traveler (and trusted companion/self) Manage trips (add a new traveler, update notifications)
Trip journey	View trip directions and notifications en-route (mobile)	View traveler en-route (web / mobile) Receive subset of notifications (start (time/location), arrive (time/location, next leg (time/destination), estimated time of arrival, notifications) Take trip with traveler

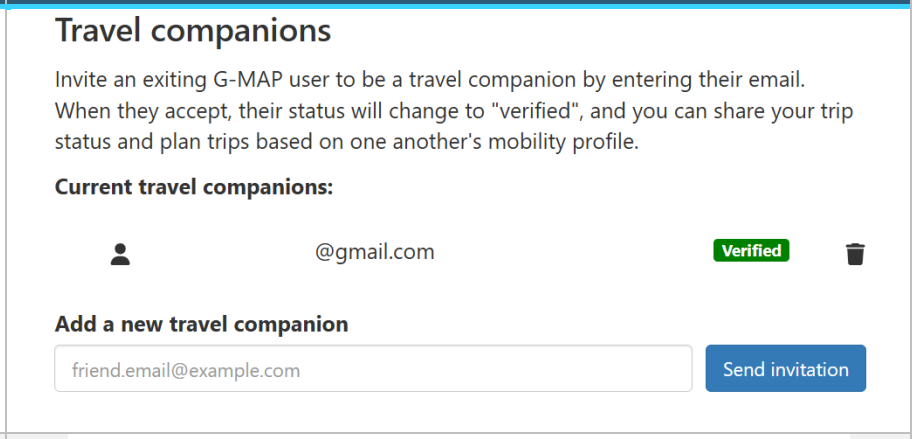
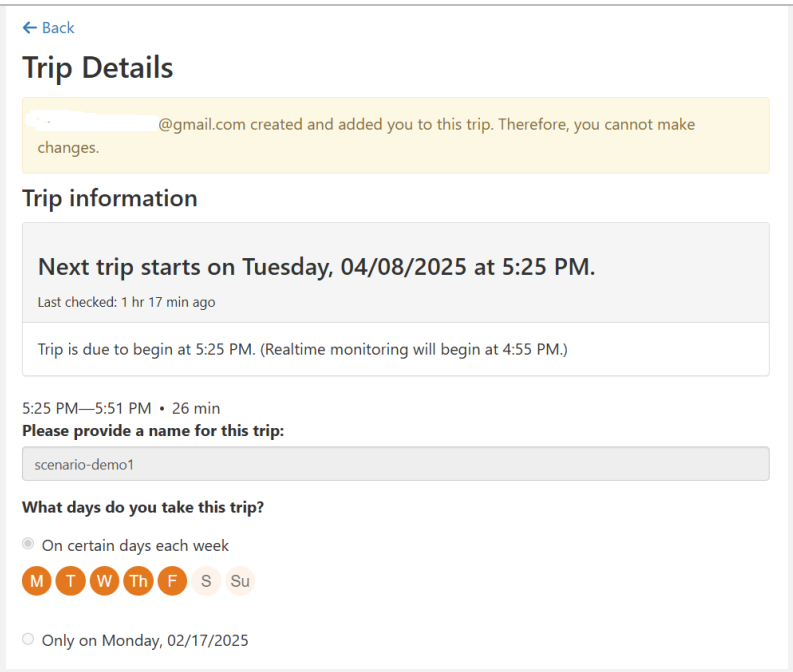
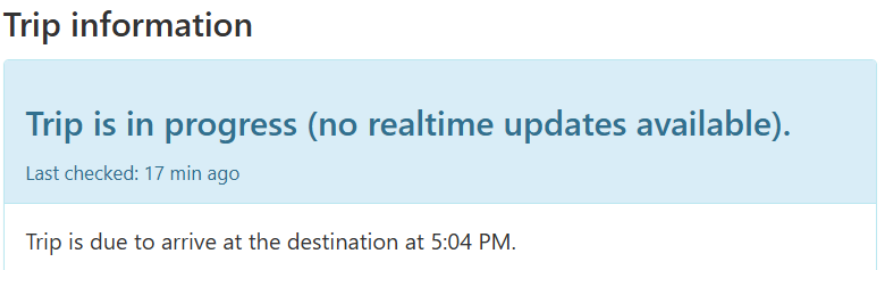
The UIs from the traveler's perspective regarding trusted companion functionality are displayed in Table 16.

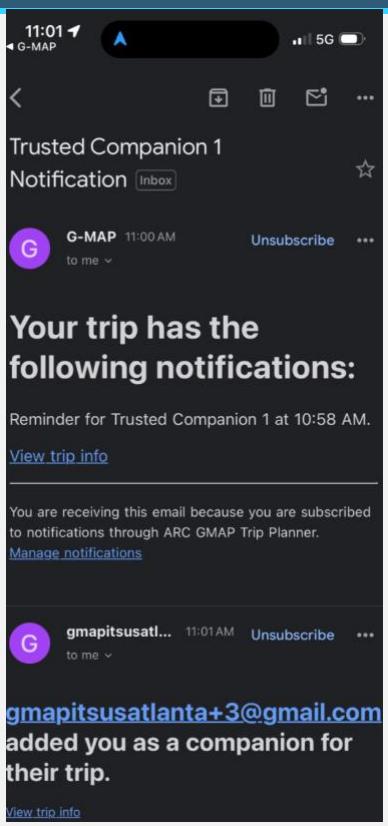
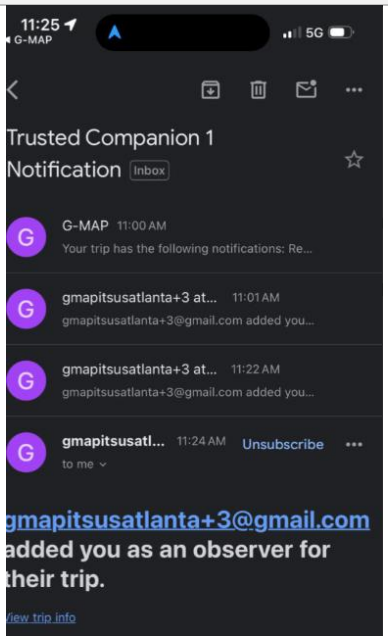
Table 16. Trusted Companion Screenshots from Traveler's Perspective

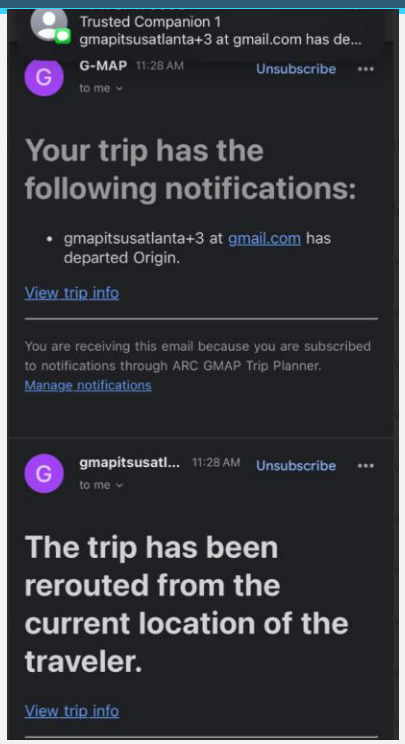
Description	Screenshot
Add / Remove / Pause Trusted Companion • Send invitation to add a travel companion • Use trash icon to remove pending or verified travel companion	
Save Trip with Trusted Companion • Use the drop down list to add one or more companions or observers on the trip • Use the “x” to remove companion or observes from the trip	

The UIs from the trusted companion’s perspective regarding trusted companion functionality are displayed in Table 17.

Table 17. Trusted Companion Screenshots from Trusted Companion's Perspective

Description	Screen Shots
Confirm Trusted Companion. Following email verification, the travel companion shows the same travel companions in the setting page.	
Configure Notifications for Trusted Companion / traveler. When added as a companion, the account holder cannot make changes to the trip and can only view Trip Details.	
View Traveler en-route (web).	

Description	Screen Shots
View Traveler en-route (mobile) as a companion.	
View Traveler en-route (mobile) as an observer.	

Description	Screen Shots
Example of a notifications for traveler to: • Begin trip • Reroute along trip	

4.4.5 Practice Mode (Epic 7)

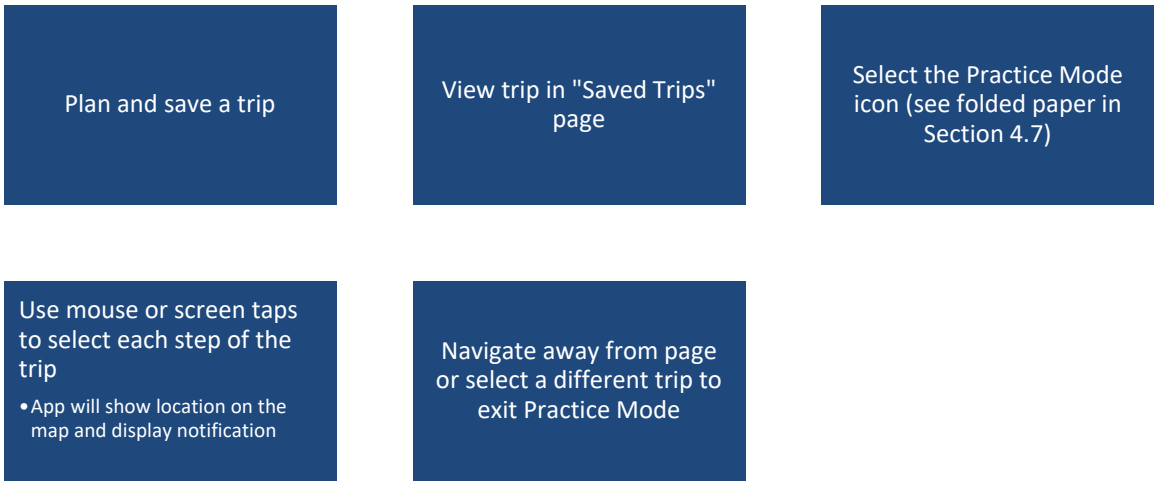
Epic 7 Description. Develop practice mode functionality that allows users to simulate their turn-by-turn directions before starting their trip.

Practice mode enables the user to view their entire trip itinerary before starting their trip including all turn-by-turn walking directions as well as transit route information, bus arrival times, and bus departure times. On the mobile app, users who initiate practice mode can remotely progress through a saved trip's turn-by-turn direction.

Design for practice mode includes the following functionality for saved trips:

- Preview the trip plan on a map where the user can visually see the path between the origin and destination.
- View turn-by-turn directions for all legs of the trip (walking, transit, and auto).
- Step through the turn-by-turn directions on the mobile app.
- Detail the scheduled or predicted (as available) arrival and departure times of buses along the trip plan and the bus routes utilized.

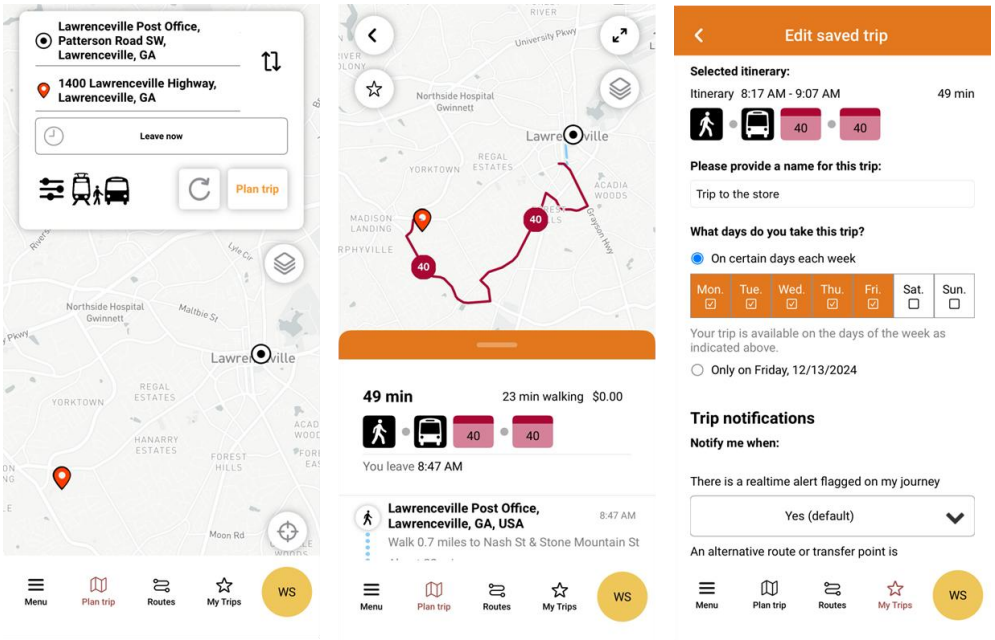
The control flow is shown in Figure 22.



Source: GDOT 2024

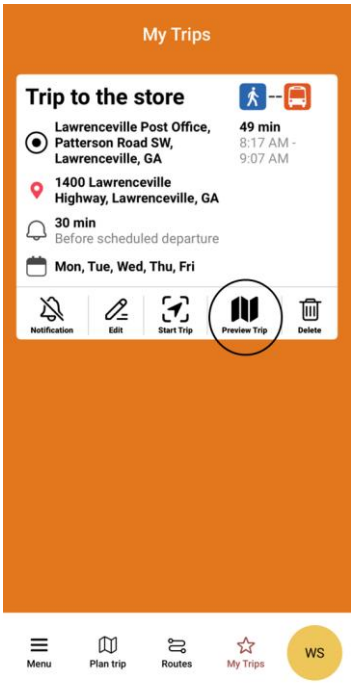
Figure 22. Flow of Practice Mode Functionality

The UIs that follow the flow of the practice mode functionality are displayed in the following figures. Figure 23 shows the screens used to plan and save a trip. Figure 24 provides a screenshot of starting practice mode. Practice mode can be accessed by selecting the folded paper icon, circled in the screenshot below. Figure 25 provides a screenshot of the option to mouse or screen tap to select each step of the trip in practice mode.



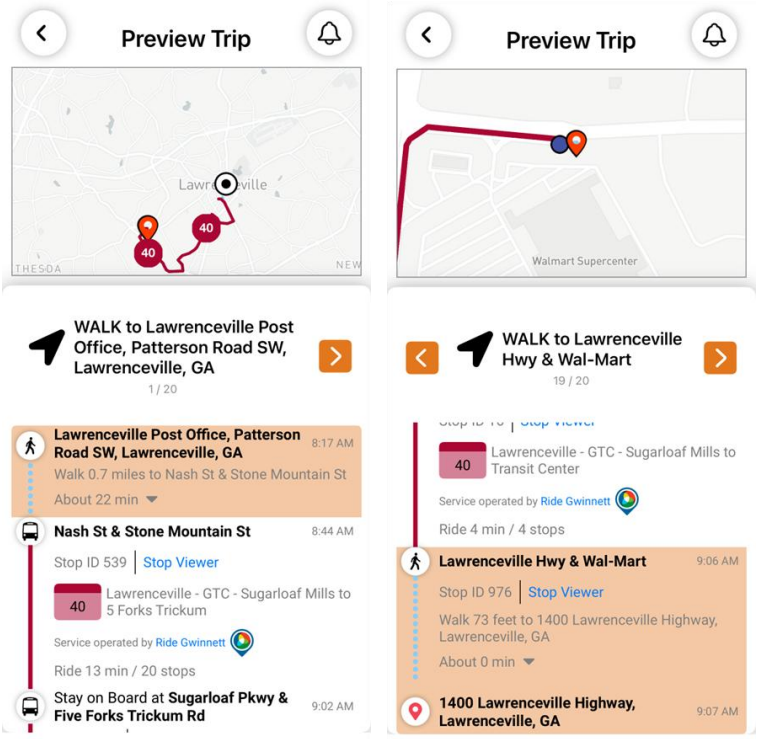
Source: GDOT, 2024

Figure 23. Plan and Save Trips



Source: GDOT, 2024

Figure 24. Select Practice Mode



Source: GDOT, 2024

Figure 25. Mouse/screen taps to click through steps of the trip

4.4.6 Call Center Web App (Epic 16)

Epic 16 Description. Set up a variation of OTP Web App to be used by call center staff which has similar and additional features in the UI, but receives the same updates as the app.

The Call Center Web App is another instance of the web-based G-MAP app using the same core functionality and services (interfaces). The call center module is used by Power Users (i.e., call center agents) planning trips, managing trips, and/or investigating issues on behalf of G-MAP users who have called in for assistance. It implements finer controls for trip planning. The call center module uses the core OTP design and interfaces with added features for the G-MAP functionality (e.g., notifications, customized trip). Web browsers supported include Chrome, Edge, Firefox and Safari.

Other core features that have been deployed include:

Power User Role Functionality. Access to call center app is controlled by a Power User role. Additional permission includes:

- Access to finer parameters when scheduling trips for callers (requires a different UI); this includes adjusted walking speeds, augmented search criteria, setting up mobility mode.
- Permission to view, create, and manage trips on behalf of a G-MAP user who has given authorization for them to do so.

- Send user trip plan via email or push to their account (will be deployed during Phase 3).

In addition, the call center module records call history associated with call agent activity.

A Trip Tools menu can be customized for call center (linked to other Uniform Resource Locators (URLs)), for example frequently asked questions (FAQ). Once set up, the call center administrators discuss business processes to include in a call center trip FAQ. In addition, the FAQ and help menu will include the call center number that will be activated upon Go Live of the app.

4.4.7 In-App Survey and Feedback

Description: Set up in-app survey instrument that is triggered after traveler deviates from their planned trip. In addition, the miscellaneous app updates epic includes setting up a feedback form for travelers to include an open ended feedback who use the app to comment and provide feedback on their user experience in particular input on accessibility that can be shared with the Gwinnett County Accessibility group.

The in-app survey and feedback forms are combined into two different epics (Epics 1 and 9 respectively). The feedback form is available at any time while using the app; the in-app survey question is triggered by a user taking an alternative path from one planned by the app. Note that the in-app survey is specialized to query travelers on their current trip while the evaluation survey is issued by through the STM Performance Measurement Computation Engine (see **Section 5.7**).

4.4.7.1 In-App Survey for Deviation (Epic 1)

The survey form, a third-party instrument, triggers when the app is tracking a traveler's deviation from a planned trip. The logic for the push notification is as follows:

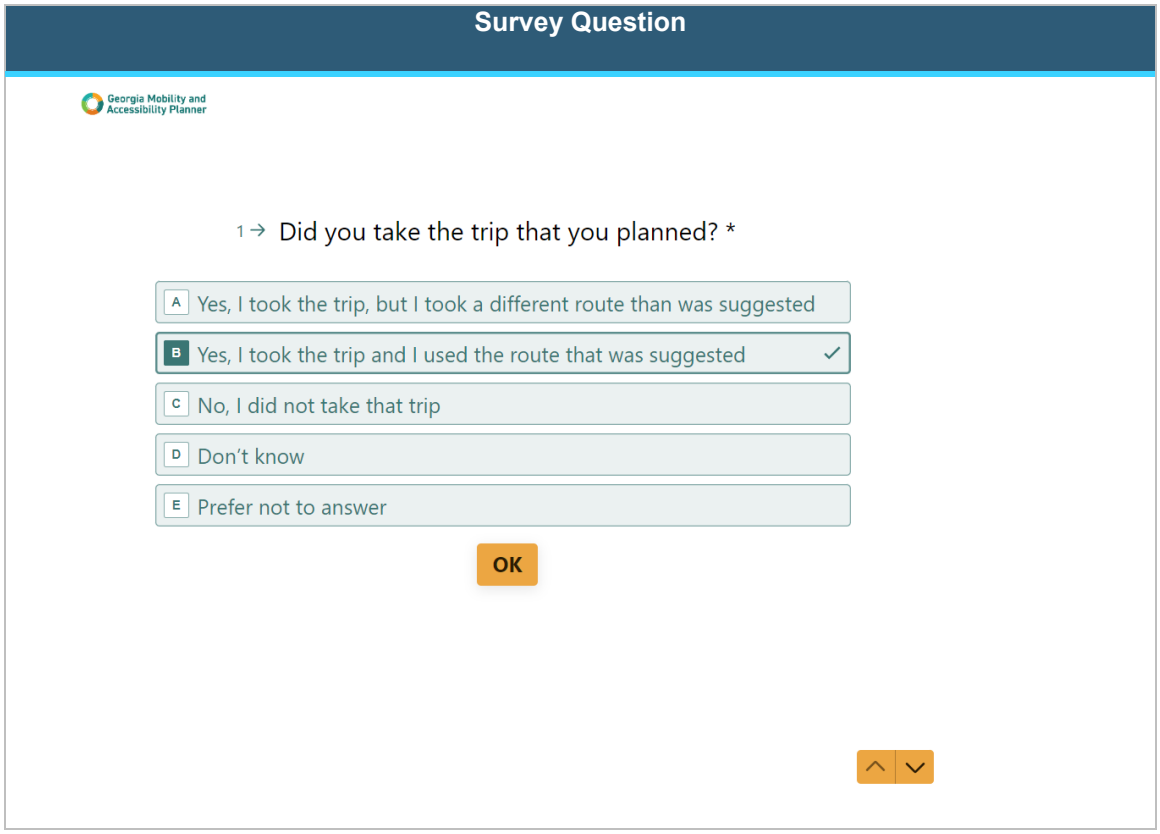
- Trip tracking is logged and matched to the planned trip in OTP-personas CDP (Epics 11 and 12).
- The CDP notes when a user deviated from their planned trip. A deviation is defined as a user who travels at least 10 meters outside their planned trip for over a minute.
- When a deviation is detected, the CDP reviews how many times the in-app survey was issued to the user.
    - If this is the first time over a week, the CDP triggers a push notification for the deviation survey to appear on the user's system and increments the counter.
    - If the counter registers at least one trigger event, the CDP increments the counter again (with no action).
- A survey is pushed to the user's mobile device within 20 to 30 minutes of the completion of their trip. The notification should appear on their mobile even if the application is turned off.

- When the survey is completed, the CDP logs the information and adds it to the daily upload to the STM AWS Simple Storage Service (S3) bucket. The content includes Hash ID (encrypted user ID), complete trip ID, and response to questions.

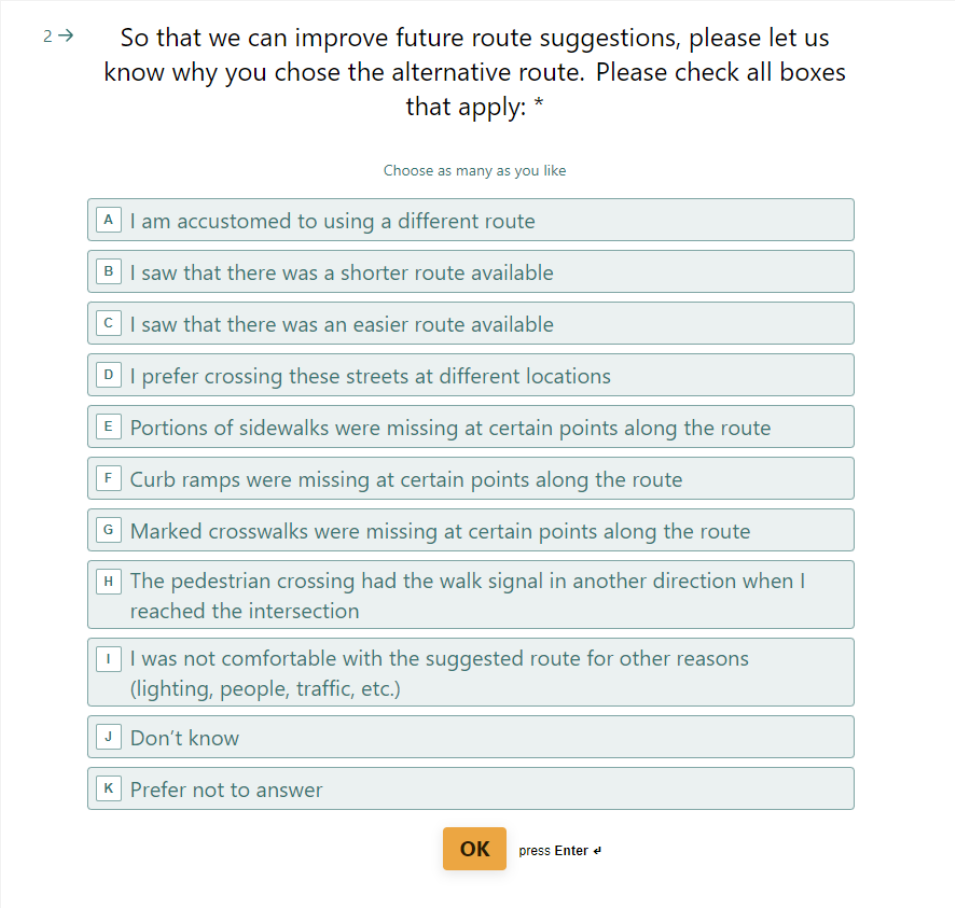
- As part of Epic 13, the data is aggregated with the daily upload to the STM/ private PMD.

There are two questions in the survey, the first is an open-ended question. The second question is dependent on the response to the first question indicating that the traveler acknowledges their deviation ("Yes, I took the trip, but I took a different route than was suggested"). The format for the two questions is shown in Table 18.

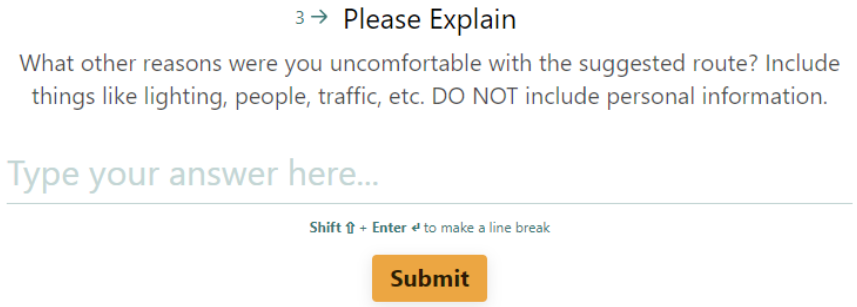
Table 18. In-App Survey Question format



Survey Question
If option #A was selected, the user is asked to respond to the second question:



If option I was selected, the user is asked to respond to the second question:



In addition, each time the user deviates from their planned path, the CDP includes the deviation planned and actual path into Trip-survey-responses file for a daily upload to the STM AWS S3 bucket (see **Section 4.5** for description of file).

4.4.7.2 Feedback Form (Epic 9)

The feedback form is available on the splash page, dropdown down menu, and on the trip scheduling page. The icon is shown as a chat bubble. 

When selected, the user is provided with a menu of topics as shown in Figure 26. The default setting is “General”. A user selects any of the five topics and then clicks “Next >”.

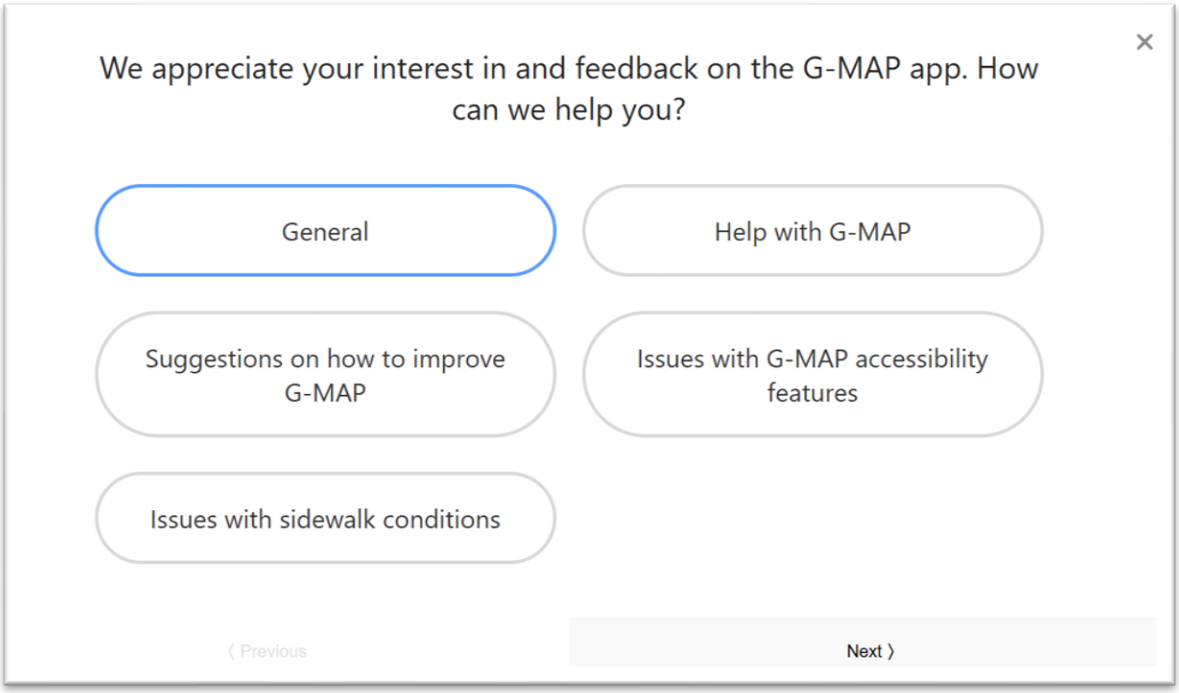


Figure 26. Feedback Menu

Upon selecting “Next>”, the user is presented with a pop-up screen in which they can insert their comment as shown in Figure 27**.**

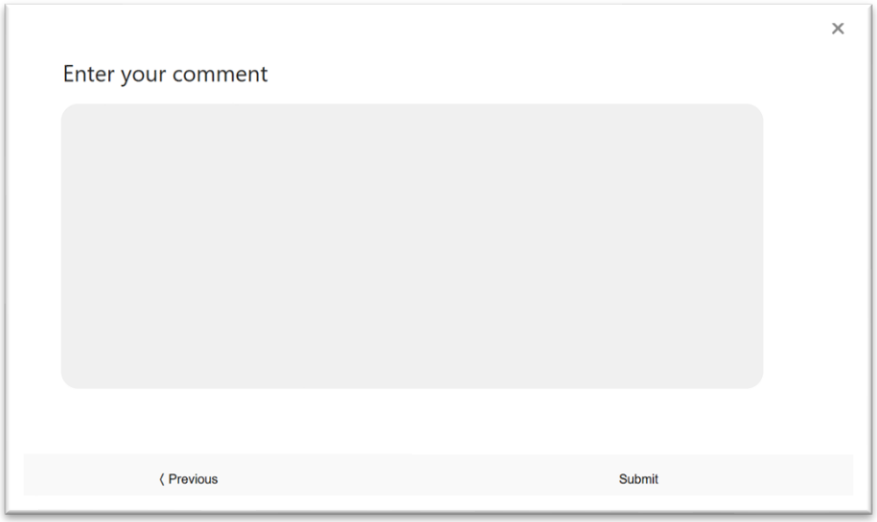


Figure 27. Feedback Comment Form

The feedback form includes an asynchronous question that users can submit at any time.

The form that collects the information includes the email address and submission date of the item in addition to the selected category and comment.

The form is manually processed to direct the feedback to the appropriate designated project team member or infrastructure owner.

4.5 G-MAP Summary Statistics

G-MAP Summary Statistics incorporates, in order, Epics 11, 12, 13 and 15.

- **Epic 11 - Trip Histories Description.** Develop functionality for logging trip histories for planned trips as well as flagging and logging trips that were taken.
- **Epic 12 - Completed Trips Logging Description.** Log route traces of completed trips.
- **Epic 13 - Travel Statistics Description.** Develop functionality to assemble general statistics on their trips and calculate summary statistics about travel patterns.
- **Epic 15 - G-MAP – PMD Integration Description.** Integration of OTP for G-MAP with the PMD.

The processes associated with each epic are depicted in Figure 28.

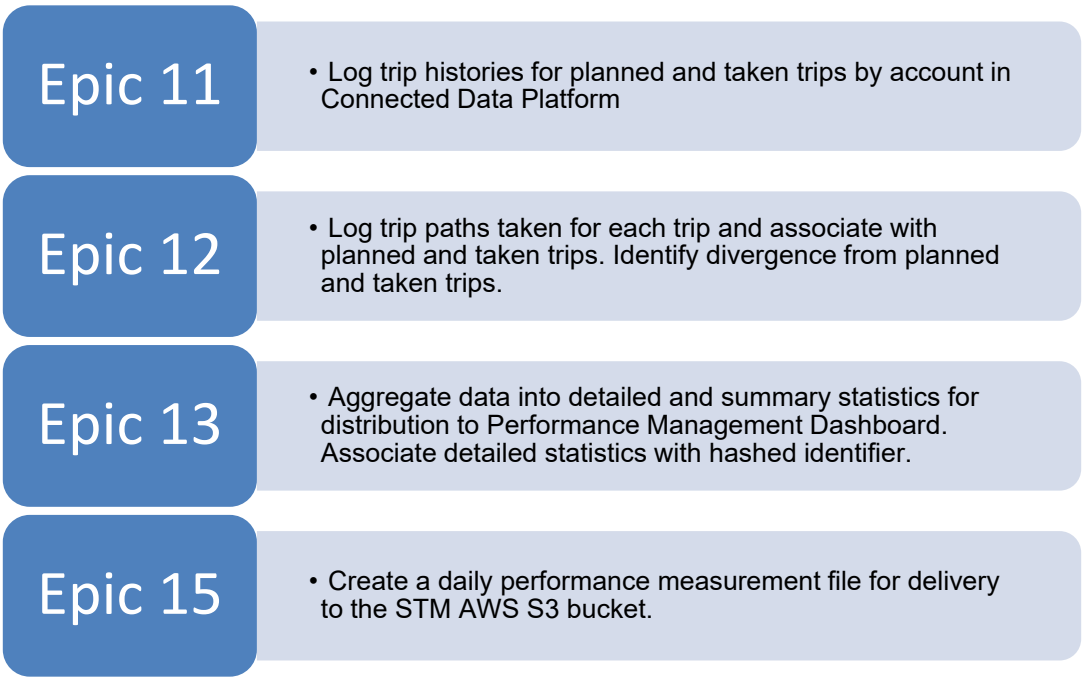


Figure 28. G-MAP Summary Statistics Process

The G-MAP API (ICD, ICD-11) is composed of a nested JSON file with hashed personally identifiable identifiers. The hash IDs obscure the personal information. Because the personal information can still be derived from the data, the data file is stored in secure storage units. The six nested records include the following:

- **TripRequest**. A trip request which contains origin and destination information, as well as a "userID" hashtag identifying the user that initiated the request. The trip request is provided to the Network Impedance API, which generates a response containing a proposed route to their destination based on user mobility profile and impedance values.
- **TripSummary**. The proposed itineraries or routes (i.e., the set of directions without user trace data) for a TripRequest. The TripSummary contains a "tripRequestId" that associates the TripSummary to a TripRequest.
- **MonitoredTrip**. A trip or itinerary with step-by-step directions that a user saves for monitoring alerts and delays, and for trusted companions to monitor someone's travel.
- **TrackedJourney.** As a user keeps the G-MAP mobile app for step-by-step navigation to their destination, a TrackedJourney is created that logs the user's positional trace data (latitude, longitude, speed, bearing, etc.) at frequent intervals (e.g. every five seconds); these are stored in a TrackedJourney file. The TrackedJourney data contains a "tripId" that associates it to a MonitoredTrip.
- **OtpUser**. Along with the collections of files associated with each trip initiated on a given day, there is a set of OtpUser file representing each unique user that requested any form of navigation that day. Each OtpUser data model contains a user's unique ID value, their mobility profile data, and an array of their "savedLocations" data. TripRequests and MonitoredTrips can be associated to a Persona via their "userId" values.
- **Trip-survey-responses.** Referencing the monitored trip and user ID, and the push notification id. The in-app deviation survey is collected into a CSV file.

Compressed archives (zipped files) of the collection and each file is uploaded to the G-MAP S3 bucket daily, and once per week is processed by the Private PMD to generate performance metrics for the previous week. Each data model has its own ZIP archive containing all the JSON files of that specific type for each day, along with an associated date stamp.

File formats appear as follows: <<YYYY-MM-DD-FileName.zip>>. For example: “2024-11-11-Persona.zip”. The collection of the travel statistics is named <<YYYY-MM-DD-merged,zip>>.

The interface is described in the ICD (Int-11).

The corresponding source code for these entities can be found at https://github.com/Arcadis-group/otp-middleware/tree/dev/src/main/java/org/opentripplanner/middleware/models.

In addition, G-MAP provides the STM with a list of registered user email addresses so that the quarterly customer satisfaction survey can be distributed. The STM’s Private PMD functionality and quarterly survey description are described in **Section 5.7**.

4.6 Integration Elements

The integration elements are components integrated with the G-MAP app. These components are integrated through application programming interfaces (API) described in the ICD and correspond to component design configurations described in **Section 6**. These elements are integrated through the G-MAP OTP middleware subcomponent which provides an open architecture design. The details of the APIs are included in the ICD. A reference to the open or proprietary API is described in the aforementioned document.

4.6.1 PED-X Integration (Epic 5)

Epic 5 Description. Develop PED-X request functionality.

Integration includes the ingestion by G-MAP of the signal locations, cycles, approaches/crossing (by pedestrians) and type of pedestrian signal system. These are listed and described in **Section 6.4**.

The PED-X traveler process works as follows:

- Traveler creates a trip that crosses an intersection.
- As the traveler begins their trip and approaches within a configurable geofence around the intersection, G-MAP PED-X process generates a PED-X API call to the Gwinnett County PED-X Proxy Server to actuate a request to cross the intersection.
- If the traveler requires extra time (based on their mobility profile other than “no assistive devices”), then the API includes a request for extra time.
- G-MAP sends the request and receives an acknowledgement of receipt from the proxy server. Note: Only acknowledgement of the API call receipt is sent back to G-MAP, not confirmation of the crossing signal actuation.

The interface is described in the ICD (Int-12) which also includes details related to security provisions.

The geofence value is configurable and can be updated for each of the intersections supported by the PED-X proxy server (see **Section 6.4**). The initial PED-X actions are triggered when approaching 30m (~100ft) of one of the end-coordinates of a particular crossing.

The G-MAP middleware and Gwinnett County PED-X proxy server maintain consistent indices of the crossings where PED-X requests are feasible including:

- Location and Name of the intersection
- Direction of travel
- Side of street

This gives the Gwinnett County PED-X proxy server the information needed from G-MAP to make the actual signal request to the signal control system.

If the traveler turns off their data or walks outside of the geofence, then G-MAP sends a cancel message to the proxy server.

4.6.2 Ride Request and Enhanced TSP Integration (Epic 17)

Epic 17 Description. Develop functionality to trigger a stop request to bus CAD/AVL.

The ride request function provides a message to the Ride Gwinnett bus operator when a traveler with a transit-related trip is planned or scheduled using G-MAP. When a transit leg occurs during a trip, the app alerts the driver that a rider is waiting for a pickup when the traveler is within 15 minutes of the bus stop (an initial default setting). If the traveler associates themselves with a mobility mode other than “no assistive devices” and needs extra time, then the Ride Request message alerts the driver that the rider needs extra time boarding and alighting the bus. In addition, concurrently with the Ride Request message, an Enhanced TSP message is sent to the enhanced TSP server (see **Section 6.1.2**).

The Ride Request Integration uses the Ride Request API (see **Section 6.3**), Live Tracking and middleware to provide the functionality.

- Traveler schedules a trip plan with a transit leg.
- G-MAP monitors user location and determines if their mobility profile indicates that they need more time.
- When a traveler is within 15 minutes of a scheduled bus stop location, G-MAP sends a request API to Ride Request server. Concurrently, G-MAP sends the same API to the TSP Proxy Server.
    - If user turns off data within the 15-minute window once API is sent, G-MAP sends a cancel request to Ride Request server.

Additional information on the integration is found in Sections **6.1.2** (Enhanced TSP) and **6.3** (Ride Request). The API specifications are describe in the ICD (Int-13).

4.6.3 Indoor Navigation Integration (Epic 14)

Epic 14 Description: Integrate OTP for G-MAP with the indoor navigation system.

The indoor navigation is primarily composed of native CXApp services provided by their SDK. Additional services were added to G-MAP to make the experience consistent with G-MAP user experience. The indoor navigation features are available at two facilities owned and operated by Gwinnett County -- Gwinnett Justice and Administration Center (GJAC) and Norcross Senior Center/OneStop.

The functions that are available include:

- View the layout and lookup destinations in a facility map from the mobile app.
- Switch view from indoor to outdoor and vice versa on the mobile app.
- Plan a route from outdoor to indoor, indoor to outdoor, and indoor to indoor including traversing different floors in the facility.
- View route path on a map rendered on the mobile app.
- Use the route to navigate based on planned trip with turn-by-turn notifications (audio and push).
- Detect current location in a facility through Bluetooth beacons.
- Be alerted to deviations from path and be provided with a detour when traveler goes off route.
- Manage map view (enlarge, re-center, etc.).

A description of the SDK is described in the ICD (Int-16).

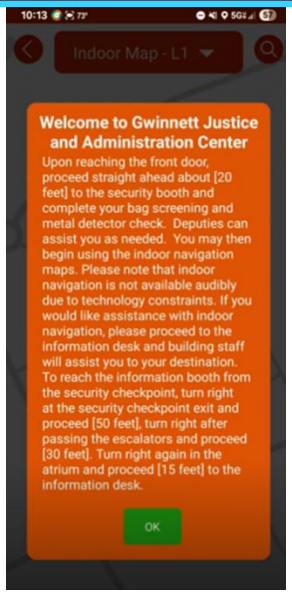
The specific functions needed to integrate these functions include the following:

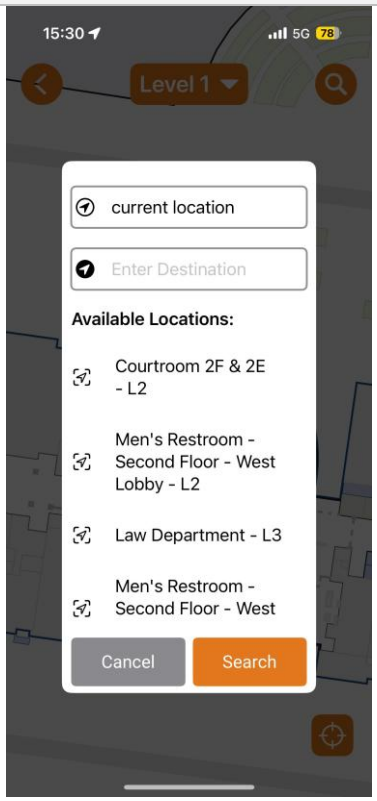
1. Live Tracking to transition from Outdoor to Indoor (and vice versa) Map Switch logic using Geo-Fence Detection (required setting up a geo-fence around facility entrances, as well as a building boundary geofence to detect users beginning indoor navigation from within the building).
2. Implemented INS (Indoor Navigation System) Button and Dialogue box UI pop-up when arriving at a destination.
3. Implemented UI for Indoor Navigation, which included the Map, individual directions, and all route directions view.
4. Implemented Floor selection and rendering based on the selection.
5. Implemented current location buttons to re-render/refocus the map to the user’s location.

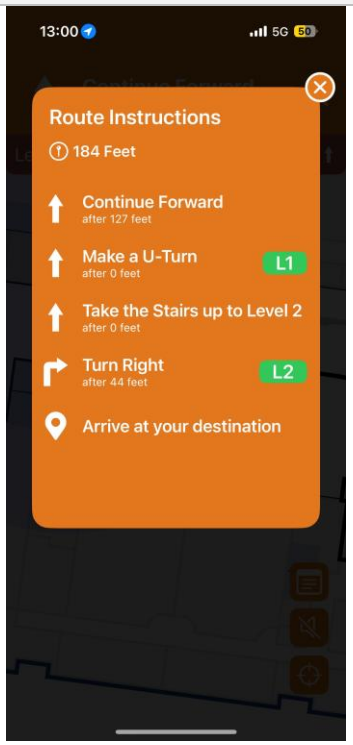
6. Implemented dialogue boxes that show the Speaker setting on/off status when switching.
7. Implemented a search View, where the user can select origin and destination from the list of rooms.
8. Implemented logic to get routes and render or draw a polyline on the Indoor map to show the route path.
9. Implemented logic to set the labels on the indoor Map when there is a change of direction.
10. Implemented distance calculation logic to convert the mm/pixel distance into Feet.
11. Implemented logic for turn-by-turn directions to show on the Directions View and the All Steps View.
12. Implemented logic that if a user deviated from the route, the app will automatically detect the route deviation.

The user interfaces for each process – outdoor to indoor, indoor-to-outdoor and indoor-to-indoor are shown in **Table 19.**

Table 19. INS Transition Processes

Description	Screenshot
Arrival message after entering an INS facility.	

Description	Screenshot
Map view of GJAC with the user's location.	
The list of available locations a user can select from to create a trip plan.	

Description	Screenshot
The route generated by G-MAP to take the traveler to their destination.	
The trip itinerary.	

4.7 User Interfaces

The user interface (UI) for all platforms – web and mobile apps comply with the Web Content Accessibility Guidelines (WCAG) version 2.1. During unit testing, all UIs were tested to ensure accessibility to support people with visual disabilities including low vision, color blindness, and more. See the System Test Plan (STP) for the tests that were conducted.

This section describes the types of icons and their related actions that are used throughout the mobile and web platforms. The UI elements include buttons, visual graphics, forms, check boxes and other tools to navigate the UI, select or enter preferences and requests to the app. The icons and actions differ by mobile and browser platforms. The sections below divide the functionality into several sections. Each section includes two tables – UI icons/elements that show mobile and browser graphics, respectively, their description and their use.

The three sections describe the following:

- **UI Screen Navigation**. How the user moves around the screen or goes from one screen to another, for example: go back, go forward, exit, cancel, commit.
- **UI Map Navigation**. How a user moves or selects elements of a map, for example right click on a location to enter the position in a form.
- **UI Functional Icons and Actions.** When the user must click on a button, enter text into a form, or check a box to use a function in the app. These functions may include preferences for notifications, trip planning, mobility modes, etc.

In addition, a fourth section enumerates the differences between the mobile and web browser-based platform.

4.7.1 User Interface Screen Navigation

This section includes two tables that describe ubiquitous functions that are available on the mobile and web browser ribbons. The mobile ribbon (see Figure 29) is located on the bottom of each page while the web ribbon (see Figure 30) is located as a ribbon on the top of the splash page.



Figure 29. Mobile App Navigation Ribbon

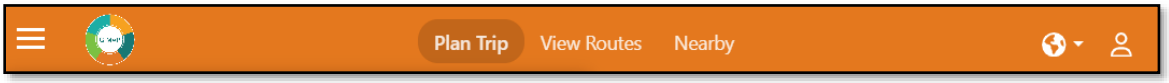
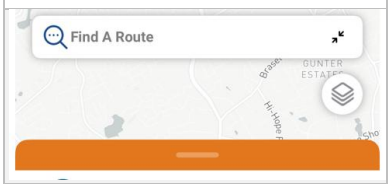


Figure 30. Web Browser Navigation Ribbon

The screen navigation icons for the mobile app are described in Table 20; equivalent icons for the web browser located on a top ribbon are described in Table 21.

Table 20. Screen Navigation Icons for Mobile App

Icon / Graphic	Description	Use
	Three parallel lines icon with “Menu”.	The menu function that includes functions: Start Over, Leave Feedback, Help and version number.
	Folded page icon with text.	Open a page that includes text. Used for Plan Trip, Toggle Map, Practice Mode and more.
	Wiggly line icon with “Routes” (i.e., line between two points).	Function to find a route or lists all the routes (lift screen to show routes).
	Star icon with “My Trips”.	Used to list saved trips and notification preferences for each trip.
	User’s initial in a circle used to list user settings and preferences.	Includes account name, selection for My Settings, Help, Sign out functions.
	Chat box with three dots.	Identifies Feedback form.
	Question mark in circle.	Identifies Help support.
	Bar with short line to extend or minimize screen. Example in “Routes” screen.	Move the bar up to expose additional text or pull it down to minimize the text.

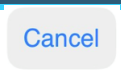
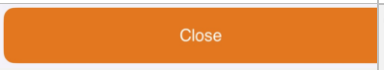
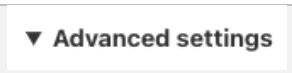
Icon / Graphic	Description	Use
	Cancel button.	Cancels input.
	Close button.	Close menu.
	Trash can icon.	Delete.
	Arrow pointing down Example: 'Advance settings'.	Opens additional settings below arrow pointing down.
	Expand icon.	Expands page to full screen.
	Arrow pointing left inside circle.	Back.
	Arrow pointing left in a circle.	Back to previous screen.
	Bell icon.	Notification button disables/enables push notifications for users.
	Blue open circle icon.	Location icon shows user where they are in itinerary. Itinerary scrolls to center the current step when app opens.

Table 21. Screen Navigation Icons/Graphics for Web

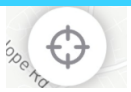
Icon / Graphic	Description	Use
	Help menu services icon that includes a drop down of help services.	Drop down menu to select: Start Over, Give Feedback or Help.
	G-MAP graphic branding icon.	No use.
	Buttons with three pages/functions in app. Note current page is highlighted in a darker oval.	Buttons to select page (functionality) options. Highlighted button indicates current page.
	Feedback icon.	Select menu to submit feedback.
	Globe icon with drop down list of languages.	List of language options.
	Person Icon displayed when user is not yet signed in.	Select to Sign In or Sign Up.

Icon / Graphic	Description	Use
	When logged in, the user's initials are located in a square located on top right-hand of page.	Click for account name (email), account information ("My account), Help and log out functions.
	Exit Help Services Menu. This icon is listed when the Help Services menu is open.	By selecting this icon, the user exits the help services menu.

4.7.2 User Interface Map Navigation

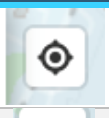
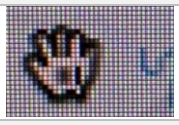
This section shows the icons and actions that describe how a user moves or selects elements of a map, for example right click on a location to enter the position in a form. The graphics or actions for the mobile app are described in Table 22; equivalent graphics or actions for the web browser are described in Table 23.

Table 22. Map Navigation UI for Mobile App

Action / Graphic	Description	Use
	Target with empty crosshairs on the bottom right side.	Find user location.
	Isometric hamburger with layers; icon on the top right side of the map.	Opens menu that includes details related to: (1) modes including transit stop, park + ride, shared vehicle locations. (2) Map type including street or satellite view. Also includes app version number.

Action / Graphic	Description	Use
NOTE: See *descriptions column* for actions used to navigate the map view	Use your finger or stylus to pan the map. Touch the map to show the orientation compass on the bottom left. Touch map to locate a point on the map (additional functions will appear for directions to or from the place). Use two fingers to enlarge map size (spread fingers away from each other) or reduce map size (move fingers towards each other).	Navigating map view, orientation, and resolution.

Table 23. Map Navigation UI for Web Browser

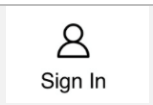
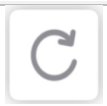
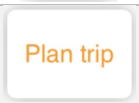
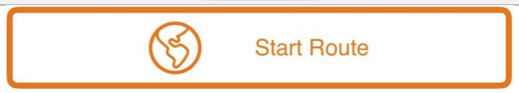
Action / Graphic	Description	Use
	Target with filled cross hairs, on the top left side of the map.	Find user location.
	Map navigation buttons. “+” = increase size of map “-“= decrease size of map “▲” = reset bearing to north	Change the resolution or reset the orientation of the map.
Scroll mouse track	Scroll mouse track forward to increase map size. Scroll mouse track back to decrease map size.	
	World Meridian icon.	When selected, transit stops are located on the map Mouse over to click on “Transit Stops” checkbox.
	Hand icon.	Moves the map in the direction pulled by a hand.
	Open circle icon represents a bus stop.	Click on an open circle to identify the stop name and number. Then select the Stop Viewer or Plan a trip “From here” or “To here”.

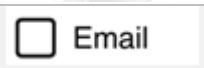
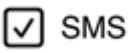
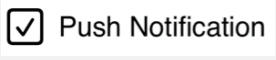
Action / Graphic	Description	Use
Right click mouse (Microsoft Web Platform) Click mouse (Apple Platform)	Select Point.	Opens a “Plan a trip” selection box that includes the address of the location, zoom in to the location by selecting the magnifying glass icon, and plan a trip “From here” or “To here”.

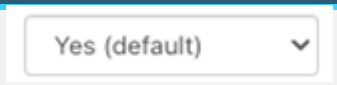
4.7.3 User Interface Functional Icons / Actions

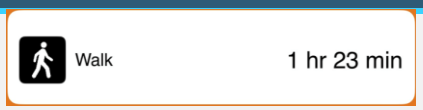
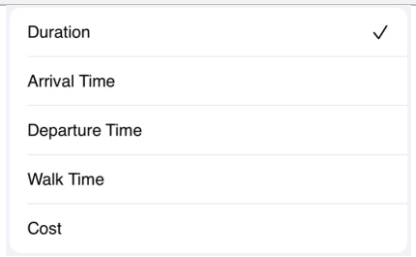
This section includes the icons and button types that are included in the mobile apps (see Table 24) and web browser (see Table 25).

Table 24. Navigation and User Interface Icons and Action Graphics for Mobile App

Icon / Action Graphic	Description	Use
	Folded page icon with text	Open a page that includes text. Used for Plan Trip, Toggle Map, Practice Mode and more.
	Person with ‘Sign In” text	Account sign
	Refresh icon	Start over
	Button with text	Select button with named function
	World icon with ‘Start Route’ text	Start route for Live Tracked trip
	Star inside a circle	Save trip to favorites
	Home icon, ‘Home,’ ‘Set your home address’ text	Home point of interest
	Briefcase icon, ‘Work,’ ‘Set your work address’ text	Work point of interest

Icon / Action Graphic	Description	Use
	Pause icon	Pause monitoring on saved trip
	Trash can icon with text	Delete ‘text’ selection
	Arrow pointing down with text revealing more selection	Open for more selections
	Hamburger menu with vertical ellipsis	Travel preferences
	Arrow pointing left in a circle	Back to previous screen
	Arrow pointing left inside circle	Back
	Expand icon	Expand origin/destination
	Checkbox for Email	Email notification option
	Checkbox for SMS	SMS notification option
	Checkbox for Push Notification	Push notification option
	Checkbox for Haptic Feedback	Haptic feedback option

Icon / Action Graphic	Description	Use
	Dropdown container with 'Yes (default), No' text	Realtime alert on monitored trip notification
	Dropdown container with 'Yes (default), No' text	Alternative route/transfer point recommendation notification
	Dropdown container with '5 min (default), 10 min, 15 min' text	Delay/disruption notification timing trigger
	Dropdown container with '15 min before, 30 min before (default), 45 min before, 1 hour before' text	Advanced trip monitoring options
	Route between two points	Route viewer
	Arrows switching directions	Switch origin and destination
	Nine o'clock icon bar 'Leave Now' text	Departure time selector
	Train, person walking and bus icon	Travel mode selector

Icon / Action Graphic	Description	Use
	Trip card with selection and travel time	Itinerary option
	Bus icon, ‘Transit’ text	Transit options
	Bike icon, ‘Bike’ text	Biking directions
	Car with person driving icon, ‘Drive’ text	Driving directions
	Bus icon, ‘Bus’ text	Bus transit option
	Train icon, ‘MARTA Rail’ text	Rail transit option
	Streetcar icon, ‘Streetcar’ text	Streetcar transit option
	Container with sorting options in drop down	Sorting options
	Arrow pointing down	Unfold granular information
	Question mark inside a black circle	Review walking / biking minutes

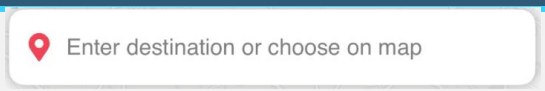
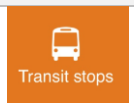
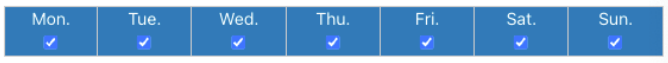
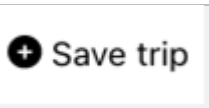
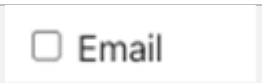
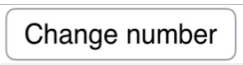
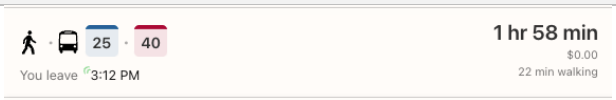
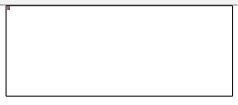
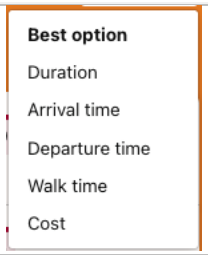
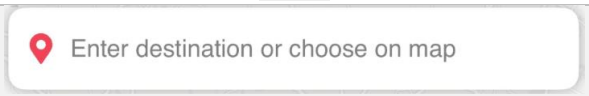
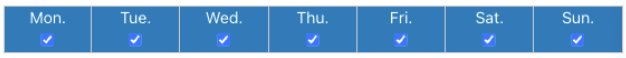
Icon / Action Graphic	Description	Use
	Map pin and instructions	Find location / point of interest by following instructions
	Bus icon, 'Transit stops' text	Transit options
	P inside a circle icon, 'Park + Ride' text	Park and Ride options
	Scooter icon 'Shared Vehicles' text	Rental/Shared vehicles options
	Angled pencil writing icon	Edit monitored trip
	Location inside a dotted line box	Start saved trip
	Abbreviated days of week above check boxes	Day of the week trip monitoring options
	Plus sign icon, 'Add another place' text	Third place point of interest
	Selected sort option text and arrow down or up	Trip sorting ascending/ descending

Table 25. Navigation and User Interface Icons and Action Graphics for Web Browser

Action Graphic	Description	Use
	Refresh icon 'Start Over' text	Start over
	Magnifying glass	Plan trip
	Refresh icon	Re-Plan trip
	Plus sign, 'Save trip' text	Save trip to favorites
	Home icon, 'Home,' 'Set your home address' text	Home point of interest
	Briefcase icon, 'Work,' 'Set your work address' text	Work point of interest
	Pause icon, 'Pause' text	Pause monitoring on saved trip
	Trash can icon	Delete
	Arrow pointing down with text revealing more selection	Open for more selections
	Arrow pointing left 'Back' text	Back to previous screen
	Arrow pointing left 'Back to trip planner' text	Back to trip planner
	Checkbox for Email	Email notification option
	Checkbox for SMS	SMS notification option
	Change verified number	Change verified number
	Checkbox for Push Notification	Push notification option
	Pause icon, 'Snooze for rest of today' text	Pause monitoring on saved trip for rest of day

Action Graphic	Description	Use
	Dropdown container with 'Yes (default), No' text	Realtime alert on monitored trip notification
	Dropdown container with 'Yes (default), No' text	Alternative route/transfer point recommendation notification
	Dropdown container with '5 min (default), 10 min, 15 min' text	Delay/disruption notification timing trigger
	Dropdown container with '15 min before, 30 min before (default), 45 min before, 1 hour before' text	Advanced trip monitoring options
	Arrows switching directions	Switch origin and destination
	Calendar icon 'Today' text and 4 o' clock icon and 'Leave now' text	Departure time selector
	Trip card with selection and travel time, departure time, fare, and walking minutes	Itinerary option
	Bus inside a square	Transit options
	Bicycle inside a square	Biking directions
	Car icon inside a square	Driving directions
	Checkbox with bus icon, 'Bus' text	Bus transit option
	Checkbox with train icon, 'MARTA Rail' text	Rail transit option
	Checkbox with streetcar icon, 'Streetcar' text	Streetcar transit option

Action Graphic	Description	Use
	Toggle with text selection	Toggle to turn on/off selection
	Container with sorting options in drop down	Sorting options
	Arrow pointing down	Unfold granular information
	Question mark inside a blue circle	Review walking / biking minutes
	Eye drop and instructions	Find location / point of interest by following instructions
	Angled pencil icon	Edit monitored trip
	Abbreviated days of week above check boxes	Day of the week trip monitoring options
	Plus sign icon, ‘Add another place’ text	Third place point of interest
	Selected sort option text and arrow down or up	Sort options by type (e.g., trip duration)

4.7.4 Mobile App versus Web App (in-browser) Differences

The web browser and mobile apps work similarly for trip planning and third-party travel planning, and preference settings/account. However, only the mobile app provides live tracking and all the dependent functions that occur during tracking including turn-by-turn directions, accessible notifications (haptic, voice and text), dynamic trip planning and rerouting, PED-X, ride request, and indoor navigation. In addition, the preview/practice mode functionality varies between the Mobile App and Web app, both in layout of the interface and user experience for how users interact with the trip preview/practice mode (see **Section 4.4.5** for details).

The Mobile App uses many UI/UX components from the iOS and Android native app component library, so the look and feel of these elements may vary, but the functionality itself is the same across platforms.

In addition, the various web browsers work differently for trip planning purposes. Edge, for example, includes settings that may present the user with restrictions on locating their current position during trip planning, as it defaults to the location of the active IP address, which is often a local internet service provider (ISP).

4.8 G-MAP Requirements Traceability to Design

The requirements met by the G-MAP design are provided in Table 26 with the following fields (note that the following fields are used for each design element's requirements traceability table throughout this document):

- **Req't ID.** Requirement identification number.
- **Req Title.** Title of requirement.
- **Req Statement.** Statement describing the action that the requirement provides.
- **Status.** description of whether a requirement has undergone a specific change.
    - **Unchanged.** The requirement has not been changed/edited, and remains as is.
    - **Updated.** The requirement has undergone the change control process and has been approved.
    - **Added.** The requirement is new/did not originally exist.
- **Section.** Indication of the section of this document that the requirement is described in.

Table 26. G-MAP Requirements Traceability

Req ID	Req Title	Req Statement	Status	Section
1.1.0-003	Data Use Agreement	An end-user data use agreement shall be developed that describes the effective uses of the data and the rights of persons using the ST-CTN tools and functions.	Unchanged	4.3.1 4.3.3.1
1.1.0-005	Enforce Security Policies	The system shall implement and enforce provisions of the system security policies. Details of policies will be developed with ST-CTN partners and IRB provisions in Phase 2.	Unchanged	4.3.3.1 4.4.6 Communications security is described in the ICD. Data security and privacy policies are described in the DPP.

Req ID	Req Title	Req Statement	Status	Section
1.1.0-006	Assign User Access	The system shall assign user access rights to all data collected by data source and classification.	Unchanged	4.3.1
1.1.0-012	Opt-in to Store and Use PII	G-MAP shall provide an option for travelers to “opt-in” and sign user agreement to allow the system to store and use specific PII. The opt-in agreement enables G-MAP account management and mobile app to register, select preferences and track travelers. Planning functions that do not need registration services will still be available for travelers. The Use Agreement will outline the data that will be kept in the account management system but not shared (e.g., name, home address, phone) and data that will be shared (e.g., trip trace and trip plan with preference choices).	Unchanged	4.3.1 4.3.3.1
1.1.0-013	Opt-out After Opt-in Option	G-MAP shall provide an option for travelers to “opt-out” of a previously selected “opt-in” state. Specifically, the system shall wipe (permanently delete) any PII travel and preference data from any storage system in the ST-CTN when a traveler transitions from opt-in to opt-out. Note: a traveler must delete their account to remove their contact information from the system.	Unchanged	4.3.1 4.3.3.3
1.1.0-014	Account Contact Information	The system shall not use contact information collected for registration purposes other than G-MAP registration. The data will remain in G-MAP and will not be shared with the research or PII servers.	Unchanged	4.3.1
1.1.0-015	No Share PII	The system shall not share PII data generated by the system to any external data storage system as designated in the ST-CTN DMP Section 2.2.	Updated	4.3.1

Req ID	Req Title	Req Statement	Status	Section
1.2.0-018	G-MAP Core Functionality	The system shall utilize the OTP and ATL RIDES (IMI grant) functionality, interfaces, architecture and infrastructure as the core G-MAP for the ST-CTN.	Updated	2.2.1, 4.2
1.2.0-022	Support Service Options	The system shall provide travelers the option to select support services they prefer to access during their journey. The types of support services and their deployment priority will be designated during the Agile Development Process in collaboration with the end-user stakeholder group. At a minimum, support services include selecting and configuring notifications, identifying triggers, directions, communications channels, and user interface (UI) methods (e.g., text, voice, haptic sensor, other).	Unchanged	4.3.3.1, 4.3.5.1
1.2.0-023	Trip Planning Communication Channel Options	The system shall provide travelers the option to select communication channel(s) they use to access services to plan their trip including mobile app, call center, telephone, SMS, and online (via web application). The functions and information provisioned through each channel will be driven by stakeholder input during the Agile Development Process.	Unchanged	4.3.3.1, 4.3.5.1, 4.4.6
1.2.0-024	Trip Execution Communication Channel Options	The system shall provide travelers the option to select the communication channel they use to access services to execute their trip including mobile app, call center, telephone, SMS, and online (via web application). The channels will support communications using data serialization and non-data methods (e.g., call center agent). The functions and information provisioned through each channel will be driven by stakeholder input during the Agile Development Process.	Unchanged	4.3.5.1, 4.4.2, 4.4.6

Req ID	Req Title	Req Statement	Status	Section
1.2.0-025	Service Preferences and Communication Channel Matching	The system shall provide travelers communications channels that support their service preferences based on their defined preferences and abilities. The functions and information provisioned through each channel will be driven by specific stakeholder input during the Agile Development Process.	Unchanged	4.3.5, 4.4.2
1.4.0-039	Notification and UI Method	G-MAP shall allow travelers to save their preferred method by which they receive notifications and navigate directions in their profile settings. The UI methods include but are not limited to voice, text, or haptic/vibration. (See Req 2.4.0-084).	Unchanged	4.3.3.1, 4.3.3.3, 4.3.5.1
1.4.0-040	Selection of Notification by UI Method	When planning a trip, G-MAP shall allow travelers to select the preferred method by which they receive specific notification including when, how, and how often the information is transmitted to them. The specific notifications and the types of notification methods will be driven by stakeholder input during the Agile Development Process.	Unchanged	4.3.5.1
1.4.0-041	Update Selection of Notification by UI Method	G-MAP shall allow travelers to update their trip plan notification selections when actuating a saved trip plan.	Unchanged	4.3.5.1
1.4.0-042	Notification Latency	G-MAP shall limit end-to-end transmission from trigger even to transmission to traveler's device of less than one second. Note: traveler's carrier and personal device are not calculated in this latency budget.	Unchanged	4.4.2

Req ID	Req Title	Req Statement	Status	Section
1.5.0-043	Trip Planning - Traveler Companion	G-MAP shall be enhanced to allow a traveler planning a trip to include a companion using their combined preferences and abilities in the trip settings. The impedance values used to calculate the shared trip shall use VRU categories as defined in Section 2.5.1.	Unchanged	4.4.4
1.5.0-044	Trip Planning - Group Travel Preference Confirmation	When traveling in a group. G-MAP shall request that the traveler rank and confirm the most critical preferences to include in the group trip plan. For example, when a traveler plans a trip with children or with companions with different abilities, G-MAP will ask the traveler to alter their default preferences to align with the preferences for the group travel needs.	Unchanged	4.4.4
1.6.0-045	Trip Planning - Practice Mode	G-MAP shall allow travelers to set a practice mode wherein they can simulate their turn-by-turn directions before the trip using their preferred notifications, device, or methods. The practice mode functionality will be driven by stakeholder input during the Agile Development Process.	Unchanged	4.4.5
2.1.2-075	Continuous Trip Planning	G-MAP shall recalculate trip plans at periodic intervals to identify dynamic challenges that may disrupt travelers enroute. The periodic interval (i.e., duration between recalculations) is subject to dynamic information that impacts travel plans (e.g., real time bus status updates). See Req 2.1.2-076 for related requirement.	Updated	4.3.4 4.4.3
2.1.2-076	Network Impedance API Ingestion	G-MAP shall base the recalculated trip plans on the updated impedance values in the STM published Network Impedance API and data that is integrated from other sources as available.	Unchanged	4.3.4 4.4.3

Req ID	Req Title	Req Statement	Status	Section
2.2.0-078	G-MAP Mobile and Web Applications	G-MAP mobile app shall provide the same functionality as described by the core functionality included in the web application (Section 3.1) for traveler account management and trip planning functions.	Unchanged	4.2
2.2.0-079	Call Center User Interface	G-MAP shall provide UIs (APIs) that support and provide call center operators with access to traveler account management and trip planning functions. The UI services are implemented in G-MAP (IMI) and specified in https://fdot-support.s3.amazonaws.com/index.html Note: processes will be implemented, and services customized to support the existing GCT call center that allows call takers to be "trusted" third parties to access traveler account information.	Updated	4.4.6
2.3.0-080	Common Communications	G-MAP shall use an open communications protocol such as Bluetooth (4 or 5), NFC (ISO/IEC 18000-3), Wi-Fi (4, 5 or 6), or LTE 4, 4G or 5G in order to pair with infrastructure devices/system (e.g., beacons).	Unchanged	4.1 4.6.3
2.3.0-081	Open Architecture	The system shall exchange data using open APIs including but not limited to REST, JavaScript Object Notation (JSON), XML or comma delimited separated datasets.	Unchanged	4.6
2.3.0-082	Native Software Development Kit (SDK)	The G-MAP mobile app shall use native SDK and implement the accessibility guidance recommended by the handset and operating system manufacturers.	Unchanged	4.2
2.3.0-083	WCAG 2.1 or Higher	The system shall comply with Web Content Accessibility Guidance (WCAG) 2.1 or higher for all user interfaces (web and mobile app).	Updated	4.7

Req ID	Req Title	Req Statement	Status	Section
2.4.0-084	Notification Types	G-MAP shall allow travelers to customize the types of notifications they prefer to receive as they journey on a planned trip. The set of notifications will be driven by stakeholder input during the Agile Development Process.	Unchanged	4.3.5 4.3.5.1
2.4.0-085	Notification Channels	G-MAP shall allow travelers to select which notifications are delivered via voice (by phone or mobile app voice), text or icon (SMS or on screen), vibration (to alert to text message or signal a "turn"). The mapping of notification types to UI methods will be driven by stakeholder input during the Agile Development Process. (See Req 2.4.0-084)	Unchanged	4.3.5 4.3.5.1
2.5.0-086	Traveler's Trusted Support	G-MAP shall allow a traveler to designate trusted persons and their role(s). Roles may include receiving notifications or accessing their account. The specific information collected to confirm authenticity of the person will be driven by stakeholder input during the Agile Development Process.	Unchanged	4.4.4
2.5.0-087	Role Based Access by Trusted Person	G-MAP shall implement role-based access for trusted persons based on the roles assigned by the account holder. The roles will include access to account details, provision of real time notifications, and other functions designated by the account holder. The types of roles and information access will be driven by stakeholder input during the Agile Development Process. Note: a call center agent or transit operator may be included as a "trusted person."	Unchanged	4.4.4

Req ID	Req Title	Req Statement	Status	Section
2.5.0-088	Track Travelers for Trusted Support	G-MAP shall allow a traveler to create triggers to alert trusted persons with notifications as they travel. Triggers may occur at transition points such as arriving at a waypoint or if a condition of the trip plan changes (i.e. delayed transit bus). More triggers will be identified through the Agile Development Process.	Unchanged	4.4.4
2.5.0-089	Help Call Number	G-MAP shall provide the traveler with a help call number that is easily accessible to the traveler in the case that they are lost or confused. Help call number placement and access will be driven by stakeholder input during the Agile Development Process.	Unchanged	4.4.6, 4.7.1
2.6.0-090	Automated Activation Messages	G-MAP shall trigger alerts and messages based on a traveler's approach to a location near a trip transition (from indoor to outdoor, sidewalk to transit stop or crosswalk, etc.). The activation function should be configurable to adjust what constitutes "near" and to extend its use to new applications. At a minimum, the transition type applications include Ride Request, PED-X and other CV applications. Additional trip transitions will be identified and ranked by the stakeholder group during the Agile Development Process.	Updated	4.4.2 4.6.1 4.6.2
2.6.0-091	Automated Rerouting	G-MAP shall recommend reroutes to the traveler's active trip plan if warranted by a traveler's pre-selected [trigger] conditions (e.g., sidewalk closure or detour, transit delay, major obstacle impacting trip coordination). The conditions will be driven by stakeholder input during the Agile Development Process.	Updated	4.3.5.2 4.4.2 4.4.3

Req ID	Req Title	Req Statement	Status	Section
3.1.0-095	Ride Request Trigger	G-MAP shall generate a ride request message to the GCT when a traveler opts in their trip plan (or preferences) for the next bus to be made aware of their presence at a stop. The message content will be developed with stakeholder input during the Agile Development Process including how much personal information about the traveler will be included in the message.	Updated	4.4.2 4.6.2
3.1.0-098	Ride Request Performance	G-MAP shall transmit a request to the GCT CAD at a time convenient for an operator to stop at the next stop (prior to the expected arrival of the bus to the transit stop where the traveler waits). The time duration maximum and minimum time will be driven by the GCT and G-MAP developer during Phase 2 of the ST-CTN project.	Updated	4.6.2
4.1.0-112	Identify Intersection and Crossing	G-MAP shall generate navigation directions for crossing intersections using the intersection reference, crossing direction, and traveler orientation.	Updated	4.3.4 4.6.1
4.1.0-114	Track Traveler Location	G-MAP shall track the traveler's approach to an intersection crossing from the trace data collected from their G-MAP mobile app.	Unchanged	4.4.2 4.6.1 4.4.3 4.6.2
4.1.0-115	Trigger to Send PED-X Request (for intersection crossing)	G-MAP shall trigger a request to generate a PED-X message when the traveler arrives at the intersection.	Updated	4.4.2 4.6.1
4.1.0-116	Generate and Transmit PED-X Priority Request Message	G-MAP shall generate and transmit to the ATMS a PED-X Priority request message to alert the signal controller that a traveler has arrived at a signalized crosswalk.	Updated	4.6.1

Req ID	Req Title	Req Statement	Status	Section
5.1.0-252	SMUG Security Protocols	G-MAP operator, SMUG Server operator, and Signal Control operator shall agree upon and implement security procedures, policies and protocols to authenticate, validate and restrict traffic between G-MAP, SMUG and signal controllers.	Added	4.6.1 (see ICD security protocol)
6.1.0-154	Import Transit Data (static and real time)	The system shall implement a data curation process for static and dynamic transit data including GTFS and GTFS-RT (from MARTA and GCT). Note: The requirement for a curation process for each dataset is described in Section 3.10.1.	Unchanged	4.2
6.1.0-167	G-MAP - Signal Locations	G-MAP shall ingest the traffic signal control locations that provide PED-X services into the network used to generate trip itineraries.	Updated	4.6.1
6.2.0-181	Beacons Pairing	G-MAP shall provide information for travelers to pair with [interconnect to] facility-deployed beacons enabled by transceivers (communications devices) that provide indoor wayfinding and navigation support.	Unchanged	6.2.1
6.2.0-182	Indoor Navigation Using Beacons	G-MAP shall interface with beacons using communications technologies including Wi-Fi, Bluetooth, or near field communication (NFC) available on mobile devices to provide supplemental location data for indoor navigation.	Unchanged	4.6.3

Req ID	Req Title	Req Statement	Status	Section
6.2.0-183	Indoor Tracking Using Beacons	G-MAP shall use facility-deployed beacon fixed location mapping data to supplement Mobile Unit (MU) native navigation sensors commonly available on cell phones such as, WiFi, Bluetooth, or NFC, to track performance of indoor navigation and wayfinding. Note: The assumption is that the mobile app will integrate the vendor's SDK used to detect the local beacons and present to the user the complete workflow for indoor navigation.	Updated	6.2.1
6.2.0-184	Indoor Navigation	G-MAP shall provide wayfinding instructions indoors at selected facilities. Wayfinding includes navigation, orientation, and destination finding through notifications to the traveler.	Unchanged	4.6.3
6.2.0-188	Acquire Beacon Asset Inventory	G-MAP shall acquire beacon asset inventory to support indoor mapping. The curation process, as described by Req 6.1.0-148, will be developed in Phase 2 of the ST-CTN project, including processing, integration and application in the routing service.	Unchanged	6.2.1.4
6.2.0-239	INS Wayfinding	The SDK shall provide G-MAP app via SDK with wayfinding instructions and door to door (facility entrance to indoor navigation destination) including notifications. Notifications should include alerts via audio, text, and visual navigation instructions to support hands off and other communities that need more mobility support.	Added	4.6.3

Req ID	Req Title	Req Statement	Status	Section
7.1.0-199	Store Planned Trip Histories	G-MAP shall store the trip history for trips planned with the ST-CTN system. Trip history data shall include at a minimum: • Planned route including modes, crossing, pathways • Preferred notifications, navigation instructions and automated requests • Support services including notification to third parties and companions accompanied on travel The types of trip history information will be driven by stakeholder input during the Agile Development Process and the PMESP metric needs.	Unchanged	4.5
7.1.0-200	Store Actual Trip Histories	G-MAP shall store the trip history for trips taken with the ST-CTN system. Trip history data shall include at a minimum: • Origin trip plan identifier for loaded and actuated (begin) • Actual (deviations from) trip pathways, modes and crossings taken, including time and condition of travel • Notifications and direction instructions received (by channel) • Automated messages for rerouting or requests (PED-X, Ride Request) • Notifications sent to third parties • Additional services requested or received (e.g., emergency call, call center help) The types of actual trip history information will be driven by stakeholder input during the Agile Development Process and the PMESP metric needs.	Updated	4.5
7.1.0-201	Traveler Trip Tracking Data	The G-MAP shall acquire traveler trip tracking data at a frequency sufficient for the STM Performance Measure module to analyze metrics in accordance with the PMESP. The rate of collection will be developed during Phase 2. The data will be stored and forwarded as part of Req 7.3.0-209 Publish Travel Statistics.	Unchanged	4.4.2

Req ID	Req Title	Req Statement	Status	Section
7.1.0-204	Generate Travel Statistics	G-MAP shall provide account holders with general statistics on their trips. The types of statistics will be driven by stakeholder input during the Agile Development Process. The statistics may include: • Average duration (by leg) and standard deviation of saved trips (e.g., typical commute) • Miles traveled (by each mode) • Number of notifications received by different communication channels and UI methods • Deviations from planned trip plans for actual trips taken • Trip histories • Complete trip travel times • Number and variety of destination types	Unchanged	4.5
7.2.0-206	Traveler Impact Form	G-MAP shall provide a traveler feedback form in which travelers can report on impediments of travel. Impediments include obstacles and sidewalk conditions.	Updated	4.4.7.2
7.2.0-207	Trip Feedback Reports	G-MAP shall request that users provide feedback on their complete trip travel experience through a survey. Response to the survey shall be limited such that a traveler is not requested to respond after every trip. Survey questions shall include topics such as, complete trip experience, features and functions, usability, caregiver support, call center support, persons with limited English proficiency (LEP) usability, employment, quality of life, trip type, traveler perception of safety, traveler non-incident experiences, and missed connections.	Unchanged	4.4.7.1 4.5

5 STM Design Elements

5.1 STM Overview and Roadmap

The STM subsystem of the ITS4US project is hosted on a cloud-based server application that maintains a database storing a network graph and processing components including three major processing components. The suite of STM components described in the following sections include:

- STM Graph Database
- Data Ingestion Engine
- Impedance Computational Engine
- Performance Metrics Computational Engine

In addition, the system required pre-requisite algorithm and data collection activities to pre-populate the design. The approach and design elements that were implemented in the software or stored in the database include sidewalk data collection, the database design (also called the Whole Road Network (WRN) design), and the mobility categories used for the G-MAP Mobility Profiles.

The WRN is designed as a topologically connected graph of links and nodes. The **Graph Database** (designed to use AWS Neptune) is a representation of the road and sidewalk network for roads, sidewalks, and indoor paths. The area covered is Gwinnett County as described in the **ST-CTN ConOps**. The database contains nodes representing intersections and junctions between links, and links representing roads, sidewalks, or paths connected to nodes. Neptune graph database design elements and related AWS components are described in **Section 5.3**.

The data linked to the network graph is consumed, stored and integrated by the **Data Ingestion Engine.** The Data Ingestion Engine (DInE) is designed to ingest data from a wide variety of sources, including GDOT NaviGAtor data feeds, GTFS data feeds from Ride Gwinnett (transit) and MARTA, ARC's planning network, and any third-party system capable of providing real-time feeds for roadway traffic conditions. The STM attaches data to the network as node and link attributes in five-minute time bins through a process of data transformation and data fusion. The DInE design elements are described in **Section 5.4**.

The STM stores historic traffic condition data for every link in the modeled transportation system at 5-minute temporal resolution, along with more than 100 infrastructure parameters, for use in **Impedance Computation Engine** (which includes deep learning tools). The goal of this system is to predict trajectories through the network as congestion evolves in time and space and to provide users with more realistic estimates of commute duration, impedance value, and energy

use across alternative departure times, routes, and transportation modes. The Impedance Computation Engine is described in **Section 5.5**.

The systems as well as external data sources provides the **STM Performance Measurement Computation Engine** with planned and actual trip data along with other on-time performance data to generate metrics. The Performance Measurement Computation Engine is described in **Section 5.6.** The PII associated data is aggregated and anonymized prior to sending it to the Public PMD (detailed in **Section 7**).

5.2 Operational Environment

The STM platform is an AWS service that processes traffic volume and speed data from multiple monitoring and modeling sources, tracks network performance measures, and predicts evolving route conditions using regularly updated impedance metrics.

The AWS environment provides a variety of tools to support client queries. As shown in Figure 31, the core of the STM is the STM database where the data is ingested through the Amazon S3 bucket used for loading comma-separated values (CSV) data through fast, parallel processes. The data is then formatted and translated to the graph database, AWS database -- Neptune. Neptune has a built-in graphic database that stores nodes, links and their relationships. Each node and link support a dataset ID that can be used to conflate features and attributes associated with other networks (e.g., OSM, Activity Based Model (ABM), GTFS) with the Whole Roads Network. The Whole Roads Network is a term coined to represent the conflation approach to merge the various networks.

Once the data is stored in Neptune, client services can access the data through openCypher APIs. These are RESTful APIs – PUT, POST, DELETE with a simple structure:

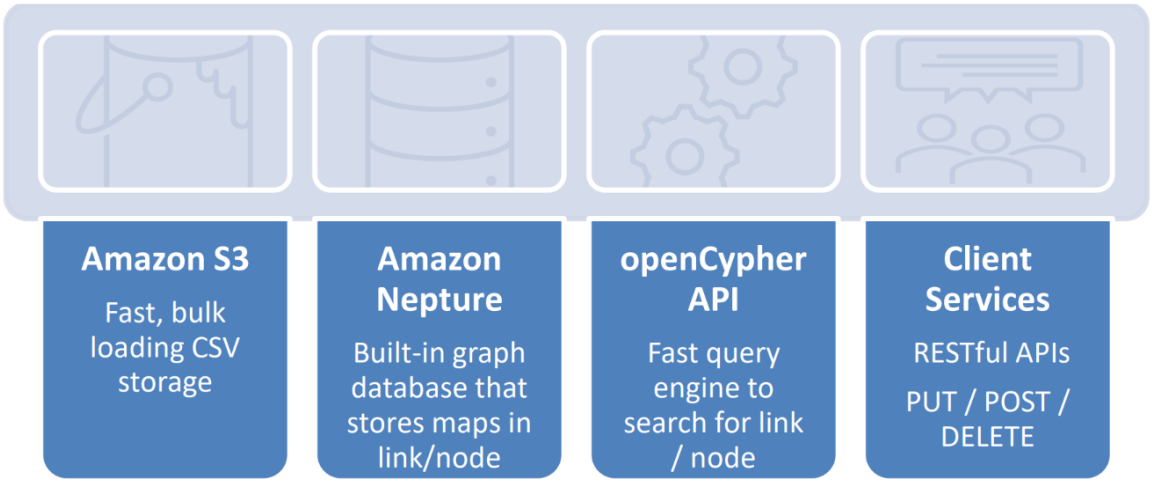
PUT / api / *dataset type* / *action*?id=*datasetID*

POST / api / *dataset type* / *action*?id=*datasetID*

In some cases, a bounding box may be specified to describe the geographic area.

The following error codes may be issued from openCypher API based on a query request:

- **400 (Bad Request).** If the URL parameters are not formatted correctly.
- **404 (Not Found).** If a POST or DELETE is requested and the provided “id” cannot be found.
- **409 (Not Acceptable)**. If a PUT or POST is requested and either the Upstream or Downstream Node IDs do not match any (e.g., OSM-NODE) node IDs currently in the STM database.



Source: GDOT ITS4US

Figure 31. STM Database Amazon Services

5.3 Data Components

The DInE is a group of processes and/or services that are a part of the STM service which access data from external systems, process the data, and store the data into the STM database. Though only processed data is stored in the STM database, generally the raw unprocessed data received from the external source is saved on the AWS servers, most likely in the AWS S3 service. The DInE receives both static and dynamic data. Static data is considered data that is either received one time or at infrequent intervals. Dynamic data is considered data received continuously or at frequent short intervals.

5.3.1 Sidewalk Data Collection and Processes

The Sidewalk Data Collection is applied in several parts:

- Vehicle Video Data Collection
- Wheelchair Video Data Collection
- Pedestrian Network Development which includes OSM Quality Assurance (QA) / Quality Control (QC) Verification

The field data collection team captures pedestrian infrastructure data to assess conformance with Americans with Disabilities Act (ADA) design and condition criteria. Videos are collected from vehicle-based and wheelchair-based platforms by 52 undergraduate data collectors. Four graduate students are applying machine vision (MV) and spatial analytics to enhance the efficiency of traditional data collection and assessment techniques.

Data collection teams are trained and familiarized with the equipment and techniques prior to deployment.

The study area is 20% of Gwinnett County (90 square miles) with a 5-mile buffer around major transit routes. The vehicle video data includes 90 miles collected on arterials. In addition, when the vehicle video detected an anomaly, detailed processing was conducted using the Wheelchair-based video data in a zone-by-zone collection process.

A demonstration zone was collected as a pilot for the data collection process around the downtown Lawrenceville area. This demonstration zone comprises about 60 miles of road, 12 miles (about 20% of demonstration zone miles of road) with adjacent sidewalks. The two methods are described in **Sections 5.3.1.1** and **5.3.1.2**.

5.3.1.1 Vehicle Video Data Collection Approach

The video data collection used off-the-shelf (OTS) tools to collect data from a vehicle. The collection system consisted of seven GoPro cameras mounted on the vehicle roof – facing forward and toward the sidewalk on the passenger side as shown in Figure 32.



Figure 32. Vehicle Data Collection Camera Positions

The GoPro cameras are set up to calculate 5.3K resolution video for MV training. Cameras capture a wide view at 30 frames per second (~120 gigabytes of data per 15 miles), yielding an exceptionally large MV training set. Figure 33 shows the equipment setup (49-components) used. When collected and downloaded, each column represents one complete data stream of the seven simultaneous outputs.



Figure 33. Vehicle Collection Equipment Setup and Camera Perspective

In addition, a ZED 2i Depth camera is also mounted on the vehicle. The sample frame is a depth image with each pixel at the image assigned a z-dimension. This allows calculation of topological measurements such as width, rise, and disjoints. The setup and camera perspective are shown in Figure 34.



Figure 34. ZED 2i Depth Camera Setup and Camera Perspective

The purpose of the vehicle video data is to:

- Identify sidewalks, ramps, curb cuts, and crossings
  - Manual flythrough
  - MV processes
- Prevent inspection crews dispatch errors
- Capture lateral videos -- both sides (at set angles) to detect sidewalk presence
- Pinpoint ramps, curb cuts, and crossings for inspection (on passenger side)

The complete inventory per vehicle including device, mounting, connector, power, data storage and device hardening / safety cases are shown in Figure 35.



Figure 35. Vehicle Data Collection Equipment Inventory

5.3.1.2 Wheelchair Video Data Collection Approach

The zone for which the wheelchair video collection was used is driven by the vehicle "fly-overs." The vehicle video identifies where sidewalks and crosswalks are present. In the initial vehicle video data collection about 20% of the roads included pedestrian pathway features. The vehicle data collection served to identify where the wheelchair-based video should be staged.

The wheelchair-based video data is collected for two primary purposes:

- To perform first-level, web-interface video inspections of pedestrian assets (sidewalks, crossings, ramps, and curb cuts) for ADA design and condition compliance.
- To refine the location data for these pedestrian assets. The vast majority of ADA design and condition issues can be identified during an online review of the wheelchair video. Even more complicated compliance issues can be identified reliably by video playback. For example, a curb cut cross slope significantly greater than 2% is easy to identify (problems are typically much greater than 2%).

The wheelchairs are modified and outfitted with cameras, GPS, accelerometer, and gyroscope. In addition, the field data collector carries an inspection app to monitor the wheelchair operations. The wheelchair set up are shown in Figure 36 and Figure 37. Wheelchair components include the following:

- **Wheelchair Modification.** Seat removed; High Density Polyethylene platform added.
- **Camera Setup.** Two GoPro Black 11 cameras mounted.
- **Camera Function.** One camera faces straight-ahead for travel view, while the other is angled down 45 degrees to capture sidewalk surface.
- **Video Specs.** High resolution, 30 feet per second, linear field of view.

- **Data Collection.** GPS at 10 Hertz (Hz), accelerometer and gyroscope at 200 Hz.
- **Inspection App.** Displays dual camera views with map for sidewalk assessment.

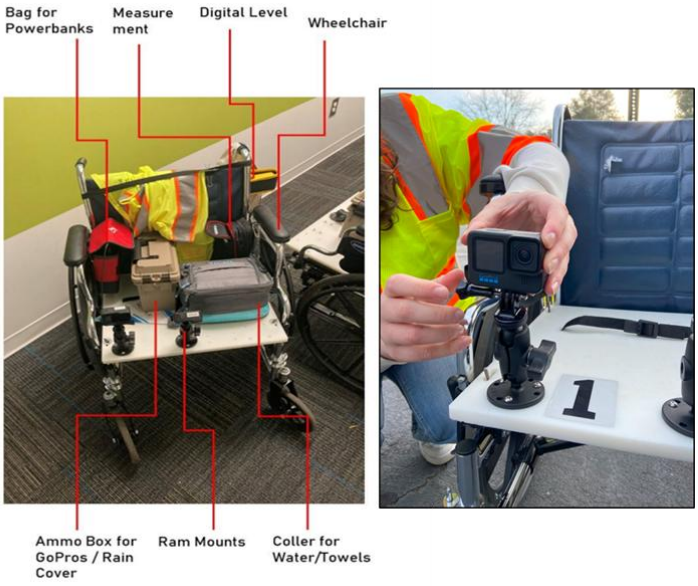


Figure 36. Wheelchair Data Collection Equipment Setup



Step 1
Wheelchair and HDPE platform setup

Step 2
Camera setup

Step 3
Other necessary tools and gadgets setup

Step 4
Wheelchair setup complete

Figure 37. Wheelchair Setup - Step by Step

Significantly more team members were needed to collect wheelchair data since the tools are pushed along each path. To that end, the team lead developed a schedule for 4 teams of field collectors who collected data simultaneously over 15-20 trips per week. The schedule includes the date, zone and status for each team that covered the necessary collection area. Each day the field teams checked in and reported on their progress.

The teams were trained to comply with safety policies including the safety equipment and policies that apply: safety vests, obey signals, cross only at crosswalks and look both ways before crossing, carry water and a cell phone. Team members downloaded an app so that their location can be tracked and were requested to only walk on pedestrian ways.

Field teams were trained on how and what data to collect. The wheelchair data collection focused on collecting sidewalk design and conditions related to ADA Compliance including:

- Widths
- Obstructions
- Grade and cross slope
- Surface conditions
- Presence and absence of curb ramps
- Curb ramp and curb cut design and condition

For example, intersection inspections required teams to capture images of all pushbuttons, signs, and signal heads, providing 360-degree perspectives.

The full list of pedestrian features is included in the training materials (ITS4US GDOT Course 1 a-e - Sidewalk Data Collection). (Editor's note: URL will be added when published).

5.3.1.3 Pedestrian Network Development

The collected sidewalk attributes were linked to a reference pedestrian network. The reference network uses the OSM crowd-sourced map of roads and public right of ways. Prior to building the association between the field data collected and OSM, OSM needed to be validated through overlay on aerial overflight photography (fly-overs) and the field data collection procedures.

OSM was selected as the reference network for STM because G-MAP uses the OSM network to generate continuous trip plans. OSM includes features with *tags* (encoded attributes) that are associated with modal paths, places, obstacles, and other primary features. Because these tags are understood by the G-MAP OTP routing engine, the sidewalk data collection process used the OSM ways and node geometry and basic characteristics for cataloging ADA compliance features when collecting sidewalk data.

OSM codes pedestrian infrastructure links (called "ways") in a similar manner to street networks using links defined by network nodes, for which longitude and latitude data are available, and elements such as sidewalk length, sidewalk width, and surface material that can be associated with the links. This allows for the application of impedance factors on pedestrian pathways. However, OSM only contains fragments of link and node structures for sidewalks, resulting in an incomplete pedestrian pathways network. In addition, the OSM network includes parcel access paths, private driveways, service roads, and parking lot cut-through paths. This creates an inaccurate pathway network with paths that may be unsafe for travel for some mobility groups. The inaccurate pathways were corrected using orthophotos, vehicle video data, and wheelchair video data.

Training (see *ITS4US GDOT Course 1e - Sidewalk Data Collection*) for correcting the OSM sidewalks consisted of guidance on the following:

- **Card 1**. Tracing New Sidewalks.
- **Card 2a**. Breaking Long Pedestrian Ways into Logical Links.
- **Card 2b**. Extracting Crossings from Long Pedestrian Ways.

- **Card 3**. Correcting Crossing Labels (Feature Type).
- **Card 4**. Correcting Roadway Crossings.
- **Card 5**. Adding Missing Street Crossings at Intersections.
- **Card 6**. Adding Midblock Crossings.
- **Card 7**. Adding Median Refuge Islands.
- **Card 8**. Adding Pork Chop Refuge Islands.
- **Card 9**. Adding Parking Lot Way/Pedestrian Way Intersection Nodes.

The guidance included corrections related to establishing spatial accuracy through complete QA/QC analyses and fresh data collection of sidewalk elements such as width, surface material, surface condition, etc. When ingesting the OSM data, all existing OSM links remained as the base network layer of the routing system, while all parcel paths and cut-throughs needed to be filtered out and excluded from the routing system, ensuring the ST-CTN routing system includes complete, safe and dedicated walking paths for pedestrian travel. To do so, the team manually tracked the links that are acceptable and safe to use in the routing process to which impedance values were assigned.

The most common impedance used in shortest path routing applications is the travel-time cost of a network link, known as travel-time impedance, which is calculated as a function of link distance and average travel speed. However, there are several additional factors or attributes that influence individuals' perception of travel costs such as number of lanes, speed limit, traffic volumes, percent heavy-duty trucks, and even the presence or absence of shade. These attributes can be expressed in time and added to the link travel time, resulting in the net impedance values (travel-time impedance + attribute impedance). The server-based ST-CTN network replaces the OSM travel-time-only impedance values with the net impedance values which are written in the cloud and made available for download, allowing the routing algorithm to update the impedance values for each link in the ST-CTN network at any given time.

As discussed previously, The ST-CTN research team generated the sidewalk network for the study area through a specific set of procedures including complete QA/QC analyses and fresh data collection of sidewalk elements. These elements are then associated with the sidewalk network with adjacent roadway and adjacent property parcel data. The link-and-node structure is spatially reconciled through analysis of aerial overflight photography.

5.3.2 Whole Road Network Design

The WRN is a comprehensive roadway network for Metro Atlanta, including all facility type roadways, sidewalks, and crosswalks (referred to as links) and intersections (referred to as nodes). The network is mapped to, and reconciled with, all other network data sources (serving as the master network). The full dataset serves as the underlying disaggregate link-node structure for all roadway networks in the region. The network is stored in the STM Graph Database (see **Section 5.4**) and is used as the schema for the STM network to integrate the features, attributes, and conditions of these networks into a disaggregated model wherein impedance factors can be generated. The conflated networks use the OSM nodes and ways (links) as the reference network wherein the reconciled maps (future ABM and land use networks, e.g., large parking lots that input/absorb demand) are conflated and feature condition data

including SidewalkSim (i.e., sidewalk assets and conditions) and real time data (e.g., GDOT NaviGAtor and WAZE) are associated.

The WRN is the basis for link-to-link mapping between multi-provider roadway and sidewalk networks in order to generate the impedance factors delivered to G-MAP, tailoring travel-time impedances for the various mobility categories identified in the project. The graph database schema is described in **Section 5.4.**

5.3.3 Impedance Calculations and Mobility Categories

The impedance factors are based on different mobility categories based on mobility, auditory or visual limitations, or use of assistive devices that people may designate about themselves. Five major mobility categories were defined to capture specific mobility challenges (see Table 27). Research assumed that, except for the category “persons with no mobility limitations,” persons may associate more than one mobility challenge. For example, a person who uses a wheelchair may also have low vision. Hence, the impedance categories may be combined into eighteen (18) impedance values. This section describes the methodology and analysis to define the appropriate impedance value for a person’s self-described mobility challenges.

Table 27. Mobility Category Descriptions

Mobility Category	Description
Persons with no mobility limitations	Individuals are able to navigate through a wide variety of sidewalk design and condition issues with no impedance (i.e., no major impacts on their route choice). Travel time along each link in the pedestrian network is the primary impedance for persons with no mobility limitations (the default user group). Attribute impedance factors are not used in shortest path navigation for persons with no mobility limitations. Travel time along each link (hours) is calculated as the link length (miles) divided by the pedestrian speed (miles/hour).
Persons with some mobility limitations	Individuals with some mobility limitations include users who have difficulty raising their feet above the level sidewalk surface or users of canes, walkers, or other assistive devices including parents with a child in a stroller. Persons with mobility limitations generally move more slowly than average pedestrians and are more adversely affected by path grade (slope). As such, path-driven impedance factors can be implemented to penalize links that constitute more strenuous or dangerous routes for users (e.g., steep uphill paths or exposure to high traffic volumes on adjacent streets). ADA design standards for sidewalks, ramps, curb cuts, crossings, were based entirely upon the goal of reducing mobility impedances for persons with mobility limitations. Hence, violations of most of these ADA design standards constitute some event-driven impedance for each applicable user group.

Mobility Category	Description
Persons who use a standard manual wheelchair	It should be noted that some factors that impede the travel of users with some mobility limitations may not be as severe for manual wheelchair users, while other factors are likely to be much more severe. For example, a user with some mobility limitations can still navigate a four-inch step to and from the sidewalk for crossing a road, while the wheelchair user may not be able to navigate the crossing without traversing into the street from a driveway curb cut. On the other hand, a moderately rough sidewalk may be more safely traversed by wheelchair than by an individual who has difficulty raising their foot above the sidewalk surface on each step. Therefore, impedance factors are somewhat different for each of the mobility categories.
Persons who use an electric wheelchair or mobility scooter	A standard electric wheelchair or mobility scooter provides better performance and significantly more mobility than a manual wheelchair. For example, the effort required to move parallel to the roadway when encountering a severe cross-slope deviation is relatively minor in an electric wheelchair compared to a manual wheelchair. Hence, the same general sidewalk, crossing, ramp, and curb cut design and condition variables will be employed in the electric and manual wheelchair user groups, but impedance factors are significantly lower for the electric wheelchair group.
Persons who are blind or have some visual impairment (low vision)	All of the same general mobility elements that apply to persons with some mobility limitations can be applied to persons who are blind or low vision (e.g., surface roughness and trip hazards). However, additional ADA standards require that vertical and horizontal protrusions into the walkway be removed and that surface warnings (e.g., texture pads at ramps) be installed to help prevent unknowing pedestrian travel into vehicle traffic. Hence, additional impedance attributes for users that are blind or have some visual impairment (low-vision) are predicated upon the impact of these factors on route desirability.

5.3.3.1 Mobility Category and Impedance Calculations

There may be some impedance interaction effects when users self-select into more than one mobility category. For individuals with multiple disabilities, the ST-CTN impedance calculations simply use the highest impedance value for each variable within each mobility mode. The team anticipated that the number of users from each mobility category would allow the research team to compare routes recommended by the system to routes taken by the user using ML processes so that impedance factors can be calibrated over time. Consistent deviations from recommended routes are an indication that the impedance functions are penalizing attributes too severely, or not penalizing attributes enough. As the team monitors differences in route selection between users that fall into one mode versus multiple modes, potential interaction effects can be explored during calibration.

Users of the G-MAP application, both mobile and web users, have the ability to create profiles based on their needs and preferences. The user is asked to complete a mobility and accessibility profile questionnaire in which the users' responses are stored in the application to be used in the generation of trip plans that are most suitable to their mobility needs and preferences. The users are able to access and adjust their account settings to change their preferences after the initial three questions in the G-MAP registration is completed (see **Section 4.3.3.2** for more information, specifically registration screen shots are shown in Figure 12 and Figure 13**,** and the preferences screen shots is shown in Figure 14).

The research team developed a logical flow for assigning users to the mobility mode categories based on their answers to the questionnaire. The users are first asked if they regularly use a mobility assistive device, as shown in Figure 12 which assigns all users to one of following five mobility mode categories: no mobility limitations (None), an assistive device such as manual walker, wheeled walker, cane, crutches, stroller, service animal (Device), a mobility scooter (MScooter), Manual Wheelchair (WChairM), Electric Wheelchair (WChairE). If the user uses a white cane, they are assigned to the Blind vision category (to be discussed further below). Based on their response, the user is assigned to one of the mobility categories using the following logical flow:

- If white cane = yes
  set VisionTemp = Blind

- If no assistive device = yes
  set MModeTemp = None

- If manual walker, wheeled walker, cane, crutches, stroller, service animal = yes
  set MModeTemp = Device

- If mobility scooter = yes
  set MModeTemp = MScooter

- If electric wheelchair = yes
  set MModeTemp = WChairE

- If electric wheelchair = yes
  set MModeTemp = WChairM

The assigned mobility mode category and vision category is stored as “temp” as it is a temporary assignment that may change as the user progresses through the questionnaire.

The user is then asked if they have any mobility limitations that causes them to walk more slowly or more carefully than other people, as shown as question 2 in Figure 13. Based on the answer to this question, some users are moved from the “no mobility limitations” category to “some mobility limitations” with the following logical flow:

- If MModeTemp = None and Limitations = Yes
  set MModeTemp = Some

Responses from this question assign users to, now, one of the six following mobility mode categories: None, Device, MScooter, WChairM, WChairE, and some mobility limitations (Some).

The final question asks the user if they have any vision limitations, as shown as question 3 in Figure 13**.** Based on their answer, the user is assigned to one of the following three vision categories: No vision limitations (None), low vision (LowVision), and legally blind (Blind). If the user had answered question 1 indicating the use of a white cane and then selects low-vision when answering question 3, the user is assigned to the low-vision category (LowVision). If the user had answered question 1 indicating the use of a white cane and then selects legally blind when answering question 3, the user is assigned to the legally blind category (Blind). If the user had answered question 1 indicating the use of a white cane and then selects no vision limitations

when answering question 3, the user is assigned to the no vision limitations category (None). The logical flow used to assign users to vision categories is as follows:

- If VisionTemp <> Blind and Low-Vision = yes
  set VisionTemp = Low Vision

- If VisionTemp <> Blind and Legally blind = yes
  set VisionTemp = Blind

- If VisionTemp <> Blind and no vision limitations = yes
  set VisionTemp = None

Based on the final answers from the questionnaire, there are several combinations of mobility mode categories and vision categories that can be assigned to a user. For example, if the user has no mobility limitations and no vision limitations, they are assigned to the no mobility limitations category (None). Similarly, if the user uses an electric wheelchair and has no vision limitations, they are assigned to the electric wheelchair mobility category. The logical flow for these 2 examples is as follows, respectively:

- If MModeTemp = None and VisionTemp = None
  set MMode = None

- If MModeTemp = WChairE and VisionTemp = None
  set MMode = WChairE

As mentioned previously, the user is able to self-select into more than one mobility category, assigning them to a category that is a combination of a mobility mode category and vision category. For example, if the user has some mobility limitation and has low-vision, they are assigned to a combination category of some mobility limitations with low vision (Some-LowVision), with the following logical flow:

- If MModeTemp = Some and VisionTemp = LowVision
  set MMode = Some-LowVision

The full list of mobility category combination logical flows can be found in Appendix B. Logical Flow for Mobility Mode and Vision Combinations

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5.4 STM Graph Database Implementation

The STM database deploys a node-link system as implemented using a node-link based database, also called a graph database. Since the goal is to implement the STM as a service on AWS, the system uses AWS's Neptune database service.

The AWS Neptune database service supports three APIs:

- Apache TinkerPop Gremlin

- World Wide Web Consortium's (W3C) Resource Description Framework (RDF) 1.1 and SPARQL Protocol and RDF Query Language (SPARQL) 1.1 (RDF/SPARQL)

- openCypher v9

openCypher API uses a traditional node-link model for storing data whereas the RDF/SPARQL API uses a subject–predicate–object format. To that end, the project team selected openCypher API to query graph links and nodes.

5.4.1 The STM Database Schema

The STM is populated with data that references nodes, links, their relationships, and specific information about the places represented by the node (i.e., places) and connected links (e.g., routes).

Data ingested by the STM uses normalized methods that associate data with its related node or link as described in **Section 5.5**. All nodes and links in the STM database have unique IDs and are referenced from its source (dataset ID). The defined methods take data ingested from outside sources and associate the data with the node or link ID within the STM. Outside datasets may use various methods for identifying how the data is associated with a node or link. Such methods may include:

- GPS coordinates

- Street names

- Addresses

- IDs that are not necessarily the same as used by the STM

The methods normalize these various identification methods into the STM node and link IDs. It may also be necessary for STM node/link IDs to be translated to other forms to convey outbound data to external systems. These formats are described in the PMD engine (**Section 5.6**).

The STM database supports attaching attributes to both nodes and links. These attributes are in the form of key/value pairs. The format of the attributes is not restricted, so attributes can be added or removed at any time and there is no requirement that each node or link of the same type have all of or the same attributes as other nodes/links of that type.

The reference base map used is based on an instance of data verified as walking paths from the OSM. The unique link/node identifiers conform to those IDs. To that end, it is critical that the reference map graph structure be persistent and synchronized with the G-MAP OSM map. To that end, changes to the ***reference network*** are made to the STM graph and shared with G-MAP as updates are incorporated. The shared, corrected network will be accomplished through manual processes.

STM ingestion processes assign attributes to an equivalent model as the OSM in order to associate assets and conditions with the reference model. An STM node is associated with an OSM <node> tag and a link is associated with each OSM <way=footpath> tag. Links are directed from first node to last node for all link descriptions. All the OSM tagged elements are also migrated to the STM structure. Additionally, an STM relationship entity is associated with an OSM

<relation> in order to build a one-to-one (1:1) between the OSM and STM pedestrian links and nodes particularly when the STM is updated (for added or removed links).

An example of the ingested OSM model that is imported into Neptune is shown in Figure 38.

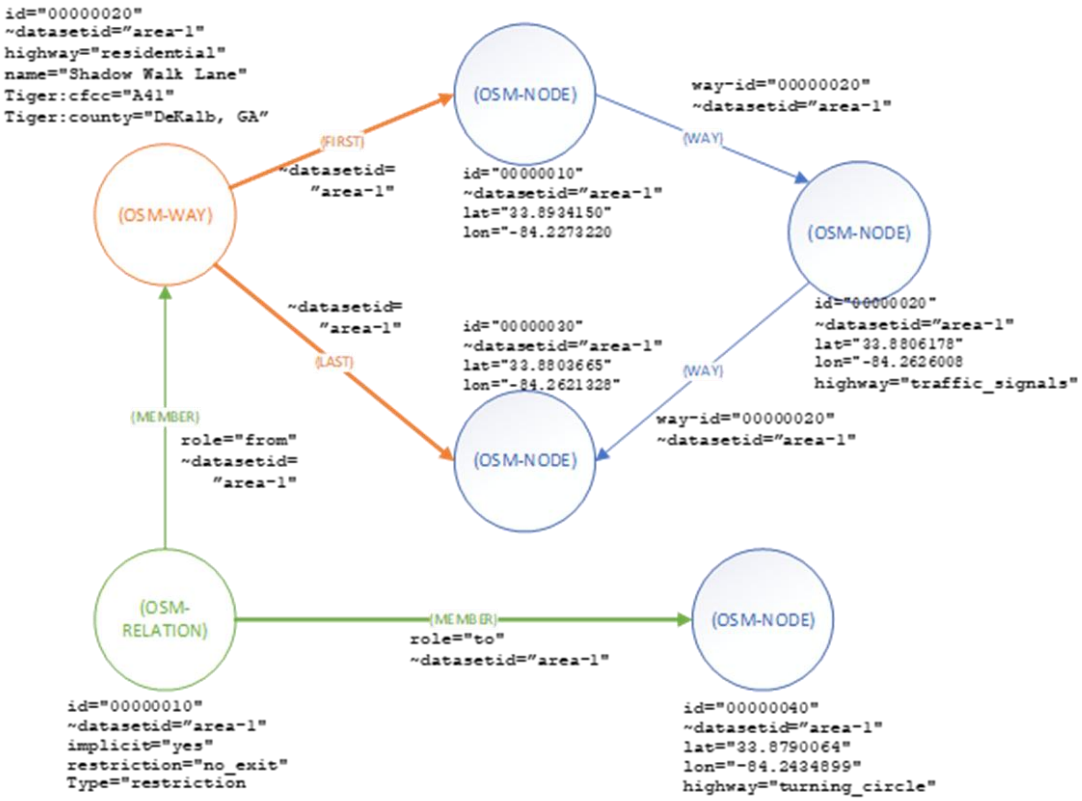


Figure 38. Example of imported OSM model in STM AWS Neptune

The STM graph provides a 1:1 correspondence with the OSM model built in Neptune as depicted in Figure 39.

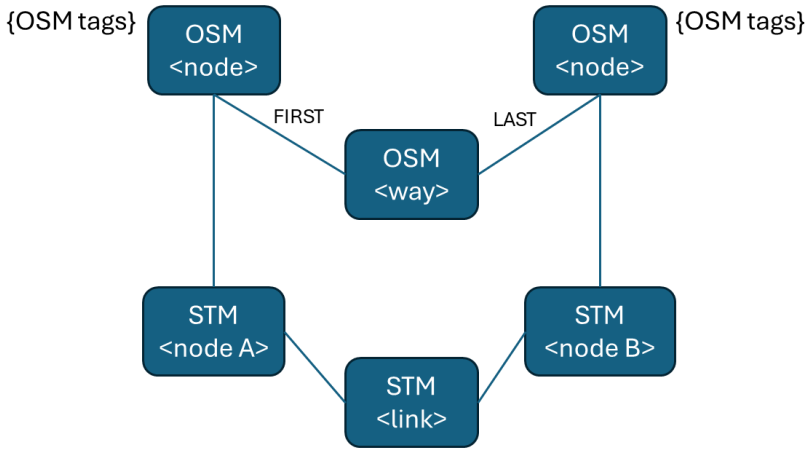


Figure 39. STM Model Relationship with OSM Imported Model

The sidewalk and real time assets and conditions are associated with the STM <link>. These include the data described in the **Section 5.4.2**. These values are used to compute impedance calculations. An initial set of calculations are developed until usage data can be analyzed to tune and set up ML methods to update the impedance factors. The impedance factors are generated for the mobility categories (**Section 5.3.3**) and the initial calculations are described in Appendix C. Initial Impedance Calculations for Sidewalk Assets and Conditions.

5.4.2 Neptune Database Data Dictionary

Table 28 shows all mobility mode link asset and conditions. These are the assets and conditions collected from sidewalk and the real time data ingestion. The data includes link attributes for sidewalk paths, ramps, and obstacles.

Variable name employed in the Neptune Database tables, its description, format (numeric or text), unit, and enumeration values are shown in Table 28. Note that each line represents an entity-enumeration pair. To that end, an entity may be listed in more than one row.

Table 28. Neptune Database Data Dictionary

Variable Name	Variable Description	Format (Numeric/Text)	Units	Enumeration
ADA Mobility Mode Speed	Speed of ADA Mobility Mode (miles per hour (mph))	NUMERIC	Miles/Hour	NA
stmPedLinkID	Link ID	NUMERIC	NA	NA
stmAdaPathNodeAID	Node A ID	NUMERIC	NA	NA
stmAdaPathNodeBID	Node B ID	NUMERIC	NA	NA
stmPedLinkLength	Link length	NUMERIC	Miles	NA
stmPedLinkImpedanceBase	Link Travel Time by Mode	NUMERIC	Hours	NA
stmPedLinkImpedanceMultiplier	Impedance Multiplier Effect	NUMERIC	NA	NA
stmPedLinkImpedanceEvents	Impedance Event Additions	NUMERIC	Hours	NA
stmPedLinkImpedanceTotal	Link Total Impedance	NUMERIC	Hours	NA
stmPedLinkWidth	Link width	NUMERIC	Inches	NA
stmPedLinkWidth	Link width	NUMERIC	Inches	NA

Variable Name	Variable Description	Format (Numeric/Text)	Units	Enumeration
stmPedLinkWidth	Link width	NUMERIC	Inches	NA
stmPedLinkSlopeA_B	Link slope in direction A-B	NUMERIC	Degrees (decimal)	NA
stmPedLinkSlopeA_B	Link slope in direction A-B	NUMERIC	Degrees (decimal)	NA
stmPedLinkSlopeA_B	Link slope in direction A-B	NUMERIC	Degrees (decimal)	NA
stmPedLinkSlopeB_A	Link slope in direction B-A	NUMERIC	Degrees (decimal)	NA
stmPedLinkSlopeB_A	Link slope in direction B-A	NUMERIC	Degrees (decimal)	NA
stmPedLinkSlopeB_A	Link slope in direction B-A	NUMERIC	Degrees (decimal)	NA
stmPedLinkMaterial	Link surface material	TEXT	Enumerated	Concrete (Smooth)
stmPedLinkMaterial	Link surface material	TEXT	Enumerated	Concrete (Rough)
stmPedLinkMaterial	Link surface material	TEXT	Enumerated	Asphalt
stmPedLinkMaterial	Link surface material	TEXT	Enumerated	Brick
stmPedLinkMaterial	Link surface material	TEXT	Enumerated	Hexagonal Pavers
stmPedLinkMaterial	Link surface material	TEXT	Enumerated	Rectangular Pavers

Variable Name	Variable Description	Format (Numeric/Text)	Units	Enumeration
stmPedLinkMaterial	Link surface material	TEXT	Enumerated	Cobblestone
stmPedLinkMaterial	Link surface material	TEXT	Enumerated	Plastic
stmPedLinkMaterial	Link surface material	TEXT	Enumerated	Wood
stmPedLinkMaterial	Link surface material	TEXT	Enumerated	Metal
stmPedLinkMaterial	Link surface material	TEXT	Enumerated	Gravel
stmPedLinkMaterial	Link surface material	TEXT	Enumerated	Grass
stmPedLinkMaterial	Link surface material	TEXT	Enumerated	Earth
stmPedLinkMaterial	Link surface material	TEXT	Enumerated	Sand
stmPedLinkMaterial	Link surface material	TEXT	Enumerated	Other
stmPedLinkSurfaceRoughnessScore	Sidewalk roughness score (very poor to excellent)	TEXT	Enumerated	Very Poor
stmPedLinkSurfaceRoughnessScore	Sidewalk roughness score (very poor to excellent)	TEXT	Enumerated	Poor
stmPedLinkSurfaceRoughnessScore	Sidewalk roughness score (very poor to excellent)	TEXT	Enumerated	Good
stmPedLinkSurfaceRoughnessScore	Sidewalk roughness score (very poor to excellent)	TEXT	Enumerated	Very Good
stmPedLinkSurfaceRoughnessScore	Sidewalk roughness score (very poor to excellent)	TEXT	Enumerated	Excellent

Variable Name	Variable Description	Format (Numeric/Text)	Units	Enumeration
stmPedLinkAreaType	Area type	TEXT	Enumerated	CBD
stmPedLinkAreaType	Area type	TEXT	Enumerated	Very High Density Urban
stmPedLinkAreaType	Area type	TEXT	Enumerated	High Density Urban
stmPedLinkAreaType	Area type	TEXT	Enumerated	Medium Density Urban
stmPedLinkAreaType	Area type	TEXT	Enumerated	Low Density Urban
stmPedLinkAreaType	Area type	TEXT	Enumerated	Suburban
stmPedLinkAreaType	Area type	TEXT	Enumerated	Exurban
stmPedLinkAreaType	Area type	TEXT	Enumerated	Rural
stmPedLinkAreaResidentialDensity	Residential density	NUMERIC	per square-mile	-
stmPedLinkAreaEmploymentDensity	Employment density	NUMERIC	per square-mile	-
stmPedLinkAreaRestaurantDensity	Restaurant density	NUMERIC	per square-mile	-
stmPedLinkAreaShoppingDensity	Shopping density	NUMERIC	per square-mile	-
stmPedLinkAreaParkDensity	Public park/recreation area density	NUMERIC	per square-mile	-
stmPedLinkAttributeLighting	Street lighting	TEXT	Enumerated	Not Lighted
stmPedLinkAttributeLighting	Street lighting	TEXT	Enumerated	Minimally Lighted
stmPedLinkAttributeLighting	Street lighting	TEXT	Enumerated	Somewhat Lighted

Variable Name	Variable Description	Format (Numeric/Text)	Units	Enumeration
stmPedLinkAttributeLighting	Street lighting	TEXT	Enumerated	Mostly Lighted
stmPedLinkAttributeLighting	Street lighting	TEXT	Enumerated	Heavily Lighted
stmPedLinkAttributeShadeTrees	Presence of trees providing shade	TEXT	Enumerated	Not Shaded
stmPedLinkAttributeShadeTrees	Presence of trees providing shade	TEXT	Enumerated	Minimally Shaded
stmPedLinkAttributeShadeTrees	Presence of trees providing shade	TEXT	Enumerated	Somewhat Shaded
stmPedLinkAttributeShadeTrees	Presence of trees providing shade	TEXT	Enumerated	Mostly Shaded
stmPedLinkAttributeShadeTrees	Presence of trees providing shade	TEXT	Enumerated	Heavily Shaded
stmRoadLinkFacilityType	Adjacent road facility type	TEXT	Enumerated	Centroid Connector
stmRoadLinkFacilityType	Adjacent road facility type	TEXT	Enumerated	Interstate/Freeway
stmRoadLinkFacilityType	Adjacent road facility type	TEXT	Enumerated	Parkway
stmRoadLinkFacilityType	Adjacent road facility type	TEXT	Enumerated	HOV Buffer Separated
stmRoadLinkFacilityType	Adjacent road facility type	TEXT	Enumerated	HOV Barrier Separated
stmRoadLinkFacilityType	Adjacent road facility type	TEXT	Enumerated	High Speed Ramp/CD Road

Variable Name	Variable Description	Format (Numeric/Text)	Units	Enumeration
stmRoadLinkFacilityType	Adjacent road facility type	TEXT	Enumerated	Medium Speed Ramp
stmRoadLinkFacilityType	Adjacent road facility type	TEXT	Enumerated	Low Speed Ramp
stmRoadLinkFacilityType	Adjacent road facility type	TEXT	Enumerated	Loop Ramp
stmRoadLinkFacilityType	Adjacent road facility type	TEXT	Enumerated	Off Ramp w/Intersection
stmRoadLinkFacilityType	Adjacent road facility type	TEXT	Enumerated	On Ramp w/Intersection
stmRoadLinkFacilityType	Adjacent road facility type	TEXT	Enumerated	Expressway
stmRoadLinkFacilityType	Adjacent road facility type	TEXT	Enumerated	Principal Arterial Class I
stmRoadLinkFacilityType	Adjacent road facility type	TEXT	Enumerated	Principal Arterial Class II
stmRoadLinkFacilityType	Adjacent road facility type	TEXT	Enumerated	Minor Arterial Class I
stmRoadLinkFacilityType	Adjacent road facility type	TEXT	Enumerated	Minor Arterial Class II
stmRoadLinkFacilityType	Adjacent road facility type	TEXT	Enumerated	HOV Arterial (all classes)
stmRoadLinkFacilityType	Adjacent road facility type	TEXT	Enumerated	Major Collector
stmRoadLinkFacilityType	Adjacent road facility type	TEXT	Enumerated	Minor Collector/Other Local
stmRoadLinkFacilityType	Adjacent road facility type	TEXT	Enumerated	Planned Ramps w/Intersections
stmRoadLinkFacilityType	Adjacent road facility type	TEXT	Enumerated	Planned Directional Ramps
stmRoadLinkFacilityType	Adjacent road facility type	TEXT	Enumerated	Transit Only Link

Variable Name	Variable Description	Format (Numeric/Text)	Units	Enumeration
stmRoadLinkFacilityType	Adjacent road facility type	TEXT	Enumerated	Neighborhood Local
stmRoadLinkFacilityType	Adjacent road facility type	TEXT	Enumerated	Transit Only Link: Local Roads and Collectors
stmRoadLinkFacilityType	Adjacent road facility type	TEXT	Enumerated	Transit Only Link: Park-n-ride lot connector
stmRoadLinkFacilityType	Adjacent road facility type	TEXT	Enumerated	Transit Only Link: Transfer links between rail and bus
stmRoadLinkFacilityType	Adjacent road facility type	TEXT	Enumerated	Associated with BRT Routes
stmRoadLinkAadtA_B	Adjacent road AADT for direction A-B	NUMERIC	NA	NA
stmRoadLinkAadtB_A	Adjacent road AADT for direction B-A	NUMERIC	NA	NA
stmRoadLinkPercentHDTA_B	Percent heavy-duty trucks for direction A-B	NUMERIC	Percent	NA
stmRoadLinkPercentMDTA_B	Percent medium-duty trucks for direction A-B	NUMERIC	Percent	NA
stmRoadLinkPercentHDTB_A	Percent heavy-duty trucks for direction B-A	NUMERIC	Percent	NA
stmRoadLinkPercentMDTB_A	Percent medium-duty trucks for direction B-A	NUMERIC	Percent	NA

Variable Name	Variable Description	Format (Numeric/Text)	Units	Enumeration
stmRoadLinkLanesA_B	Number of lanes for direction A-B	NUMERIC	NA	NA
stmRoadLinkLanesB_A	Number of lanes for direction B-A	NUMERIC	NA	NA
stmRoadLinkLaneWidthA_B	Average travel lane width	NUMERIC	Feet	NA
stmRoadLinkLaneWidthB_A	Average travel lane width	NUMERIC	Feet	NA
stmRoadLinkShoulderWidthA_B	Shoulder width for direction A-B	NUMERIC	Feet	NA
stmRoadLinkShoulderWidthB_A	Shoulder width for direction B-A	NUMERIC	Feet	NA
stmRoadLinkSpeedLimit	Posted speed limit	NUMERIC	MPH	NA
stmRoadLinkObservedSpeed	Observed speed	NUMERIC	MPH	NA
stmRoadLinkObservedPedestrianCount	Average daily count of sidewalk pedestrians	NUMERIC	NA	NA
stmRoadLinkObservedCollisions	Traffic collisions	NUMERIC	NA	NA
stmRoadLinkObservedInjuries	Injuries	NUMERIC	NA	NA
stmRoadLinkObservedFatalities	Fatalities	NUMERIC	NA	NA
stmCrossingCrossingPathCrossSlope	Crossing path cross slope percent (must be <2% under ADA)	NUMERIC	Percent	NA

Variable Name	Variable Description	Format (Numeric/Text)	Units	Enumeration
stmCrossingCrossingPathCrossSlope	Crossing path cross slope percent (must be <2% under ADA)	NUMERIC	Percent	NA
Applies to Links and Crossings	-	-	-	-
stmAssetDefectReportProblemLinkDisjoint	Defect report sidewalk problem (surface) disjoint	TEXT	Enumerated	Problem
stmAssetDefectReportProblemLinkPothole	Defect report sidewalk problem pothole	TEXT	Enumerated	Problem
stmAssetDefectReportProblemLinkBlocked	Defect report sidewalk problem link is completely blocked	TEXT	Enumerated	Problem
stmAssetDefectReportProblemLinkObstruction	Defect report sidewalk problem partial obstruction	TEXT	Enumerated	Problem
stmAssetDefectReportProblemLinkDebris	Defect report sidewalk problem debris	TEXT	Enumerated	Problem
stmAssetDefectReportProblemLinkWater	Defect report sidewalk problem standing water	TEXT	Enumerated	Problem
stmRampType	Ramp type	TEXT	Enumerated	Standard Perpendicular Ramp
stmRampType	Ramp type	TEXT	Enumerated	Diagonal Ramp
stmRampType	Ramp type	TEXT	Enumerated	Parallel Ramp

Variable Name	Variable Description	Format (Numeric/Text)	Units	Enumeration
stmRampType	Ramp type	TEXT	Enumerated	Perpendicular Ramp with Return Edges
stmRampType	Ramp type	TEXT	Enumerated	Combination Perpendicular Parallel Ramp
stmRampType	Ramp type	TEXT	Enumerated	Combination Diagonal Parallel Ramp
stmRampType	Ramp type	TEXT	Enumerated	Built-Up Ramp
stmRampType	Ramp type	TEXT	Enumerated	Linear Ramp
stmRampType	Ramp type	TEXT	Enumerated	At Grade
stmRampWidth	Ramp width	NUMERIC	Inches	NA
stmRampWidth	Ramp width	NUMERIC	Inches	NA
stmRampWidth	Ramp width	NUMERIC	Inches	NA
stmRampSlope	Ramp slope	NUMERIC	Percent	NA
stmRampSlope	Ramp slope	NUMERIC	Percent	NA
stmRampCrossSlope	Ramp cross slope	NUMERIC	Percent	NA
stmRampCrossSlope	Ramp cross slope	NUMERIC	Percent	NA
stmRampGutterSlope	Ramp gutter slope	NUMERIC	Percent	NA
stmRampGutterSlope	Ramp gutter slope	NUMERIC	Percent	NA

Variable Name	Variable Description	Format (Numeric/Text)	Units	Enumeration
stmRampPassingWidth	Ramp passing width	NUMERIC	Inches	NA
stmRampPassingWidth	Ramp passing width	NUMERIC	Inches	NA
stmRampPassingCrossSlope	Ramp passing cross slope	NUMERIC	Percent	NA
stmRampPassingCrossSlope	Ramp passing cross slope	NUMERIC	Percent	NA
stmRampFlareSlopeLeft	Ramp left flare slope	NUMERIC	Percent	NA
stmRampFlareSlopeLeft	Ramp left flare slope	NUMERIC	Percent	NA
stmRampFlareSlopeRight	Ramp right flare slope	NUMERIC	Percent	NA
stmRampFlareSlopeRight	Ramp right flare slope	NUMERIC	Percent	NA
stmRampSmooth	Ramp smooth	TEXT	Enumerated	Problem
stmRampSmooth	Ramp smooth	TEXT	Enumerated	Not Smooth
stmRampFlushAtTop	Ramp flush at top	TEXT	Enumerated	Problem
stmRampFlushAtTop	Ramp flush at top	TEXT	Enumerated	Not Flush
stmRampFlushAtBottom	Ramp flush at bottom (ramp to gutter)	TEXT	Enumerated	Problem
stmRampFlushAtBottom	Ramp flush at bottom (ramp to gutter)	TEXT	Enumerated	Not Flush
stmRampFlushAtStreet	Ramp flush at street (gutter to street)	TEXT	Enumerated	Problem

Variable Name	Variable Description	Format (Numeric/Text)	Units	Enumeration
stmRampFlushAtStreet	Ramp flush at street (gutter to street)	TEXT	Enumerated	Not Flush
stmRampTransitionSlopeLeft	Ramp transition slope left	NUMERIC	Percent	NA
stmRampTransitionSlopeLeft	Ramp transition slope left	NUMERIC	Percent	NA
stmRampTransitionCrossSlopeLeft	Ramp transition cross slope left	NUMERIC	Percent	NA
stmRampTransitionCrossSlopeLeft	Ramp transition cross slope left	NUMERIC	Percent	NA
stmRampTransitionSlopeRight	Ramp transition slope right	NUMERIC	Percent	NA
stmRampTransitionSlopeRight	Ramp transition slope right	NUMERIC	Percent	NA
stmRampTransitionCrossSlopeRight	Ramp transition cross slope right	NUMERIC	Percent	NA
stmRampTransitionCrossSlopeRight	Ramp transition cross slope right	NUMERIC	Percent	NA
stmRampLandingMinimumWidth	Ramp landing minimum width (360 degrees)	NUMERIC	Inches	NA
stmRampLandingMinimumWidth	Ramp landing minimum width (360 degrees)	NUMERIC	Inches	NA
stmRampLandingCrossSlope	Ramp landing cross slope (360 degrees)	NUMERIC	Percent	NA

Variable Name	Variable Description	Format (Numeric/Text)	Units	Enumeration
stmRampLandingCrossSlope	Ramp landing cross slope (360 degrees)	NUMERIC	Percent	NA
stmPedRampDetectableWarningPresent	Ramp warning surface present	TEXT	Enumerated	Absent
stmPedRampDetectableWarningCondition	Ramp warning surface condition	TEXT	Enumerated	Problem
stmPedRampDetectableWarningCondition	Ramp warning surface condition	TEXT	Enumerated	Good
stmPedRampDetectableWarningCondition	Ramp warning surface condition	TEXT	Enumerated	Fair
stmPedRampDetectableWarningCondition	Ramp warning surface condition	TEXT	Enumerated	Poor
stmCurbCutType	Curb cut type	TEXT	Enumerated	Standard Curb Cut
stmCurbCutType	Curb cut type	TEXT	Enumerated	Historic Curb Cut
stmCurbCutType	Curb cut type	TEXT	Enumerated	Sidewalk Diversion Curb Cut
stmCurbCutType	Curb cut type	TEXT	Enumerated	Sidewalk Depression Curb Cut
stmCurbCutType	Curb cut type	TEXT	Enumerated	Other Curb Cut
stmCurbCutWidthTop	Curb cut width top	NUMERIC	Inches	NA

Variable Name	Variable Description	Format (Numeric/Text)	Units	Enumeration
stmCurbCutPassingWidth	Curb cut passing width	NUMERIC	Inches	NA
stmCurbCutPassingWidth	Curb cut passing width	NUMERIC	Inches	NA
stmCurbCutCrossSlope	Curb cut passing cross slope	NUMERIC	Percent	NA
stmCurbCutCrossSlope	Curb cut passing cross slope	NUMERIC	Percent	NA
stmCurbCutFlareSlopeLeft	Curb cut left flare slope	NUMERIC	Percent	NA
stmCurbCutFlareSlopeLeft	Curb cut left flare slope	NUMERIC	Percent	NA
stmCurbCutFlareSlopeRight	Curb cut right flare slope	NUMERIC	Percent	NA
stmCurbCutFlareSlopeRight	Curb cut right flare slope	NUMERIC	Percent	NA
stmCurbCutRampSlopeLeft	Curb cut left ramp slope	NUMERIC	Percent	NA
stmCurbCutRampSlopeLeft	Curb cut left ramp slope	NUMERIC	Percent	NA
stmCurbCutRampCrossSlopeLeft	Curb cut left ramp cross slope	NUMERIC	Percent	NA
stmCurbCutRampCrossSlopeLeft	Curb cut left ramp cross slope	NUMERIC	Percent	NA
stmCurbCutRampSlopeRight	Curb cut right ramp slope	NUMERIC	Percent	NA
stmCurbCutRampSlopeRight	Curb cut right ramp slope	NUMERIC	Percent	NA
stmCurbCutRampCrossSlopeRight	Curb cut right ramp cross slope	NUMERIC	Percent	NA

Variable Name	Variable Description	Format (Numeric/Text)	Units	Enumeration
stmCurbCutRampCrossSlopeRight	Curb cut right ramp cross slope	NUMERIC	Percent	NA
stmCurbCutDepressionSidewalkWidth	Curb cut depression sidewalk width	NUMERIC	Inches	NA
stmCurbCutDepressionSidewalkWidth	Curb cut depression sidewalk width	NUMERIC	Inches	NA
stmCrossingSignalControlledIntersection	Signal controlled intersection	TEXT	Enumerated	No
stmCrossingSignalControlledIntersection	Signal controlled intersection	TEXT	Enumerated	Yes
stmCrossingStopControlledIntersection	Stop controlled intersection	TEXT	Enumerated	No
stmCrossingStopControlledIntersection	Stop controlled intersection	TEXT	Enumerated	Yes
stmCrossingCrosswalkPresent	Crosswalk present	TEXT	Enumerated	No
stmCrossingCrosswalkPresent	Crosswalk present	TEXT	Enumerated	Yes
stmCrossingCrosswalkComplete	Crosswalk complete	TEXT	Enumerated	No
stmCrossingCrosswalkComplete	Crosswalk complete	TEXT	Enumerated	Yes
stmCrossingCrosswalkandRampsAligned	Crosswalk and ramps aligned	TEXT	Enumerated	No
stmCrossingCrosswalkandRampsAligned	Crosswalk and ramps aligned	TEXT	Enumerated	Yes

Variable Name	Variable Description	Format (Numeric/Text)	Units	Enumeration
stmCrossingCrosswalkStyle	Crosswalk lines and design style	TEXT	Enumerated	Parallel (Standard)
stmCrossingCrosswalkStyle	Crosswalk lines and design style	TEXT	Enumerated	Perpendicular Dash (Continental)
stmCrossingCrosswalkStyle	Crosswalk lines and design style	TEXT	Enumerated	Diagonal Stripe (Zebra)
stmCrossingCrosswalkStyle	Crosswalk lines and design style	TEXT	Enumerated	Other
stmCrossingCrosswalkStyle	Crosswalk lines and design style	TEXT	Enumerated	None
stmCrossingCrosswalkPaintConditions	Crosswalk paint conditions	TEXT	Enumerated	Good
stmCrossingCrosswalkPaintConditions	Crosswalk paint conditions	TEXT	Enumerated	Fair
stmCrossingCrosswalkPaintConditions	Crosswalk paint conditions	TEXT	Enumerated	Poor
stmCrossingNSRamp	Nearside ramp condition	TEXT	Enumerated	Absent
stmCrossingNSLanding	Nearside landing condition	TEXT	Enumerated	Absent
stmCrossingNSPushButtonConditionAndAlignment	Nearside push button condition and alignment	TEXT	Enumerated	Good
stmCrossingNSPushButtonConditionAndAlignment	Nearside push button condition and alignment	TEXT	Enumerated	Fair

Variable Name	Variable Description	Format (Numeric/Text)	Units	Enumeration
stmCrossingNSPushButtonConditionAndAlignment	Nearside push button condition and alignment	TEXT	Enumerated	Poor
stmCrossingNSPushButtonConditionAndAlignment	Nearside push button condition and alignment	TEXT	Enumerated	Absent
stmCrossingNSPushButtonVoiceSystem	Nearside push button voice system	TEXT	Enumerated	Good
stmCrossingNSPushButtonVoiceSystem	Nearside push button voice system	TEXT	Enumerated	Fair
stmCrossingNSPushButtonVoiceSystem	Nearside push button voice system	TEXT	Enumerated	Poor
stmCrossingNSPushButtonVoiceSystem	Nearside push button voice system	TEXT	Enumerated	Absent
stmCrossingNSPushButtonHeightOK	Nearside push button height OK	TEXT	Enumerated	No
stmCrossingNSPushButtonHeightOK	Nearside push button height OK	TEXT	Enumerated	Yes
stmCrossingNSPushButtonReachOK	Nearside push button reach OK	TEXT	Enumerated	No
stmCrossingNSPushButtonReachOK	Nearside push button reach OK	TEXT	Enumerated	Yes
stmCrossingNSSigns	Nearside signs	TEXT	Enumerated	Good

Variable Name	Variable Description	Format (Numeric/Text)	Units	Enumeration
stmCrossingNSSigns	Nearside signs	TEXT	Enumerated	Fair
stmCrossingNSSigns	Nearside signs	TEXT	Enumerated	Poor
stmCrossingNSSigns	Nearside signs	TEXT	Enumerated	Absent
stmCrossingFSSignalHeadCondition	Farside signal head condition	TEXT	Enumerated	Good
stmCrossingFSSignalHeadCondition	Farside signal head condition	TEXT	Enumerated	Fair
stmCrossingFSSignalHeadCondition	Farside signal head condition	TEXT	Enumerated	Poor
stmCrossingFSSignalHeadCondition	Farside signal head condition	TEXT	Enumerated	Absent
stmCrossingFSSignalHeadLampWorking	Farside signal head lamp working	TEXT	Enumerated	No
stmCrossingFSSignalHeadLampWorking	Farside signal head lamp working	TEXT	Enumerated	Yes
stmCrossingFSSignalHeadVisible	Farside signal head visible	TEXT	Enumerated	No
stmCrossingFSSignalHeadVisible	Farside signal head visible	TEXT	Enumerated	Yes
stmCrossingFSRamp	Farside ramp condition	TEXT	Enumerated	Absent
stmCrossingFSLanding	Farside landing condition	TEXT	Enumerated	Absent

Variable Name	Variable Description	Format (Numeric/Text)	Units	Enumeration
stmCrossingFSPushButtonConditionAndAlignment	Farside push button cond./dir.	TEXT	Enumerated	Good
stmCrossingFSPushButtonConditionAndAlignment	Farside push button cond./dir.	TEXT	Enumerated	Fair
stmCrossingFSPushButtonConditionAndAlignment	Farside push button cond./dir.	TEXT	Enumerated	Poor
stmCrossingFSPushButtonConditionAndAlignment	Farside push button cond./dir.	TEXT	Enumerated	Absent
stmCrossingFSPushButtonVoiceSystem	Farside push button voice system	TEXT	Enumerated	Good
stmCrossingFSPushButtonVoiceSystem	Farside push button voice system	TEXT	Enumerated	Fair
stmCrossingFSPushButtonVoiceSystem	Farside push button voice system	TEXT	Enumerated	Poor
stmCrossingFSPushButtonVoiceSystem	Farside push button voice system	TEXT	Enumerated	Absent
stmCrossingFSPushButtonHeightOK	Farside push button height OK	TEXT	Enumerated	No
stmCrossingFSPushButtonHeightOK	Farside push button height OK	TEXT	Enumerated	Yes
stmCrossingFSPushButtonReachOK	Farside push button reach OK	TEXT	Enumerated	No

Variable Name	Variable Description	Format (Numeric/Text)	Units	Enumeration
stmCrossingFSPushButtonReachOK	Farside push button reach OK	TEXT	Enumerated	Yes
stmCrossingFSSigns	Farside signs	TEXT	Enumerated	Good
stmCrossingFSSigns	Farside signs	TEXT	Enumerated	Fair
stmCrossingFSSigns	Farside signs	TEXT	Enumerated	Poor
stmCrossingFSSigns	Farside signs	TEXT	Enumerated	Absent
stmCrossingNSSignalHeadConditionAndAlignment	Nearside signal head condition and alignment	TEXT	Enumerated	Good
stmCrossingNSSignalHeadConditionAndAlignment	Nearside signal head condition and alignment	TEXT	Enumerated	Fair
stmCrossingNSSignalHeadConditionAndAlignment	Nearside signal head condition and alignment	TEXT	Enumerated	Poor
stmCrossingNSSignalHeadConditionAndAlignment	Nearside signal head condition and alignment	TEXT	Enumerated	Absent
stmCrossingNSSignalHeadLampWorking	Nearside signal head lamp working	TEXT	Enumerated	No
stmCrossingNSSignalHeadLampWorking	Nearside signal head lamp working	TEXT	Enumerated	Yes
stmCrossingNSSignalHeadVisible	Nearside signal head visible	TEXT	Enumerated	No
stmCrossingNSSignalHeadVisible	Nearside signal head visible	TEXT	Enumerated	Yes

Variable Name	Variable Description	Format (Numeric/Text)	Units	Enumeration
stmCrossingLinkVehicleVolumeRightA_B	Traffic volume per hour A_B turning right across crossing	NUMERIC	Vehicles/Hour	No
stmCrossingLinkVehicleVolumeLeftA_B	Traffic volume per hour A_B turning left across crossing	NUMERIC	Vehicles/Hour	No
stmCrossingLinkVehicleVolumeThroughA_B	Traffic volume per hour A_B going straight across crossing	NUMERIC	Vehicles/Hour	No
stmCrossingLinkVehicleVolumeRightB_A	Traffic volume per hour B_A turning right across crossing	NUMERIC	Vehicles/Hour	No
stmCrossingLinkVehicleVolumeLeftB_A	Traffic volume per hour B_A turning left across crossing	NUMERIC	Vehicles/Hour	No
stmCrossingLinkVehicleVolumeThroughB_A	Traffic volume per hour B_A going straight across crossing	NUMERIC	Vehicles/Hour	No

5.4.3 STM Database Operations

There are a number of operations that are performed on data stored in the STM database. Some are one-time operations, others are continuous. These operations include:

- Database initialization and populations
- Database backup
- Database restore
- Inbound data ingestion
- Outbound data (on-demand requests and scheduled exports)
- Database history tracking
- Data analysis
- Ongoing calculation of computed node/link attributes

5.4.3.1 Database Initialization and Population

A process for creating and initializing the STM database is necessary. This process could involve using online tools provided by AWS for the Neptune database or developing code to perform this, or a combination of both. Even if initialization may be accomplished using exclusively AWS provided tools, the ability to run a script to perform this should be pursued.

The initial population of data involves the DInE and is described in **Section 5.5** below.

5.4.3.2 Database Backup

Backing up the STM database should be implemented on a recurring basis. This should be accomplished with tools provided by AWS but may need some coding for triggering the process at regular intervals. Turning on automatic backups should be part of the provisioning script.

Complete backup capability involves tracking all database changes. This is necessary to recover changes made since the last full backup. AWS Neptune provides a change log system called “Neptune Streams” that is utilized for this purpose. Turning this feature on should be part of the provisioning script.

5.4.3.3 Database Restore

In the event of a database failure, there is a method to recover the database from previous backups. This involves rebuilding the database from the last full backup and then updating that snapshot with changes that were logged post backup. AWS provides tools for performing this process. This needs to be evaluated (and tested) and at a minimum, documented for the specifics of the STM. If necessary, code or a script should be developed to make this process as easy and reliable as possible.

5.4.3.4 Inbound Data Ingestion

Inbound data ingestion is discussed in the **Section 5.5**.

5.4.3.5 Outbound Data

The STM database provides data to other systems. The main external systems that place demands on the STM for data are:

- Network Impedance API (see **Section 5.6**)
- PMD (see **Section 7**)

5.4.3.5.1 Network Impedance API

The Network Impedance API provides impedance data that it uses to plan the most appropriate route for the user's needs and/or situation. The API that G-MAP uses to access the STM service is described in **Section 5.5**. Integration in G-MAP is described in **Section 4.6**.

5.4.3.5.2 Performance Measurement Dashboard

The PMD serves as the performance measurement engine for the project, both for evaluation of Phase 3 as well as computing and tracking performance and safety measures. The performance measurement engine tracks performance characteristics, such as volume and frequency of requests, response speeds, and data throughput. Comprehensive performance metrics were developed and included in the PMESP. The performance measurement engine is described in **Section 5.7**.

5.4.3.6 Database History Tracking

Database history tracking must be performed to configure STM data (and snapshots of the database) to conduct research. The database backup system and change logs captured by the Neptune Streams system are utilized for this purpose.

5.4.3.7 Data Analysis

Data analysis is conducted using tools both integrated and external to the STM. Various APIs, routines, and services were developed throughout the deployment to conduct this research.

5.4.3.8 Ongoing Calculations

Several calculations are needed to be performed on the STM database on an ongoing basis. These calculations can be triggered by events or on a time schedule. One of the primary drivers of these calculations is the impedance computation engine.

5.5 Data Ingestion Engine (DInE) (Epic STM-1)

The DInE provides the functions of the Dynamic Data Broker that is shown in the high-level function diagram (see Figure 5). The Ingestion Engine serves to retrieve, transform, load, and archive data streams from external sources from the following data items:

1. OSM Geometry (link – node structure)
2. Sidewalk attributes from sidewalk data collection
3. Waze Alerts
4. NaviGAtor Alerts and Traffic Data
5. G-MAP App Usage, Trace, Persona and Deviation Data

Each of these data items is retrieved from the external source in the native format it is published in, translated to an STM compatible format, spatially geocoded and attached to WRN links, and temporally aggregated and loaded into the STM for further use by the DInE or the Performance Metrics Computation Engine. In addition, the default set of impedance values is stored when it is necessary to reset the impedance API (see **Section 5.6**).

5.5.1 Dataset IDs

A unique dataset ID is associated with a grid area that is referenced by WRN in the Neptune database. The geographic area referenced by the dataset ID contains an area that is 0.1 degrees latitude by 0.1 degrees longitude in size. The dataset ID is formed by the latitude/longitude coordinates of the southwest corner of the area. For example: if an area is defined by the coordinates (33.8N 84.3W, 33.9N 84.3W, 33.9N 84.2W, 33.8N 84.2W) and these coordinates define the four corners of the areas in the order of southwest, northwest, northeast, southeast, the dataset ID would be “33.8N84.3W”. The fact that all areas are 0.1 by 0.1 degrees in size, the southwest corner is all that is necessary to define the area and the dataset.

The system uses these dataset IDs to conflate or integrate other data into the map geometry. In addition, the system uses these IDs to export the impedance data.

To facilitate efficient data export, the following process is executed to assign dataset IDs using the 0.1°/0.1° latitude/longitude grid defined below, and use these dataset IDs for all links formed in the database and test that the impedance data export efficiently exports data using the IDs.

- "33.8N84.3W": [33.8N 84.3W, 33.9N 84.3W, 33.9N 84.2W, 33.8N 84.2W]
- "33.9N84.3W": [33.9N 84.3W, 34.0N 84.3W, 34.0N 84.2W, 33.9N 84.2W]
- "33.8N84.2W": [33.8N 84.2W, 33.9N 84.2W, 33.9N 84.1W, 33.8N 84.1W]
- "33.9N84.2W": [33.9N 84.2W, 34.0N 84.2W, 34.0N 84.1W, 33.9N 84.1W]
- "34.0N84.2W": [34.0N 84.2W, 34.1N 84.2W, 34.1N 84.1W, 34.0N 84.1W]
- "33.9N84.1W": [33.9N 84.1W, 34.0N 84.1W, 34.0N 84.0W, 33.9N 84.0W]
- "34.0N84.1W": [34.0N 84.1W, 34.1N 84.1W, 34.1N 84.0W, 34.0N 84.0W]
- "33.9N84.0W": [33.9N 84.0W, 34.0N 84.0W, 34.0N 83.9W, 33.9N 83.9W]
- "34.0N84.0W": [34.0N 84.0W, 34.1N 84.0W, 34.1N 83.9W, 34.0N 83.9W]

5.5.2 OSM Geometry

OSM map data for the area of interest is obtained from the OSM server and converted into a format that will be stored in the STM (represented by an AWS Neptune database). The data received from the OSM server is in an Extensible Markup Language (XML) format as explained in the wiki.openstreetmap.org wiki.

The initial creation of the STM database matches the OSM elements to each STM link / node structure. Subsequent ingestion processes use the Dataset ID described in **Section 5.5.1** to match updates to the database. The user stories describe the function of updating and matching the following OSM elements to STM database features:

- <osm> element
- <bounds> element
- <node> element
- <way> element
- <relation> element
- <custom tags>

5.5.3 Sidewalk Data

The augmented sidewalk data, collected by the sidewalk data collection process (**Section 5.3.1**), is accessed from a directory containing the data collection. The data contains video footage and measurements. The video footage may contain pedestrian faces which needs to be masked prior to publication. The data is stored with the STM OSS GitHub site (https://github.com/gti-gatech/STM4US/tree/main/asset_data).

This function ingests remaining sidewalk data tables using the sidewalk “link” data endpoint as a model, adding endpoints to ingest the remaining sidewalk data tables, i.e., “defect,” “ramp,” “curb,” and “curb cut.”

The following functions were implemented:

1. Import the Sidewalk data set using RESTful APIs PUT or POST.
    a. Using a REST PUT function, import the formatted Sidewalk dataset. This replaces any previous import with the same identifier.
    b. A POST imports a new file with the same ID from a previous import.
    c. If no previous import by that ID exists in the STM database, the “404 Not Found” error code is returned. The ID parameter is an ID provided to uniquely identify the dataset and can be any string.
    d. Delete a dataset by using the REST DELETE request.
2. Translate the Sidewalk data to STM database format including sidewalk links and nodes, and defects. Additional features supported include ramp, curb, curb cut, crossing, bus stop, and more.

An example of a **sidewalk link CSV file** appears as follows:

```
sidewalksimLinkID, sidewalksimLinkNodeA, sidewalksimLinkNodeB, sidewalksimLinkType

0000100, 00000010, -0000200, Sidewalk

0000110, -0000200, -0000210, Sidewalk

0000120, -0000210, -0000220, Sidewalk

0000130, -0000220, 00000020, Sidewalk
```

An example of a **sidewalk defect CSV file** is described as follows:

```
sidewalksimDefectReportID, sidewalksimDefectReportLinkID, sidewalksimDefectReportProblemRamp

0000200, 0000100, Problem

0000210, 0000120, Problem
```

An example of a **sidewalk ramp CSV file** is described as follows:

```
sidewalksimRampID, sidewalksimRampLinkID, sidewalksimRampType

0000300, 0000100, Standard Perpendicular Ramp

0000310, 0000120, Diagonal Ramp
```

These features can then be matched to the OSM link / node structure to derive impedance values based on the impedance values associated with each mobility category.

5.5.4 Waze

Waze data is retrieved from the Waze Partner Hub server and stored as AWS S3 files in the JSON format. The Waze data is polled from the Waze server at regular intervals and is initiated with an API call. The Waze JSON data is processed upon download from the Waze server. The data is contained in two sub-groups, “alerts” and “jams.” The main section also contains start and end timestamps in both date/time and millisecond formats.

5.5.4.1 WAZE Alerts Process

The WAZE Alerts process includes the following:

- Creates a process in the AWS instance to periodically poll the Waze API for alerts in the project area. The requests are saved to an S3 Bucket. The requests sent to Waze must be at most 0.1 degree by 0.1 degree latitude and longitude squares.

- Using the downloaded Waze data in the S3 bucket, attach the data to existing links in the network database. This involves de-duplicating Waze alerts and removing stale Waze alerts.

The “alerts” sub-section contains a sub-section for each alert. Each alert sub-section contains a number of attributes along with a single sub-section called “location.” The “location” sub-section contains two attributes “x” and “y,” in which the “x” attribute denotes the longitude coordinate of the alert location and the “y” attribute denotes the latitude coordinate. The “roadType” attribute denotes an integer

representation of road type, and the “type” and “subtype” attributes contain descriptive type names for each alert sub-section. The full list of road types and alert types/sub-types are provided in Table 29.

For each alert sub-section, a new STM node should be created with the label “WAZE-ALERT.” This new node should have attributes set that mirror the timestamp attributes contained in the Waze root JSON section. All attributes in the alert JSON sub-section except the “location” should be set as attributes on the new Waze node. A “location-x” attribute should be set to the value of the “x” attribute in the “location” sub-section and a “location-y” attribute should be set to the value of the “y” attribute in the “location” sub-section. Alert JSON sub-sections with a “roadType” value of “3” represent freeways, and should be discarded. The alert that has “type” value of “JAM” is also discarded. This new STM node must be connected to the nearest “OSM-WAY” STM node containing the “footway: sidewalk” or “footway: crossing” attribute (representing a sidewalk or a crosswalk, respectively) via an STM link from the located sidewalk/crosswalk node to the new “WAZE-ALERT” node.

Jam alerts are currently ignored because they do not directly impact pedestrians or pedestrian crossings.

The impedance values currently implemented are shown in Table 29**.**

Table 29. Impedance for WAZE Alert Subtypes

Alert Type	Alert Subtype	Impedance / Crosswalk (sec)	Impedance / Sidewalk (sec)
ACCIDENT	ACCIDENT_MINOR	1.5x180=270	2x
ACCIDENT	ACCIDENT_MAJOR	1.5x180=270	2x
ACCIDENT	NO_SUBTYPE	1.5x180=270	2x
JAM	all subtypes	Ignore	Ignore
WEATHERHAZARD / HAZARD	HAZARD_ON_ROAD		
WEATHERHAZARD / HAZARD	HAZARD_ON_SHOULDER HAZARD_WEATHER HAZARD_ON_ROAD_OBJECT HAZARD_ON_ROAD_POT_HOLE HAZARD_ON_ROAD_ROAD_KILL HAZARD_ON_SHOULDER_MISSING_SIGN	Ignore	Ignore

Alert Type	Alert Subtype	Impedance / Crosswalk (sec)	Impedance / Sidewalk (sec)
WEATHERHAZARD / HAZARD	HAZARD_ON_SHOULDER_CAR_STOPPED	Ignore	60
WEATHERHAZARD / HAZARD	HAZARD_ON_SHOULDER_ANIMALS	Ignore	60
WEATHERHAZARD / HAZARD	HAZARD_WEATHER_FOG	2x	2x
WEATHERHAZARD / HAZARD	HAZARD_WEATHER_HAIL	5x	5x
WEATHERHAZARD / HAZARD	HAZARD_WEATHER_HEAVY_RAIN	5x	5x
WEATHERHAZARD / HAZARD	HAZARD_WEATHER_HEAVY_SNOW	5x	5x
WEATHERHAZARD / HAZARD	HAZARD_WEATHER_FLOOD	10x	10x
WEATHERHAZARD / HAZARD	HAZARD_WEATHER_MONSOON	10x	10x
WEATHERHAZARD / HAZARD	HAZARD_WEATHER_TORNADO	20x	20x
WEATHERHAZARD / HAZARD	HAZARD_WEATHER_HEAT_WAVE	2x	2x
WEATHERHAZARD / HAZARD	HAZARD_WEATHER_HURRICANE	20x	20x
WEATHERHAZARD / HAZARD	HAZARD_WEATHER_FREEZING_RAIN	5x	5x
WEATHERHAZARD / HAZARD	HAZARD_ON_ROAD_LANE_CLOSED	1.5x180=270	60
WEATHERHAZARD / HAZARD	HAZARD_ON_ROAD_OIL	1.5x180=270	60
WEATHERHAZARD / HAZARD	HAZARD_ON_ROAD_ICE	1.5x180=270	60

Alert Type	Alert Subtype	Impedance / Crosswalk (sec)	Impedance / Sidewalk (sec)
WEATHERHAZARD / HAZARD	HAZARD_ON_ROAD_CONSTRUCTION	1.5x180=270	2x
WEATHERHAZARD / HAZARD	HAZARD_ON_ROAD_CAR_STOPPED	1.5x180=270	60
WEATHERHAZARD / HAZARD	HAZARD_ON_ROAD_TRAFFIC_LIGHT_FAULT	2x180=360	Ignore
WEATHERHAZARD / HAZARD	NO_SUBTYPE	Ignore	Ignore
MISC	NO_SUBTYPE	Ignore	Ignore
CONSTRUCTION	NO_SUBTYPE	1.5x180=270	2x
ROAD_CLOSED	ROAD_CLOSED_HAZARD	1.5x180=270	2x
ROAD_CLOSED	ROAD_CLOSED_CONSTRUCTION	1.5x180=270	2x
ROAD_CLOSED	ROAD_CLOSED_EVENT	1.5x180=270	2x
ROAD_CLOSED	NO_SUBTYPE	1.5x180=270	2x

5.5.5 GDOT NaviGAtor

This section describes how GDOT's NaviGAtor data is retrieved, processed, and used within the system.

5.5.5.1 NaviGAtor Processing Description

NaviGAtor data is retrieved from the GDOT NaviGAtor Structured Query Language (SQL) database server and stored as AWS S3 files in the CSV format. The NaviGAtor data is polled from the database at regular intervals and is initiated with an API call.

The steps include the following:

- **Set-up access to Navigator Event Stream.** Set-up AWS to provide a static IP address and provide that address to GDOT so that they can configure their firewall to allow access.
- **Ingest Navigator Event Stream.** Ingest three tables from Navigator event stream
  - Event Log
  - Event Comments

- Event Properties

- Ingest Navigator ITS Stream: Ingest speed and flow data and attach that data to node pairs in the Neptune database based on nearest latitude and longitude. This data is generated by a small number of fixed-location devices, therefore, depending on the architecture design, it may be necessary to create a lookup table to identify which network node pair to associate with the device.

- Process Navigator ITS/VDS Stream: First, de-duplicate data, then ingest speed and flow data and attach that data to node pairs in the Neptune database based on nearest latitude and longitude. Finally, data is generated by a small number of fixed-location devices, therefore, depending on the architecture design, it may be necessary to create a lookup table to identify which network node pair to associate with the device.

- Process Navigator Event Stream: Process the three tables (event log, comments, and properties) from Navigator event stream from the files saved in the S3 bucket and include in the dynamic impedance calculation algorithm. Explore possible duplication with Waze alerts and exclude Waze data from navigator events. Also exclude data from outside the study area.

5.5.5.2 NaviGAtor Processing

NaviGAtor data is ingested from a number of SQL database tables, including the following:

- Event Comment Table
- Scheduled Event Table
- Unscheduled Event Table
- Event Property Table
- Vehicle Sensor Device (VSD) Data table
- VSD Detector Table (static)
- VSD Device Table (static)

When data is retrieved, the STM checks for events that are outside of the service area or that do not impact sidewalks (e.g., interstate). Data is assigned an event node and associated with all OSM nodes within a 50-foot radius. Event comment data are saved with the same timestamp in the S3 bucket while event property data are saved in the event table.

When new data is received, the older data is replaced in the database.

Scheduled and unscheduled events may modify impedance of associated sidewalks. Events may have a numerical severity value associated with them that is used as a multiplicative modifier for certain event types. Events with a “road_type” value of “interstate” represent freeways and should be discarded. Impedance modification factors are provided in Table 30.

Table 30. Impedance for NaviGAtor Events

Schedule Type	Event Type	Event Subtype	Impedance / Crosswalk	Impedance / Sidewalk
UNSCHEDULED	Signals	-	3x60=180	Ignore
UNSCHEDULED	All other types	-	2x(Severity)x	2x(Severity)x
SCHEDULED	Planned	Construction	2x	2x
SCHEDULED	Planned	Emergency Roadwork	2x	2x
SCHEDULED	Planned	Maintenance Activity	2x	2x
SCHEDULED	Planned	Rolling Closures	1.25x	1.25x
SCHEDULED	Planned	ATL UTD	2x	2x
SCHEDULED	Planned	Braves	2x	2x
SCHEDULED	Planned	Falcons	2x	2x
SCHEDULED	Planned	Hawks	2x	2x
SCHEDULED	Planned	Sporting Event	2x	2x
SCHEDULED	Planned	Other (Road Race)	2x	2x
SCHEDULED	Planned	Peachtree (Road Race)	2x	2x
SCHEDULED	Planned	Crash Investigation	2x	2x
SCHEDULED	Planned	Other (Police Operations)	3x	3x

5.5.6 G-MAP API

As users plan trips through the G-MAP mobile app, their requests result in the generation of five JSON files: a TripRequest, TripSummary, MonitoredTrip, TrackedJourney, and Persona. Compressed archives of these files are uploaded to an AWS S3 bucket daily. Each data model has its own ZIP archive containing a single JSON file of that specific type for data associated with all trips completed during each day, along with an associated date stamp.

The uploads are written to the S3 bucket with a subdirectory naming structure based on weekly (Sunday to Saturday) date bounds, in the format “PMD_<YYYY-MM-DD_YYYY-MM-DD>”. For example, the week beginning Sunday March 31st and ending Saturday April 6th would use the subdirectory name “PMD_2024-03-31_2024-04-06”. Within each of these weekly subdirectories, there is a set of ZIP files for each of the five file types, and for each day of the associated week. The files follow the timestamped naming structure described in the sections below.

5.5.6.1 TripRequest File

A trip request JSON file, in a format described in the ICD INT-11, contains an array of elements for each TripRequest generated during the day. Each element contains origin and destination information, as well as a “userID” identifying the user that initiated the request. The trip request is provided to the GMAP API, which generates a response containing a proposed route to their destination based on user mobility profile and impedance values.

The ZIP file uploaded to the S3 bucket containing a TripRequest JSON file for all trips in a given day includes a date stamp in its file name, structured like the following example: “2024-02-16-TripRequest.zip”.

5.5.6.2 TripSummary File

The proposed routes returned from the G-MAP API for any Trip Requests are represented by an array of elements in a TripSummary JSON file. The TripSummary contains a “tripRequestId” that associates the TripSummary to a TripRequest.

Additional data within each TripSummary element are values indicating the origin and destination, an “itineraries” array with one or more elements containing data related to each leg of the suggested route, and within each a “steps” array indicating the latitude, longitude, heading, and street names for the step-by-step directions.

For trips where a user has opted to use real-time navigation and GPS trace data, a more pertinent associated element is present within the MonitoredTrip file outlined below.

The ZIP file uploaded to the S3 bucket containing a TripSummary JSON file for all trips in a given day includes a date stamp in its file name, structured like the following example: “2024-02-16-TripSummary.zip”.

5.5.6.3 MonitoredTrip File

As long as a user keeps the G-MAP mobile app active for step-by-step navigation to their destination, elements associated with the trip are generated in two additional files. Outlines of the users’ step-by-step directions in the form of elements within a MonitoredTrip file and logging the users’ latitude and longitude positional trace data, stored as elements within a TrackedJourney file.

If a user only leverages the G-MAP mobile application for trip planning purposes, and not live navigation, the MonitoredTrip and TrackedJourney data are absent. The contents of a MonitoredTrip are similar to a TripSummary; an array of elements, each including origin and destination values, itinerary information, and a “steps” array indicating the latitude, longitude, heading, and street names for the step-by-step directions, as well as a “userID” identifying the user that initiated the MonitoredTrip. Each MonitoredTrip element within this file contains a “tripRequestId” that associates it with a TripRequest.

The MonitoredTrip JSON file is compressed in a ZIP file and uploaded to S3 daily. The ZIP file uploaded to the S3 bucket containing a MonitoredTrip JSON file for all associated trips in a given day includes a date stamp in its file name, structured like the following example: “2024-02-16-MonitoredTrip.zip”.

5.5.6.4 TrackedJourney File

Coupled with the MonitoredTrip file outlined above, if a user leverages the G-MAP mobile app for real time navigation to their destination and GPS trace data, an associated element within a TrackedJourney file is present. Each element within the TrackedJourney data contains a “locations” array of latitude and longitude values logged during their trip, as well as data recording the user’s speed and bearing. The TrackedJourney data contains a “tripId” that associates it to a MonitoredTrip.

The ZIP file uploaded to the S3 bucket containing the TrackedJourney JSON file for a given day includes a date stamp in its file name, structured like the following example: “2024-02-16-TrackedJourney.zip”.

5.5.6.5 Persona File

Along with the collections of files associated with each trip initiated on a given day, there is a Persona JSON file representing all unique users that requested any form of navigation that day. This data is uploaded to S3 in the form of a ZIP archive containing the Persona JSON file. Each element within the Persona file contains a user's unique ID value, their mobility profile data, and an array of their "savedLocations" data. TripRequests and MonitoredTrips can be associated to a Persona via their "userId" values.

The ZIP file uploaded to the S3 bucket containing the Persona JSON file for users in a given day includes a date stamp in its file name, structured like the following example: "2024-02-16-Persona.zip".

5.5.6.6 Trip-survey-responses Files

The trip survey response file is a collection of the daily responses to the in-app survey (see **Section 4.4.7.1** for details of the survey). The file includes each response on a given day. The response references the monitored trip and user hashtag ID, and the in-app deviation survey response.

The ZIP file uploaded to the S3 bucket containing the Persona JSON file for users in a given day includes a date stamp in its file name, structured like the following example: "2024-02-16-Trip-survey-response.zip".

5.5.7 Default Impedance Data

A set of default impedance values are defined and formatted into a CSV file. This file is uploaded via a RESTful API as follows:

1. The header (first) row of the CSV file must contain columns for "Timestamp," "Upstream Node," "Downstream Node," and one column for impedance for each "Mobility Categories" described in **Section 5.3.3**. The "Upstream Node" is Node-A as referenced in the SidewalkSim links datasets and "Downstream Node" is Node-B.
2. All following rows must contain data in columns that align with the matching header row column.
3. The order of the columns should be "Timestamp," "Upstream Node," "Downstream Node," followed by the impedance columns in any order.
4. The "Timestamp" data should be in "MM/DD/YYY HH:MM:SS" 24-hour format.
5. The "Upstream Node" and "Downstream Node" data should be node IDs that match Node IDs in the SidewalkSim link datasets, which should in kind match Node IDs in the OSM datasets.
6. The impedance values should be fixed point values with two digits to the right of the decimal point.

RESTful APIs (PUT or POST) are used to load the data to the STM database and match the impedance data to the database graph structure using the Database IDs.

5.6 Impedance Computation Engine (Epic STM-2)

The Impedance Computation Engine (ICE) is the core of the Space Time Platform. The Engine performs calculations using various data imported by the STM DInE (**Section 5.5**) to compute impedance values, expressed in minutes of travel time, for each of the various mobility modes.

5.6.1 ICE Process Flow

The ICE calculates the customized impedance values for traveling on a segment of the trip. Different penalties are associated with sidewalk features based on different user class vulnerabilities. For example, rough sidewalks, crosswalks without curb cuts (or narrow curb cuts), debris, or potholes in pathways score high impedances for people with mobility challenges. Permanent protrusions (i.e., architectural features) and temporary protrusions (i.e., low hanging branches) narrow the walking path and score high impedance values for people with vision loss. Permanent protrusions are documented during the sidewalk inventory and temporary protrusions are crowd sourced.

In addition, dynamic attributes such as NaviGAtor data and WAZE alerts that impact intersections and roadways are added to the impedance values when they impact traveler travel times.

The algorithms assign impedance values to different features (i.e., nodes and paths) based on an enumerated set of preferences that are consistent with the G-MAP user-created profiles. The functionality of the proposed system is highly adaptive, allowing the system to specify any set of impedance functions for various disabilities and ranges, modes, or sub-modes.

A subprocess within the ICE is the operational and prediction analysis which serves as the ML function of the system. This module consumes feedback from traveler's execution of their trip plans and updates the Cost Analysis edge costs based on changes made by users of the tools. The processes interpret planned versus actual travel of various user classes (i.e., mobility modes).

To ensure compatibility with the G-MAP app, the OSM network is reviewed regularly to reflect changes in static network elements identified via SidewalkSim inventory and inspection tools.

The network impedance engine flow is depicted in **Figure 40**. Each function is described in Error! Reference source not found..

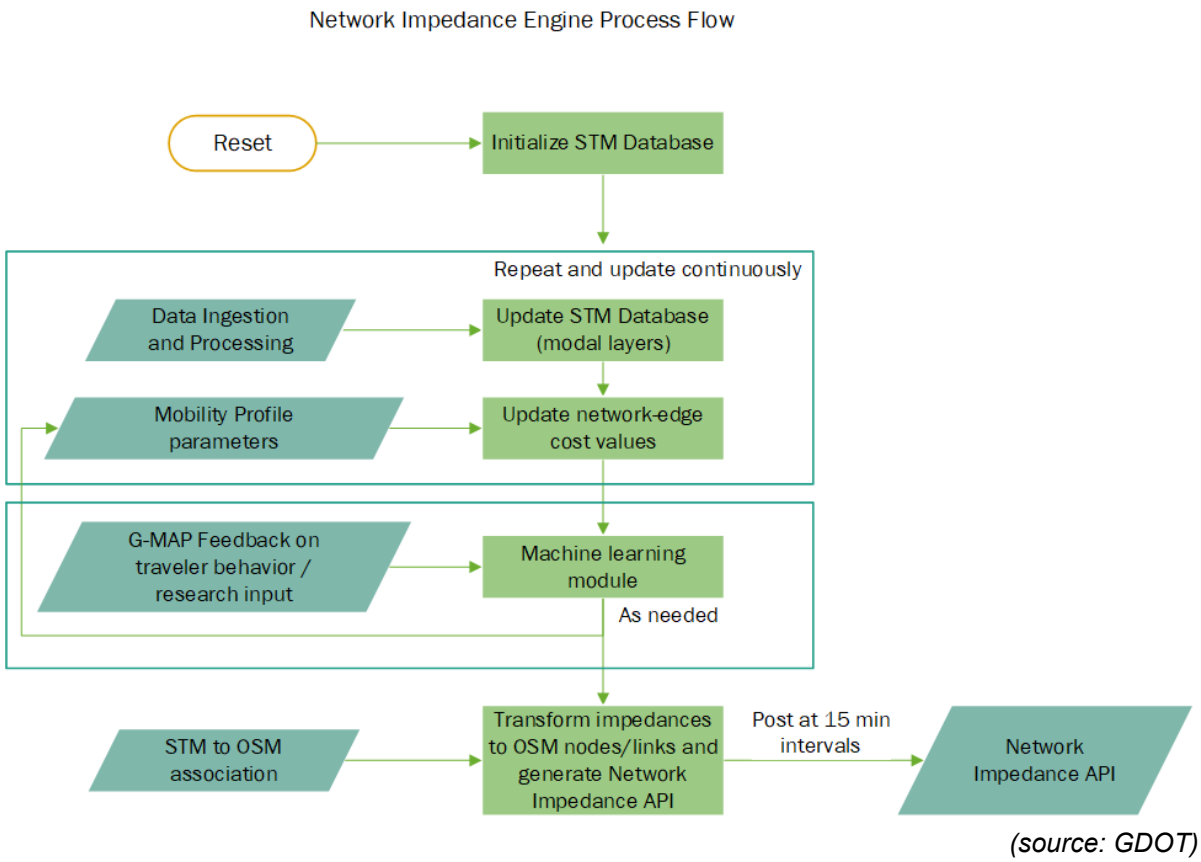


Figure 40. Network Impedance Engine Flow

Table 31. Impedance Computational Engine Functional Elements

Function	Functional Description
Reset / Initialize STM Database	For initialization and resetting STM, regenerate STM database with default network and network edge values**.**
Data Ingestion and Processing	The Impedance Engine transforms the continuously updated simulations (transit, traffic and sidewalk Sim models) from the DInE to an STM database. The updated SIM graphs include awareness of current impedance penalties by integrating real-time information about disruptions, obstacles, and traffic on roads and pathways.
Update STM Database	Update STM database network model with new graph features and conditions from data ingested from DInE.
Mobility Profile Parameters	Existing and dynamic conditions that impact mobility profiles for sidewalk edge costs. The mobility parameter algorithms assign impedance values to different features based on an enumerated set of preferences that are consistent with the G-MAP user-created profiles. The functionality is highly adaptive, allowing GA Tech (STM Operators) to specify any set of impedance functions for various disabilities and ranges, mode, or sub-mode. Initially, each profile is assigned a default set of parameters used to calculate edge costs based on sidewalk conditions.
Update network-Edge Cost calculations	Engine calculates the customized impedance values for traveling on a segment of the trip. Different penalties are associated with sidewalk features based on different mobility profile vulnerabilities. For example, rough sidewalks, crosswalks without curb cuts (or narrow curb cuts), debris or potholes in pathways will score high impedances for people with mobility challenges. Permanent protrusions (i.e., architectural features) and temporary protrusions (i.e., low hanging branches) narrow the walking path and score high impedance values for people with vision loss. Permanent protrusions are documented during the sidewalk inventory.
G-MAP Feedback on Traveler behavior	Information is transmitted from G-MAP on metrics related to traveler trips and their behavior. These are input into the ML module for analysis and updating profile parameters.

Function	Functional Description
Machine Learning (ML) Module	The ML Module serves as the ML function of the STM. This module consumes feedback from traveler's execution of their trip plans and updates the Cost Analysis Engine edge costs based on changes made by users of the tools. The processes interpret planned versus actual travel of various user classes. The ML module is associated with network operating conditions (for use in the real-time impedance elements). These traffic conditions are changing during the pedestrian trip. The assessment of impedance factors based upon deviation from advised trips happens in the research server. There are no set algorithms for doing this (a wide variety of ML approaches were explored), this research and resulting impedance factor updates are managed on-the-fly.
Transform impedance to OSM nodes/links	The STM Network Impedance API communicate changes in network impedance values in OSM/OTP data structures that can be used by the G-MAP app and provided to the public through the Public PMD.
STM to OSM Association	To ensure compatibility with the G-MAP app, the OSM network is regularly updated as machine-learning processes identify network refinements that can increase route efficiency
Network Impedance API	Network impedances for each mobility profile assigned to the OSM network. The API is posted every 15 minutes with incremental changes or the full network. Publication cycles are configurable.

5.6.2 Impedance Calculation Table

The impedance calculation table, a CSV formatted file, provides the impedance calculations used to calculate the impedances for paths and nodes. The impedance calculation table is initially imported to the ICE and may be adjusted depending on tweaks by researchers. However, the ML tools eventually update the embedded table once the system is fully live.

The Impedance Calculation Table is defined as shown in Table 32. **Sections 5.6.2.1** through **5.6.2.8** describe the values that are included in the column "Column Name". An instance of the table is shown in .

When applied, the impedance table results in the generation of the impedance values for each path and node for each mobility mode that is published and transmitted to G-MAP.

Table 32. Impedance Calculation Table

Column Name	Purpose	Notes
Variable Name	The variable from one of the various “SIDEWALK” STM nodes to be used in the calculation.	The “Impedance Effect Type” identifies the STM node to reference.
Variable Description	Description of the variable.	Can be ignored.
Format	Format of the variable value.	Can be ignored but may be useful.
Units	The unit of measure of the variable.	Can be used to determine whether a variable is an enumeration.
Enumeration	For variables that are enumerations, there are multiple rows with the same variable name. Each row has a different value in this column to indicate that it contains the calculation factors to use when the variable is set to that enumeration.	Only one of these rows should be used for any given enumeration variable. If the variable is not an enumeration, this column is empty.
Impedance Effect Type	Indicates the calculation to be performed.	See list of enumerated mnemonic values in Table 33.
Lower Bound	The lower bound in determining how the calculation will be performed.	Empty if not used.
Upper Bound	The upper bound in determining how the calculation will be performed.	Empty if not used.
(Mobility Mode)	The calculation factor for the named mobility mode.	There are multiple columns, one for each mobility mode, indicating the name of the mobility mode for which the calculation factor is to be applied.

5.6.2.1 Variable Name Column

The variables named in this column for each row in the impedance calculation table identify the variable attribute of each “SIDEWALK” STM node that is used in the impedance calculation for that sidewalk link STM node. The “Impedance Effect Type” identifies the node type that should be referenced.

5.6.2.2 Variable Description Column

This column describes the variable and has no utility with regard to the impedance calculation.

5.6.2.3 Format Column

This column describes the format of the variable’s data. This can be “NUMERIC” or “TEXT.” This may be useful information for impedance calculations.

5.6.2.4 Units Column

This column describes the unit of measure represented by the variable's data. Its only utility is to identify variables that are enumerations with a value of "Enumerated" in this column.

5.6.2.5 Impedance Effect Type Column

This column contains instructions for how the impedance calculation is to be performed. It consists of a comma separated list of mnemonics, each one indicates either an operation, a conditional, or a variable type indicator. The mnemonic action is listed in Table 33. Note the actions refer to how the Neptune database impedance attributes (see **Section 5.4**) are calculated.

Table 33. Impedance Effect Type

Mnemonic	Action	Notes
ADD	For each mobility mode column, **add** the column value to the mobility mode impedance in the "IMPEDANCE" link between the two "OSM-NODE" STM nodes being processed.	This mnemonic is mutually exclusive of SUB, MUL, and DIV.
SUB	For each mobility mode column, **sub**tract the column value from the mobility mode impedance in the "IMPEDANCE" link between the two "OSM-NODE" STM nodes being processed.	This mnemonic is mutually exclusive of ADD, MUL, and DIV.
MUL	For each mobility mode column, **mul**tiply the mobility mode impedance in the "IMPEDANCE" link between the two "OSM-NODE" STM nodes being processed by the column value.	This mnemonic is mutually exclusive of ADD, SUB, and DIV.
DIV	For each mobility mode column, **div**ide the mobility mode impedance in the "IMPEDANCE" link between the two "OSM-NODE" STM nodes being processed by the column value.	This mnemonic is mutually exclusive of ADD, SUB, and MUL.
INB	Indicates that the value of the mobility mode impedance in the "IMPEDANCE" link between the two "OSM-NODE" STM nodes must be between the "Lower Bound" and "Upper Bound" column values (inclusive, >= lower and <= upper) before the action can be performed.	This mnemonic is mutually exclusive of INBX, OUTB, and OUTBX.

Mnemonic	Action	Notes
INBX	Indicates that the value of the mobility mode impedance in the “IMPEDANCE” link between the two “OSM-NODE” STM nodes must be between the “Lower Bound” and “Upper Bound” column values (exclusive, > lower and < upper) before the action can be performed.	This mnemonic is mutually exclusive of INB, OUTB, and OUTBX.
OUTB	Indicates that the value of the mobility mode impedance in the “IMPEDANCE” link between the two “OSM-NODE” STM nodes must be outside of the “Lower Bound” and “Upper Bound” column values (inclusive, <= lower or >= upper) before the action can be performed.	This mnemonic is mutually exclusive of INB, INBX, and OUTBX.
OUTBX	Indicates that the value of the mobility mode impedance in the “IMPEDANCE” link between the two “OSM-NODE” STM nodes must be outside of the “Lower Bound” and “Upper Bound” column values (exclusive, < lower or > upper) before the action can be performed.	This mnemonic is mutually exclusive of INB, INBX, and OUTB.
DEFECT	Indicates that this variable references a “-SIDEWALK-DEFECT” STM node.	If none of the following variable type indicators (DEFECT through BUSS) are listed, this variable references a “-SIDEWALK” STM node. All of the variable type indicators are mutually exclusive to all of the others.
RAMP	Indicates that this variable references a “-SIDEWALK-RAM” STM node.	Variable type indicator
CURB	Indicates that this variable references a “-SIDEWALK-CURB” STM node.	Variable type indicator
CUT	Indicates that this variable references a “-SIDEWALK-CURB-CUT” STM node.	Variable type indicator
CROSS	Indicates that this variable references a “-SIDEWALK-CROSSING” STM node.	Variable type indicator
BUSS	Indicates that this variable references a “-SIDEWALK-BUS-STOP” STM node.	Variable type indicator

Mnemonic	Action	Notes
ATOB	Indicates that this row should apply only to the A to B travel direction.	If neither this nor the BTOA mnemonic appear in the list, the row calculation is applied in both travel directions.
BTOA	Indicates that this row should apply only to the B to A travel direction.	If neither this nor the ATOB mnemonic appear in the list, the row calculation is applied in both travel directions.
SPEED	Indicates that the mobility mode columns in this row contain base travel speeds in miles per hour.	No variable is referenced for this type indicator. The speed values are used in calculating travel time.

5.6.2.6 Lower Bound Column

This column is used when the “Impedance Effect Type” column contains one of the bounds conditionals (INB, INBX, OUTB, or OUTBX.) It contains the value to compare for the lower bound condition. If the column is empty, no lower bound should be checked.

5.6.2.7 Upper Bound Column

This column is used when the “Impedance Effect Type” column contains one of the bounds conditionals (INB, INBX, OUTB, or OUTBX.) It contains the value to compare for the upper bound condition. If the column is empty, no upper bound should be checked.

5.6.2.8 Mobility Mode Columns

Each mobility mode as described in **Section 5.3.3** is represented by a column with a heading of the same name. The values in these columns are values used in the calculations dictated by the “Impedance Effect Type” column.

5.6.3 Impedance Calculation

The purpose of the ICE is to calculate impedance values for each mobility mode on each “IMPEDANCE” STM link. The impedance value for a given mobility mode is actually the estimated travel time for a person with that mobility mode to travel the path identified by the “SIDEWALK” STM node associated with the “IMPEDANCE” link. When invoked, it runs one pass through all of the “IMPEDANCE” links currently in the STM database.

Impedance calculations begin with travel time serving as the base impedance for each pedestrian link (travel time = (link distance)/(average speed by mobility mode)). Then the base impedance is adjusted for factors affecting route choice. Some are multiplicative (e.g., uphill grades affect full path), some are additive (e.g., navigating around an obstruction which is considered an event). This calculates to what is referred to as “impedance time.” Each link is assigned a travel time which is multiplied by link factors and then added by event-based impedance factors).

Specifically for a given variable from the impedance calculation table, the associated “Impedance Effect Type,” and a given “SIDEWALK” STM node along with its associated “IMPEDANCE” STM links, the system calculates impedance as defined by these steps:

1. Obtain the value of the variable using the method defined in Table 34**.**

Table 34. Impedance Effect Type and Location of Variable Values

Impedance Effect Type Contains	Location of Variable Value
DEFECT	The “SIDEWALK-DEFECT” STM node linked to the given “SIDEWALK” node via a “DEFECT” STM link if present.
RAMP	The “SIDEWALK-RAMP” STM node linked to the given “SIDEWALK” node via a “RAMP” STM link if present.
CURB	The “SIDEWALK-CURB” STM node linked to the given “SIDEWALK” node via a “CURB” STM link if present.
CUT	The “SIDEWALK-CURB-CUT” STM node linked to the given “SIDEWALK” node via a “CURB-CUT” STM link if present.
CROSS	The “SIDEWALK-CROSSING” STM node linked to the given “SIDEWALK” node via a “CROSSING” STM link if present.
BUSS	The “SIDEWALK-BUS-STOP” STM node linked to the given “SIDEWALK” node via a “BUS-STOP” STM link if present.
None of the above	The “SIDEWALK” STM node.

If the variable value cannot be obtained due to the target STM node not being present, the calculation is aborted.

2. For each of the associated “IMPEDANCE” links:
   a. If the ATOB mnemonic is present in the given “Impedance Effect Type,” the following calculation is only applied to the “IMPEDANCE” link if it links the A node to the B node.
   b. If the BTOA mnemonic is present in the given “Impedance Effect Type,” the following calculation is only applied to the “IMPEDANCE” link if it links the B node to the A node.
   c. If neither the ATOB nor the BTOA mnemonic is present, the following calculation is applied to both “IMPEDANCE” links.
3. Determine if the variable meets the bounds requirements. If not, the calculation is aborted. The bounds check is performed as described in Error! Reference source not found..

Table 35. Impedance Effect Type and Bounds Check

Impedance Effect Type Contains	Lower Bound	Upper Bound	Units
INB	Meets requirement if variable value is greater than or equal to the Lower Bound value or the Lower Bound has no value.	Meets requirement if variable value is less than or equal to the Upper Bound value or the Upper Bound has no value.	If “Units” is “Enumerated”, the bounds check fails and an error is reported to system log.
INBX	Meets requirement if variable value is greater than the Lower Bound value or the Lower Bound has no value.	Meets requirement if variable value is less than the Upper Bound value or the Upper Bound has no value.	If “Units” is “Enumerated”, the bounds check fails and an error is reported to system log.
OUTB	Meets requirement if variable value is less than or equal to the Lower Bound value or the Lower Bound has no value.	Meets requirement if variable is greater than or equal to the Upper Bound value or the Upper Bound has no value.	If “Units” is “Enumerated”, the bounds check fails and an error is reported to system log.
OUTBX	Meets requirement if variable value is less than the Lower Bound value or the Lower Bound has no value.	Meets requirement if variable is greater than the Upper Bound value or the Upper Bound has no value.	If “Units” is “Enumerated”, the bounds check fails and an error is reported to system log.
None of the above	Not used.	Not used.	Meets if “Units” is “Enumerated” and “Enumeration” matches the variable value. If “Units” is not “Enumerated”, the bounds check is always met.

Note that the variable value is only used to determine if the calculation is to be performed. It is not used in the calculation itself.

4. Assuming the calculation has not been aborted, the accumulated impedance value for each of the mobility modes is adjusted using a calculation involving the variable value and the mobility mode factor value associated with the variable from the impedance calculation table. This calculation adjustment is described in Table 36**.**

Table 36. Impedance Effect Type and Adjustment Calculation

Impedance Effect Type Contains	The Accumulated Impedance Value for Each Mobility Mode is Adjusted By
ADD	Adding the mobility mode value from the impedance calculation table to the accumulated impedance value.
SUB	Subtracting the mobility mode value from the impedance calculation table from the accumulated impedance value.
MUL	Multiplying the mobility mode value from the impedance calculation table by the accumulated impedance value.
DIV	Dividing the mobility mode value from the impedance calculation table by the accumulated impedance value.

Note that the mobility mode value in the impedance calculation table is only used as a factor in the impedance calculation. It is not used to determine if the calculation should be performed.

5.6.4 Generating the STM Network Impedance API

The STM Impedance API (ICD Int-6) is generated from Neptune database, formatted into a CSV, as described in **Section 5.5.7**, and transmitted to the G-MAP S3 bucket for retrieval. The file is generated every 15 minutes or when requested by G-MAP. G-MAP is able to request a section of the region using a map grid ID that uniquely identifies the region (see **Section 5.5.1** for grid regions).

An example of the database model and associated table is shown below in Figure 41 and Table 37.

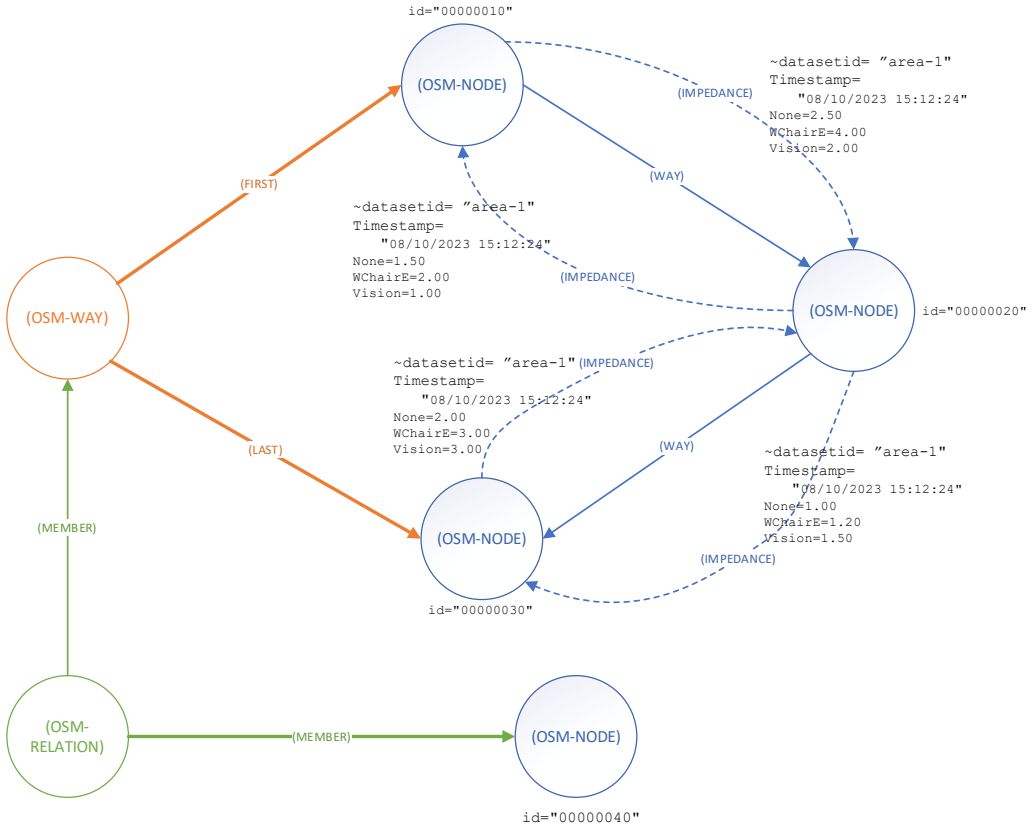


Figure 41. Example Neptune Database Model with Impedance Values associated with OSM-Nodes

Table 37. Example STM Impedance API

Timestamp	Upstream Node	Downstream Node	None	Vision	WChairE
08/10/2023 15:12:24	00000010	00000020	2.50	2.00	4.00
08/10/2023 15:12:24	00000020	00000030	1.00	1.50	1.20
08/10/2023 15:12:24	00000020	00000010	1.50	1.00	2.00
08/10/2023 15:12:24	00000030	00000020	2.00	3.00	3.00

5.7 Performance Measurement Computation Engine (Epic STM-3)

The PMD is used to measure performance for evaluation of the ST-CTN system as well as computing and tracking performance and safety measures. A set of performance measures (

Table 38) measuring the effectiveness, usability, accuracy, and user experience of the ITS4US project are defined in the Extended Metrics Table in Appendix F. Performance Measures and Metrics The majority of the metrics are based on qualitative survey data collected from users, but a subset of these metrics relies on quantitative data collected by the G-MAP mobile application and shared with the STM database. The latter data is ingested through the DInE (see **Section 5.5.6**).

The performance measurement computational engine tracks performance characteristics, such as volume and frequency of requests, response speeds, and data throughput. Comprehensive performance measurement including descriptions and lineage of each metric is described in the PMESP (PMESP2).

Table 38. Performance Measures and Metrics

Performance Measure ID	Performance Measure Name	Goal
CT-PM-1	Enhance Traveler Experience	Goal 1 – Enhance Traveler Experience
CT-PM-2	Improve Accessibility	Goal 1 – Enhance Traveler Experience Goal 4 – Improve Mobility and Accessibility
CT-PM-3	Enhance Complete Trip Pedestrian Safety	Goal 2 – Enhance Safety
CT-PM-4	Enhance Fixed-Route Transit	Goal 1 – Enhance Traveler Experience Goal 3 – Improve Reliability Goal 4 – Improve Mobility and Accessibility
CV-PM-1	Enhance Safety and Awareness with Connected Vehicles	Goal 2 – Enhance Safety
CV-PM-2	Improve Transit Reliability	Goal 3 – Improve Reliability Goal 4 – Improve Mobility and Accessibility

5.7.1 Performance Measurements and Metrics

The performance measures are composed of data processed from user surveys and trace data ingested from G-MAP. The user surveys are divided into two types – in-app survey provided to users who deviate from their trip plan and email distributed links (URL) to a commercial survey instrument provided to users quarterly throughout Phase 3. The quarterly surveys and other data used to generate metrics are collected and published infrequently; hence the data is not stored in the STM or processed automatically.

5.7.2 Processing Performance Measures

Performance measures are calculated for three types of data:

- Previous week's trace data (and in-app surveys)
- Quarterly surveys
- Summary metrics calculated near the end of Phase 3

The following sections describe the weekly performance data, weekly deviation data (including related surveys), quarterly survey data and other performance metrics.

5.7.2.1 Weekly Performance Metrics Process

The trace data or data ingested from G-MAP is the core data that generates the weekly performance metrics. Of the performance metrics being tracked, there are four evaluation values that leverage the G-MAP trace data stored in the STM database. These include the following values (and associated metrics):

1. Average daily user's deviation between recommended ST-CTN system complete trip plan vs. actual ST-CTN system travel routes that were taken. (The information partially supports CT-ME-1.8. The deviation data is used to trigger pop-up surveys in the app to obtain answers to the confidence question).
2. Number of unique ST-CTN system users per day. (CT-ME-1.11).
3. Total number of trips planned and completed by unique ST-CTN system users per day. (CT-ME-1.12).
4. Average daily user's deviation between ST-CTN system complete trip plan and actual ST-CTN system travel routes taken at signalized intersection crossings. (CT-ME-3.2).

For weekly data, the finalized trace data is retrieved from the G-MAP S3 and static metrics are preserved. The endpoint for initiating a refresh of metrics data can be called manually or scheduled to run at the beginning of each week. These weekly metric files are generated and deposited in the STM S3 bucket to be retrieved by the Public PMD (**Section 7**).

The step-by-step process for generating the weekly performance metrics is as follows:

1. Create a weekly metrics JSON file to store calculated metrics for each of the 7 days, as well as the final aggregate values for the week.
2. For each day within the set:
    a. Store the count of TripRequest elements within the TripRequest JSON file; this is the number of trips requested for the day
    b. Store the count of Persona elements within the Persona JSON file; this is the count of unique users for the day associated with CT-ME-1.12 (value 3 from list above).

c. For each TrackedJourney:

    i. Pass the associated MonitoredTrip and TrackedJourney JSON data to a function to calculate the Route Deviation value for the trip (see below).

    ii. Store the returned deviation value.

d. Calculate the daily average trip deviation value based on results from previous step.

e. Append a JSON element to the weekly metrics JSON file containing the calculated daily values for the current date. Logged daily values should include:

    i. Unique user count

    ii. Trips requested count

    iii. Completed trip count

    iv. Average trip deviation

3. Once each set of daily metrics is completed, calculate the aggregate metrics for the week using the daily metrics from the seven-day period and their associated counts related to the list of values above.

4. Append a JSON element to the weekly metrics JSON file containing the calculated weekly values.

5. Copy the weekly metrics JSON file to the STM S3 bucket.

5.7.2.2 Weekly Route Deviation Calculation Process

The most complex metrics being calculated from trip data are those associated with route deviation. This includes CT-ME-1.8 and CT-ME-3.2. The implementation is defined in a dedicated function, called from G-MAP API data ingested from the MonitoredTrip and TrackedJourney pair. The route deviation value is calculated for each trip separately and returned as two numerical values indicative of how much the user's actual route differed from the suggested route, in terms of how far the user had to detour and the number of skipped nodes before returning to the suggested route. The primary route deviation tracks skipped nodes at any point along the route, and a secondary route deviation only tracks skipped nodes that originate at signalized intersections.

Access to the weekly route deviation data is the same as retrieval of the weekly trace data (see **Section 5.7.2.1** above).

The process for calculating route deviation follows:

1. Receive MonitoredTrip and TrackedJourney JSON as parameters

2. Create list for storage of traversed nodes

3. For each element in TrackedJourney “locations” array:
    a. Match each latitude and longitude pair to nearest OSM-WAY nodes based on orthogonal distance
    b. Repeated nodes are typically the result of user’s traversal time or stationary periods
    c. If associated node is valid/non-repeated, append to list of traversed nodes
4. Store index of initial suggested node from MonitoredTrip “steps” array
5. Initialize both route deviation and signalized intersection route deviation values to 0
6. Initialize signalized intersection crossing flag to false
7. For each element in ordered list of traversed nodes:
    a. Compare to current index suggested nodes from MonitoredTrip “steps” array(s)
    b. If (traversed node matches suggested node):
        i. If traversed node is at a signalized intersection crossing:
            1. Set signalized intersection crossing flag to true
        ii. Else:
            1. Set signalized intersection crossing flag to false
        iii. No deviation at this step
        iv. Increment suggested node index
        v. Proceed to next traversed node
    c. Else:
        i. Iterate through traversed nodes from current position until reaching a node that exists within suggested node values
        ii. Increment route deviation value by number of iterations; this is effectively the count of skipped nodes before returning to suggested route
        iii. If signalized intersection crossing flag is true:
            1. Increment signalized intersection route deviation value by the same number calculated above
        iv. Set suggested node index to next position
        v. Proceed to next traversed node
8. Return calculated route deviation value

The function returns a JSON object containing multiple route deviation values associated with deviations initiated along any point of the route which corresponds to metric: CT-ME-1.8. It also deviates at a signalized intersection which corresponds to metric: CT-ME-3.2. Within the returned

JSON object, the CT-ME-1.8, or those initiated at signalized intersections CT-ME-3.2. The primary keys for each deviation type is “numDeviations” or “numIntersectionDeviations”.

There are two types of route deviation values returned from the calculate_deviations function, along with a few related values. An example of the JSON object returned from the function is provided below:


```
{
"deviatedLinks": 3,
"timestampsDeviated": 5,
"numDeviations": 8,
"numIntersectionDeviations": 13,
"completed": 21,
"fixedTransit": 34
}
```


5.7.2.3 Processing for Quarterly Survey Performance Metrics

On a quarterly basis, the performance measurement team includes a pop-up in the app with a link to a commercial survey instrument. The survey remains the same for each of the four quarters during which the survey is conducted. The survey questions, shown in Table 39, address user experience measures. The aggregated results are sent via comma delimited file to the Public PMD with metadata that includes number of responses, time period, and publication date. All PII is removed from the aggregated file.

Table 39. User Experience Survey Questions

ID	Survey Question	Associated Metric ID
1	Has G-MAP enhanced your overall travel experience? 1 - Definitely yes 2 - Probably yes 3 - Maybe 4 - Probably not 5 - Definitely not 6 - Don't know 7 - Prefer not to answer	CT-ME-1.1.1
2	Please indicate on a scale of 10 (extremely likely) to 10 (not at all likely) how likely you are to recommend G-MAP to others? Extremely Likely ○ 10 ○ 9 ○ 8 ○ 7 ○ 6 ○ 5 ○ 4 ○ 3 ○ 2 ○ 1 Not at all Likely ○ Don’t know ○ Prefer not to answer	CT-ME-1.1.2
3	Is G-MAP easy to use for planning your travel? 1 - Definitely yes 2 - Probably yes 3 - Maybe	CT-ME-1.2

ID	Survey Question	Associated Metric ID
	4 - Probably not 5 - Definitely not 6 - Don't know 7 - Prefer not to answer	
4	Do G-MAP's features and functions enhance your travel experience? 1 - Definitely yes 2 - Probably yes 3 - Maybe 4 - Probably not 5 - Definitely not 6 - Don't know 7 - Prefer not to answer	CT-ME-1.3.1
5	What features and functions do you value most (please check all that apply): 1 - Suggested routing 2 - App alerts and notifications 3 - Advance transit stop requests 4 - Automated activation of pedestrian crossing signals 5 - Other (please specify): [comment field] 6 - Don't know 7 - Prefer not to answer	CT-ME-1.3.2
6	Do you have a trusted companion that uses G-MAP with you? [If yes, ask the next question, otherwise skip the next question] 1 - Yes 2 - No 3 - Don’t know 4 - Prefer not to answer	CT-ME-1.4.1
7	Does G-MAP's access by your trusted companion enhance your travel experience? 1 - Definitely yes 2 - Probably yes 3 - Maybe 4 - Probably not 5 - Definitely not 6 - Don’t know 7 - Prefer not to answer	CT-ME-1.4.2
8	Have you used G-MAP's call center support in the past three months? [If yes, ask the next question] 1 - Yes 2 - No	CT-ME-1.5.1

ID	Survey Question	Associated Metric ID
	3 - Don't know 4 -Prefer not to answer	
9	Does G-MAP's call center support help you complete your trip independently? 1 - Definitely yes 2 - Probably yes 3 - Maybe 4 - Probably not 5 - Definitely not 6 - Don't know 7 - Prefer not to answer	CT-ME-1.5.2
10	Did you travel to any of the following destinations using G-MAP? Please select all new destinations that apply. 1 - Employment 2 - Education 3 - Social or recreational activities 4 - Health care 5 - Shopping 6 - Other (please specify): [Comment field] 7 - Don’t know 8 - Prefer not to answer	CT-ME-1.9
11	Does G-MAP help give you additional time in your schedule to do other activities? 1 - Always 2 - Most of the time 3 - Some of the time 4 - Hardly ever 5 - Never 6 - Don't Know 7 - Prefer not to answer	CT-ME-2.2.1
12	Does G-MAP help you reduce time and stress in travel planning? 1 - Always 2 - Most of the time 3 - Some of the time 4 - Hardly ever 5 - Never 6 - Don't Know 7 - Prefer not to answer	CT-ME-2.2.2
13	Does G-MAP increase your awareness and confidence to travel independently? 1 - Always 2 - Most of the time 3 - Some of the time	CT-ME-2.2.3

ID	Survey Question	Associated Metric ID
	4 - Hardly ever 5 - Never 6 - Don't Know 7 - Prefer not to answer	
14	Does G-MAP help you schedule trips more reliably? 1 - Always 2 - Most of the time 3 - Some of the time 4 - Hardly ever 5 - Never 6 - Don't Know 7 - Prefer not to answer	CT-ME-2.2.4
15	Has G-MAP improved your quality of life? 1 - Definitely yes 2 - Probably yes 3 - Maybe 4 - Probably not 5 - Definitely not 6 - Don’t know 7 - Prefer not to answer	CT-ME-2.2.5
16	Do you feel safer using G-MAP to plan and take trips? 1 - Definitely yes 2 - Probably yes 3 - Maybe 4 - Probably not 5 - Definitely not 6 - Don’t know 7 - Prefer not to answer	CT-ME-3.1
17	How often do you take a different route than the one G-MAP's recommended? 1 - Very frequently 2 - Frequently 3 - Sometimes 4 - Not very often 5 - Never 6 - Don’t know 7 - Prefer not to answer	CT-ME-3.3.1
18	If you sometimes take different routes than are recommended by G-MAP, can you please tell us why you take these routes so that we can improve our directions? For example, have you found that recommended routes are too long, too steep, too rough, missing a curb ramp, etc.? Please	CT-ME-3.3.2

ID	Survey Question	Associated Metric ID
	provide any input that you feel is relevant in the box below. Please explain: [Comment Field]	
19	Do you use G-MAP when making trips by transit (e.g., RIDE Gwinnett)? [If yes, ask the following eight transit questions] 1 - Yes 2 - No 3 - Don't know 4 - Prefer not to answer	CT-ME-4.3.1
20	Has G-MAP enhanced your experience while using regular transit service? 1 - Definitely yes 2 - Probably yes 3 - Maybe 4 - Probably not 5 - Definitely not 6 - Don't know 7 - Prefer not to answer	CT-ME-4.3.2
21	Is it easier to ride the bus when you use G-MAP? 1 - Definitely yes 2 - Probably yes 3 - Maybe 4 - Probably not 5 - Definitely not 6 - Don't know 7 - Prefer not to answer	CT-ME-4.3.3
22	Do you feel safer taking the bus when you use G-MAP? 1 - Definitely yes 2 - Probably yes 3 - Maybe 4 - Probably not 5 - Definitely not 6 - Don't know 7 - Prefer not to answer	CT-ME-4.3.4
23	Has G-MAP reduced the amount of time you have to wait for the bus to arrive? 1 - Definitely yes 2 - Probably yes 3 - Maybe 4 - Probably not 5 - Definitely not 6 - Don't know 7 - Prefer not to answer	CT-ME-4.3.5

ID	Survey Question	Associated Metric ID
24	Does G-MAP help you feel more confident to ride the bus? 1 - Definitely yes 2 - Probably yes 3 - Maybe 4 - Probably not 5 - Definitely not 6 - Don't know 7 - Prefer not to answer	CT-ME-4.3.6
25	Does G-MAP enhance your ability to plan trips using the bus? 1 - Definitely yes 2 - Probably yes 3 - Maybe 4 - Probably not 5 - Definitely not 6 - Don't know 7 - Prefer not to answer	CT-ME-4.3.7
26	Do you feel safer crossing the street using G-MAP? 1 - Definitely yes 2 - Probably yes 3 - Maybe 4 - Probably not 5 - Definitely not 6 - Don't know 7 - Prefer not to answer	CV-ME-1.1
27	Do you miss fewer transit pickups by using G-MAP? 1 - Definitely yes 2 - Probably yes 3 - Maybe 4 - Probably not 5 - Definitely not 6 - Don't know 7 - Prefer not to answer	CV-ME-2.4

5.7.2.4 Processing for other Performance Metrics

Processing for other performance metrics is completed manually and formatted into a comma delimited file with headers. Along with the weekly metrics files, these summarized performance measurement files are deposited into the STM S3 bucket for retrieval by the public PMD. Data summaries include PPA, enhanced TSP and PED-X actuation request operational data summaries from the CV subsystem, and transit on-time performance, schedule (GTFS/GTFS-realtime), and complaints (anonymous) / commendations from Ride Gwinnett and the G-MAP feedback responses, among other data. Refer to the PMESP and CMOP documents for further details regarding data collection and schedule.

As listed in the metrics table (Table 62), many of these files are generated once or only a few times throughout the Phase 3 period.

5.8 STM Requirements Traceability to Design

The CV design elements that meet the requirements are listed in Table 40.

Table 40. STM Design to Requirements Traceability

Req ID	Req Title	Req Statement	Status	Section
1.3.0-026	STM Core Functionality	The system shall leverage the existing STM functionality and interfaces as the core STM subsystem for the ST-CTN. Leverage implies that we adapt and enhance existing functionality.	Unchanged	5.2 5.3.1 5.3.2 5.5
1.3.0-027	Logical Mobility Categories	The system shall define logical groupings of "VRU categories" that will be used to tailor impedance values based on transportation network features, attributes and conditions (as selected by travelers of similar abilities and preferences). Specifically, the VRU categories are characterized by their severity of movement with respect to ADA design features.	Updated	5.3.3
1.3.0-028	Impedance Factor Algorithms	The STM platform shall implement processes (algorithms) that produce impedance values that apply to VRU group abilities and are associated with the Whole Road Network (see DMP Data ID-3).	Unchanged	5.3.3
1.3.0-029	Learning Impedance Factors	The STM platform shall incorporate feedback from traveler choices including but not limited to deviations from planned trip and traveler comments on trip plan to update the coefficient impedance values.	Unchanged	5.6.1
1.3.0-030	Updating Network Impedance Factors	The STM Platform shall incorporate feedback on updated static features including but not limited to, from work zone, event data, to tailor the	Updated	5.6.1

Req ID	Req Title	Req Statement	Status	Section
		impedance values in the operational engine (using existing algorithms).		
1.3.0-031	Updating Real-Time Impedance Factors	The STM platform shall incorporate feedback on updated dynamic features, attributes, and condition, including but not limited to, from work zone and event data, to tailor the impedance values in the operational engine (using existing algorithms).	Updated	5.6.1
1.3.0-032	Static Generating Impedance Factors	The STM platform shall regenerate the impedance values for each Mobility Category by incorporating any updated static changes to the network features, attributes or conditions at a frequency that is commensurate with the incoming information. The rate of regeneration will be identified during Phase 2 of the ST-CTN project.	Updated	5.6.1
1.3.0-033	Dynamic Generating Impedance Factors (Pedestrian Network)	The STM Platform shall regenerate the impedance values for each Mobility Category by incorporating any updated dynamic changes to the network features, attributes or conditions at a frequency that is commensurate with the incoming information.	Updated	5.3.1.3 5.6.1
1.3.0-034	Publish Impedance Factors (network impedance API)	The STM platform shall publish impedance values by VRU group via the network impedance API (DMP Data ID-25) to subscribers including G-MAP. The rate of publication will be identified during Phase 2 of the ST-CTN project.	Unchanged	5.6.4
1.3.0-035	Complete Paths Network Composition	The STM Platform shall reconcile multiple transportation networks to generate a Whole Road Network (DMP Data ID-3). The Whole Road Network (DMP Data ID-3) will relate planning, operations, transit, public right of way, public transportation networks, their features, assets,	Updated	5.3.2

Req ID	Req Title	Req Statement	Status	Section
		attributes, and conditions. Specific transportation networks that will be conflated to generate the Whole Road Network are listed in the DMP Table 6. Details of the reconciliation will be documented in the data curation plan associated with the Whole Road Network as specified by Req 6.1.0-148.		
1.3.0-036	Whole Road Network Attributes Update	The STM platform shall update the Whole Road Network attributes as new conditions are ingested. The updated datasets that contribute to the road network include at a minimum: 1. signal control data, and 2. traffic congestion	Updated	5.3.2
1.3.0-037	Complete Paths Network and OSM: Related to Ped Network	The system shall employ the same link-and-node structure for the Whole Road Network and OSM such that all network links tracked in the STM are mapped to routing links in the OSM for impedance data flow. Use of the OSM nodes and attributes will provide scalability beyond the ST-CTN project and also be compatible with the OTP upon which the G-MAP subsystem is based.	Updated	5.3.2 5.5.2
1.3.0-038	Import Road Network Data	The STM platform shall apply a curation process for each network road dataset. The curation process shall consist of the following processes: import (acquisition), extract, validate, transform, and load functions. (See data curation Req 6.1.0-148)	Updated	5.3.2 5.5.2 5.5.3
2.1.3-077	Continuous Publication of Network Impedance API	The STM Platform shall publish, at periodic intervals, the Network Impedance API that disseminates updated impedance values based on complete paths updates. At a	Updated	5.6.4

Req ID	Req Title	Req Statement	Status	Section
		minimum, the duration between distribution will be at 15 minutes intervals.		
2.3.0-081	Open Architecture	The system shall exchange data using open APIs including but not limited to REST, JavaScript Object Notation (JSON), XML or comma delimited separated datasets.	Unchanged	5.2 5.5
3.1.0-100	GCT Registered Inaccessibility Complaints	GCT shall provide anonymized inaccessibility complaints when received by their existing customer complaint systems to the STM Performance Measurement Dashboard.	Unchanged	5.7.2.4
3.1.0-101	GCT Fixed Route Ridership	GCT shall provide fixed-route ridership data to the STM Performance Measurement Dashboard at a minimum on a monthly basis. The specific content and frequency of the dataset shall be specified during Phase 2 of the ST-CTN project.	Unchanged	5.7.2.4
3.1.0-103	GCT GTFS	GCT shall provide GTFS data feeds to the STM Performance Measurement Dashboard.	Unchanged	5.7.2.4
3.1.0-104	GCT GTFS-RT	GCT shall provide GTFS-RT data feeds to the STM Performance Measurement Dashboard.	Unchanged	5.7.2.4
6.1.0-158	STM Manage Signal Control Data	The STM Platform shall subscribe to and implement a data curation process for signal control data from the CV subsystem.	Updated	5.5.5, 5.7.2.4
6.1.0-249	STM Ingestion of Traffic Information Data	The STM Platform shall ingest traffic information data, which includes Waze and TMC data.	Added	5.5.4.1 5.5.5.1
7.1.0-201	Traveler Trip Tracking Data	The G-MAP shall acquire traveler trip tracking data at a frequency sufficient for the STM Performance Measure module to analyze metrics in accordance with the PMESP. The	Unchanged	5.7.2.1 5.7.2.2

Req ID	Req Title	Req Statement	Status	Section
		rate of collection will be developed during Phase 2. The data will be stored and forwarded as part of Req 7.3.0-209 Publish Travel Statistics.		
7.2.0-207	Trip Feedback Reports	G-MAP shall request that users provide feedback on their complete trip travel experience through a survey. Response to the survey shall be limited such that a traveler is not requested to respond after every trip. Survey questions shall include topics such as, complete trip experience, features and functions, usability, caregiver support, call center support, persons with LEP usability, employment, quality of life, trip type, traveler perception of safety, traveler non-incident experiences, and missed connections.	Unchanged	5.7.2.3
7.3.0-208	Ingest Travel Statistics	"The STM Platform shall ingest general trip statistics for account holders. The types of statistics will be driven by PMESP and stakeholder input during the Agile Development Process. The general trip statistics may include: • Average duration (by leg) and standard deviation of saved trips (e.g., typical commute) • Miles traveled (by each mode) • Number of notifications received by different communication channels and UI methods • Deviations from planned trip plans for actual trips taken • Anonymized trip histories (planned, actual) • Complete trip travel times • Number and variety of destination types	Unchanged	5.7.2.1 5.7.2.2

Req ID	Req Title	Req Statement	Status	Section
7.3.0-210	Subscribe and Ingest CV Message Logs	The STM subsystem shall ingest message logs from the central signal control system which includes PED-X application transactions on a daily basis at a minimum.	Updated	5.7.2.4
7.3.0-211	STM Ingestion of G-MAP Subsystem Monitoring	The STM Platform shall ingest the G-MAP subsystem health and operational status logs (defined in Req 2.1.1-063) to the STM performance measurement dashboard on a daily basis.	Unchanged	5.7.2.4
7.3.0-212	STM Ingestion of STM Subsystem Monitoring	The STM Platform shall ingest the STM subsystem health and operational status logs (defined in Req 2.1.1-064) to the STM performance measurement dashboard on a daily basis.	Unchanged	5.7.2.4
7.3.0-213	STM Ingestion of CV Subsystem Monitoring	The STM Platform shall ingest the CV subsystem health and operational status logs (defined in Req 2.1.1-065) to the STM performance measurement dashboard on a daily basis.	Unchanged	5.7.2.4
7.3.0-214	STM Ingestion of GCT Registered Inaccessibility Complaints	The STM Platform shall ingest GCT provided anonymized complaints on inaccessibility.	Unchanged	5.7.2.4
7.3.0-215	STM Ingestion of GCT Fixed Route Ridership	The STM Platform shall ingest GCT fixed-route ridership data daily. At a minimum, ridership data includes the local service and may include the express routes.	Unchanged	5.7.2.4
7.3.0-217	STM Ingestion of GCT GTFS	The STM Platform shall ingest GCT GTFS data feeds as the updated files are published.	Unchanged	5.7.2.4
7.3.0-218	STM Ingestion of GCT GTFS-RT	The STM Platform shall ingest GCT GTFS-RT data feeds as published.	Unchanged	5.7.2.4
7.3.0-219	Analyze Trip Performance	The STM performance measurement computation engine shall generate measures that show traveler	Updated	5.7

Req ID	Req Title	Req Statement	Status	Section
		behavior based on the planned and actual trips. The details of the statistics will be driven by the PMESP.		

6 Integrated COTS/Existing Systems

This section includes elements (COTS and existing systems) that are integrated with the STM or G-MAP or existing systems that we leverage to provide additional safety features for travelers, particularly pedestrians. The specific integration elements include the following:

- CV Subsystem applications (**Section 6.1**) -- data feeds and enhanced TSP operations
- INS – SaaS and hardware (**Section 6.2**)
- Ride Request – Related Ride Gwinnett's CAD/AVL features (**Section 6.3**)
- PED-X – proxy server PED-X handler software (**Section 6.4**)

This section describes the COTS and existing system features. Specifics about integration with G-MAP and STM are discussed in **Sections 4** and **5**, respectively.

6.1 Connected Vehicle Subsystem

6.1.1 CV Data Feeds

The CV Data feeds include data retrieved from the GDOT NaviGAtor system and PPA from the CV Data Hub which is part of the Gwinnett Smart Corridor. The ST-CTN uses the security controls inherited from the CV system for all access to data.

GDOT NaviGAtor data is acquired as a STM subscription and described in **Section 5.5.5**.

The PPA broadcast from the set of signalized intersections deployed with PED-X is used to generate metrics (see Appendix F. Performance Measures and Metrics). Summary data is requested from GCDOT and manually delivered from the CV Data Hub and compared to the G-MAP Travel Histories (G-MAP API).

The PPA is issued from the Roadside Units (RSU) that are managed by GCDOT. A list of RSU locations deployed by ST-CTN are included in the CMOP Appendix (Section 11.1). The data curation and maintenance processes for managing the units are internal to GCDOT. The process for requesting and updating the devices is included in the CMOP.

Signal control cycle timing and TSP results are stored and managed by GCDOT. The data curation and maintenance processes for managing the systems and data are internal to GCDOT. The process for requesting and updating the system data is included in the CMOP.

The deployment of additional RSUs in the corridor extends the functionality of the CV PED-SIG functionality (e.g., PPA broadcasts) to additional intersections. The implementation is triggered by the PED-X actuation request (see **Section 6.4**). Furthermore, it is used by the TSP deployment to

track the bus OBU along the road network through MAP data (see **Section 6.1.2**). RSU configuration is the responsibility of GDOT and Gwinnett DOT external service contracts.

6.1.2 Enhanced TSP

The enhanced TSP provides a G-MAP traveler with a mobility profile who is waiting at a transit stop. A bus wherein a traveler requests a Ride Request (**Sections 4.6.2** and **6.3**) is prioritized through all the intersections between its current location and the passenger's destination stop. The priority is reduced to no delay (from any configurable delay buffer that may exist).

The current TSP is implemented using an OBU which is a Cradlepoint modem on each bus deployed with TSP. The vehicle request for TSP did not change. The only change is the logic that triggers the priority timing. For example, if the TSP is triggered when the bus is 5 minutes behind schedule, the enhanced TSP logic reduces the delay buffer to 1 minute behind schedule.

A TSP Policy Server was created to interface to the GCT vehicles that are part of the Smart Corridor Deployment Program. This server acts as a security gateway to manage the request from the G-MAP server.

High-Level Operation

The County currently sets a default TSP policy defined as the number of minutes behind schedule that a bus is allowed to request TSP if the threshold is exceeded. This can be anywhere from 1 minute to 30 minutes. Enhanced TSP is implemented as a specific TSP policy that deviates from the County's default TSP policy for only a segment of a G-MAP rider's trip, such that the behind schedule threshold is set to 1 minute behind schedule. The logic is detailed in Table 41.

Table 41. Default TSP Policy vs. Enhanced TSP Policy

Default TSP Policy	ITS4US Enhanced TSP Policy
IF bus is X minutes behind schedule **THEN** request tsp **ELSE** do not request tsp Note: Threshold can be 1min $\leq$ X $\leq$ 30min	**IF** enable enhanced tsp **AND IF** bus is 1 minute behind schedule **AND IF** current bus stop id **NOT EQUAL** to rider stop id **THEN** request tsp **ELSE** do not request tsp

When G-MAP generates a ride request and sends a payload to the Avail (aka Ride Request / Gwinnett CAD) system, G-MAP sends the same payload to the TSP Policy Server to populate a policy bulletin. This policy bulletin is accessed by all Transit buses equipped with TSP capability. If enhanced TSP is enabled for a particular transit vehicle, the TSP logic on the transit vehicle will change its behind schedule policy to 1 minute and maintain this Enhanced TSP policy until either (1) it reaches the rider's destination stop or (2) the rider cancels the request. The transit vehicle then changes the policy back to the County's default policy.

The enhanced TSP remains active while all users request the service. If there are multiple users on the same vehicle, then the enhanced TSP remains active from the earliest stop to the farthest stop requested.

To illustrate this in action, it is helpful to show it visually through a sequence diagram (see Figure 42). Each box at the top represents a system. Dashed lines indicate communication between the systems. The diagram is read from top to bottom, with time increasing downwards. The cancel request follows a similar flow with the payload (msg_type = 0).

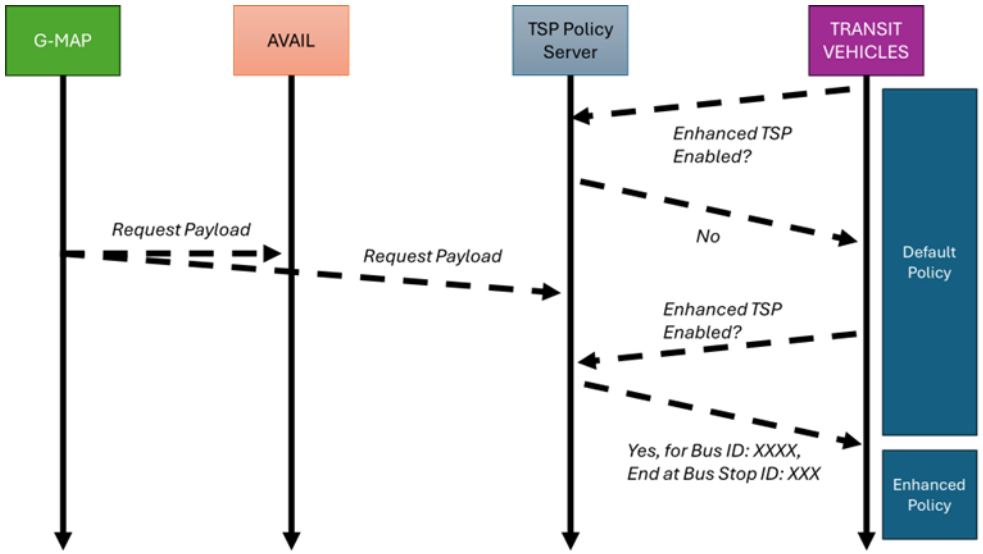


Figure 42. Enhanced TSP Message Logic Diagram including Ride Request (AVAIL)

The following is assumed:

- It is **not** possible to determine if a rider is at the stop or on the bus. This is a privacy preserving feature of the G-MAP system that was instated in collaboration with Gwinnett County.
- Gwinnett has a 10 minute default threshold currently; therefore, all buses currently follow a 1 minute behind schedule threshold. However, this could change as the GCDOT may decide to increase the threshold.

As shown in Figure 42, G-MAP sends a message with trip and stop information to the TSP Policy Server when it detects the traveler is near the bus stop. The policy server is a message queue that stores the requests to activate or cancel enhanced priority. It operates independently from the Ride Request API described in **Sections 4.6.2** and **6.3** and the ICD Int-12. The TSP Policy is polled by the TSP Cradlepoint Agent at a configurable frequency (initially every 5 minutes). It then directs the message to the modem in the appropriate bus, activates the logic (Figure 43), and, when it nears an RSU, sends a message to prioritize the vehicle at the signalized intersection.

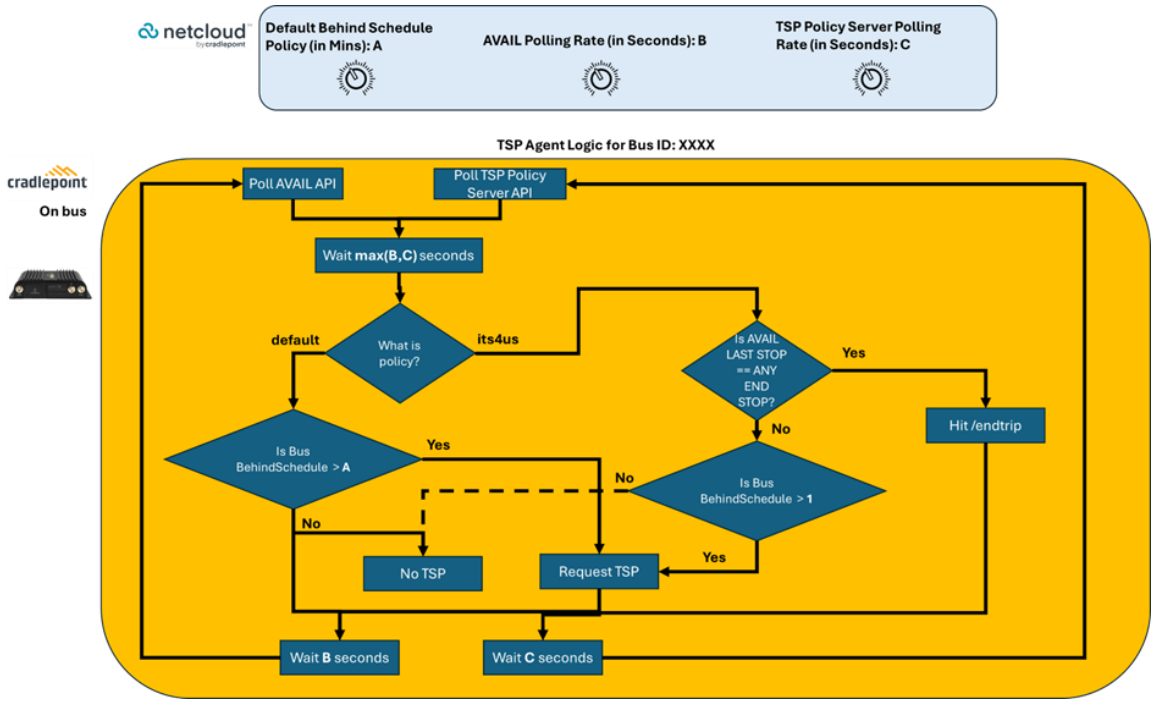


Figure 43. Enhanced TSP Logic Flow

TSP Policy Server Updates the Policy Enable Bulletin

TSP Policy Server Uses the **from_trip_id** value to poll GTFS, to resolve the Vehicle ID number. With the vehicle ID and the **to_stop_id** from G-MAP, the TSP Policy Server populates a JSON data structure called a Policy Enable Bulletin, hosted at: *tsppolicyserver.gcdot/policy?vid=XXXX* where XXXX is the vehicle ID of the transit vehicle currently polling the TSP Policy Server.

If Enhanced TSP is enabled for the current vehicle, the Policy Enable Bulletin returns:

```
{
policy: "its4us",
end_stop_id: xxx
}
```

Where `xxx`, is the **to_stop_id** from the initial G-MAP trip/route request.

If enhanced TSP is disabled for the current vehicle, the Policy Enable Bulletin returns:

```
{
policy: "default"
}
```

TSP Policy Server Updates the Policy Enable Bulletin When Same Bus Gets Multiple Requests from G-MAP

The TSP Policy Server handles multiple rider requests by appending the latest **to_stop_id** to the end stop id field of the Policy Enable Bulletin.

If Enhanced TSP is enabled for the current vehicle, the Policy Enable Bulletin returns:

```
{
policy: "its4us",
end_stop_id: xxx, yyy
}
```

Where `xxx and yyy`, are the **to_stop_id** from the initial G-MAP trip/route request and latest G-MAP trip/route request. The TSP logic on the bus tracks if the bus has reached any of the **end_stop_ids.** When it does reach an **end_stop_id**, it will configure the TSP Policy Server to remove the current matching **end_stop_id** by triggering:
tsppolicyserver.gcdot/endtrip?vid=XXXX,stopid=yyy

Once all **end_stop_ids** are removed, the Policy Enabled Bulletin disables the Enhanced TSP Policy, changing the TSP policy back to the default settings. See Table 42 for the sequence of messages sent to the OBU to activate Enhanced TSP, end Enhanced TSP, and revert to default settings. The functional architecture diagram is depicted in Figure 44.

Table 42. Sequence of Message for Enhanced TSP to OBU

Current Policy Enable Bulletin	After / endtrip	After end_stop_id empty

{
policy: "its4us",
end_stop_id: xxx
}
	{
	policy: "its4us",
	end_stop_id:
	[empty]
	}
		{
		policy: "default"
		}

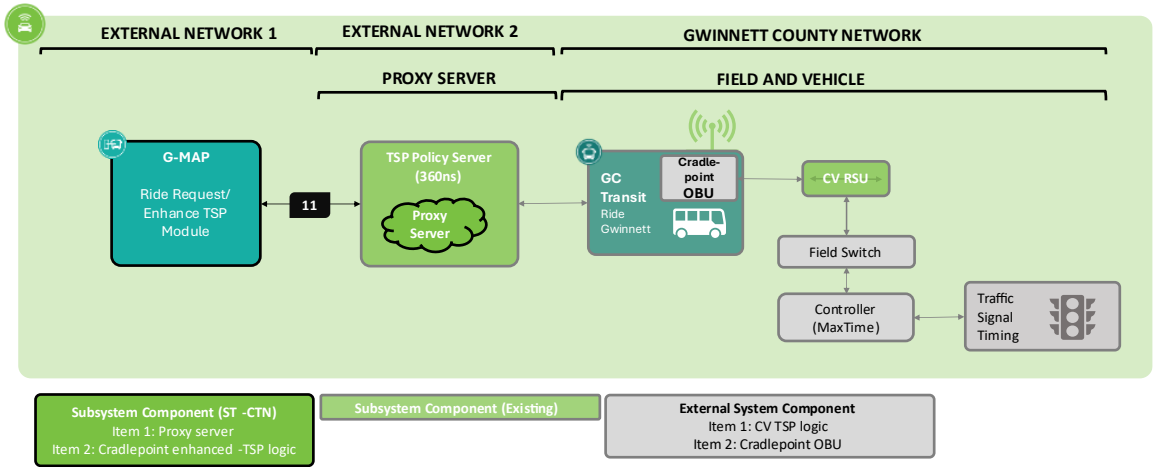


Figure 44. Enhanced TSP Functional Architecture and Information Flow

The RSU tracks the vehicle OBU to match it against MAP data. When the OBU deviates from the MAP path, the TSP is temporarily suspended.

6.1.3 CV Requirements Traceability to Design

The CV design elements that meet the requirements are listed in Table 43.

Table 43. Connected Vehicle Design to Requirements Traceability

Req ID	Req Title	Req Statement	Status	Section
1.1.0-005	Enforce Security Policies	The system shall implement and enforce provisions of the system security policies (see SyRS Section 3.9). Details of policies will be developed with ST-CTN partners and IRB provisions in Phase 2.	Unchanged	6.1.1 6.1.2
3.3.0-107	Smart Corridor TSP Core Functionality	The system shall utilize the Smart Corridor TSP functionality, interfaces, architecture and infrastructure as the core CV platform for the ST-CTN. Smart Corridor core functionality will be documented and published during Phase 2.	Unchanged	6.1.2

Req ID	Req Title	Req Statement	Status	Section
3.3.0-109	Smart Corridor Pedestrian Presence Core Functionality	The system shall utilize the Smart Corridor Pedestrian Presence functionality, interfaces, architecture and infrastructure as the core CV platform for the ST-CTN. Smart Corridor core functionality will be documented and published during Phase 2.	Unchanged	6.1.1
3.3.0-110	Smart Corridor Pedestrian Presence Alert Enhancements	The system shall enhance the Pedestrian Presence Alert by identifying additional strategies. Strategies include but are not limited to remote activation of pedestrian crossing request.	Unchanged	6.1.1, 6.4
4.1.0-111	CV and ATMS Core Functionality	The system shall utilize the existing core CV and ATMS functionality, interfaces, architecture, infrastructure (including RSU, OBU, communications and security) to provide mobile accessible pedestrian features at signalized intersections. CV and ATMS core functionality will be documented and published during Phase 2.	Unchanged	6.1.1
5.1.0-137	CV Core Functionality	The system shall utilize the existing core CV functionality, interfaces, architecture, infrastructure (including RSU, OBU, communications and security).	Unchanged	6.1.1 6.1.2
5.1.1-143	Smart Corridor Pedestrian at Intersection - for Bus Alerts	The ST-CTN project team shall coordinate testing to verify Smart Corridor implementation of pedestrian bus alerts. The CV RSU shall send a safety warning to a transit vehicle via its OBU as it approaches or turns at an intersection where the RSU received a PPA or PED-X SRM. The Smart Corridor project will implement this function as part of the Smart Corridor core functionality.	Unchanged	6.1.1

Req ID	Req Title	Req Statement	Status	Section
5.1.1-144	Smart Corridor Pedestrian at Intersection - for Vehicle Alerts	The ST-CTN project team shall coordinate testing to verify Smart Corridor implementation of pedestrian vehicle alerts. The CV RSU shall send a safety warning to vehicles via their OBUs as it approaches or turns at an intersection where the RSU received a PPA or PED-X SRM. The Smart Corridor project will implement this function as part of the Smart Corridor core functionality.	Unchanged	6.1.1
5.1.2-145	ST-CTN and CV Applications Testing Coordination - PED-SIG	The ST-CTN project team shall coordinate CV PED-SIG testing, including elements related to end-to-end timing, security, message processing and management.	Unchanged	6.1.1 Testing included end-to-end coordination to ensure that the RSUs included the correct modules to broadcast the PPAs. This effort was part of the Gwinnett DOT responsibility.
6.1.0-150	CV Signal Control Data Access	The CV subsystem shall provide access to traffic management system data and control data including: 1. PPA, 2. signal control data.	Updated	

Req ID	Req Title	Req Statement	Status	Section
6.1.0-153	Import Traffic/Transit Asset Data	The system shall implement a data curation process for IOO asset information (e.g., traffic signal locations, RSU locations) as described by the DMP. Note: The requirement for a curation process for each dataset is described in [SyRS] Section 3.10.1.	Unchanged	6.1.1 Maintenance issues associated with CV data are shown the CMOP.
6.1.0-164	ST-CTN and CV Publish and Subscribe Testing Coordination - MAP	The ST-CTN project team shall coordinate CV publish and subscribe testing to verify receipt of existing published CV subsystem MAP data.	Unchanged	6.1.1, 6.1.2
6.1.0-180	ST-CTN and CV Publish and Subscribe Testing Coordination - PPA	The ST-CTN project team shall coordinate CV publish and subscribe testing to verify receipt of existing published CV subsystem PPA data.	Updated	6.1.1

6.2 Indoor Navigation System

The INS design aims to assist users in navigating complex indoor environments. The design leverages mobile applications, BLE beacons, and supporting SaaS to provide real-time navigation, location-based information, and optimal routes to users within a specified environment.

By leveraging a Mapping and Indoor Positioning System Engine(s) composed of Native SDKs (for web, iOS and Android operating systems), RESTful APIs, combined with BLE Beacons, the system used backoffice SaaS solutions supplied by CXApp to create location-aware wayfinding applications for the public.

The system is composed of two major components described below and illustrated in Figure 45:

- Beacons: BLE Beacons installed throughout the site emit short-range radio signals at regular intervals. These signals typically contain a unique identifier that helps devices identify the specific beacon. The most common technology used for this purpose is BLE, which is energy-efficient and well-suited for transmitting data over short distances.

- SaaS Platform: Using a variety of internal smartphone sensors, Indoor Positioning technology detects and tracks data about a device's location. This location data is ingested by the positioning system generating accurate coordinates which are displayed on an indoor map.

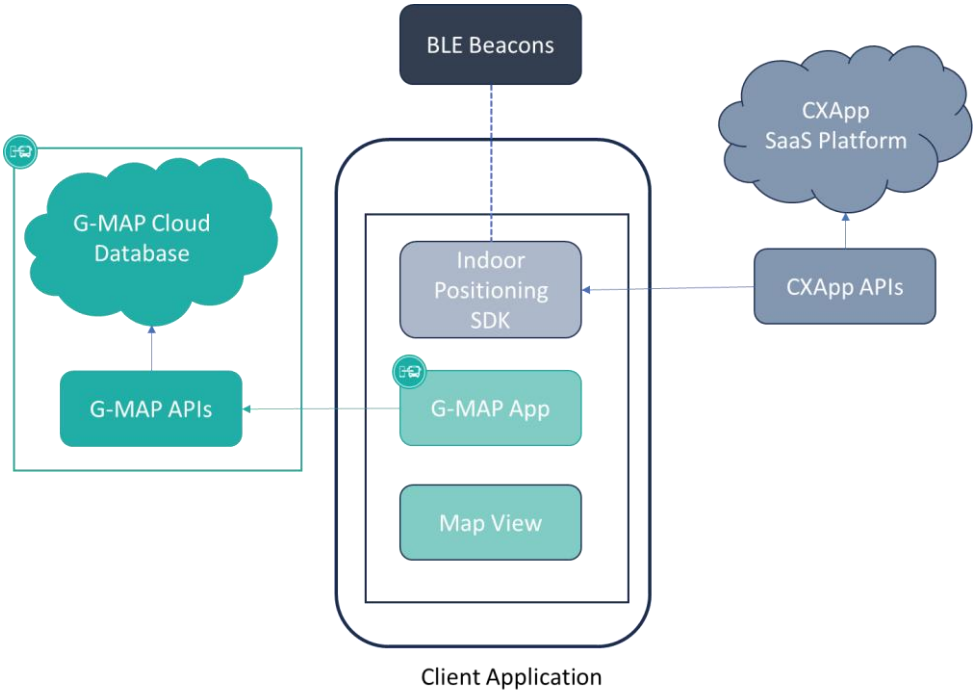


Figure 45. INS System Components

6.2.1 Beacons

6.2.1.1 BLE Beacons

BLE is a radio frequency (RF) technology that is used to provide proximity services to support indoor navigation. BLE is a technology that is native to modern smartphones which consumes very low power. It is compliant with BLE 5.1.

BLE beacons repeatedly pulse out BLE signals. These signals can be detected by surrounding devices, including smartphones. Deployed in fixed positions throughout an indoor space, the signal continuously broadcasted by the beacon contains its unique identifier. This identifying code is sent out periodically, along with other data, depending on the beacon communication protocol being used.

The G-MAP mobile app, that is integrated with the CXApp SDK and SaaS mapping engine, when in range of the beacon, receives and analyzes the signal from the beacon when off-line or send this information to a server when on-line. The detection between one beacon and a mobile device can determine the distance between them. This function is called Received Signal Strength Indicator (RSSI). Once the smartphone assesses the distance between more than three beacons, triangulation is performed to more precisely identify the position of the smartphone within a mapped environment.

6.2.1.2 Beacon Units and Specifications

The INS uses beacons for indoor environments. The Norcross Senior Center/OneStop (hereafter referred to as OneStop) and GJAC buildings are both environmentally controlled facilities with all the beacons installed in an indoor space.

6.2.1.2.1 Indoor Beacon Specifications

The beacons are deployed at the GJAC and OneStop facilities. They use the Kontact.io Anchor Beacon 2 (Figure 46). The technical specifications are described in Table 44.



Figure 46. Kontakt.io Anchor Beacon 2

Table 44. Technical Specifications for Kontakt.io Anchor Beacon 2

Technical Category	Technical Measure	Description
Dimensions and weight	Height	1.9 inches (49 milimeters)
	Width	1.9 inches (49 milimeters)
	Depth	0.5 inches (15 milimeters)
	Weight	1.34 ounces (38 grams)
Electronics	Microcontroller	nRF52832
Connectivity and Standards Compatibility	Bluetooth	BLE 5.0
	Type	iBeacon
	Range	Up to 328 feet (100 meters)
	Available transmission power levels	-20 to +4 decibel-milliwatt
	Sensitivity	-96dBm
Battery and power	Model	ER14250 (1.2 ampere-hour)
	Total capacity	2400mAh
	Number of batteries	2

Technical Category	Technical Measure	Description
	Replaceable	Yes
	Operating temperature range	-140°F to 185°F (-60°C to +85°C)
	Battery life	+8 years (iBeacon / 1 seconds / -12 dMb)
Environmental requirements	Operational temperature	-77°F to 185°F | -25°C to +85°C
	Humidity	Non condensing
Casing and Installation	Material	PC-550k (V0 anti-flammable)
	Colors	off white, RAL 9003
	Protection	IP 52
	Mounting	Slot for ZIP ties, double-sided tape
Certification		CE/FCC/RoHS/REACH/IC/UKCA

6.2.1.3 Beacon Placement

Placement of the beacons should provide uniform coverage over the public indoor space. The variation in uniform spacing should be less than 30% when the space is divided into grids. Additional beacons should be placed in areas that require increased accuracy or at junctions, such as entrances to stairs and doors along hallways.

The beacons should be placed in areas without obstruction to provide a physical line of sight from the beacon to the user. For example, the beacon should not be placed behind an elevated sign or behind a door. The best location to place the beacon is on the ceiling of a facility. However, placement should not be too high above the users. Beacons should not be placed in the ceilings of the facilities or the escalator shafts, where there are open levels that are two or three stories above the first floor.

The beacons should be spaced about 7 to 8 meters apart with a density of about 600 square feet per beacon coverage and 20 meters apart to yield 1-3 meter accuracy.

Note that different mobile phones will receive Bluetooth beacon signals at varying strengths. The signal strength should be adjusted following installation to optimize the outcomes of different handsets. The Kontakt.io tool or equivalent (e.g., MobileBeaconer for Android) supports the detection and optimization of beacon signal strength.

Beacons were configured and inventoried by the vendor to provide maximum coverage prior to providing them to the installation team. The inventory and configuration information are available in the Content Management System (CMS), described in **Section 6.2.2**.

6.2.1.4 Configuring Indoor Navigation Beacons and Facility Paths

This section provides high level information about additional tuning of the configuration of the indoor navigation beacons. Additional information can be found in the CIP and more detailed updates to the beacon and facility maintenance are included in proprietary information associated with the CXApp Map Manager and referenced the CMOP. The following configurations were adjusted to enhance the indoor navigation functionality:

- As noted in the CIP, the RSSI signal levels need to be adjusted to cover the facility path. Beacon locations were adjusted as well as transmission strength. The kontakt.io app (https://support.kontakt.io/hc/en-gb/articles/4413258518930-Beacon-transmission-power-range-and-RSSI) registered to CXApp was used to implement configuration changes. Note: transfer lead to project following verified operations.

- CXApp's jibestream Map Manager and Editor tools (see Figure 48) were used to simplify paths (e.g, straight single lines through corridors, right angles to destinations, elevators, escalators, and reduce entry/exit to destinations).

- The geofence around the facility was adjusted to trigger indoor navigation.

6.2.2 Backoffice Software as a Service (SaaS)

The SaaS platform is composed of a CMS that catalogs and maps venues, buildings, floors, destinations and amenities, and provide localization services (Figure 47). The CMS also provides tools to update maps and style them **(**Figure 48). The CXApp CMS is accessed with secure user credentials through Single Sign-On (SSO) with Google or Okta SSO. The SaaS toolset includes:

- **API and CMS Map Data Update:** Integrate with third-party data sources to push changes to end-user applications or choose to store the latest mapping point of interest data on the cloud-hosted mapping database. See changes reflected in real-time in all applications by publishing.

- **API and CMS Map Interoperability:** Import and export updated maps in GeoJSON, Drawing Exchange Format (DXF), Scalable Vector Graphics (SVG), Portable Document Format (PDF), and Portable Network Graphic (PNG) to update live maps, and/or share the latest version statically.

- **CMS Map Structure Edit:** Edit maps on demand with a web-based map editor. This self-serve tool makes it easy to keep maps up to date for minor structural changes. The maps shall render the path and destination of multiple floors including paths between floors. This includes adding dynamic condition and status attributes such as elevator outages, escalator outages, and building entrance closures.

- **CMS Draft:** Incrementally make changes to venues, or take the time needed to coordinate and detail for a larger change to publish.

- **API and CMS Map Structure Versioning:** Easily restore any version of your previously saved maps at any point by selecting the auto-generated map version name and seeing the date and time that the map was published.

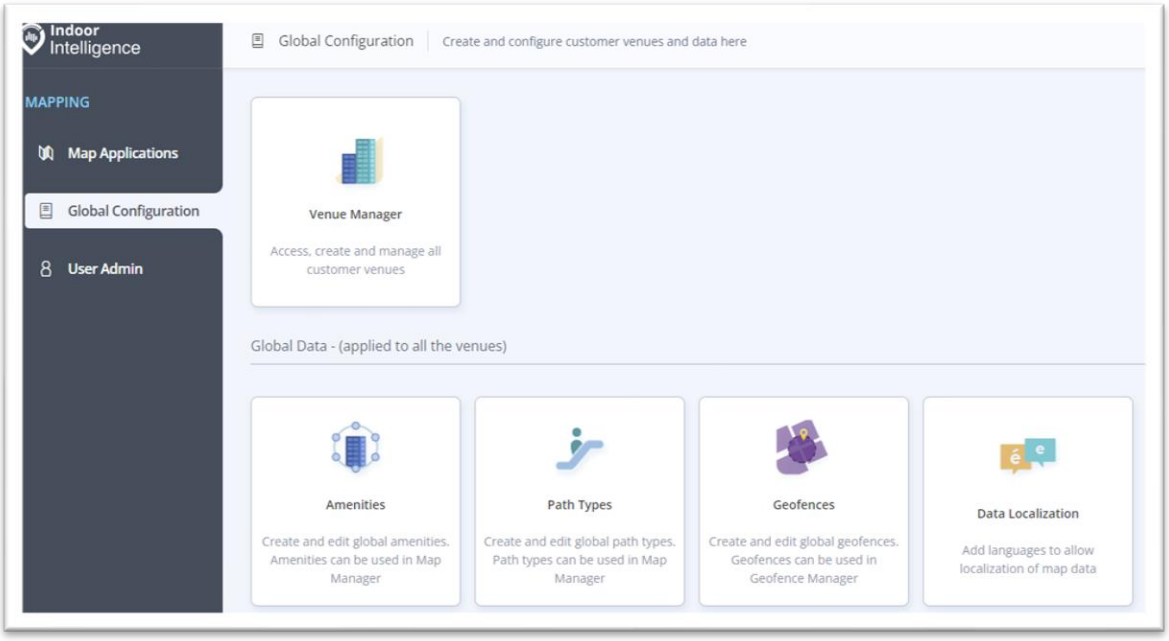


Figure 47. Global Configuration for all Venues (source: CXApp)

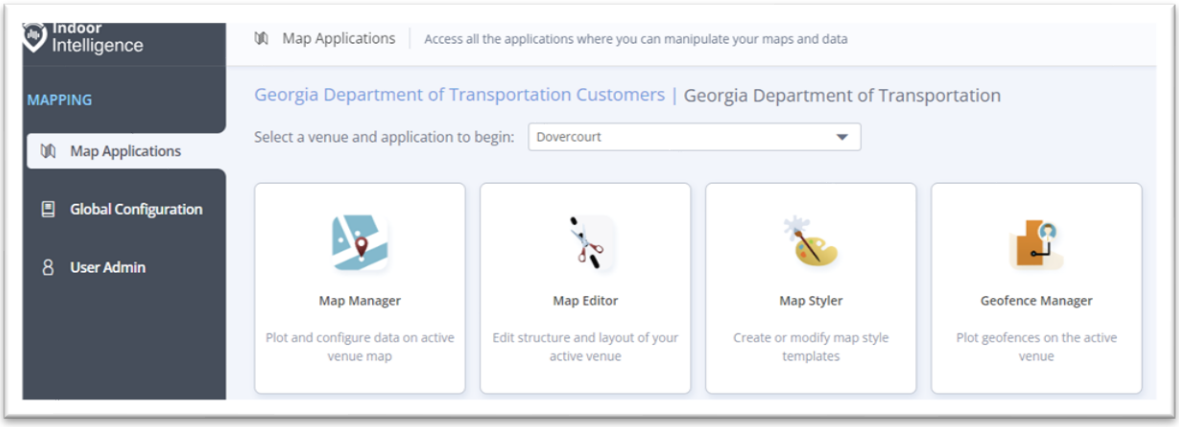


Figure 48. Map Applications for Each Venue (source: CXApp)

6.2.3 Software Development Kit (SDK)

Three SDK toolkits are supported including web, iOS and Android. The current SDKs are listed in Table 45.

Table 45. CXApp SDK Operating System Integrated in G-MAP

Platform	SDK Operating System Version
iOS	JMap-iOS-SDK-Pod : 5.12.2 NavigationKit-iOS-Pod : 2.2.0 On-Device-Positioning-Pod : 1.5.7.1
Android	jmapandroidsdk v6.0.4 mapuikit1v.1.3 navigationkit v2.0.1 com.cxapp.odp:extend v1.5.6.6

CMS functions include:

- Positioning & Tracking: Indoor location accuracy using universal low-cost beacons and sensor fusion technology.
    - Dead Reckoning: Leveraging the sensors available in most smart phones – accelerometers, gyroscopes, magnetometers, and pressure sensors – along with mobile processing algorithms to compute responsive and accurate location, motion, and user context.
- Map Matching: Detailed map data, when available, are used both for aiding the positioning solution down to meter-accurate levels, and for determining way-finding guidance that can be provided to a user seeking out known points of interest within a customer-expandable database.
- Navigation: Provision turn-by-turn guidance to app users, through hallways, across buildings, and between floors (e.g., elevators, stairs, escalators). Turn-by-turn static directions are provided to the user as a list by selection of the indoor trip itinerary as shown in Table 19.
- Navigation Algorithms: User locations are triangulated using BLE Beacons. The user's x/y location is converted as a latitude and longitude position and precisely rendered on the map as a Blue Dot. As the user's location changes, the position of the Blue Dot is updated. Due to technology constraints, the blue dot may jump locations briefly, so a semi-static route shows the user's path to their destination. This allows the user to navigate without interruption.
- Trip Planning: Create a navigation experience by providing the end-users with a staged route to reach their destination. End-users may select destinations to create routes and see their location updated in real-time against their planned route.

6.2.4 INS Requirements Traceability

The INS design elements that meet the requirements are listed in Table 46.

Table 46. INS Design to Requirements Traceability

Req ID	Req Title	Req Statement	Status	Section
6.1.0-152	Import Indoor Asset Condition Data	The system shall implement the data curation process for static and dynamic indoor asset data including elevator outages, escalator outages, and building entrance closures.	Updated	6.2.2
6.2.0-185	Beacon Asset Inventory Collection	The INS Vendor (system) shall collect asset information on beacons that are installed in facilities to support indoor navigation.	Updated	6.2.1.1
6.2.0-186	Beacon Asset Inventory	The Beacon Asset Inventory shall contain at a minimum, beacon identifier, location relative to facility map, location attributes, date installed, last maintenance date, and other pertinent information to support traveler navigation and wayfinding as well as asset maintenance. The details of the asset information will be determined in Phase 2 of the ST-CTN project.	Unchanged	6.2.1.1 Note: preventive maintenance activities are identified in the CMOP.
6.2.0-187	Access to Beacon Asset Inventory	The INS shall provide access to the beacon asset inventory to authorized users including G-MAP, STM, and building owners.	Updated	6.2.2
6.2.0-188	Acquire Beacon Asset Inventory	G-MAP shall acquire beacon asset inventory to support indoor mapping. The curation process, as described by [SyRS] Req 6.1.0-148, will be developed in Phase 2 of the ST-CTN project, including processing, integration and application in the routing service.	Unchanged	6.2

Req ID	Req Title	Req Statement	Status	Section
6.2.0-189	Beacon Environmental Conditions	The beacon shall operate in the following environment conditions without degradation: • Operational temperature (-20 to +60ºC) • Waterproof (IP67)"	Unchanged	6.2.1.2.1
6.2.0-190	Beacon Power	The beacon shall be powered by replaceable battery power with an average life of 5 years (depending on usage).	Unchanged	6.2.1.2.1
6.2.0-191	Beacon Communication Channel and Pairing	The beacon shall support Bluetooth Low Energy (BLE) 5 or above.	Unchanged	6.2.1.2.1
6.2.0-192	Beacon Transmission Small Space Distance	The beacon shall have a broadcast range of between 50-100 feet.	Unchanged	6.2.1.2.1
6.2.0-193	Beacon Transmission Large Space Distance	The beacon shall be able to be configured to have a broadcast range for between 200-300 feet.	Unchanged	6.2.1.2.1
6.2.0-194	Beacon	A beacon technology shall be deployed at key waypoints to aid indoor wayfinding and navigation by G-MAP.	Unchanged	6.2.1.3
6.2.0-195	Beacon Installation and Mounting	The beacon shall be constructed to be installed using adhesive or screws for mounting the device.	Unchanged	6.2.1.3 6.2.1.2.1
6.2.0-196	Beacon App SDK	The beacon/INS shall include an SDK to interface with iOS and Android to receive and resolve message content.	Updated	6.2.3
6.2.0-197	Beacon Message Configuration	The beacon/INS shall provide an administration module to configure the content and operations of each beacon.	Updated	6.2.2

Req ID	Req Title	Req Statement	Status	Section
6.2.0-198	Beacon Broadcast	The beacon shall broadcast its message (or identifier) at configurable intervals or when connected to a mobile app.	Unchanged	6.2.1
6.2.0-240	Re-routing	The SDK should be capable of re-routing users if the user navigates away from the initial defined route.	Added	6.2.3
6.2.0-241	SDK Navigation Experience	The SDK shall support the ability to fully integrate the navigation experience (audio, visual, text based commands) within third party apps developed using native technology.	Added	6.2.3
6.2.0-243	Location Positioning and Beacon Configuration	The beacons shall be installed and configured to provide accurate positioning in multiple architectural layouts.	Added	6.2.1.3
6.2.0-244	Beacon Configuration to Support Accurate Position Multiple Floors	The beacon deployment shall ensure that positioning determination can differentiate different floors in an open space (i.e., as laid out in the Gwinnett Justice and Administration Center – GJAC).	Added	6.2.1.3
6.2.0-245	Beacon Configuration to Support Accurate Positioning	The beacon deployment shall ensure positioning determine can precisely (within 2-4 meters) describe the pathways between and around the two facilities.	Added	6.2.1.3

Req ID	Req Title	Req Statement	Status	Section
6.2.0-246	Generate Facility Map	The vendor shall develop the facility map inclusive of routable/connected paths through the facility and between floors. The indoor network shall include features such as entrances, conveyances (elevator, escalator, stairs), rooms, destination and special areas. Features shall also include attributes that describe condition and status including time-based access and accessibility (e.g., for people in wheelchairs). Places shall include attributes that describe their condition and status.	Added	6.2.2
6.2.0-247	Map Updates	The vendor shall provide a web-based mapping tool for facility owners to manage and update facility map updates and feature status (e.g., special events in geofenced areas, elevator outages, etc.).	Added	6.2.2
6.2.0-248	Map Download	The vendor mapping tool shall export map data in a standard-based map format (e.g., shape files, OGC map service / OGC feature service, Open Street Map, KML).	Added	6.2.2

6.3 Ride Request

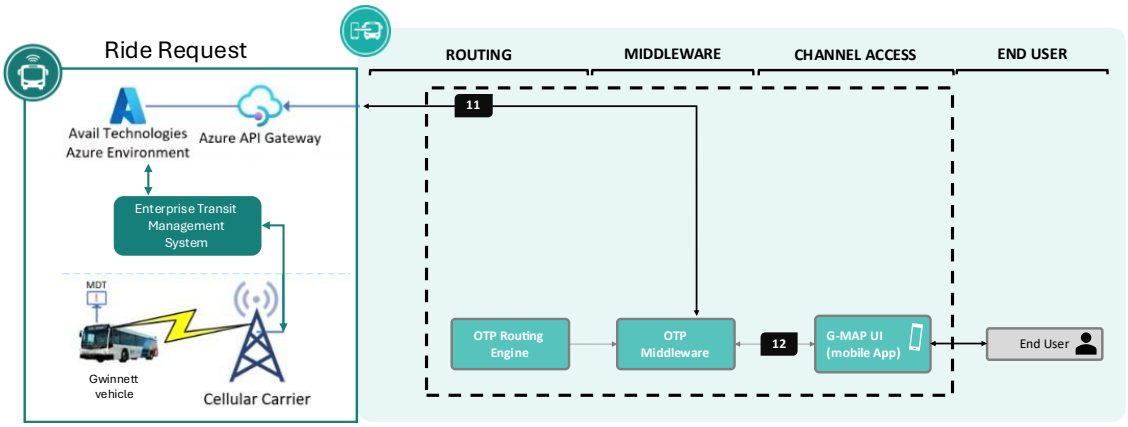
The Ride Request function addresses the following use cases:

- **Trip Request:** A Ride Gwinnett rider plans a trip and accepts the suggested route using G-MAP. The G-MAP mobile app communicates with the G-MAP server who then sends a message using Ride Request API. The Avail AVL system in turn generates and sends a message to the Ride Gwinnett transit vehicle's MDT, notifying the operator that a rider needing extra time may be at the specified stop. There is not delay from the time message is received from G-MAP to when it is transmitted to the operator's mobile data terminal (MDT)

- **Trip Cancellation:** A rider plans a trip and accepts the suggested route using G-MAP. G-MAP sends a message to the Ride Request API which in turn generates and sends a message to the Ride Gwinnett transit vehicle's MDT, notifying the operator that a rider

needing extra time may be at the specified stop. Prior to the pickup time, the rider cancels their trip from inside G-MAP. G-MAP sends a message to the Ride Request API, which in turn generates and sends a message to the applicable transit vehicle's MDT, notifying the operator that the previous message has been rescinded.

As shown in Figure 49, the Ride Request function is built to work with the Ride Gwinnett existing Enterprise Transit Management System (ETMS) which contains the CAD system deployed in the Avail Azure Environment. The system also includes the AVL and MDT installed in the Gwinnett vehicle.



Source: GDOT and Avail Technologies

Figure 49. Ride Request Implementation Architecture

The ETMS includes existing modules to send messages to the operator. The Ride Request message is added to the established list of messages. The MDT message, shown in Figure 50, contains the stop location and a message that a passenger is waiting who needs extra time boarding. The operator is asked to acknowledge the message when it is safe and convenient.

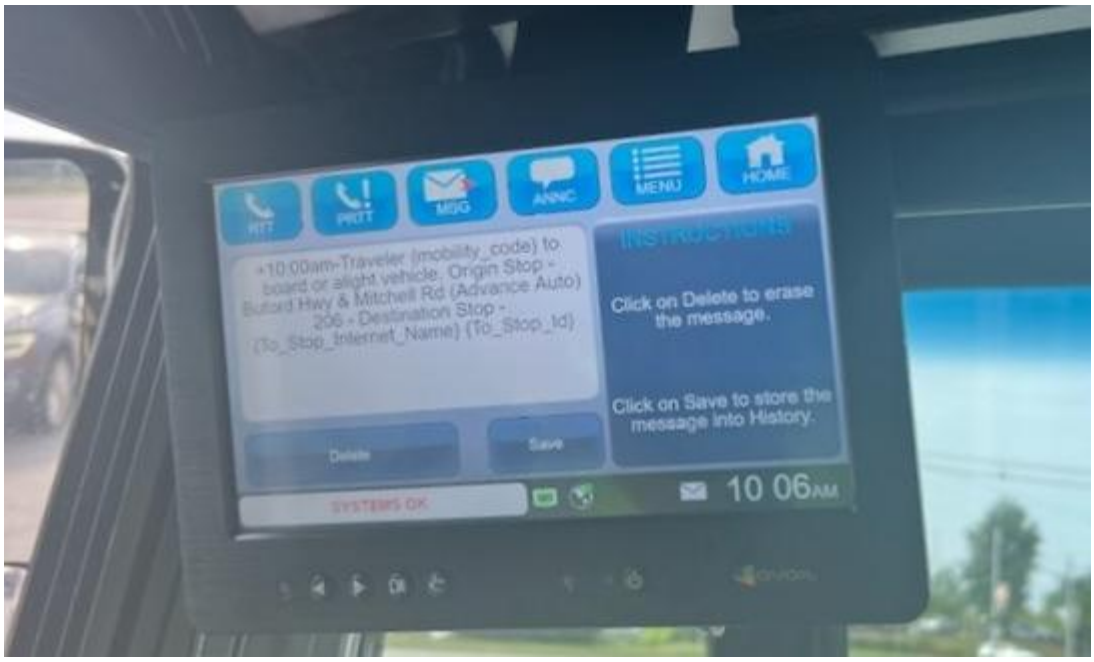
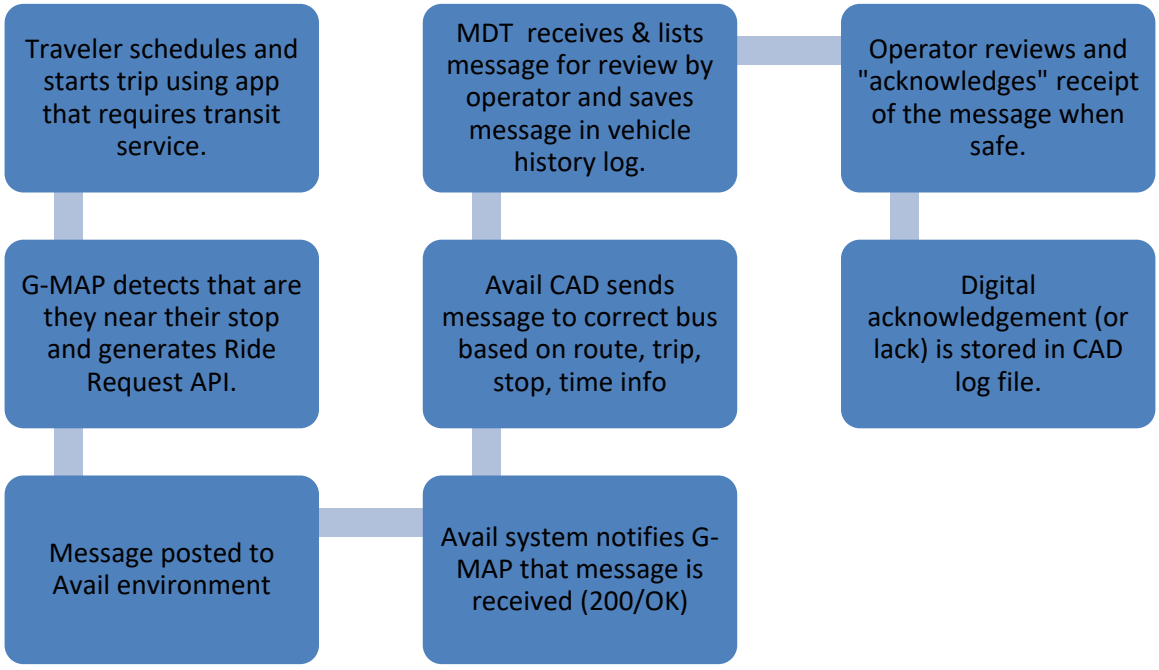


Figure 50. Ride Request MDT Message

The API between the G-MAP and Ride Request are described in the ICD Int-13 and the system shall minimize latency to within 1 minute from G-MAP message generation to receipt by vehicle's MDT.

The flow follows the sequence defined in Figure 51.



Source: GDOT, 2024

Figure 51. Ride Request Operational Flow

A new table is created in the ETMS Self Service Reporting Module that allows authorized GCT users to query raw data pertaining to the usage of the Ride Request interface. The following fields are posted:

- Delivery Time of Message to Vehicle
- Route ID
- Block ID
- Trip ID
- Stop ID
- Delivered Yes/No
- Driver ID
- Acknowledged by driver Yes/No

The reporting data is provided in a CSV format to the performance measurement team upon request.

6.3.1 Ride Request Requirements Traceability

The Ride Request design elements that meet the requirements are listed in Table 47.

Table 47. Ride Request Design to Requirements Traceability

Req ID	Req Title	Req Statement	Status	Section
1.1.0-002	System Security Policy	System security policies shall be developed that ensures end-to-end data protection and is consistent with each subsystem's internal security provisions.	Unchanged	6.3
1.1.0-017	Network Security	The system shall provide end-to-end encrypted and secure communications including at intermediate points within the wireless and wired infrastructure when exchanging information between subsystems (CV-STM; CV-G-MAP; G-MAP-GCT; and RSU-OBU). The design of the network security features will be developed in Phase 2.	Unchanged	6.3 Details are included in the ICD.
3.1.0-092	Ride Request Core Functionality	The ST-CTN system shall leverage the existing GCT CAD Ride Request core functionality and interfaces for the purpose of providing ST-CTN travelers with the ability to request transit stops. Leverage implies that we adapt and enhance existing functionality.	Updated	6.3
3.1.0-093	Next Bus Request	"The GCT CAD shall send out messages when a ride is requested by a traveler via their G-MAP. The request message includes the following: 3. alert an approaching vehicle of their presence at a bus stop; 4. alert operator of any special need, such as additional time for boarding or alighting	Updated	6.3

Req ID	Req Title	Req Statement	Status	Section
3.1.0-094	Ride Request APIs	The GCT CAD system shall provide transaction services (APIs) for G-MAP to request a transit ride.	Updated	6.3
3.1.0-096	Ride Request Acknowledgement	The GCT CAD shall send a notification to G-MAP that the transit operator confirmed receipt of the request for next stop pickup.	Updated	6.3
3.1.0-097	Log Ride Request Transactions	The GCT CAD shall log ride request event information including trip identification, time, and location. Other pertinent information will be identified by the GCT and G-MAP developers during Phase 2 of the ST-CTN project.	Updated	6.3
3.1.0-099	Ride Request Transaction Latency	For the ride request transaction, the system shall minimize latency to within 1 minute from G-MAP message generation to receipt by vehicle's MDT.	Updated	6.3 Verified by testing and comparing transmission times from each leg
3.2.0-106	ST-CTN and GCT Ride Request Testing Coordination	The ST-CTN project team shall coordinate GCT Ride Request testing, including elements related to end-to-end timing, security, message processing and management.	Updated	6.3 See Test Procedure R4.48 for test coordination steps

6.4 Pedestrian Crossing (PED-X) Actuation Request

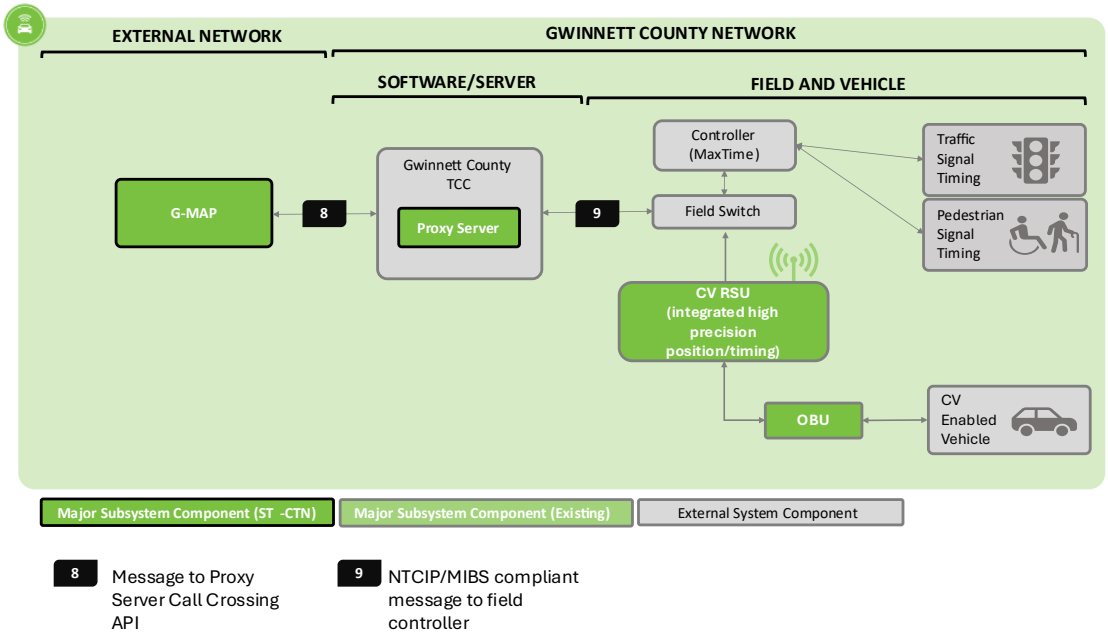
The pedestrian crossing (PED-X) actuation request implements an interim solution until the GDOT centralized traffic operations system is completed and deployed throughout the state. In the meantime, a secure gateway server (Proxy Server) also known as the SMUG, is set up at the Gwinnett facility with logic to receive a request from G-MAP for a specific intersection with a request for actuation. Figure 52 shows the flow from the G-MAP server to the Gwinnett County TCC through the proxy server. The PED-X SMUG is deployed on a secure proxy server within Gwinnett's system to ensure the security between internal and external messaging. The Proxy Server acts as a secure and reliable intermediary, connecting external pedestrian services to internal MaxTime intersection controllers. The connection is established at designated

intersections, enabling effective monitoring and management of pedestrian crossings. The PED-X API facilitates external services in querying intersection data and making requests for pedestrian crossing assistance. It ensures robust data transmission and authorized access through API key security measures.

The flow from G-MAP to the Proxy Server implements the following:

- Message from G-MAP to the proxy server contains only information that is necessary for the proxy server to function.
- Proxy server *whitelists* the G-MAP end-point and assigns secure information to the G-MAP Message (IP address, phase information, etc.).
- Proxy server determines the type of message that needs to be sent to the field controller and use National Transportation Communications for Intelligent Transportation Systems (NTCIP) Management Information Base (MIB) protocols to communicate to the signal controller. These include priority request, extended time, buffer, cancel and clear messages per NTCIP 1202 and 1201 message.
- Proxy server verifies status of pedestrian phase service for verification.
- Message from proxy server to G-MAP contains only information that is necessary to verify that a pedestrian call was placed/served.

The PED-X functionality is integrated with the existing Gwinnett County connected vehicle system (and Smart Corridor project), including the PPA.



Source: GDOT, 2024

Figure 52. PED-X Proxy Server Implementation

Once the signal controller is alerted and the signal displays a walk, the signal relays a message (already deployed by the GDOT and Gwinnett CV programs) to the RSU to broadcast a PPA that pedestrians are present in the intersection to CVs.

Eleven intersections are deployed with the PED-X functionality. The intersections were inspected to ensure that they were connected to the Gwinnett signal controllers (MaxTime). A mix of pedestrian signal system types are incorporated into the PED-X functionality, e.g., Accessible Pedestrian Signals (APS), countdown, and traditional walk/don't walk signals. Table 48 includes Gwinnett signal identifiers (Gwinnett ID column), their location (Intersection column), type information about the signal system and related projects nearby (Notes column), and notes from the site visit to the intersection (Site Visit column).

Table 48. Intersection Locations and Types

Signal ID	Intersection	Notes	Site Visit
241	SR 20 at Gwinnett Drive	Proposed RSU location	No APS. Full countdown pedestrian signals
238	SR 20/Perry Street at Nash Street	Proposed RSU location	No APS. Full countdown pedestrian signals
759	Beaver Ruin Road at Light Circle	HAWK signal location	No APS. Full countdown pedestrian signals. Pedestrian refuge

Signal ID	Intersection	Notes	Site Visit
713	East Crogan Street and east of North Clayton Street	Midblock crossing, Downtown Lawrenceville	APS working. Full countdown pedestrian signals
350	Old Norcross Road at Davenport Road	Southeast (SE) corner malfunctioning. Northeast (NE) corner not full countdown pedestrian signal	APS partially functional
085	Jimmy Carter Boulevard at Hayes Drive	Near Singleton Road ITS project	APS working. Full countdown pedestrian signals. Ped 4 push button (PB) on SE corner is loose
086	Jimmy Carter Boulevard at Dawson Boulevard/Live Oak Parkway	Near Singleton Road ITS project	No APS. Full countdown pedestrian signals. Ped 4 on NE corner needs to be turned
555	SR 141 at Forum Drive	High pedestrian activity	No APS. Full countdown pedestrian signals. Ped 2 PB on SW corner seems stuck
606	Satellite Boulevard at Gwinnett Plantation Way	Gwinnett Place Mall, existing transit center	No APS. Full countdown pedestrian signals
230	Satellite Boulevard at Merchants Way	Gwinnett Place Mall, existing transit center	No APS. Full countdown pedestrian signals
468	Indian Trail Lilburn Road at Georgia Belle Court	Adjacent to OneStop	No APS. Crosswalk on two legs. Pedestrian refuge

Queries on the Interim NTCIP Handler were augmented to enable the requesting physical entity (i.e., G-MAP) to discover additional intersections and approach parameters. These include:

- **List Intersections** – retrieves a list of all intersections and their descriptions wherein the user can request actuation.
- **Get Intersection** – retrieves details of a specific intersection specific intersection that a user can request actuation.
- **List of Crossings for Intersection** – retrieves a list of crossings for a specific intersection (to actuate the direction the user travels across the intersection).
- **Get Specific Crossing** – retrieves details of the crossing for a specific intersection

The interface to request actuation is the Call Crossing API.

- **Call Crossing** – initiates a call on a specific crossing and if the call should be extended.

Crossing descriptions for each intersection are listed in Table 49**.** The information includes the intersection ID, the intersection description, the direction of crossing (Crossing ID), and the signal phase (Phase) that actualizes a walk signal for the crossing direction at the intersection.

Table 49. Intersection Crossing Description and Phase

Intersection ID	Intersection Description	Crossing ID	Crossing Description	Phase
241	SR 20 at Gwinnett Drive	NB	Northbound SR 20	2
241	SR 20 at Gwinnett Drive	WB	Westbound Driveway	4
241	SR 20 at Gwinnett Drive	SB	Southbound SR 20	6
241	SR 20 at Gwinnett Drive	EB	Eastbound Gwinnett Drive	8
238	SR 20/Perry Street at Nash Street	SB	Southbound Perry Street	2
238	SR 20/Perry Street at Nash Street	EB	Eastbound Nash Street	4
238	SR 20/Perry Street at Nash Street	NB	Northbound Perry Street	6
238	SR 20/Perry Street at Nash Street	WB	Westbound Nash Street	8
759	Beaver Ruin Road at Light Circle	NS	Hawk Pedestrian Crossing North Side	2
759	Beaver Ruin Road at Light Circle	SS	Hawk Pedestrian Crossing South Side	6
713	East Crogan Street and east of North Clayton St	NBSB	Northbound and Southbound Pedestrian Crossing	2
350	Old Norcross Road at Davenport Road	SB	Southbound Old Norcross Road	2
350	Old Norcross Road at Davenport Road	WB	Westbound Old Davenport Road	3
85	Jimmy Carter Boulevard at Hayes Drive	WB	Westbound Jimmy Carter Boulevard	2
85	Jimmy Carter Boulevard at Hayes Drive	NB	Northbound Hayes Drive	4
85	Jimmy Carter Boulevard at Hayes Drive	EB	Eastbound Jimmy Carter Boulevard	6
85	Jimmy Carter Boulevard at Hayes Drive	SB	Southbound Driveway	8
86	Jimmy Carter Boulevard at Dawson Blvd/Live Oak Pkwy	EB	Eastbound Jimmy Carter Boulevard	2
86	Jimmy Carter Boulevard at Dawson Blvd/Live Oak Pkwy	NB	Northbound Dawson Boulevard	4
86	Jimmy Carter Boulevard at Dawson Blvd/Live Oak Pkwy	WB	Westbound Jimmy Carter Boulevard (Two Crossings)	6
86	Jimmy Carter Boulevard at Dawson Blvd/Live Oak Pkwy	SB	Southbound Live Oak Parkway	8
555	SR 141 at Forum Drive	SB	Southbound SR 141	2

Intersection ID	Intersection Description	Crossing ID	Crossing Description	Phase
555	SR 141 at Forum Drive	EB	Eastbound Forum Drive	4
555	SR 141 at Forum Drive	NB	Northbound Forum Drive	6
555	SR 141 at Forum Drive	WB	Westbound Forum Drive	8
606	Satellite Blvd at Gwinnett Plantation Way	WB	Westbound Satellite Boulevard	2
606	Satellite Blvd at Gwinnett Plantation Way	SB	Southbound Plantation Way	4
606	Satellite Blvd at Gwinnett Plantation Way	EB	Eastbound Satellite Boulevard	6
606	Satellite Blvd at Gwinnett Plantation Way	NB	Northbound Transit Center	8
230	Satellite Blvd at Merchants Way	SB	Southbound Satellite Boulevard	2
230	Satellite Blvd at Merchants Way	EB	Eastbound Merchants Way	4
230	Satellite Blvd at Merchants Way	NB	Northbound Satellite Boulevard	6
230	Satellite Blvd at Merchants Way	WB	Westbound Merchants Way	8
468	Indian Trail Lilburn Road at Georgia Belle Court	WB	Westbound Indian Trail Lilburn Road	2
468	Indian Trail Lilburn Road at Georgia Belle Court	NB	Northbound Indian Trail Lilburn Road	4
468	Indian Trail Lilburn Road at Georgia Belle Court	EB	Eastbound Indian Trail Lilburn Road	6

Where SB = southbound, NB = northbound, EB = eastbound, WB = westbound, NS = northside and SS = southside.

The discovery APIs enable the system to be extended to add more intersections while the requesting entity can learn about the expanded inventory. The Proxy gateway software open source code is found at the USDOT CodeHUB.

6.4.1 PED-X Requirements Traceability

The PED-X design elements that meet the requirements are listed in Table 50.

Table 50. PED-X Design to Requirements Traceability

Req ID	Req Title	Req Statement	Status	Section
1.1.0-002	System Security Policy	System security policies shall be developed that ensures end-to-end data protection and is consistent with each subsystem's internal security provisions.	Unchanged	6.4

Req ID	Req Title	Req Statement	Status	Section
1.1.0-017	Network Security	The system shall provide end-to-end encrypted and secure communications including at intermediate points within the wireless and wired infrastructure when exchanging information between subsystems (CV-STM; CV-G-MAP; G-MAP-GCT; and RSU-OBU). The design of the network security features will be developed in Phase 2.	Unchanged	6.4
3.3.0-109	Smart Corridor Pedestrian Presence Core Functionality	The system shall utilize the Smart Corridor Pedestrian Presence functionality, interfaces, architecture and infrastructure as the core CV platform for the ST-CTN. Smart Corridor core functionality will be documented and published during Phase 2.	Unchanged	6.4
3.3.0-110	Smart Corridor Pedestrian Presence Alert Enhancements	The system shall enhance the Pedestrian Presence Alert by identifying additional strategies. Strategies include but are not limited to remote activation of PED-X request.	Unchanged	6.4
4.1.0-111	CV and ATMS Core Functionality	The system shall utilize the existing core CV and ATMS functionality, interfaces, architecture, infrastructure (including RSU, OBU, communications and security) to provide mobile accessible pedestrian features at signalized intersections. CV and ATMS core functionality will be documented and published during Phase 2.	Unchanged	6.4
4.1.0-120	Verify and Forward Pre-Defined Messages	The SMUG shall serve as a gateway to exchange messages between G-MAP and specific signal controllers to authenticate and forward pre-defined message(s).	Updated	6.4
4.1.0-121	Activate PED-X Walk Request	Upon receipt of the PED-X Priority Request message, the signal controller shall activate the PED-X signal during its next cycle (by crosswalk direction).	Unchanged	6.4
4.1.0-132	PED-X Priority Status Buffer Message	The PED-X buffer message shall adapt the prgPriorityStatusBuffer information and the signal control status information. The message contents the status of the phase information from the signal controller.	Unchanged	6.4

Req ID	Req Title	Req Statement	Status	Section
4.1.0-133	PED-X Priority Cancel Message	The PED-X cancel message shall adapt the prgPriorityCancel message and is used to indicate that the request is no longer needed.	Unchanged	6.4
4.1.0-134	PED-X Priority Clear Message	The PED-X priority clear message shall adapt the prgPriorityClear message and is used to indicate that the requesting pedestrian has cleared the intersection and priority is no longer needed.	Unchanged	6.4
4.1.0-238	PED-X Message Interface	The system shall provide interface for the PED-X message that will include information about the intersection, the path through the intersection, and whether the traveler would need the extended crossing time.	Added	6.4
4.2.0-135	Traveler Notification of PED-X Request Receipt	Upon receipt of the PED-X Priority Status message, G-MAP shall send a notification to traveler that request was received.	Unchanged	6.4
5.1.0-252	SMUG Security Protocols	G-MAP operator, SMUG Server operator, and Signal Control operator shall agree upon and implement security procedures, policies and protocols to authenticate, validate and restrict traffic between G-MAP, SMUG and signal controllers.	Added	6.4
5.1.1-143	Smart Corridor Pedestrian at Intersection - for Bus Alerts	The ST-CTN project team shall coordinate testing to verify Smart Corridor implementation of pedestrian bus alerts. The CV RSU shall send a safety warning to a transit vehicle via its OBU as it approaches or turns at an intersection where the RSU received a PPA or PED-X SRM. The Smart Corridor project will implement this function as part of the Smart Corridor core functionality.	Unchanged	6.4

Req ID	Req Title	Req Statement	Status	Section
5.1.1-144	Smart Corridor Pedestrian at Intersection - for Vehicle Alerts	The ST-CTN project team shall coordinate testing to verify Smart Corridor implementation of pedestrian vehicle alerts. The CV RSU shall send a safety warning to vehicles via their OBUs as it approaches or turns at an intersection where the RSU received a PPA or PED-X SRM. The Smart Corridor project will implement this function as part of the Smart Corridor core functionality.	Unchanged	6.4
6.1.0-153	Import Traffic/Transit Asset Data	The system shall implement a data curation process for IOO asset information (e.g., traffic signal locations, RSU locations) as described by the DMP. Note: The requirement for a curation process for each dataset is described in SyRS Section 3.10.1.	Unchanged	6.4

7 Public Performance Measurement Dashboard

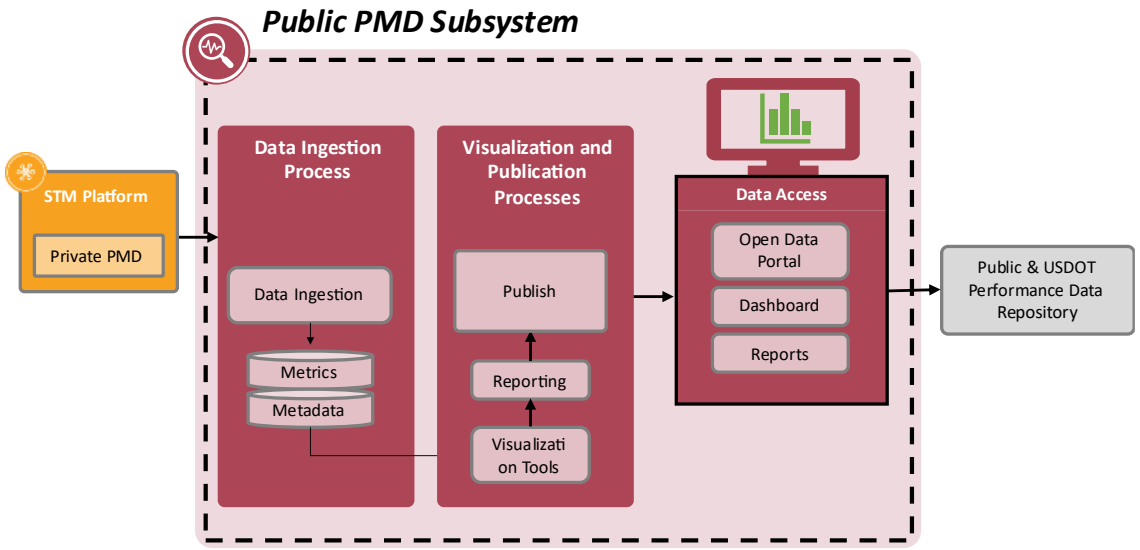
The PMD is a data storage and distribution subsystem that provides operational, survey, and performance metrics of the ST-CTN system. The overall PMD subsystem is comprised of private and public components where the private PMD (described in **Section 5.7**) manages and performs analytics on private data, including PII and then provides anonymized data to the public PMD (shown in Figure 53). The public PMD displays the performance measures within a public facing dashboard and provides access to the anonymized metrics to the public. The dashboard and data analytics identified in the public PMD support the evaluation of performance measures, consistent with the Performance Measurement and Evaluation Support Plan (PMESP2).

Through the use case scenarios and performance measures previously developed in the PMESP2, the public PMD provides an online interface that displays information and statistics regarding the performance measures based upon feedback reports and anonymized user data. The PMD supports the evaluation of the ST-CTN project concept by storing, managing, analyzing, and displaying data regarding the derived performance measures in the PMESP2.

Performance measures, metrics, and associated targets were developed through an iterative process in which a core team of researchers and engineers created and vetted measures, metrics, and targets with the ST-CTN technical team.

7.1 Public PMD Overview

The public PMD is a configuration of the COTS Microsoft PowerBI, Version: 2.138.1203.0 64-bit (November 2024) platform used to display and provide access to performance data. The public PMD is composed of several processes as illustrated in Figure 53.



Source: GDOT, 2024

Figure 53. Public PMD Processes

The public PMD processes include the following:

- **Data Ingestion and Curation Processes.** Function to ingest data input from the private PMD. These include the anonymized metrics and metadata information which are securely held and made available from a private PMD S3 Bucket.
- **Visualization and Publication Processes.** Processes to visualize the metrics, generate reports and publish these artifacts to the public PMD website.
- **Data Access.** Processes deployed to allow the public to interact with or download the performance measurement data and reports.

These processes are supported by the PowerBI administration console that provides the following services. Documentation and user support is provided by Microsoft online in a searchable format or in guided user training, Power BI get started documentation - Power BI | Microsoft Learn.

- Import data from private PMD S3 Bucket
- Configure quality control procedures
- Define and associate data fields to generate charts for data visualization
- Define and associate data fields to generate reports
- Save and publish charts or reports to web

7.2 Dashboard User Interface

The Dashboard UI provides access to performance measurements. These measures are organized by use case and focus on the user experience, safety, mobility, and accessibility. The performance measures for the ST-CTN system are included in Table 51**.** Each performance measure was given a unique identifier that was previously defined in the PMESP2. The PM ID convention is as follows:

AB-CD-E.F, where:

- AB = Performance measurement category
  - CT = Complete Trip (Use Case 1)
  - CV = Connected Vehicle (Use Case 2)
- CD = Measure or metric
  - PM = Performance Measure
  - ME = Metric
- E = Performance Measure ID
- F = Metric ID (not applicable for performance measure)

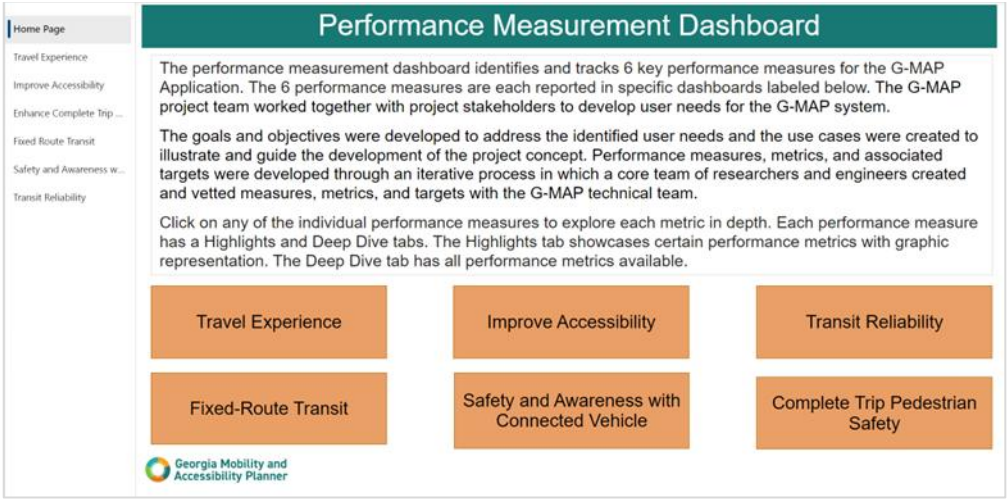
Detailed metrics by performance measure, survey question or dataset are listed in Appendix F. Performance Measures and Metrics.

Table 51. Performance Measures and Metrics

Performance Measure ID	Performance Measure Name	Goal
CT-PM-1	Enhance Traveler Experience	Goal 1 – Enhance Traveler Experience
CT-PM-2	Improve Accessibility	Goal 1 – Enhance Traveler Experience Goal 4 – Improve Mobility and Accessibility
CT-PM-3	Enhance Complete Trip Pedestrian Safety	Goal 2 – Enhance Safety
CT-PM-4	Enhance Fixed-Route Transit	Goal 1 – Enhance Traveler Experience Goal 3 – Improve Reliability Goal 4 – Improve Mobility and Accessibility
CV-PM-1	Enhance Safety and Awareness with Connected Vehicles	Goal 2 – Enhance Safety
CV-PM-2	Improve Transit Reliability	Goal 3 – Improve Reliability Goal 4 – Improve Mobility and Accessibility

The UIs for the Dashboard are composed of a home page, a page for each performance measure, and two tabs within each measurement page – a highlights tab and deep dive tab. These are described as follows:

Home Page. The home page of the public PMD provides a simple introductory message with six (6) selectable performance measure category boxes – one for each performance measure. The user is instructed at the end of the introductory message to explore any of the performance measures by clicking on one of the boxes. If the user selects one of the performance measures from the home page, it opens a new page displaying specific analytical data for that performance measure. Each performance measure identified in Table 51 has a dedicated page within the dashboard. Additionally, the performance measures are listed on the left-hand side of the dashboard, allowing for easy navigation back to the home page or to different performance measure pages. The home page of the public PMD is shown in Figure 54.

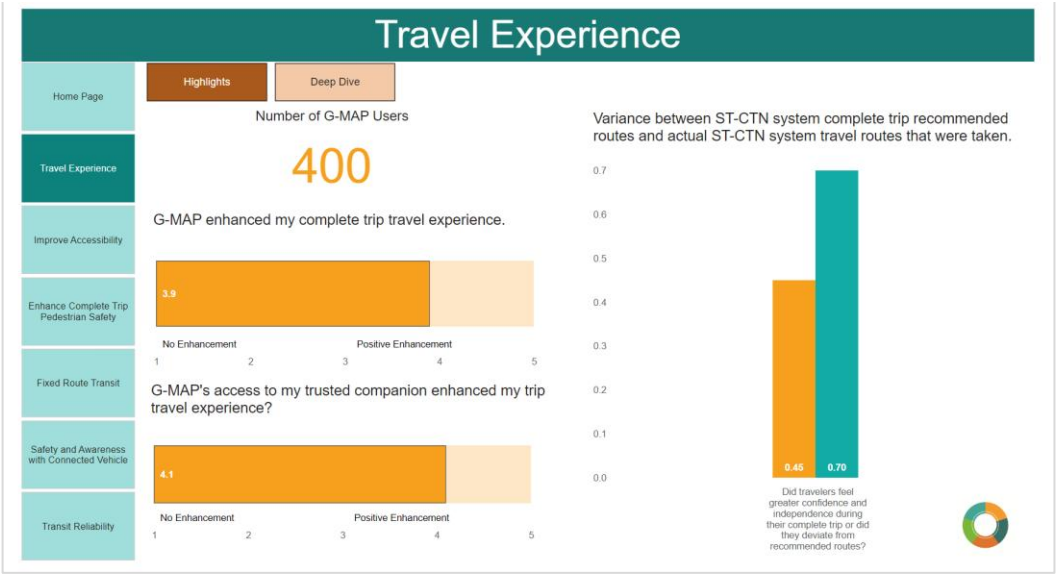


Source: GDOT, 2024

Figure 54. G-MAP Home Page

Performance Measure Pages. Each performance measure page has a similar structure, including two tabs – highlights and deep dive.

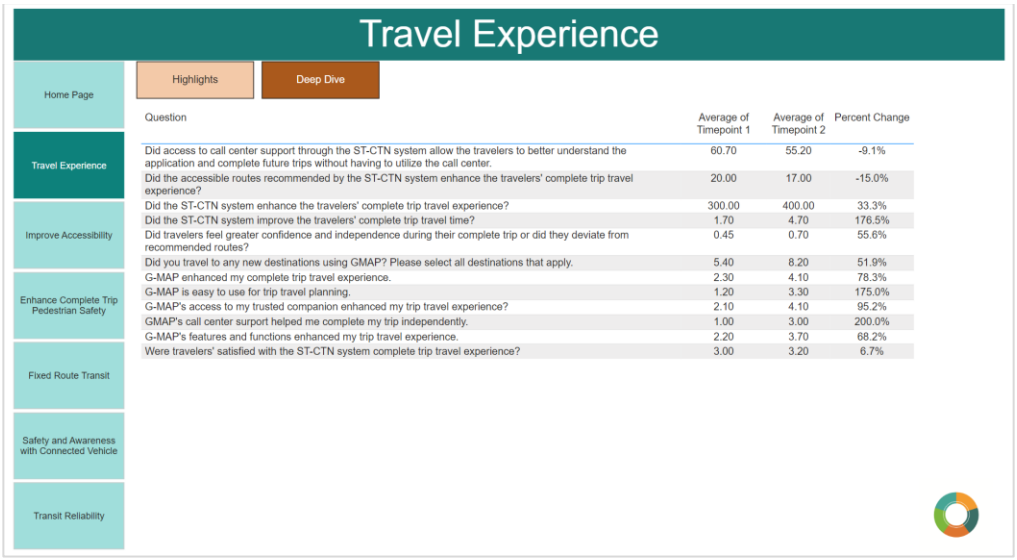
The highlights tab (example of the Enhance Traveler Experience shown in Figure 55 – to be updated), provides a visual summary of selected metrics displayed in charts and graphs. These metrics were selected to best represent the overall summary of the Traveler Experience performance measure.



Source: GDOT, 2024

Figure 55. Example of Performance Measure Page Showing Highlights Tab

The deep dive tab (example of the Enhance Traveler Experience shown in Figure 56 – *to be updated, format has changed*) provides additional metrics within each performance measure, providing more detail and data related to the performance measure.



Source: GDOT, 2024

Figure 56. Example of Performance Measure Page Showing Deep Dive Tab

The full list of performance measures and associated metrics, consistent with the PMESP2, are provided in Appendix F. Performance Measures and Metrics**.**

7.3 Data Ingestion and Curation Processes

The public PMD ingests and curates data by ingesting information from the private PMD's AWS S3 bucket. Data is processed and anonymized as described in **Section 5.7** and made available in a JSON file format (see ICD Int-15) on a weekly and quarterly basis.

The datasets are stored within the PMD so that they can be viewed and accessed based on user roles. The datasets are analyzed and curated within Power BI before uploading to the public PMD. The public PMD is refreshed daily to represent any updates within the private PMD.

Weekly Data. The weekly data file comprises the latest 7-day period as well as the final aggregated values for the week.

This file is copied to the STM AWS S3 bucket for retrieval by the public PMD. The public PMD is automated to ingest the data file; the ingestion process is configured to perform quality checks to verify that the structure and content of the data is consistent with its storage format. Table 52 lists the metrics that are included in the public PMD weekly dataset.

In addition, the file includes the count of requested and monitored journeys for each day in the 7-day period. These aggregated counts for daily and weekly values include:

- Unique user count
- Trips requested count
- Average trip deviation

Table 52. Public PMD Weekly Dataset

ID	Performance Measure	Data Source
CT-ME-1.8	Variance between recommended ST-CTN system complete trip recommended routes and actual ST-CTN system travel routes that were taken.	Traverse Data
CT-ME-1.11	Number of unique ST-CTN system users per day.	Mobile App Logs
CT-ME-1.12	Number of trips planned and completed by unique ST-CTN system users per day.	Mobile App Logs
CT-ME-3.2	Variance in geographic location between ST-CTN system complete trip recommended routes and actual ST-CTN system travel routes taken at signalized intersection crossings.	Traverse Data

Quarterly Data. The quarterly data file comprises the trip feedback responses from the quarterly report as well as manual data pulled from partners, i.e., Ride Gwinnett call center complaints. The curation process of the manually acquired data will be determined during Phase 3. Data is anonymized and made available in the STM AWS S3 bucket for retrieval by the public PMD. The public PMD is automated to ingest, check, and store the data file. Table 53 lists metrics acquired from the public PMD quarterly dataset.

Table 53. Public PMD Quarterly Dataset

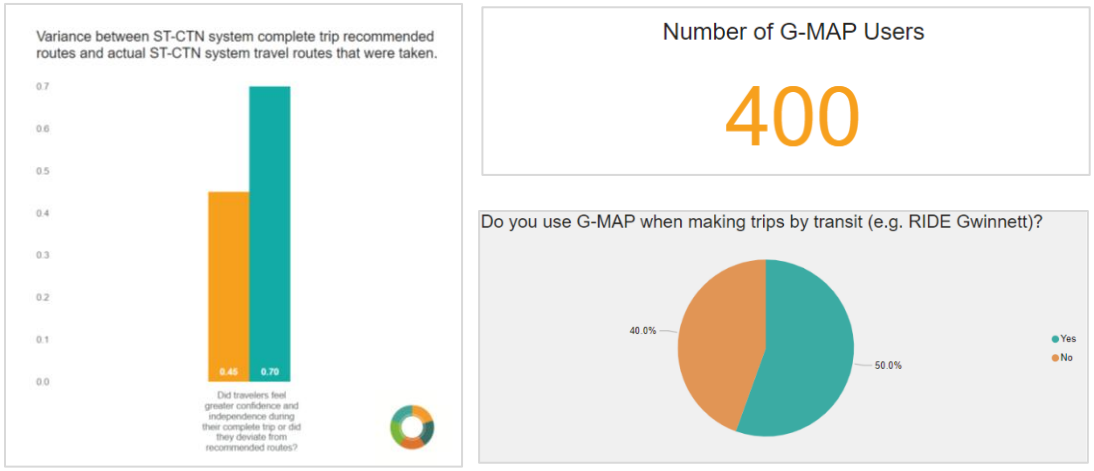
ID	Performance Measure	Data Source
CT-ME-1.1	1. The average survey response of travelers' complete trip travel experience. 2. The average survey response of how likely a user is to recommend G-MAP to other travelers.	Trip Feedback Reports
CT-ME-1.2	The average survey response of travelers' rating of how the usability of the ST-CTN system enhanced their complete trip travel experience.	Trip Feedback Reports
CT-ME-1.3	1. The average survey response of travelers' rating of how the ST-CTN system features and functions enhanced their complete trip travel experience. 2. Number of features and functions the traveler finds most valuable.	Trip Feedback Reports
CT-ME-1.4	1. Survey response to determine if the traveler has a trusted companion who uses G-MAP. 2. The average survey response, from those requiring caregiver support, of travelers' rating of how the ability to access support from their caregiver through the ST-CTN system during travel enhanced their complete trip travel experience.	Trip Feedback Reports
CT-ME-1.5	1. Survey response to determine if the traveler has used G-MAP's call center support in the last three months. 2. The average survey response of travelers' rating of how access to the call center through the ST-CTN system enhanced their complete trip travel experience.	Trip Feedback Reports
CT-ME-1.6	The average monthly number of call center support calls per user through the ST-CTN system.	Ride Gwinnett Complaint Log
CT-ME-1.9	Number of destination types accessed by ST-CTN system users. If the traveler selects "other", they will be prompted to specify the destination. The destination types will be defined based on data reviewed in Phase 3 of the ST-CTN project.	A. Traverse Data B. Trip Feedback Reports
CT-ME-1.10	Number of complaints filed to Ride Gwinnett per month pertaining to lack of accessible routes to transit stops.	Ride Gwinnett Complaint Log
CT-ME-2.2	1. The average survey response for if G-MAP gives back additional time in the traveler's schedule. 2. The average survey response for if G-MAP reduces the traveler's time and stress in travel planning. 3. The average survey response for if G-MAP increases the traveler's awareness and confidence in traveling independently. 4. The average survey response for if G-MAP helps the traveler schedule trips more reliably. 5. The average survey response for the traveler's quality of life rating.	Trip Feedback Reports
CT-ME-3.1	The average survey response of travelers' perception of safety while using the ST-CTN system.	Trip Feedback Reports

ID	Performance Measure	Data Source
CT-ME-3.3	1. The average survey response of taking a different route than the ST-CTN system complete trip recommended route. 2. Survey response to understand the variance between ST-CTN system complete trip recommended routes and actual ST-CTN system travel routes taken at signalized intersection crossings.	Trip Feedback Reports
CT-ME-4.1	Average number of fixed-route aggregate riders within the ST-CTN project area.	Fixed-Route Transit Ridership
CT-ME-4.3	1. Survey response of travelers' perception of fixed-route transit service while using the ST-CTN system (i.e., was service enhanced). 2. Survey response of travelers' perception of regular transit service while using the ST-CTN system (i.e., was service enhanced). 3. Survey response of travelers' perception of bus service while using the ST-CTN system (i.e., is it easier to ride the bus). 4. Survey response of travelers' perception of bus safety while using the ST-CTN system (i.e., did the traveler feel safer). 5. Survey response for the time associated with waiting for a bus while using the ST-CTN system (i.e., was waiting time decreased). 6. Survey response of travelers' perception of confidence while riding a bus using the ST-CTN system. 7. Survey response of travelers' perception of trip planning competence for trips with a bus using the ST-CTN system.	Trip Feedback Reports
CV-ME-1.1	The average survey response of travelers' (end user of the ST-CTN system) rating of their perception of enhanced safety while using pedestrian crossing extensions through the ST-CTN system.	Quarterly Survey
CV-ME-2.1	Average transit schedule adherence within the project area, measured by Ride Gwinnett as 0 minutes before / 5 minutes after scheduled time for on-time performance (OTP) for users who received enhanced TSP.	GTFS-Realtime Ride Gwinnett
CV-ME-2.2	Standard deviation of average OTP distribution by route when enhanced TSP is utilized.	GTFS-Realtime Ride Gwinnett
CV-ME-2.4	The average survey response of travelers' (end user of the ST-CTN system) rating of their perception of number of missed pickups with use of the ST-CTN system.	Trip Feedback Reports

Metadata is provided for each dataset submission and project information to support research and enable search and discovery. The DMP, Section 3.3, describes the definitions for entries into the Metadata files, including information about the datasets, their source(s), processes, quality, restrictions, and usage.

7.4 Visualizations and Data Access

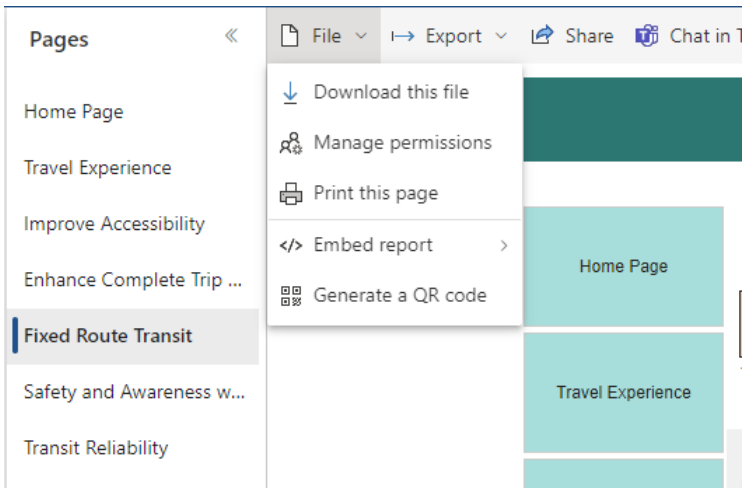
The public PMD is accessible to the public and all users on web browsers including Edge, Chrome, and Safari. Data is presented in a clear manner to transparently share the performance of the ST-CTN system. As stated above, data is displayed on the highlights tab in a visually accessible way with the use of emphasized text, pie charts, bar charts, etc. Examples of PMD visualization methods are shown in **Figure 57.**



Source: GDOT, 2024

Figure 57. Example PMD Visualization Methods

Data shared on the public PMD are accessible and available for download via the File>Download and Export functions shown in **Figure 58**. Metadata is provided and managed to ensure that when data is moved to an open format, it includes comprehensive metadata to maintain the context, source, and history of the data. Metadata are available for review and access from the dashboard site with links to published references such as the PMESP2 and DMP2.



Source: GDOT, 2024

Figure 58. Power BI Download and Export Functions

7.5 Administration Console

The Power BI administration console provides the designer with customizable templates and configurable options to create visualizations and reports, dashboards, and apps. The Power BI basic concepts are described here: The Power BI service - basic concepts for beginners - Power BI | Microsoft Learn.

The public PMD was designed as an app with related dashboards, reports, and semantic models that display performance data.

7.6 Security Approach

Power BI offers a secure platform to design and display data with the following security provisions:

- **Authentication and Authorization.** Open Authorization (OAuth) is used to authorize the user.
- **Data Encryption.** Hypertext Transfer Protocol Secure (HTTPS) for data in transit is used and ensures that any sensitive data is encrypted at rest.
- **Access Controls.** Role-based access controls (RBAC) is used to limit who can see and do what within the system.
- **Audit Logging.** Detailed logs of who accesses the public PMD and what actions they perform are kept.
- **Monitoring and Incident Response.** Site is continuously monitored for unusual access patterns or data breaches and have an incident response plan in place.
- **API Security.** For any API endpoints, rate limiting is used and considered when implementing an API gateway to manage and secure API traffic.
- **Data Integrity Checks.** Checksums or other data integrity checks are used to ensure that the data has not been tampered with during transfer.

The Private PMD ensures that all PII is removed or anonymized prior to being made available to the Public PMD as is described in **Section 5.7**.

7.7 Public PMD Requirement Traceability

The public PMD design elements that meet the requirements are listed in Table 54.

Table 54. Public PMD Design to Requirements Traceability

Req ID	Req Title	Req Statement	Status	Section
1.1.0-017	Network Security	The system shall provide end-to-end encrypted and secure communications including at intermediate points within the wireless and wired infrastructure when exchanging information between subsystems (CV-STM; CV-G-MAP; G-MAP-GCT; and RSU-OBU). The design of the network security features will be developed in Phase 2.	Unchanged	7.6
2.3.0-081	Open Architecture	The system shall exchange data using open APIs including but not limited to REST, JSON, XML or comma delimited separated datasets.	Unchanged	7.3
7.3.0-209	Display Travel Statistics	Public PMD shall display general trip statistics. The types of statistics will be driven by PMESP and stakeholder input during the Agile Development Process. The general trip statistics may include: • Average duration (by leg) and standard deviation of saved trips (e.g., typical commute) • Miles traveled (by each mode) • Number of notifications received by different communication channels and UI methods • Deviations from planned trip plans for actual trips taken • Anonymized trip histories (planned, actual) • Complete trip travel times • Number and variety of destination types"	Updated	7.2
7.3.0-250	Public PMD Display	The public PMD shall display summary of performance measures in graphic and tabular format.	Updated	7.2 7.4
7.3.0-251	Public PMD Access	The public PMD shall provide access to public of the summary performance measures.	Updated	7.1 7.4

8 References

Table 55. Referenced Documents

ID	Referenced Documents
[CVTMP]	AECOM. "Gwinnett County Connected Vehicle Technology Master Plan (CVTMP)." Duluth: Gwinnett County Department of Transportation. (2019).
[CV1K]	Georgia Department of Transportation. "The Regional Connected Vehicle Program Scope of Work." Atlanta: Georgia Department of Transportation.
[ConOps]	Georgia Department of Transportation. Deliverable Task 2 Concept of Operations (Phase 2 Update). Atlanta: U.S. Department of Transportation. (2024).
[SAD]	Georgia Department of Transportation. Deliverable Task 2B System Architecture Document. Atlanta: U.S. Department of Transportation. (2023).
[ICD]	Georgia Department of Transportation. Deliverable Task 2B Interface Control Document. Atlanta: U.S. Department of Transportation. (2024).
[SyRS]	Georgia Department of Transportation. Deliverable Task 2 System Requirements Specification (Phase 2 Update). Atlanta: U.S. Department of Transportation. (2024).
[DMP]	Georgia Department of Transportation. Deliverable Task 2C Data Management Plan. Atlanta: U.S. Department of Transportation. (2023).
[DPP]	Georgia Department of Transportation. Deliverable Task 2C Data Privacy Plan. Atlanta: U.S. Department of Transportation. (2023).
[PMESP]	Georgia Department of Transportation. Deliverable Task 2K Performance Measurement and Evaluation Support Plan. Atlanta: U.S. Department of Transportation. (2023).
[HUA]	Georgia Department of Transportation. Deliverable Task 2K Human Use Approval Summary. Atlanta: U.S. Department of Transportation. (2023).
[ICTDP]	Georgia Department of Transportation. Deliverable Task 13 Integrated Complete Trip Deployment Plan (Phase 2 Update). Atlanta: U.S. Department of Transportation. (2024).

ID	Referenced Documents
[CIP]	Georgia Department of Transportation. Deliverable Task 2D Comprehensive Installation Plan. Atlanta: U.S. Department of Transportation. (2023).
[CMOP]	Georgia Department of Transportation. Deliverable Task 2I Comprehensive Maintenance and Operations Plan. Atlanta: U.S. Department of Transportation. (2024).
[SEMP]	Georgia Department of Transportation. Deliverable Task 12 Systems Engineering Management Plan. Atlanta: U.S. Department of Transportation. (2022).

lists the documents that were used to support the development of the ST-CTN SDD. References to these documents are identified with the acronym provided in brackets.

Table 55. Referenced Documents

ID	Referenced Documents
[CVTMP]	AECOM. "Gwinnett County Connected Vehicle Technology Master Plan (CVTMP)." Duluth: Gwinnett County Department of Transportation. (2019).
[CV1K]	Georgia Department of Transportation. "The Regional Connected Vehicle Program Scope of Work." Atlanta: Georgia Department of Transportation.
[ConOps]	Georgia Department of Transportation. Deliverable Task 2 Concept of Operations (Phase 2 Update). Atlanta: U.S. Department of Transportation. (2024).
[SAD]	Georgia Department of Transportation. Deliverable Task 2B System Architecture Document. Atlanta: U.S. Department of Transportation. (2023).
[ICD]	Georgia Department of Transportation. Deliverable Task 2B Interface Control Document. Atlanta: U.S. Department of Transportation. (2024).
[SyRS]	Georgia Department of Transportation. Deliverable Task 2 System Requirements Specification (Phase 2 Update). Atlanta: U.S. Department of Transportation. (2024).
[DMP]	Georgia Department of Transportation. Deliverable Task 2C Data Management Plan. Atlanta: U.S. Department of Transportation. (2023).
[DPP]	Georgia Department of Transportation. Deliverable Task 2C Data Privacy Plan. Atlanta: U.S. Department of Transportation. (2023).
[PMESP]	Georgia Department of Transportation. Deliverable Task 2K Performance Measurement and Evaluation Support Plan. Atlanta: U.S. Department of Transportation. (2023).
[HUA]	Georgia Department of Transportation. Deliverable Task 2K Human Use Approval Summary. Atlanta: U.S. Department of Transportation. (2023).
[ICTDP]	Georgia Department of Transportation. Deliverable Task 13 Integrated Complete Trip Deployment Plan (Phase 2 Update). Atlanta: U.S. Department of Transportation. (2024).
[CIP]	Georgia Department of Transportation. Deliverable Task 2D Comprehensive Installation Plan. Atlanta: U.S. Department of Transportation. (2023).
[CMOP]	Georgia Department of Transportation. Deliverable Task 2I Comprehensive Maintenance and Operations Plan. Atlanta: U.S. Department of Transportation. (2024).

ID	Referenced Documents
[SEMP]	Georgia Department of Transportation. Deliverable Task 12 Systems Engineering Management Plan. Atlanta: U.S. Department of Transportation. (2022).

Appendix A. Definitions, Acronyms, and Abbreviations

The acronyms and abbreviations used throughout this document are defined in Table 56.

Table 56. Acronyms

Acronym	Definition
ABM	Activity based model
ADA	Americans with Disabilities Act
API	Application programming interfaces
APN	All-path networks
APS	Accessible Pedestrian Signals
ARC	Atlanta Regional Commission
ARCADIS	Arcadis Group
ATMS	Advanced Transportation Management System
Avail	Avail Technologies
AVL	Automatic Vehicle Location
AWS	Amazon Web Services
BLE	Bluetooth Low Emitting
BSM	Basic Safety Message
C2C	Center to center
CAD	Computer Aided Dispatch
CDP	Connected Data Platform
CIP	Comprehensive Installation Plan

Acronym	Definition
CMOP	Comprehensive Maintenance and Operations Plan
CMS	Content Management System
ConOps	Concept of Operations
COTS	Commercial off-the-shelf
CSV	Comma-separated values
CV	Connected Vehicle
CV1K	Connected Vehicle Infrastructure Deployment Program
C-V2X	Cellular Vehicle to Everything
CVTMP	Connected Vehicle Technology Master Plan
DInE	Data Ingestion Engine
DSRC	Dedicated Short-Range Communications
DXF	Drawing Exchange Format
ETMS	Enterprise Transit Management System
FAQ	frequently asked questions
FCC	Federal Communications Commission
FTA	Federal Transit Administration
GA Tech	Georgia Institute of Technology
GCDOT	Gwinnett County Department of Transportation
GCT	Gwinnett County Transit
GDOT	Georgia Department of Transportation
GDPR	General Data Protection Regulation
GeoJSON	Geographic JavaScript Object Notation
GJAC	Gwinnett Justice and Administration Center

Acronym	Definition
G-MAP	Georgia Mobility and Accessible Planner
GOSystems	GO Systems and Solutions
GPS	Global Positioning System
GTFS	General Transit Feed Specification
GTFS-RT	General Transit Feed Specification Real Time
GTRI	Georgia Tech Research Institute
HNTB	HNTB Corporation
HTTPS	Hypertext Transfer Protocol Secure
Hz	Hertz
IAM	Identity and Access Management
ICD	Interface Control Document
ICE	Impedance Computation Engine
ICF	ICF International, Inc.
ICTDP	Integrated Complete Trip Deployment Plan
ID	Identification
IEEE	Institute of Electrical and Electronics Engineers
IMI	Integrated Mobility Innovation
INS	Indoor navigation system
IOO	Infrastructure owner-operators
iOS	iPhone Operating System
IP	Internet Protocol
ISO/IEC	International Organization for Standardization and the International Electrotechnical Commission

Acronym	Definition
ITS	Intelligent Transportation System
JSON	JavaScript Object Notation
KHA	Kimley-Horn and Associates, Inc.
LEP	Limited English proficiency
LTE	Long-term evolution
MDT	Mobile Data Terminal
MIB	Management Information Base
ML	Machine Learning
MPH	Miles per hour
MU	Mobile Unit
MV	Machine vision
NA	Not applicable
NFC	Near field communication
NTCIP	National Transportation Communications for Intelligent Transportation Systems
OAuth	Open Authorization
OBE	On-board equipment
OBU	On-board Unit
OSM	OpenStreetMap
OSS	Open Source Software
OTP	OpenTripPlanner
OTS	Off-the-shelf
PACE	Partnership for an Advanced Computing Environment
PB	Push button

Acronym	Definition
PDF	Portable Document Format
PED-SIG	Mobile Accessible Pedestrian Signal System
PED-X	Pedestrian Crossing
PII	Personal Identifiable Information
PMD	Performance Measurement Dashboard
PMESP	Performance Measurement and Evaluation Support Plan
PNG	Portable Network Graphic
PPA	Pedestrian Presence Alert
QA	Quality Assurance
QC	Quality Control
RAM	Random-access memory
RBAC	Role-Based Access Controls
RDF	Resource Description Framework
REST	Representational State Transfer
RF	Radio frequency
RSE	Roadside Equipment
RSSI	Received Signal Strength Indicator
RSU	Roadside Unit
S3	Simple Storage Service
SaaS	Software as a Service
SAD	System Architecture Document
SCMS	Security Credential Management System
SDD	System Design Document

Acronym	Definition
SDK	Software Development Kit
SDLC	Software Development Life Cycle
SEMP	Systems Engineering Management Plan
SILCGA	Statewide Independent Living Council of Georgia
SMS	Short Message Service
SOI	System of Interest
SPARQL	SPARQL Protocol and RDF Query Language
SQL	Structured Query Language
SRT	Stakeholder review team
SSO	Single Sign-On
ST-CTN	Safe Trips in a Connected Transportation Network
STM	Space Time Memory
SVG	Scalable Vector Graphics
SyRS	System Requirements Specification
TCC	Transportation Control Center
TMC	Traffic Management Center
TSP	Transit Signal Priority
UI	User Interface
URL	Uniform Resource Locator
USDOT	United States Department of Transportation
VRU	Vulnerable road user
VSD	Vehicle Sensor Device
WCAG	Web Content Accessibility Guidance

Acronym	Definition
XML	Extensible Markup Language

Appendix B. Logical Flow for Mobility Mode and Vision Combinations

The G-MAP includes settings that drive the assignment of mobility mode to the user (see **Section 4.3.3.2).** The rules for setting the categories are based on the three questions asked during the registration process or inferred through selected user preferences. The description of the settings is described in **Section 5.3.3.** This section provides a summary of the logical flow for making the assignments. Table 57 describes the questions and corresponding mobility categories, while Table 58 describes the assignments of the question responses to the 18 impedance levels.

Table 57. Mobility Question Corresponding to Mobility Mode Categories

Question	Response Assigned to None Category	Response Assigned to Mobility Category	Response Assigned to Visual Category
Do you regularly use mobility assistive devices? (please select all that apply)	No assistive device	Manual wheelchair (WChairM) Electric wheelchair (WChairE) Mobility scooter (MScooter) Manual walker (Device) Wheeled walker (Device) Cane (Device) Crutches (Device) Baby stroller (Device)	White cane Service animal Other visual assistance device

Question	Response Assigned to None Category	Response Assigned to Mobility Category	Response Assigned to Visual Category
Do you have any mobility limitations that cause you to walk more slowly or more carefully than other people?	No	Yes (Some)	NA
Do you have any vision limitations?	No vision limitations	NA	Low vision (LowVision) Legally-blind (Blind)

Based on the user's answers to the questionnaire, the user is assigned to one of the following mobility mode categories: no mobility limitations (None), some mobility limitations (Some), an assistive device such as manual walker, wheeled walker, cane, crutches, stroller, service animal (Device), a mobility scooter (MScooter), Manual Wheelchair (WChairM), Electric Wheelchair (WChairE). The user will also be assigned to one of the following vision categories: No vision limitations (None), low-vision (LowVision), and legally blind (Blind), or a combination mobility and visual category. The different mobility mode and vision combination logical flows are assigned to one of 18 categories listed in Table 58.

Table 58. Mobility/Vision Mode and Combination Category Descriptions

MMCode	Mobility Mode Description	Mobility Mode Category	Vision Category
None	Person walking who has no mobility limitations	None	No vision limitations
Some	Person walking who has minor mobility limitations (potentially greater impact of pavement disjoints)	Some	NA
Device	Person walking with a mobility device (cane, walker, etc.) or pushing a stroller	Device	NA
WChairM	Person using a standard manual wheelchair	WChairM	NA
WChairE	Person using an electric wheelchair (perhaps across a few wheelchair technology levels)	WChairE	NA
MScooter	Person using a mobility scooter (may not be significantly different than electric wheelchair)	MScooter	NA

MMCode	Mobility Mode Description	Mobility Mode Category	Vision Category
LowVision	Person walking with some Low Vision limitations	LowVision	NA
Blind	Person walking who is blind or has major Low Vision limitations	Blind	NA
Some-LowVision	Person walking who has minor mobility limitations (potentially greater impact of pavement disjoints) with some Low Vision limitations	Some	LowVision
Device-LowVision	Person walking with a mobility device (cane, walker, etc.) or pushing a stroller with some Low Vision limitations	Device	LowVision
WChairM-LowVision	Person using a standard manual wheelchair with some Low Vision limitations	WChairM	LowVision
WChairE-LowVision	Person using an electric wheelchair (perhaps across a few wheelchair technology levels) with some Low Vision limitations	WChairE	LowVision
MScooter-LowVision	Person using a mobility scooter (may not be significantly different than electric wheelchair) with some Low Vision limitations	MScooter	LowVision
Some-Blind	Person walking who has minor mobility limitations (potentially greater impact of pavement disjoints) with major Low Vision limitations	Some	Blind
Device-Blind	Person walking with a mobility device (cane, walker, etc.) or pushing a stroller with major Low Vision limitations	Device	Blind
WChairM-Blind	Person using a standard manual wheelchair with major Low Vision limitations	WChairM	Blind
WChairE-Blind	Person using an electric wheelchair (perhaps across a few wheelchair technology levels) with major Low Vision limitations	WChairE	Blind
MScooter-Blind	Person using a mobility scooter (may not be significantly different than electric wheelchair) with major Low Vision limitations	MScooter	Blind

Appendix C. Initial Impedance Calculations for Sidewalk Assets and Conditions

The initial impedance calculations for sidewalk assets and conditions include values that may be dynamic (Table 59). These are indicated as “TBD”. The matrix and values will be updated and published in the STM GitHub repository at https://github.com/gti-gatech/STM4US.

Table 59. Impedance Calculation Limitations

Variable Name	Impedance Effect Type	Impedance Equation Constraint	Lower Constraint Bound	Upper Constraint Bound	Calculation Notes
ADA Mobility Mode Speed	NA	NA	NA	NA	Use slowest value for mode speed
stmPedLinkID	NA	NA	NA	NA	NA
stmAdaPathNodeAID	NA	NA	NA	NA	NA
stmAdaPathNodeBID	NA	NA	NA	NA	NA
stmPedLinkLength	NA	NA	NA	NA	NA
stmPedLinkImpedanceBase	NA	NA	NA	NA	Divide Length by mode speed
stmPedLinkImpedanceMultiplier	NA	NA	NA	NA	Net multiplier effect
stmPedLinkImpedanceEvents	NA	NA	NA	NA	Add all event effects

Variable Name	Impedance Effect Type	Impedance Equation Constraint	Lower Constraint Bound	Upper Constraint Bound	Calculation Notes
stmPedLinkImpedanceTotal	NA	NA	NA	NA	Multiply and add to get total impedance
stmPedLinkWidth	Multiplier	EQ	-999	-999	Multiply base time by value if = -999
stmPedLinkWidth	Multiplier	EQ	0	0	Multiply base time by value if = 0
stmPedLinkWidth	Multiplier	INBX	0.001	30	Multiply base time by value if < 30"
stmPedLinkSlopeA_B	Multiplier	EQ	-999	-999	Multiply base time by value if = -999
stmPedLinkSlopeA_B	Multiplier	INBX	3	4.999	Multiply base time by value if > 3
stmPedLinkSlopeA_B	Multiplier	INBX	5	100	Multiply base time by value if > 5
stmPedLinkSlopeB_A	Multiplier	EQ	-999	-999	Multiply base time by value if > 3
stmPedLinkSlopeB_A	Multiplier	INBX	3	4.999	Multiply base time by value if > 3
stmPedLinkSlopeB_A	Multiplier	INBX	5	100	Multiply base time by value if > 5

Variable Name	Impedance Effect Type	Impedance Equation Constraint	Lower Constraint Bound	Upper Constraint Bound	Calculation Notes
stmPedLinkMaterial	Multiplier	EQ	Concrete (Smooth)	Concrete (Smooth)	Multiply base time by value if present
stmPedLinkMaterial	Multiplier	EQ	Concrete (Rough)	Concrete (Rough)	Multiply base time by value if present
stmPedLinkMaterial	Multiplier	EQ	Asphalt	Asphalt	Multiply base time by value if present
stmPedLinkMaterial	Multiplier	EQ	Brick	Brick	Multiply base time by value if present
stmPedLinkMaterial	Multiplier	EQ	Hexagonal Pavers	Hexagonal Pavers	Multiply base time by value if present
stmPedLinkMaterial	Multiplier	EQ	Rectangular Pavers	Rectangular Pavers	Multiply base time by value if present
stmPedLinkMaterial	Multiplier	EQ	Cobblestone	Cobblestone	Multiply base time by value if present
stmPedLinkMaterial	Multiplier	EQ	Plastic	Plastic	Multiply base time by value if present
stmPedLinkMaterial	Multiplier	EQ	Wood	Wood	Multiply base time by value if present
stmPedLinkMaterial	Multiplier	EQ	Metal	Metal	Multiply base time by value if present

Variable Name	Impedance Effect Type	Impedance Equation Constraint	Lower Constraint Bound	Upper Constraint Bound	Calculation Notes
stmPedLinkMaterial	Multiplier	EQ	Gravel	Gravel	Multiply base time by value if present
stmPedLinkMaterial	Multiplier	EQ	Grass	Grass	Multiply base time by value if present
stmPedLinkMaterial	Multiplier	EQ	Earth	Earth	Multiply base time by value if present
stmPedLinkMaterial	Multiplier	EQ	Sand	Sand	Multiply base time by value if present
stmPedLinkMaterial	Multiplier	EQ	Other	Other	Multiply base time by value if present
stmPedLinkSurfaceRoughnessScore	Multiplier	EQ	Very Poor	Very Poor	Multiply base time by value if present
stmPedLinkSurfaceRoughnessScore	Multiplier	EQ	Poor	Poor	Multiply base time by value if present
stmPedLinkSurfaceRoughnessScore	Multiplier	EQ	Good	Good	Multiply base time by value if present
stmPedLinkSurfaceRoughnessScore	Multiplier	EQ	Very Good	Very Good	Multiply base time by value if present
stmPedLinkSurfaceRoughnessScore	Multiplier	EQ	Excellent	Excellent	Multiply base time by value if present

Variable Name	Impedance Effect Type	Impedance Equation Constraint	Lower Constraint Bound	Upper Constraint Bound	Calculation Notes
stmPedLinkAreaType	Multiplier	EQ	CBD	CBD	Multiply base time by value if present
stmPedLinkAreaType	Multiplier	EQ	Very High Density Urban	Very High Density Urban	Multiply base time by value if present
stmPedLinkAreaType	Multiplier	EQ	High Density Urban	High Density Urban	Multiply base time by value if present
stmPedLinkAreaType	Multiplier	EQ	Medium Density Urban	Medium Density Urban	Multiply base time by value if present
stmPedLinkAreaType	Multiplier	EQ	Low Density Urban	Low Density Urban	Multiply base time by value if present
stmPedLinkAreaType	Multiplier	EQ	Suburban	Suburban	Multiply base time by value if present
stmPedLinkAreaType	Multiplier	EQ	Exurban	Exurban	Multiply base time by value if present
stmPedLinkAreaType	Multiplier	EQ	Rural	Rural	Multiply base time by value if present
stmPedLinkAreaResidentialDensity	Multiplier	TBD			Multiply base time by value if [condition TBD]
stmPedLinkAreaEmploymentDensity	Multiplier	TBD			Multiply base time by value if [condition TBD]

Variable Name	Impedance Effect Type	Impedance Equation Constraint	Lower Constraint Bound	Upper Constraint Bound	Calculation Notes
stmPedLinkAreaRestaurantDensity	Multiplier	TBD			Multiply base time by value if [condition TBD]
stmPedLinkAreaShoppingDensity	Multiplier	TBD			Multiply base time by value if [condition TBD]
stmPedLinkAreaParkDensity	Multiplier	TBD			Multiply base time by value if [condition TBD]
stmPedLinkAttributeLighting	Multiplier	EQ	Not Lighted	Not Lighted	Multiply base time by value if present
stmPedLinkAttributeLighting	Multiplier	EQ	Minimally Lighted	Minimally Lighted	Multiply base time by value if present
stmPedLinkAttributeLighting	Multiplier	EQ	Somewhat Lighted	Somewhat Lighted	Multiply base time by value if present
stmPedLinkAttributeLighting	Multiplier	EQ	Mostly Lighted	Mostly Lighted	Multiply base time by value if present
stmPedLinkAttributeLighting	Multiplier	EQ	Heavily Lighted	Heavily Lighted	Multiply base time by value if present
stmPedLinkAttributeShadeTrees	Multiplier	EQ	Not Shaded	Not Shaded	Multiply base time by value if present
stmPedLinkAttributeShadeTrees	Multiplier	EQ	Minimally Shaded	Minimally Shaded	Multiply base time by value if present

Variable Name	Impedance Effect Type	Impedance Equation Constraint	Lower Constraint Bound	Upper Constraint Bound	Calculation Notes
stmPedLinkAttributeShadeTrees	Multiplier	EQ	Somewhat Shaded	Somewhat Shaded	Multiply base time by value if present
stmPedLinkAttributeShadeTrees	Multiplier	EQ	Mostly Shaded	Mostly Shaded	Multiply base time by value if present
stmPedLinkAttributeShadeTrees	Multiplier	EQ	Heavily Shaded	Heavily Shaded	Multiply base time by value if present
stmRoadLinkFacilityType	Multiplier	EQ	Centroid Connector	Centroid Connector	Multiply base time by value if present
stmRoadLinkFacilityType	Multiplier	EQ	Interstate/Freeway	Interstate/Freeway	Multiply base time by value if present
stmRoadLinkFacilityType	Multiplier	EQ	Parkway	Parkway	Multiply base time by value if present
stmRoadLinkFacilityType	Multiplier	EQ	HOV Buffer Separated	HOV Buffer Separated	Multiply base time by value if present
stmRoadLinkFacilityType	Multiplier	EQ	HOV Barrier Separated	HOV Barrier Separated	Multiply base time by value if present
stmRoadLinkFacilityType	Multiplier	EQ	High Speed Ramp/CD Road	High Speed Ramp/CD Road	Multiply base time by value if present
stmRoadLinkFacilityType	Multiplier	EQ	Medium Speed Ramp	Medium Speed Ramp	Multiply base time by value if present

Variable Name	Impedance Effect Type	Impedance Equation Constraint	Lower Constraint Bound	Upper Constraint Bound	Calculation Notes
stmRoadLinkFacilityType	Multiplier	EQ	Low Speed Ramp	Low Speed Ramp	Multiply base time by value if present
stmRoadLinkFacilityType	Multiplier	EQ	Loop Ramp	Loop Ramp	Multiply base time by value if present
stmRoadLinkFacilityType	Multiplier	EQ	Off Ramp w/Intersection	Off Ramp w/Intersection	Multiply base time by value if present
stmRoadLinkFacilityType	Multiplier	EQ	On Ramp w/Intersection	On Ramp w/Intersection	Multiply base time by value if present
stmRoadLinkFacilityType	Multiplier	EQ	Expressway	Expressway	Multiply base time by value if present
stmRoadLinkFacilityType	Multiplier	EQ	Principal Arterial Class I	Principal Arterial Class I	Multiply base time by value if present
stmRoadLinkFacilityType	Multiplier	EQ	Principal Arterial Class II	Principal Arterial Class II	Multiply base time by value if present
stmRoadLinkFacilityType	Multiplier	EQ	Minor Arterial Class I	Minor Arterial Class I	Multiply base time by value if present
stmRoadLinkFacilityType	Multiplier	EQ	Minor Arterial Class II	Minor Arterial Class II	Multiply base time by value if present
stmRoadLinkFacilityType	Multiplier	EQ	HOV Arterial (all classes)	HOV Arterial (all classes)	Multiply base time by value if present

Variable Name	Impedance Effect Type	Impedance Equation Constraint	Lower Constraint Bound	Upper Constraint Bound	Calculation Notes
stmRoadLinkFacilityType	Multiplier	EQ	Major Collector	Major Collector	Multiply base time by value if present
stmRoadLinkFacilityType	Multiplier	EQ	Minor Collector/Other Local	Minor Collector/Other Local	Multiply base time by value if present
stmRoadLinkFacilityType	Multiplier	EQ	Planned Ramps w/Intersections	Planned Ramps w/Intersections	Multiply base time by value if present
stmRoadLinkFacilityType	Multiplier	EQ	Planned Directional Ramps	Planned Directional Ramps	Multiply base time by value if present
stmRoadLinkFacilityType	Multiplier	EQ	Transit Only Link	Transit Only Link	Multiply base time by value if present
stmRoadLinkFacilityType	Multiplier	EQ	Neighborhood Local	Neighborhood Local	Multiply base time by value if present
stmRoadLinkFacilityType	Multiplier	EQ	Transit Only Link: Local Roads and Collectors	Transit Only Link: Local Roads and Collectors	Multiply base time by value if present
stmRoadLinkFacilityType	Multiplier	EQ	Transit Only Link: Park-n-ride lot connector	Transit Only Link: Park-n-ride lot connector	Multiply base time by value if present
stmRoadLinkFacilityType	Multiplier	EQ	Transit Only Link: Transfer links	Transit Only Link: Transfer links	Multiply base time by value if present

Variable Name	Impedance Effect Type	Impedance Equation Constraint	Lower Constraint Bound	Upper Constraint Bound	Calculation Notes
			between rail and bus	between rail and bus	
stmRoadLinkFacilityType	Multiplier	EQ	Associated with BRT Routes	Associated with BRT Routes	Multiply base time by value if present
stmRoadLinkAadtA_B	Multiplier	TBD			Multiply base time by value if [condition TBD]
stmRoadLinkAadtB_A	Multiplier	TBD			Multiply base time by value if [condition TBD]
stmRoadLinkPercentHDTA_B	Multiplier	INBX	3	5.999	Multiply base time by value if ≥ 3 and < 6
stmRoadLinkPercentMDTA_B	Multiplier	INBX	6	100	Multiply base time by value if ≥ 6
stmRoadLinkPercentHDTB_A	Multiplier	INBX	3	5.999	Multiply base time by value if ≥ 3 and < 6
stmRoadLinkPercentMDTB_A	Multiplier	INBX	6	100	Multiply base time by value if ≥ 6
stmRoadLinkLanesA_B	Multiplier	INBX	3	20	Multiply base time by value if ≥ 3
stmRoadLinkLanesB_A	Multiplier	INBX	3	20	Multiply base time by value if ≥ 3

Variable Name	Impedance Effect Type	Impedance Equation Constraint	Lower Constraint Bound	Upper Constraint Bound	Calculation Notes
stmRoadLinkLaneWidthA_B	Multiplier	INBX	120	1000	Multiply base time by value if ≥ 120"
stmRoadLinkLaneWidthB_A	Multiplier	INBX	120	1000	Multiply base time by value if ≥ 120"
stmRoadLinkShoulderWidthA_B	Multiplier	INBX	0	35.999	Multiply base time by value if < 36"
stmRoadLinkShoulderWidthB_A	Multiplier	INBX	0	35.999	Multiply base time by value if < 36"
stmRoadLinkSpeedLimit	Multiplier	INBX	30	100	Multiply base time by value if ≥ 30
stmRoadLinkObservedSpeed	Multiplier	INBX	30	100	Multiply base time by value if ≥ 30
stmRoadLinkObservedPedestrianCount	Multiplier	TBD			Multiply base time by value if [condition TBD]
stmRoadLinkObservedCollisions	Multiplier	TBD			Multiply base time by value if [condition TBD]
stmRoadLinkObservedInjuries	Multiplier	TBD			Multiply base time by value if [condition TBD]
stmRoadLinkObservedFatalities	Multiplier	TBD			Multiply base time by value if [condition TBD]

Variable Name	Impedance Effect Type	Impedance Equation Constraint	Lower Constraint Bound	Upper Constraint Bound	Calculation Notes
stmCrossingCrossingPathCrossSlope	Multiplier	EQ	-999	-999	Multiply if crossing cross slope problem identified
stmCrossingCrossingPathCrossSlope	Multiplier	INBX	2.01	1000	Mutiply if cross slope > 2%
Applies to Links and Crossings					
stmAssetDefectReportProblemLinkDisjoint	Event	EQ	Problem	Problem	Add for each defect report associated with the link
stmAssetDefectReportProblemLinkPothole	Event	EQ	Problem	Problem	Add for each defect report associated with the link
stmAssetDefectReportProblemLinkBlocked	Event	EQ	Problem	Problem	Add for each defect report associated with the link
stmAssetDefectReportProblemLinkObstruction	Event	EQ	Problem	Problem	Add for each defect report associated with the link
stmAssetDefectReportProblemLinkDebris	Event	EQ	Problem	Problem	Add for each defect report associated with the link
stmAssetDefectReportProblemLinkWater	Event	EQ	Problem	Problem	Add for each defect report associated with the link

Variable Name	Impedance Effect Type	Impedance Equation Constraint	Lower Constraint Bound	Upper Constraint Bound	Calculation Notes
stmRampType	Event	EQ	Standard Perpendicular Ramp	Standard Perpendicular Ramp	Add per Event
stmRampType	Event	EQ	Diagonal Ramp	Diagonal Ramp	Add per Event
stmRampType	Event	EQ	Parallel Ramp	Parallel Ramp	Add per Event
stmRampType	Event	EQ	Perpendicular Ramp with Return Edges	Perpendicular Ramp with Return Edges	Add per Event
stmRampType	Event	EQ	Combination Perpendicular Parallel Ramp	Combination Perpendicular Parallel Ramp	Add per Event
stmRampType	Event	EQ	Combination Diagonal Parallel Ramp	Combination Diagonal Parallel Ramp	Add per Event
stmRampType	Event	EQ	Built-Up Ramp	Built-Up Ramp	Add per Event
stmRampType	Event	EQ	Linear Ramp	Linear Ramp	Add per Event
stmRampType	Event	EQ	At Grade	At Grade	Add per Event
stmRampWidth	Calculate for Defect	EQ	0	0	Add if ramp is absent (width=0)
stmRampWidth	Calculate for Defect	EQ	-999	-999	Add if defect identified in video inspection

Variable Name	Impedance Effect Type	Impedance Equation Constraint	Lower Constraint Bound	Upper Constraint Bound	Calculation Notes
stmRampWidth	Calculate for Defect	INBX	1	37	Add if less than 36"
stmRampSlope	Calculate for Defect	EQ	-999	-999	Add if defect identified in video inspection
stmRampSlope	Calculate for Defect	INBX	8.34	100	Add if greater than 8.33%
stmRampCrossSlope	Calculate for Defect	EQ	-999	-999	Add if defect identified in video inspection
stmRampCrossSlope	Calculate for Defect	INBX	2.01	1000	Add if greater than 2%
stmRampGutterSlope	Calculate for Defect	EQ	-999	-999	Add if defect identified in video inspection
stmRampGutterSlope	Calculate for Defect	INBX	0.6	100	Add if greater than 0.5%
stmRampPassingWidth	Calculate for Defect	EQ	-999	-999	Add if defect identified in video inspection
stmRampPassingWidth	Calculate for Defect	INBX	0.1	1000	Add if less than 36"
stmRampPassingCrossSlope	Calculate for Defect	EQ	-999	-999	Add if defect identified in video inspection

Variable Name	Impedance Effect Type	Impedance Equation Constraint	Lower Constraint Bound	Upper Constraint Bound	Calculation Notes
stmRampPassingCrossSlope	Calculate for Defect	INBX	2.01	1000	Add if greater than 2%
stmRampFlareSlopeLeft	Calculate for Defect	EQ	-999	-999	Add if defect identified in video inspection
stmRampFlareSlopeLeft	Calculate for Defect	INBX	10.01	1000	Add if greater than 10%
stmRampFlareSlopeRight	Calculate for Defect	EQ	-999	-999	Add if defect identified in video inspection
stmRampFlareSlopeRight	Calculate for Defect	INBX	10.01	1000	Add if greater than 10%
stmRampSmooth	Event	EQ	Problem	Problem	Add per Event
stmRampSmooth	Event	EQ	Not Smooth	Not Smooth	Add per Event
stmRampFlushAtTop	Event	EQ	Problem	Problem	Add per Event
stmRampFlushAtTop	Event	EQ	Not Flush	Not Flush	Add per Event
stmRampFlushAtBottom	Event	EQ	Problem	Problem	Add per Event
stmRampFlushAtBottom	Event	EQ	Not Flush	Not Flush	Add per Event
stmRampFlushAtStreet	Event	EQ	Problem	Problem	Add per Event
stmRampFlushAtStreet	Event	EQ	Not Flush	Not Flush	Add per Event

Variable Name	Impedance Effect Type	Impedance Equation Constraint	Lower Constraint Bound	Upper Constraint Bound	Calculation Notes
stmRampTransitionSlopeLeft	Calculate for Defect	EQ	-999	-999	Add if defect identified in video inspection
stmRampTransitionSlopeLeft	Calculate for Defect	INBX	8.34	100	Add if greater than 8.33%
stmRampTransitionCrossSlopeLeft	Calculate for Defect	EQ	-999	-999	Add if defect identified in video inspection
stmRampTransitionCrossSlopeLeft	Calculate for Defect	INBX	2.01	1000	Add if greater than 2%
stmRampTransitionSlopeRight	Calculate for Defect	EQ	-999	-999	Add if defect identified in video inspection
stmRampTransitionSlopeRight	Calculate for Defect	INBX	8.34	100	Add if greater than 8.33%
stmRampTransitionCrossSlopeRight	Calculate for Defect	EQ	-999	-999	Add if defect identified in video inspection
stmRampTransitionCrossSlopeRight	Calculate for Defect	INBX	2.01	100	Add if greater than 2%
stmRampLandingMinimumWidth	Calculate for Defect	EQ	-999	-999	Add if defect identified in video inspection
stmRampLandingMinimumWidth	Calculate for Defect	INBX	0	35.99	Add if less than 48" (PROWAG)

Variable Name	Impedance Effect Type	Impedance Equation Constraint	Lower Constraint Bound	Upper Constraint Bound	Calculation Notes
stmRampLandingCrossSlope	Calculate for Defect	EQ	-999	-999	Add if defect identified in video inspection
stmRampLandingCrossSlope	Calculate for Defect	INBX	2.01	100	Add if greater than 2% (level 360 degrees)
stmPedRampDetectableWarningPresent	Event	EQ	Absent	Absent	Add per Event
stmPedRampDetectableWarningCondition	Event	EQ	Problem	Problem	Add per Event
stmPedRampDetectableWarningCondition	Event	EQ	Good	Good	Add per Event
stmPedRampDetectableWarningCondition	Event	EQ	Fair	Fair	Add per Event
stmPedRampDetectableWarningCondition	Event	EQ	Poor	Poor	Add per Event
stmCurbCutType	Event	EQ	Standard Curb Cut	Standard Curb Cut	Add per Event
stmCurbCutType	Event	EQ	Historic Curb Cut	Historic Curb Cut	Add per Event
stmCurbCutType	Event	EQ	Sidewalk Diversion Curb Cut	Sidewalk Diversion Curb Cut	Add per Event
stmCurbCutType	Event	EQ	Sidewalk Depression Curb Cut	Sidewalk Depression Curb Cut	Add per Event
stmCurbCutType	Event	EQ	Other Curb Cut	Other Curb Cut	Add per Event

Variable Name	Impedance Effect Type	Impedance Equation Constraint	Lower Constraint Bound	Upper Constraint Bound	Calculation Notes
stmCurbCutWidthTop	Calculate for Defect	OUTBX	0	200	Add if greater than 200 inches
stmCurbCutPassingWidth	Calculate for Defect	EQ	-999	-999	Add if defect identified in video inspection
stmCurbCutPassingWidth	Calculate for Defect	INBX	0	35.9	Add if less than 36"
stmCurbCutCrossSlope	Calculate for Defect	EQ	-999	-999	Add if defect identified in video inspection
stmCurbCutCrossSlope	Calculate for Defect	INBX	2.01	1000	Add if greater than 2%
stmCurbCutFlareSlopeLeft	Calculate for Defect	EQ	-999	-999	Add if defect identified in video inspection
stmCurbCutFlareSlopeLeft	Calculate for Defect	INBX	10.1	100	Add if greater than 10%
stmCurbCutFlareSlopeRight	Calculate for Defect	EQ	-999	-999	Add if defect identified in video inspection
stmCurbCutFlareSlopeRight	Calculate for Defect	INBX	10.1	100	Add if greater than 10%
stmCurbCutRampSlopeLeft	Calculate for Defect	EQ	-999	-999	Add if defect identified in video inspection

Variable Name	Impedance Effect Type	Impedance Equation Constraint	Lower Constraint Bound	Upper Constraint Bound	Calculation Notes
stmCurbCutRampSlopeLeft	Calculate for Defect	INBX	8.34	100	Add if greater than 8.33%
stmCurbCutRampCrossSlopeLeft	Calculate for Defect	EQ	-999	-999	Add if defect identified in video inspection
stmCurbCutRampCrossSlopeLeft	Calculate for Defect	INBX	2.01	1000	Add if greater than 2%
stmCurbCutRampSlopeRight	Calculate for Defect	EQ	-999	-999	Add if defect identified in video inspection
stmCurbCutRampSlopeRight	Calculate for Defect	INBX	8.34	100	Add if greater than 8.33%
stmCurbCutRampCrossSlopeRight	Calculate for Defect	EQ	-999	-999	Add if defect identified in video inspection
stmCurbCutRampCrossSlopeRight	Calculate for Defect	INBX	2.01	100	Add if greater than 2%
stmCurbCutDepressionSidewalkWidth	Calculate for Defect	EQ	-999	-999	Add if defect identified in video inspection
stmCurbCutDepressionSidewalkWidth	Calculate for Defect	INBX	0	35.9	Add if less than 36"
Crossing impedance logic updates pending					
stmCrossingSignalControlledIntersection	Event	EQ	No	No	Add per Event

Variable Name	Impedance Effect Type	Impedance Equation Constraint	Lower Constraint Bound	Upper Constraint Bound	Calculation Notes
stmCrossingSignalControlledIntersection	Event	EQ	Yes	Yes	Add per Event
stmCrossingStopControlledIntersection	Event	EQ	No	No	Add per Event
stmCrossingStopControlledIntersection	Event	EQ	Yes	Yes	Add per Event
stmCrossingCrosswalkPresent	Event	EQ	No	No	Add per Event
stmCrossingCrosswalkPresent	Event	EQ	Yes	Yes	Add per Event
stmCrossingCrosswalkComplete	Event	EQ	No	No	Add per Event
stmCrossingCrosswalkComplete	Event	EQ	Yes	Yes	Add per Event
stmCrossingCrosswalkandRampsAligned	Event	EQ	No	No	Add per Event
stmCrossingCrosswalkandRampsAligned	Event	EQ	Yes	Yes	Add per Event
stmCrossingCrosswalkStyle	Event	EQ	Parallel (Standard)	Parallel (Standard)	Add per Event
stmCrossingCrosswalkStyle	Event	EQ	Perpendicular Dash (Continental)	Perpendicular Dash (Continental)	Add per Event
stmCrossingCrosswalkStyle	Event	EQ	Diagonal Stripe (Zebra)	Diagonal Stripe (Zebra)	Add per Event
stmCrossingCrosswalkStyle	Event	EQ	Other	Other	Add per Event
stmCrossingCrosswalkStyle	Event	EQ	None	None	Add per Event

Variable Name	Impedance Effect Type	Impedance Equation Constraint	Lower Constraint Bound	Upper Constraint Bound	Calculation Notes
stmCrossingCrosswalkPaintConditions	Event	EQ	Good	Good	Add per Event
stmCrossingCrosswalkPaintConditions	Event	EQ	Fair	Fair	Add per Event
stmCrossingCrosswalkPaintConditions	Event	EQ	Poor	Poor	Add per Event
stmCrossingNSRamp	Event	EQ	Absent	Absent	Add per Event
stmCrossingNSLanding	Event	EQ	Absent	Absent	Add per Event
stmCrossingNSPushButtonConditionAndAlignment	Event	EQ	Good	Good	Add per Event
stmCrossingNSPushButtonConditionAndAlignment	Event	EQ	Fair	Fair	Add per Event
stmCrossingNSPushButtonConditionAndAlignment	Event	EQ	Poor	Poor	Add per Event
stmCrossingNSPushButtonConditionAndAlignment	Event	EQ	Absent	Absent	Add per Event
stmCrossingNSPushButtonVoiceSystem	Event	EQ	Good	Good	Add per Event
stmCrossingNSPushButtonVoiceSystem	Event	EQ	Fair	Fair	Add per Event
stmCrossingNSPushButtonVoiceSystem	Event	EQ	Poor	Poor	Add per Event
stmCrossingNSPushButtonVoiceSystem	Event	EQ	Absent	Absent	Add per Event
stmCrossingNSPushButtonHeightOK	Event	EQ	No	No	Add per Event

Variable Name	Impedance Effect Type	Impedance Equation Constraint	Lower Constraint Bound	Upper Constraint Bound	Calculation Notes
stmCrossingNSPushButtonHeightOK	Event	EQ	Yes	Yes	Add per Event
stmCrossingNSPushButtonReachOK	Event	EQ	No	No	Add per Event
stmCrossingNSPushButtonReachOK	Event	EQ	Yes	Yes	Add per Event
stmCrossingNSSigns	Event	EQ	Good	Good	Add per Event
stmCrossingNSSigns	Event	EQ	Fair	Fair	Add per Event
stmCrossingNSSigns	Event	EQ	Poor	Poor	Add per Event
stmCrossingNSSigns	Event	EQ	Absent	Absent	Add per Event
stmCrossingFSSignalHeadCondition	Event	EQ	Good	Good	Add per Event
stmCrossingFSSignalHeadCondition	Event	EQ	Fair	Fair	Add per Event
stmCrossingFSSignalHeadCondition	Event	EQ	Poor	Poor	Add per Event
stmCrossingFSSignalHeadCondition	Event	EQ	Absent	Absent	Add per Event
stmCrossingFSSignalHeadLampWorking	Event	EQ	No	No	Add per Event
stmCrossingFSSignalHeadLampWorking	Event	EQ	Yes	Yes	Add per Event
stmCrossingFSSignalHeadVisible	Event	EQ	No	No	Add per Event
stmCrossingFSSignalHeadVisible	Event	EQ	Yes	Yes	Add per Event
stmCrossingFSRamp	Event	EQ	Absent	Absent	Add per Event

Variable Name	Impedance Effect Type	Impedance Equation Constraint	Lower Constraint Bound	Upper Constraint Bound	Calculation Notes
stmCrossingFSLanding	Event	EQ	Absent	Absent	Add per Event
stmCrossingFSPushButtonConditionAndAlignment	Event	EQ	Good	Good	Add per Event
stmCrossingFSPushButtonConditionAndAlignment	Event	EQ	Fair	Fair	Add per Event
stmCrossingFSPushButtonConditionAndAlignment	Event	EQ	Poor	Poor	Add per Event
stmCrossingFSPushButtonConditionAndAlignment	Event	EQ	Absent	Absent	Add per Event
stmCrossingFSPushButtonVoiceSystem	Event	EQ	Good	Good	Add per Event
stmCrossingFSPushButtonVoiceSystem	Event	EQ	Fair	Fair	Add per Event
stmCrossingFSPushButtonVoiceSystem	Event	EQ	Poor	Poor	Add per Event
stmCrossingFSPushButtonVoiceSystem	Event	EQ	Absent	Absent	Add per Event
stmCrossingFSPushButtonHeightOK	Event	EQ	No	No	Add per Event
stmCrossingFSPushButtonHeightOK	Event	EQ	Yes	Yes	Add per Event
stmCrossingFSPushButtonReachOK	Event	EQ	No	No	Add per Event
stmCrossingFSPushButtonReachOK	Event	EQ	Yes	Yes	Add per Event
stmCrossingFSSigns	Event	EQ	Good	Good	Add per Event

Variable Name	Impedance Effect Type	Impedance Equation Constraint	Lower Constraint Bound	Upper Constraint Bound	Calculation Notes
stmCrossingFSSigns	Event	EQ	Fair	Fair	Add per Event
stmCrossingFSSigns	Event	EQ	Poor	Poor	Add per Event
stmCrossingFSSigns	Event	EQ	Absent	Absent	Add per Event
stmCrossingNSSignalHeadConditionAndAlignment	Event	EQ	Good	Good	Add per Event
stmCrossingNSSignalHeadConditionAndAlignment	Event	EQ	Fair	Fair	Add per Event
stmCrossingNSSignalHeadConditionAndAlignment	Event	EQ	Poor	Poor	Add per Event
stmCrossingNSSignalHeadConditionAndAlignment	Event	EQ	Absent	Absent	Add per Event
stmCrossingNSSignalHeadLampWorking	Event	EQ	No	No	Add per Event
stmCrossingNSSignalHeadLampWorking	Event	EQ	Yes	Yes	Add per Event
stmCrossingNSSignalHeadVisible	Event	EQ	No	No	Add per Event
stmCrossingNSSignalHeadVisible	Event	EQ	Yes	Yes	Add per Event
stmCrossingLinkVehicleVolumeRightA_B	Calculate for Defect	EQ			Add if [conditions TBD]
stmCrossingLinkVehicleVolumeLeftA_B	Calculate for Defect	EQ			Add if [conditions TBD]

Variable Name	Impedance Effect Type	Impedance Equation Constraint	Lower Constraint Bound	Upper Constraint Bound	Calculation Notes
stmCrossingLinkVehicleVolumeThroughA_B	Calculate for Defect	EQ			Add if [conditions TBD]
stmCrossingLinkVehicleVolumeRightB_A	Calculate for Defect	EQ			Add if [conditions TBD]
stmCrossingLinkVehicleVolumeLeftB_A	Calculate for Defect	EQ			Add if [conditions TBD]
stmCrossingLinkVehicleVolumeThroughB_A	Calculate for Defect	EQ			Add if [conditions TBD]

Appendix D. Impedance Calculations by Mode

Table 60 provides detailed list of impedance calculations by mode.

Table 60. Impedance Calculations by Mode

Variable Name	None	Some	Device	WChairM	WChairE	MScooter	LowVision	Blind
ADA Mobility Mode Speed	2.50	2.00	1.50	3.00	4.00	5.00	2.00	1.50
stmPedLinkID	NA	NA	NA	NA	NA	NA	NA	NA
stmAdaPathNodeAID	NA	NA	NA	NA	NA	NA	NA	NA
stmAdaPathNodeBID	NA	NA	NA	NA	NA	NA	NA	NA
stmPedLinkLength	NA	NA	NA	NA	NA	NA	NA	NA
stmPedLinkImpedanceBase	NA	NA	NA	NA	NA	NA	NA	NA
stmPedLinkImpedanceMultiplier	NA	NA	NA	NA	NA	NA	NA	NA
stmPedLinkImpedanceEvents	NA	NA	NA	NA	NA	NA	NA	NA
stmPedLinkImpedanceTotal	NA	NA	NA	NA	NA	NA	NA	NA
stmPedLinkWidth	1.20	1.20	1.20	2.00	2.00	2.00	1.20	1.20

Variable Name	None	Some	Device	WChairM	WChairE	MScooter	LowVision	Blind
stmPedLinkWidth	2.00	4.00	4.00	999.00	999.00	999.00	999.00	999.00
stmPedLinkWidth	1.20	1.20	1.20	2.00	2.00	2.00	1.20	1.20
stmPedLinkSlopeA_B	1.10	1.10	1.10	1.10	1.10	1.10	1.10	1.10
stmPedLinkSlopeA_B	1.10	1.10	1.10	1.10	1.10	1.10	1.10	1.10
stmPedLinkSlopeA_B	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20
stmPedLinkSlopeB_A	1.10	1.10	1.10	1.10	1.10	1.10	1.10	1.10
stmPedLinkSlopeB_A	1.10	1.10	1.10	1.10	1.10	1.10	1.10	1.10
stmPedLinkSlopeB_A	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20
stmPedLinkMaterial	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
stmPedLinkMaterial	1.10	1.20	1.30	1.20	1.10	1.10	1.20	1.20
stmPedLinkMaterial	1.10	1.20	1.30	1.20	1.10	1.10	1.20	1.20
stmPedLinkMaterial	1.10	1.20	1.30	1.20	1.10	1.10	1.20	1.20
stmPedLinkMaterial	1.10	1.20	1.30	1.20	1.10	1.10	1.20	1.20
stmPedLinkMaterial	1.10	1.20	1.30	1.20	1.10	1.10	1.20	1.20
stmPedLinkMaterial	1.10	1.20	1.30	1.20	1.10	1.10	1.20	1.20

Variable Name	None	Some	Device	WChairM	WChairE	MScooter	LowVision	Blind
stmPedLinkMaterial	1.10	1.20	1.30	1.20	1.10	1.10	1.20	1.20
stmPedLinkMaterial	1.10	1.20	1.30	1.20	1.10	1.10	1.20	1.20
stmPedLinkMaterial	1.10	1.20	1.30	1.20	1.10	1.10	1.20	1.20
stmPedLinkMaterial	1.10	1.20	1.30	1.20	1.10	1.10	1.20	1.20
stmPedLinkMaterial	1.10	1.20	1.30	1.20	1.10	1.10	1.20	1.20
stmPedLinkMaterial	1.10	1.20	1.30	1.20	1.10	1.10	1.20	1.20
stmPedLinkMaterial	1.10	1.20	1.30	1.20	1.10	1.10	1.20	1.20
stmPedLinkMaterial	1.10	1.20	1.30	1.20	1.10	1.10	1.20	1.20
stmPedLinkSurfaceRoughnessScore	1.00	1.20	1.20	1.30	1.10	1.10	1.30	1.30
stmPedLinkSurfaceRoughnessScore	1.00	1.10	1.10	1.10	1.10	1.10	1.10	1.10
stmPedLinkSurfaceRoughnessScore	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
stmPedLinkSurfaceRoughnessScore	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
stmPedLinkSurfaceRoughnessScore	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
stmPedLinkAreaType	1.30	1.30	1.30	1.30	1.30	1.30	1.30	1.30
stmPedLinkAreaType	1.30	1.30	1.30	1.30	1.30	1.30	1.30	1.30

Variable Name	None	Some	Device	WChairM	WChairE	MScooter	LowVision	Blind
stmPedLinkAreaType	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20
stmPedLinkAreaType	1.10	1.10	1.10	1.10	1.10	1.10	1.10	1.10
stmPedLinkAreaType	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
stmPedLinkAreaType	1.10	1.10	1.10	1.10	1.10	1.10	1.10	1.10
stmPedLinkAreaType	1.30	1.30	1.30	1.30	1.30	1.30	1.30	1.30
stmPedLinkAreaType	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20
stmPedLinkAreaResidentialDensity	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
stmPedLinkAreaEmploymentDensity	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
stmPedLinkAreaRestaurantDensity	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
stmPedLinkAreaShoppingDensity	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
stmPedLinkAreaParkDensity	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
stmPedLinkAttributeLighting	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20
stmPedLinkAttributeLighting	1.15	1.15	1.15	1.15	1.15	1.15	1.15	1.15
stmPedLinkAttributeLighting	1.10	1.10	1.10	1.10	1.10	1.10	1.10	1.10
stmPedLinkAttributeLighting	1.05	1.05	1.05	1.05	1.05	1.05	1.05	1.05

Variable Name	None	Some	Device	WChairM	WChairE	MScooter	LowVision	Blind
stmPedLinkAttributeLighting	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
stmPedLinkAttributeShadeTrees	1.15	1.15	1.15	1.15	1.15	1.15	1.15	1.15
stmPedLinkAttributeShadeTrees	1.10	1.10	1.10	1.10	1.10	1.10	1.10	1.10
stmPedLinkAttributeShadeTrees	1.05	1.05	1.05	1.05	1.05	1.05	1.05	1.05
stmPedLinkAttributeShadeTrees	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
stmPedLinkAttributeShadeTrees	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
stmRoadLinkFacilityType	999.00	999.00	999.00	999.00	999.00	999.00	999.00	999.00
stmRoadLinkFacilityType	999.00	999.00	999.00	999.00	999.00	999.00	999.00	999.00
stmRoadLinkFacilityType	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00
stmRoadLinkFacilityType	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00
stmRoadLinkFacilityType	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00
stmRoadLinkFacilityType	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00
stmRoadLinkFacilityType	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00
stmRoadLinkFacilityType	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00
stmRoadLinkFacilityType	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00

Variable Name	None	Some	Device	WChairM	WChairE	MScooter	LowVision	Blind
stmRoadLinkFacilityType	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00
stmRoadLinkFacilityType	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00
stmRoadLinkFacilityType	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00
stmRoadLinkFacilityType	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20
stmRoadLinkFacilityType	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20
stmRoadLinkFacilityType	1.10	1.10	1.10	1.10	1.10	1.10	1.10	1.10
stmRoadLinkFacilityType	1.10	1.10	1.10	1.10	1.10	1.10	1.10	1.10
stmRoadLinkFacilityType	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20
stmRoadLinkFacilityType	1.10	1.10	1.10	1.10	1.10	1.10	1.10	1.10
stmRoadLinkFacilityType	1.05	1.05	1.05	1.05	1.05	1.05	1.05	1.05
stmRoadLinkFacilityType	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00
stmRoadLinkFacilityType	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00
stmRoadLinkFacilityType	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00
stmRoadLinkFacilityType	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
stmRoadLinkFacilityType	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00

Variable Name	None	Some	Device	WChairM	WChairE	MScooter	LowVision	Blind
stmRoadLinkFacilityType	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
stmRoadLinkFacilityType	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
stmRoadLinkFacilityType	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
stmRoadLinkAadtA_B	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
stmRoadLinkAadtB_A	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
stmRoadLinkPercentHDTA_B	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20
stmRoadLinkPercentMDTA_B	1.10	1.10	1.10	1.10	1.10	1.10	1.10	1.10
stmRoadLinkPercentHDTB_A	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20
stmRoadLinkPercentMDTB_A	1.10	1.10	1.10	1.10	1.10	1.10	1.10	1.10
stmRoadLinkLanesA_B	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20
stmRoadLinkLanesB_A	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20
stmRoadLinkLaneWidthA_B	1.10	1.10	1.10	1.10	1.10	1.10	1.10	1.10
stmRoadLinkLaneWidthB_A	1.10	1.10	1.10	1.10	1.10	1.10	1.10	1.10
stmRoadLinkShoulderWidthA_B	1.10	1.10	1.10	1.10	1.10	1.10	1.10	1.10
stmRoadLinkShoulderWidthB_A	1.10	1.10	1.10	1.10	1.10	1.10	1.10	1.10

Variable Name	None	Some	Device	WChairM	WChairE	MScooter	LowVision	Blind
stmRoadLinkSpeedLimit	1.10	1.10	1.10	1.10	1.10	1.10	1.10	1.10
stmRoadLinkObservedSpeed	1.10	1.10	1.10	1.10	1.10	1.10	1.10	1.10
stmRoadLinkObservedPedestrianCount	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
stmRoadLinkObservedCollisions	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
stmRoadLinkObservedInjuries	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
stmRoadLinkObservedFatalities	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
stmCrossingCrossingPathCrossSlope	1.00	1.00	1.10	1.20	1.00	1.00	1.10	1.10
stmCrossingCrossingPathCrossSlope	1.00	1.00	1.10	1.20	1.00	1.00	1.10	1.10
Applies to Links and Crossings								
stmAssetDefectReportProblemLinkDisjoint	0.0042	0.0042	0.0042	0.0083	0.0083	0.0083	0.0042	0.0042
stmAssetDefectReportProblemLinkPothole	0.0042	0.0042	0.0042	0.0125	0.0083	0.0083	0.0083	0.0083
stmAssetDefectReportProblemLinkBlocked	0.0042	0.0042	0.0042	0.0500	0.0333	0.0333	0.0333	0.0500
stmAssetDefectReportProblemLinkObstruction	0.0042	0.0042	0.0042	0.0167	0.0167	0.0083	0.0042	0.0042
stmAssetDefectReportProblemLinkDebris	0.0042	0.0042	0.0042	0.0167	0.0167	0.0083	0.0042	0.0042
stmAssetDefectReportProblemLinkWater	0.0042	0.0042	0.0042	0.0167	0.0167	0.0083	0.0042	0.0042

Variable Name	None	Some	Device	WChairM	WChairE	MScooter	LowVision	Blind
stmRampType	0.0008	0.0008	0.0008	0.0008	0.0008	0.0008	0.0008	0.0008
stmRampType	0.0042	0.0042	0.0042	0.0042	0.0042	0.0042	0.0042	0.0042
stmRampType	0.0017	0.0017	0.0017	0.0017	0.0017	0.0017	0.0017	0.0017
stmRampType	0.0008	0.0008	0.0008	0.0008	0.0008	0.0008	0.0008	0.0008
stmRampType	0.0008	0.0008	0.0008	0.0008	0.0008	0.0008	0.0008	0.0008
stmRampType	0.0042	0.0042	0.0042	0.0042	0.0042	0.0042	0.0042	0.0042
stmRampType	0.0017	0.0017	0.0017	0.0017	0.0017	0.0017	0.0017	0.0017
stmRampType	0.0008	0.0008	0.0008	0.0008	0.0008	0.0008	0.0008	0.0008
stmRampType	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
stmRampWidth	0.0000	0.0000	0.0083	0.0500	0.0500	0.0500	0.0083	0.0167
stmRampWidth	0.0000	0.0017	0.0033	0.0083	0.0083	0.0083	0.0042	0.0042
stmRampWidth	0.0000	0.0017	0.0033	0.0083	0.0083	0.0083	0.0042	0.0042
stmRampSlope	0.0000	0.0017	0.0033	0.0083	0.0042	0.0017	0.0042	0.0042
stmRampSlope	0.0000	0.0017	0.0033	0.0083	0.0042	0.0017	0.0042	0.0042
stmRampCrossSlope	0.0000	0.0017	0.0033	0.0042	0.0000	0.0000	0.0017	0.0033

Variable Name	None	Some	Device	WChairM	WChairE	MScooter	LowVision	Blind
stmRampCrossSlope	0.0000	0.0017	0.0033	0.0042	0.0000	0.0000	0.0017	0.0033
stmRampGutterSlope	0.0000	0.0000	0.0000	0.0083	0.0042	0.0000	0.0000	0.0000
stmRampGutterSlope	0.0000	0.0000	0.0000	0.0083	0.0042	0.0000	0.0000	0.0000
stmRampPassingWidth	0.0000	0.0017	0.0033	0.0083	0.0083	0.0083	0.0042	0.0042
stmRampPassingWidth	0.0000	0.0017	0.0033	0.0083	0.0083	0.0083	0.0042	0.0042
stmRampPassingCrossSlope	0.0000	0.0017	0.0033	0.0042	0.0000	0.0000	0.0017	0.0033
stmRampPassingCrossSlope	0.0000	0.0017	0.0033	0.0042	0.0000	0.0000	0.0017	0.0033
stmRampFlareSlopeLeft	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0042	0.0042
stmRampFlareSlopeLeft	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0042	0.0042
stmRampFlareSlopeRight	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0042	0.0042
stmRampFlareSlopeRight	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0042	0.0042
stmRampSmooth	0.0000	0.0008	0.0008	0.0033	0.0000	0.0000	0.0017	0.0017
stmRampSmooth	0.0000	0.0008	0.0008	0.0033	0.0000	0.0000	0.0017	0.0017
stmRampFlushAtTop	0.0000	0.0008	0.0008	0.0033	0.0000	0.0000	0.0017	0.0017
stmRampFlushAtTop	0.0000	0.0008	0.0008	0.0033	0.0000	0.0000	0.0017	0.0017

Variable Name	None	Some	Device	WChairM	WChairE	MScooter	LowVision	Blind
stmRampFlushAtBottom	0.0000	0.0008	0.0008	0.0033	0.0000	0.0000	0.0017	0.0017
stmRampFlushAtBottom	0.0000	0.0008	0.0008	0.0033	0.0000	0.0000	0.0017	0.0017
stmRampFlushAtStreet	0.0000	0.0008	0.0008	0.0033	0.0000	0.0000	0.0017	0.0017
stmRampFlushAtStreet	0.0000	0.0008	0.0008	0.0033	0.0000	0.0000	0.0017	0.0017
stmRampTransitionSlopeLeft	0.0000	0.0017	0.0033	0.0083	0.0042	0.0017	0.0042	0.0042
stmRampTransitionSlopeLeft	0.0000	0.0017	0.0033	0.0083	0.0042	0.0017	0.0042	0.0042
stmRampTransitionCrossSlopeLeft	0.0000	0.0017	0.0033	0.0042	0.0000	0.0000	0.0017	0.0033
stmRampTransitionCrossSlopeLeft	0.0000	0.0017	0.0033	0.0042	0.0000	0.0000	0.0017	0.0033
stmRampTransitionSlopeRight	0.0000	0.0017	0.0033	0.0083	0.0042	0.0017	0.0042	0.0042
stmRampTransitionSlopeRight	0.0000	0.0017	0.0033	0.0083	0.0042	0.0017	0.0042	0.0042
stmRampTransitionCrossSlopeRight	0.0000	0.0017	0.0033	0.0042	0.0000	0.0000	0.0017	0.0033
stmRampTransitionCrossSlopeRight	0.0000	0.0017	0.0033	0.0042	0.0000	0.0000	0.0017	0.0033
stmRampLandingMinimumWidth	0.0000	0.0017	0.0033	0.0083	0.0083	0.0083	0.0042	0.0042
stmRampLandingMinimumWidth	0.0000	0.0017	0.0033	0.0083	0.0083	0.0083	0.0042	0.0042
stmRampLandingCrossSlope	0.0000	0.0017	0.0033	0.0042	0.0000	0.0000	0.0017	0.0033

Variable Name	None	Some	Device	WChairM	WChairE	MScooter	LowVision	Blind
stmRampLandingCrossSlope	0.0000	0.0017	0.0033	0.0042	0.0000	0.0000	0.0017	0.0033
stmPedRampDetectableWarningPresent	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0017	0.0033
stmPedRampDetectableWarningCondition	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0017	0.0033
stmPedRampDetectableWarningCondition	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0017	0.0033
stmPedRampDetectableWarningCondition	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0017	0.0033
stmPedRampDetectableWarningCondition	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0017	0.0033
stmCurbCutType	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
stmCurbCutType	0.0000	0.0042	0.0042	0.0083	0.0042	0.0042	0.0042	0.0042
stmCurbCutType	0.0000	0.0000	0.0000	0.0042	0.0000	0.0000	0.0000	0.0000
stmCurbCutType	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
stmCurbCutType	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
stmCurbCutWidthTop	0.0083	0.0083	0.0083	0.0083	0.0083	0.0083	0.0083	0.0083
stmCurbCutPassingWidth	0.0000	0.0017	0.0033	0.0083	0.0083	0.0083	0.0042	0.0042
stmCurbCutPassingWidth	0.0000	0.0017	0.0033	0.0083	0.0083	0.0083	0.0042	0.0042
stmCurbCutCrossSlope	0.0000	0.0017	0.0033	0.0042	0.0000	0.0000	0.0017	0.0033

Variable Name	None	Some	Device	WChairM	WChairE	MScooter	LowVision	Blind
stmCurbCutCrossSlope	0.0000	0.0017	0.0033	0.0042	0.0000	0.0000	0.0017	0.0033
stmCurbCutFlareSlopeLeft	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0017	0.0017
stmCurbCutFlareSlopeLeft	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0017	0.0017
stmCurbCutFlareSlopeRight	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0017	0.0017
stmCurbCutFlareSlopeRight	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0017	0.0017
stmCurbCutRampSlopeLeft	0.0000	0.0042	0.0042	0.0083	0.0042	0.0042	0.0042	0.0042
stmCurbCutRampSlopeLeft	0.0000	0.0042	0.0042	0.0083	0.0042	0.0042	0.0042	0.0042
stmCurbCutRampCrossSlopeLeft	0.0000	0.0017	0.0033	0.0042	0.0000	0.0000	0.0017	0.0033
stmCurbCutRampCrossSlopeLeft	0.0000	0.0017	0.0033	0.0042	0.0000	0.0000	0.0017	0.0033
stmCurbCutRampSlopeRight	0.0000	0.0042	0.0042	0.0083	0.0042	0.0042	0.0042	0.0042
stmCurbCutRampSlopeRight	0.0000	0.0042	0.0042	0.0083	0.0042	0.0042	0.0042	0.0042
stmCurbCutRampCrossSlopeRight	0.0000	0.0017	0.0033	0.0042	0.0000	0.0000	0.0017	0.0033
stmCurbCutRampCrossSlopeRight	0.0000	0.0017	0.0033	0.0042	0.0000	0.0000	0.0017	0.0033
stmCurbCutDepressionSidewalkWidth	0.0000	0.0017	0.0033	0.0083	0.0083	0.0083	0.0042	0.0042
stmCurbCutDepressionSidewalkWidth	0.0000	0.0017	0.0033	0.0083	0.0083	0.0083	0.0042	0.0042

Variable Name	None	Some	Device	WChairM	WChairE	MScooter	LowVision	Blind
Crossing impedance logic updates pending								
stmCrossingSignalControlledIntersection	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
stmCrossingSignalControlledIntersection	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
stmCrossingStopControlledIntersection	0.0042	0.0042	0.0042	0.0042	0.0042	0.0042	0.0042	0.0042
stmCrossingStopControlledIntersection	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
stmCrossingCrosswalkPresent	0.0033	0.0033	0.0033	0.0033	0.0033	0.0033	0.0033	0.0033
stmCrossingCrosswalkPresent	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
stmCrossingCrosswalkComplete	0.0017	0.0017	0.0017	0.0017	0.0017	0.0017	0.0017	0.0017
stmCrossingCrosswalkComplete	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
stmCrossingCrosswalkandRampsAligned	0.0017	0.0017	0.0017	0.0017	0.0017	0.0017	0.0017	0.0017
stmCrossingCrosswalkandRampsAligned	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
stmCrossingCrosswalkStyle	0.0017	0.0017	0.0017	0.0017	0.0017	0.0017	0.0017	0.0017
stmCrossingCrosswalkStyle	0.0008	0.0008	0.0008	0.0008	0.0008	0.0008	0.0008	0.0008
stmCrossingCrosswalkStyle	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
stmCrossingCrosswalkStyle	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

Variable Name	None	Some	Device	WChairM	WChairE	MScooter	LowVision	Blind
stmCrossingCrosswalkStyle	0.0083	0.0083	0.0083	0.0083	0.0083	0.0083	0.0083	0.0083
stmCrossingCrosswalkPaintConditions	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
stmCrossingCrosswalkPaintConditions	0.0008	0.0008	0.0008	0.0008	0.0008	0.0008	0.0008	0.0008
stmCrossingCrosswalkPaintConditions	0.0017	0.0017	0.0017	0.0017	0.0017	0.0017	0.0017	0.0017
stmCrossingNSRamp	0.0025	0.0025	0.0025	0.0833	0.0833	0.0833	0.0033	0.0033
stmCrossingNSLanding	0.0025	0.0025	0.0025	0.0500	0.0500	0.0500	0.0033	0.0033
stmCrossingNSPushButtonConditionAndAlignment	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
stmCrossingNSPushButtonConditionAndAlignment	0.0008	0.0008	0.0008	0.0008	0.0008	0.0008	0.0008	0.0008
stmCrossingNSPushButtonConditionAndAlignment	0.0017	0.0017	0.0017	0.0017	0.0017	0.0017	0.0017	0.0017
stmCrossingNSPushButtonConditionAndAlignment	0.0025	0.0025	0.0025	0.0025	0.0025	0.0025	0.0025	0.0025
stmCrossingNSPushButtonVoiceSystem	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
stmCrossingNSPushButtonVoiceSystem	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0042	0.0083
stmCrossingNSPushButtonVoiceSystem	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0042	0.0083
stmCrossingNSPushButtonVoiceSystem	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0042	0.0083
stmCrossingNSPushButtonHeightOK	0.0017	0.0017	0.0017	0.0042	0.0042	0.0042	0.0042	0.0042

Variable Name	None	Some	Device	WChairM	WChairE	MScooter	LowVision	Blind
stmCrossingNSPushButtonHeightOK	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
stmCrossingNSPushButtonReachOK	0.0017	0.0017	0.0017	0.0042	0.0042	0.0042	0.0042	0.0042
stmCrossingNSPushButtonReachOK	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
stmCrossingNSSigns	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
stmCrossingNSSigns	0.0008	0.0008	0.0008	0.0008	0.0008	0.0008	0.0008	0.0008
stmCrossingNSSigns	0.0017	0.0017	0.0017	0.0017	0.0017	0.0017	0.0017	0.0017
stmCrossingNSSigns	0.0017	0.0017	0.0017	0.0017	0.0017	0.0017	0.0017	0.0017
stmCrossingFSSignalHeadCondition	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
stmCrossingFSSignalHeadCondition	0.0008	0.0008	0.0008	0.0008	0.0008	0.0008	0.0008	0.0008
stmCrossingFSSignalHeadCondition	0.0017	0.0017	0.0017	0.0017	0.0017	0.0017	0.0017	0.0017
stmCrossingFSSignalHeadCondition	0.0017	0.0017	0.0017	0.0017	0.0017	0.0017	0.0017	0.0017
stmCrossingFSSignalHeadLampWorking	0.0042	0.0042	0.0042	0.0042	0.0042	0.0042	0.0042	0.0000
stmCrossingFSSignalHeadLampWorking	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
stmCrossingFSSignalHeadVisible	0.0042	0.0042	0.0042	0.0042	0.0042	0.0042	0.0042	0.0000
stmCrossingFSSignalHeadVisible	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

Variable Name	None	Some	Device	WChairM	WChairE	MScooter	LowVision	Blind
stmCrossingFSRamp	0.0025	0.0025	0.0025	0.0833	0.0833	0.0833	0.0033	0.0033
stmCrossingFSLanding	0.0025	0.0025	0.0025	0.0500	0.0500	0.0500	0.0033	0.0033
stmCrossingFSPushButtonConditionAndAlignment	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
stmCrossingFSPushButtonConditionAndAlignment	0.0008	0.0008	0.0008	0.0008	0.0008	0.0008	0.0008	0.0008
stmCrossingFSPushButtonConditionAndAlignment	0.0017	0.0017	0.0017	0.0017	0.0017	0.0017	0.0017	0.0017
stmCrossingFSPushButtonConditionAndAlignment	0.0025	0.0025	0.0025	0.0025	0.0025	0.0025	0.0025	0.0025
stmCrossingFSPushButtonVoiceSystem	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
stmCrossingFSPushButtonVoiceSystem	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0042	0.0083
stmCrossingFSPushButtonVoiceSystem	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0042	0.0083
stmCrossingFSPushButtonVoiceSystem	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0042	0.0083
stmCrossingFSPushButtonHeightOK	0.0017	0.0017	0.0017	0.0042	0.0042	0.0042	0.0042	0.0042
stmCrossingFSPushButtonHeightOK	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
stmCrossingFSPushButtonReachOK	0.0017	0.0017	0.0017	0.0042	0.0042	0.0042	0.0042	0.0042
stmCrossingFSPushButtonReachOK	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
stmCrossingFSSigns	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

Variable Name	None	Some	Device	WChairM	WChairE	MScooter	LowVision	Blind
stmCrossingFSSigns	0.0008	0.0008	0.0008	0.0008	0.0008	0.0008	0.0008	0.0008
stmCrossingFSSigns	0.0017	0.0017	0.0017	0.0017	0.0017	0.0017	0.0017	0.0017
stmCrossingFSSigns	0.0017	0.0017	0.0017	0.0017	0.0017	0.0017	0.0017	0.0017
stmCrossingNSSignalHeadConditionAndAlignment	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
stmCrossingNSSignalHeadConditionAndAlignment	0.0008	0.0008	0.0008	0.0008	0.0008	0.0008	0.0008	0.0008
stmCrossingNSSignalHeadConditionAndAlignment	0.0017	0.0017	0.0017	0.0017	0.0017	0.0017	0.0017	0.0017
stmCrossingNSSignalHeadConditionAndAlignment	0.0017	0.0017	0.0017	0.0017	0.0017	0.0017	0.0017	0.0017
stmCrossingNSSignalHeadLampWorking	0.0042	0.0042	0.0042	0.0042	0.0042	0.0042	0.0042	0.0000
stmCrossingNSSignalHeadLampWorking	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
stmCrossingNSSignalHeadVisible	0.0042	0.0042	0.0042	0.0042	0.0042	0.0042	0.0042	0.0000
stmCrossingNSSignalHeadVisible	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
stmCrossingLinkVehicleVolumeRightA_B	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
stmCrossingLinkVehicleVolumeLeftA_B	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
stmCrossingLinkVehicleVolumeThroughA_B	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
stmCrossingLinkVehicleVolumeRightB_A	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

Variable Name	None	Some	Device	WChairM	WChairE	MScooter	LowVision	Blind
stmCrossingLinkVehicleVolumeLeftB_A	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
stmCrossingLinkVehicleVolumeThroughB_A	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

Appendix E. Impedance Calculation by Mode Combination

Table 61 provides a detailed list of impedance calculations by mode combination.

Table 61. Impedance Calculation by Mode Combination

Variable Name	Some-LowVision	Device-LowVision	WChairM-LowVision	WChairE-LowVision	MScooter-LowVision	Some-Blind	Device-Blind	WChairM-Blind	WChairE-Blind	MScooter-Blind
ADA Mobility Mode Speed	2.00	1.50	2.00	2.00	2.00	2.00	1.50	2.00	1.50	2.00
stmPedLinkID	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
stmAdaPathNodeAID	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
stmAdaPathNodeBID	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
stmPedLinkLength	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
stmPedLinkImpedanceBase	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
stmPedLinkImpedanceMultiplier	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
stmPedLinkImpedanceEvents	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
stmPedLinkImpedanceTotal	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
stmPedLinkWidth	1.20	1.20	2.00	2.00	2.00	1.20	1.20	2.00	2.00	2.00
stmPedLinkWidth	999.00	999.00	999.00	999.00	999.00	999.00	999.00	999.00	999.00	999.00

Variable Name	Some-LowVision	Device-LowVision	WChairM-LowVision	WChairE-LowVision	MScooter-LowVision	Some-Blind	Device-Blind	WChairM-Blind	WChairE-Blind	MScooter-Blind
stmPedLinkWidth	1.20	1.20	2.00	2.00	2.00	1.20	1.20	2.00	2.00	2.00
stmPedLinkSlopeA_B	1.10	1.10	1.10	1.10	1.10	1.10	1.10	1.10	1.10	1.10
stmPedLinkSlopeA_B	1.10	1.10	1.10	1.10	1.10	1.10	1.10	1.10	1.10	1.10
stmPedLinkSlopeA_B	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20
stmPedLinkSlopeB_A	1.10	1.10	1.10	1.10	1.10	1.10	1.10	1.10	1.10	1.10
stmPedLinkSlopeB_A	1.10	1.10	1.10	1.10	1.10	1.10	1.10	1.10	1.10	1.10
stmPedLinkSlopeB_A	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20
stmPedLinkMaterial	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
stmPedLinkMaterial	1.20	1.30	1.20	1.20	1.20	1.20	1.30	1.20	1.20	1.20
stmPedLinkMaterial	1.20	1.30	1.20	1.20	1.20	1.20	1.30	1.20	1.20	1.20
stmPedLinkMaterial	1.20	1.30	1.20	1.20	1.20	1.20	1.30	1.20	1.20	1.20
stmPedLinkMaterial	1.20	1.30	1.20	1.20	1.20	1.20	1.30	1.20	1.20	1.20
stmPedLinkMaterial	1.20	1.30	1.20	1.20	1.20	1.20	1.30	1.20	1.20	1.20
stmPedLinkMaterial	1.20	1.30	1.20	1.20	1.20	1.20	1.30	1.20	1.20	1.20
stmPedLinkMaterial	1.20	1.30	1.20	1.20	1.20	1.20	1.30	1.20	1.20	1.20
stmPedLinkMaterial	1.20	1.30	1.20	1.20	1.20	1.20	1.30	1.20	1.20	1.20
stmPedLinkMaterial	1.20	1.30	1.20	1.20	1.20	1.20	1.30	1.20	1.20	1.20

Variable Name	Some-LowVision	Device-LowVision	WChairM-LowVision	WChairE-LowVision	MScooter-LowVision	Some-Blind	Device-Blind	WChairM-Blind	WChairE-Blind	MScooter-Blind
stmPedLinkMaterial	1.20	1.30	1.20	1.20	1.20	1.20	1.30	1.20	1.20	1.20
stmPedLinkMaterial	1.20	1.30	1.20	1.20	1.20	1.20	1.30	1.20	1.20	1.20
stmPedLinkMaterial	1.20	1.30	1.20	1.20	1.20	1.20	1.30	1.20	1.20	1.20
stmPedLinkMaterial	1.20	1.30	1.20	1.20	1.20	1.20	1.30	1.20	1.20	1.20
stmPedLinkMaterial	1.20	1.30	1.20	1.20	1.20	1.20	1.30	1.20	1.20	1.20
stmPedLinkSurfaceRoughnessScore	1.30	1.30	1.30	1.30	1.30	1.30	1.30	1.30	1.30	1.30
stmPedLinkSurfaceRoughnessScore	1.10	1.10	1.10	1.10	1.10	1.10	1.10	1.10	1.10	1.10
stmPedLinkSurfaceRoughnessScore	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
stmPedLinkSurfaceRoughnessScore	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
stmPedLinkSurfaceRoughnessScore	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
stmPedLinkAreaType	1.30	1.30	1.30	1.30	1.30	1.30	1.30	1.30	1.30	1.30
stmPedLinkAreaType	1.30	1.30	1.30	1.30	1.30	1.30	1.30	1.30	1.30	1.30
stmPedLinkAreaType	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20
stmPedLinkAreaType	1.10	1.10	1.10	1.10	1.10	1.10	1.10	1.10	1.10	1.10
stmPedLinkAreaType	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
stmPedLinkAreaType	1.10	1.10	1.10	1.10	1.10	1.10	1.10	1.10	1.10	1.10
stmPedLinkAreaType	1.30	1.30	1.30	1.30	1.30	1.30	1.30	1.30	1.30	1.30

Variable Name	Some-LowVision	Device-LowVision	WChairM-LowVision	WChairE-LowVision	MScooter-LowVision	Some-Blind	Device-Blind	WChairM-Blind	WChairE-Blind	MScooter-Blind
stmPedLinkAreaType	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20
stmPedLinkAreaResidentialDensity	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
stmPedLinkAreaEmploymentDensity	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
stmPedLinkAreaRestaurantDensity	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
stmPedLinkAreaShoppingDensity	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
stmPedLinkAreaParkDensity	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
stmPedLinkAttributeLighting	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20
stmPedLinkAttributeLighting	1.15	1.15	1.15	1.15	1.15	1.15	1.15	1.15	1.15	1.15
stmPedLinkAttributeLighting	1.10	1.10	1.10	1.10	1.10	1.10	1.10	1.10	1.10	1.10
stmPedLinkAttributeLighting	1.05	1.05	1.05	1.05	1.05	1.05	1.05	1.05	1.05	1.05
stmPedLinkAttributeLighting	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
stmPedLinkAttributeShadeTrees	1.15	1.15	1.15	1.15	1.15	1.15	1.15	1.15	1.15	1.15
stmPedLinkAttributeShadeTrees	1.10	1.10	1.10	1.10	1.10	1.10	1.10	1.10	1.10	1.10
stmPedLinkAttributeShadeTrees	1.05	1.05	1.05	1.05	1.05	1.05	1.05	1.05	1.05	1.05
stmPedLinkAttributeShadeTrees	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
stmPedLinkAttributeShadeTrees	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
stmRoadLinkFacilityType	999.00	999.00	999.00	999.00	999.00	999.00	999.00	999.00	999.00	999.00

Variable Name	Some-LowVision	Device-LowVision	WChairM-LowVision	WChairE-LowVision	MScooter-LowVision	Some-Blind	Device-Blind	WChairM-Blind	WChairE-Blind	MScooter-Blind
stmRoadLinkFacilityType	999.00	999.00	999.00	999.00	999.00	999.00	999.00	999.00	999.00	999.00
stmRoadLinkFacilityType	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00
stmRoadLinkFacilityType	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00
stmRoadLinkFacilityType	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00
stmRoadLinkFacilityType	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00
stmRoadLinkFacilityType	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00
stmRoadLinkFacilityType	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00
stmRoadLinkFacilityType	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00
stmRoadLinkFacilityType	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00
stmRoadLinkFacilityType	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00
stmRoadLinkFacilityType	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20
stmRoadLinkFacilityType	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20
stmRoadLinkFacilityType	1.10	1.10	1.10	1.10	1.10	1.10	1.10	1.10	1.10	1.10
stmRoadLinkFacilityType	1.10	1.10	1.10	1.10	1.10	1.10	1.10	1.10	1.10	1.10
stmRoadLinkFacilityType	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20
stmRoadLinkFacilityType	1.10	1.10	1.10	1.10	1.10	1.10	1.10	1.10	1.10	1.10

Variable Name	Some-LowVision	Device-LowVision	WChairM-LowVision	WChairE-LowVision	MScooter-LowVision	Some-Blind	Device-Blind	WChairM-Blind	WChairE-Blind	MScooter-Blind
stmRoadLinkFacilityType	1.05	1.05	1.05	1.05	1.05	1.05	1.05	1.05	1.05	1.05
stmRoadLinkFacilityType	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00
stmRoadLinkFacilityType	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00
stmRoadLinkFacilityType	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00
stmRoadLinkFacilityType	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
stmRoadLinkFacilityType	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
stmRoadLinkFacilityType	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
stmRoadLinkFacilityType	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
stmRoadLinkFacilityType	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
stmRoadLinkAadtA_B	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
stmRoadLinkAadtB_A	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
stmRoadLinkPercentHDTA_B	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20
stmRoadLinkPercentMDTA_B	1.10	1.10	1.10	1.10	1.10	1.10	1.10	1.10	1.10	1.10
stmRoadLinkPercentHDTB_A	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20
stmRoadLinkPercentMDTB_A	1.10	1.10	1.10	1.10	1.10	1.10	1.10	1.10	1.10	1.10
stmRoadLinkLanesA_B	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20
stmRoadLinkLanesB_A	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20

Variable Name	Some-LowVision	Device-LowVision	WChairM-LowVision	WChairE-LowVision	MScooter-LowVision	Some-Blind	Device-Blind	WChairM-Blind	WChairE-Blind	MScooter-Blind
stmRoadLinkLaneWidthA_B	1.10	1.10	1.10	1.10	1.10	1.10	1.10	1.10	1.10	1.10
stmRoadLinkLaneWidthB_A	1.10	1.10	1.10	1.10	1.10	1.10	1.10	1.10	1.10	1.10
stmRoadLinkShoulderWidthA_B	1.10	1.10	1.10	1.10	1.10	1.10	1.10	1.10	1.10	1.10
stmRoadLinkShoulderWidthB_A	1.10	1.10	1.10	1.10	1.10	1.10	1.10	1.10	1.10	1.10
stmRoadLinkSpeedLimit	1.10	1.10	1.10	1.10	1.10	1.10	1.10	1.10	1.10	1.10
stmRoadLinkObservedSpeed	1.10	1.10	1.10	1.10	1.10	1.10	1.10	1.10	1.10	1.10
stmRoadLinkObservedPedestrianCount	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
stmRoadLinkObservedCollisions	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
stmRoadLinkObservedInjuries	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
stmRoadLinkObservedFatalities	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
stmCrossingCrossingPathCrossSlope	1.10	1.10	1.20	1.10	1.10	1.10	1.10	1.20	1.10	1.10
stmCrossingCrossingPathCrossSlope	1.10	1.10	1.20	1.10	1.10	1.10	1.10	1.20	1.10	1.10
Applies to Links and Crossings										
stmAssetDefectReportProblemLinkDisjoint	0.0042	0.0042	0.0083	0.0083	0.0083	0.0042	0.0042	0.0083	0.0083	0.0083
stmAssetDefectReportProblemLinkPothole	0.0083	0.0083	0.0125	0.0083	0.0083	0.0083	0.0083	0.0125	0.0083	0.0083
stmAssetDefectReportProblemLinkBlocked	0.0333	0.0333	0.0500	0.0333	0.0333	0.0500	0.0500	0.0500	0.0500	0.0500
stmAssetDefectReportProblemLinkObstruction	0.0042	0.0042	0.0167	0.0167	0.0083	0.0042	0.0042	0.0167	0.0167	0.0083

Variable Name	Some-LowVision	Device-LowVision	WChairM-LowVision	WChairE-LowVision	MScooter-LowVision	Some-Blind	Device-Blind	WChairM-Blind	WChairE-Blind	MScooter-Blind
stmAssetDefectReportProblemLinkDebris	0.0042	0.0042	0.0167	0.0167	0.0083	0.0042	0.0042	0.0167	0.0167	0.0083
stmAssetDefectReportProblemLinkWater	0.0042	0.0042	0.0167	0.0167	0.0083	0.0042	0.0042	0.0167	0.0167	0.0083
stmRampType	0.0008	0.0008	0.0008	0.0008	0.0008	0.0008	0.0008	0.0008	0.0008	0.0008
stmRampType	0.0042	0.0042	0.0042	0.0042	0.0042	0.0042	0.0042	0.0042	0.0042	0.0042
stmRampType	0.0017	0.0017	0.0017	0.0017	0.0017	0.0017	0.0017	0.0017	0.0017	0.0017
stmRampType	0.0008	0.0008	0.0008	0.0008	0.0008	0.0008	0.0008	0.0008	0.0008	0.0008
stmRampType	0.0008	0.0008	0.0008	0.0008	0.0008	0.0008	0.0008	0.0008	0.0008	0.0008
stmRampType	0.0042	0.0042	0.0042	0.0042	0.0042	0.0042	0.0042	0.0042	0.0042	0.0042
stmRampType	0.0017	0.0017	0.0017	0.0017	0.0017	0.0017	0.0017	0.0017	0.0017	0.0017
stmRampType	0.0008	0.0008	0.0008	0.0008	0.0008	0.0008	0.0008	0.0008	0.0008	0.0008
stmRampType	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
stmRampWidth	0.0083	0.0083	0.0500	0.0500	0.0500	0.0167	0.0167	0.0500	0.0500	0.0500
stmRampWidth	0.0042	0.0042	0.0083	0.0083	0.0083	0.0042	0.0042	0.0083	0.0083	0.0083
stmRampWidth	0.0042	0.0042	0.0083	0.0083	0.0083	0.0042	0.0042	0.0083	0.0083	0.0083
stmRampSlope	0.0042	0.0042	0.0083	0.0042	0.0042	0.0042	0.0042	0.0083	0.0042	0.0042
stmRampSlope	0.0042	0.0042	0.0083	0.0042	0.0042	0.0042	0.0042	0.0083	0.0042	0.0042
stmRampCrossSlope	0.0017	0.0033	0.0042	0.0017	0.0017	0.0033	0.0033	0.0042	0.0033	0.0033

Variable Name	Some-LowVision	Device-LowVision	WChairM-LowVision	WChairE-LowVision	MScooter-LowVision	Some-Blind	Device-Blind	WChairM-Blind	WChairE-Blind	MScooter-Blind
stmRampCrossSlope	0.0017	0.0033	0.0042	0.0017	0.0017	0.0033	0.0033	0.0042	0.0033	0.0033
stmRampGutterSlope	0.0000	0.0000	0.0083	0.0042	0.0000	0.0000	0.0000	0.0083	0.0042	0.0000
stmRampGutterSlope	0.0000	0.0000	0.0083	0.0042	0.0000	0.0000	0.0000	0.0083	0.0042	0.0000
stmRampPassingWidth	0.0042	0.0042	0.0083	0.0083	0.0083	0.0042	0.0042	0.0083	0.0083	0.0083
stmRampPassingWidth	0.0042	0.0042	0.0083	0.0083	0.0083	0.0042	0.0042	0.0083	0.0083	0.0083
stmRampPassingCrossSlope	0.0017	0.0033	0.0042	0.0017	0.0017	0.0033	0.0033	0.0042	0.0033	0.0033
stmRampPassingCrossSlope	0.0017	0.0033	0.0042	0.0017	0.0017	0.0033	0.0033	0.0042	0.0033	0.0033
stmRampFlareSlopeLeft	0.0042	0.0042	0.0042	0.0042	0.0042	0.0042	0.0042	0.0042	0.0042	0.0042
stmRampFlareSlopeLeft	0.0042	0.0042	0.0042	0.0042	0.0042	0.0042	0.0042	0.0042	0.0042	0.0042
stmRampFlareSlopeRight	0.0042	0.0042	0.0042	0.0042	0.0042	0.0042	0.0042	0.0042	0.0042	0.0042
stmRampFlareSlopeRight	0.0042	0.0042	0.0042	0.0042	0.0042	0.0042	0.0042	0.0042	0.0042	0.0042
stmRampSmooth	0.0017	0.0017	0.0033	0.0017	0.0017	0.0017	0.0017	0.0033	0.0017	0.0017
stmRampSmooth	0.0017	0.0017	0.0033	0.0017	0.0017	0.0017	0.0017	0.0033	0.0017	0.0017
stmRampFlushAtTop	0.0017	0.0017	0.0033	0.0017	0.0017	0.0017	0.0017	0.0033	0.0017	0.0017
stmRampFlushAtTop	0.0017	0.0017	0.0033	0.0017	0.0017	0.0017	0.0017	0.0033	0.0017	0.0017
stmRampFlushAtBottom	0.0017	0.0017	0.0033	0.0017	0.0017	0.0017	0.0017	0.0033	0.0017	0.0017
stmRampFlushAtBottom	0.0017	0.0017	0.0033	0.0017	0.0017	0.0017	0.0017	0.0033	0.0017	0.0017

Variable Name	Some-LowVision	Device-LowVision	WChairM-LowVision	WChairE-LowVision	MScooter-LowVision	Some-Blind	Device-Blind	WChairM-Blind	WChairE-Blind	MScooter-Blind
stmRampFlushAtStreet	0.0017	0.0017	0.0033	0.0017	0.0017	0.0017	0.0017	0.0033	0.0017	0.0017
stmRampFlushAtStreet	0.0017	0.0017	0.0033	0.0017	0.0017	0.0017	0.0017	0.0033	0.0017	0.0017
stmRampTransitionSlopeLeft	0.0042	0.0042	0.0083	0.0042	0.0042	0.0042	0.0042	0.0083	0.0042	0.0042
stmRampTransitionSlopeLeft	0.0042	0.0042	0.0083	0.0042	0.0042	0.0042	0.0042	0.0083	0.0042	0.0042
stmRampTransitionCrossSlopeLeft	0.0017	0.0033	0.0042	0.0017	0.0017	0.0033	0.0033	0.0042	0.0033	0.0033
stmRampTransitionCrossSlopeLeft	0.0017	0.0033	0.0042	0.0017	0.0017	0.0033	0.0033	0.0042	0.0033	0.0033
stmRampTransitionSlopeRight	0.0042	0.0042	0.0083	0.0042	0.0042	0.0042	0.0042	0.0083	0.0042	0.0042
stmRampTransitionSlopeRight	0.0042	0.0042	0.0083	0.0042	0.0042	0.0042	0.0042	0.0083	0.0042	0.0042
stmRampTransitionCrossSlopeRight	0.0017	0.0033	0.0042	0.0017	0.0017	0.0033	0.0033	0.0042	0.0033	0.0033
stmRampTransitionCrossSlopeRight	0.0017	0.0033	0.0042	0.0017	0.0017	0.0033	0.0033	0.0042	0.0033	0.0033
stmRampLandingMinimumWidth	0.0042	0.0042	0.0083	0.0083	0.0083	0.0042	0.0042	0.0083	0.0083	0.0083
stmRampLandingMinimumWidth	0.0042	0.0042	0.0083	0.0083	0.0083	0.0042	0.0042	0.0083	0.0083	0.0083
stmRampLandingCrossSlope	0.0017	0.0033	0.0042	0.0017	0.0017	0.0033	0.0033	0.0042	0.0033	0.0033
stmRampLandingCrossSlope	0.0017	0.0033	0.0042	0.0017	0.0017	0.0033	0.0033	0.0042	0.0033	0.0033
stmPedRampDetectableWarningPresent	0.0017	0.0017	0.0017	0.0017	0.0017	0.0033	0.0033	0.0033	0.0033	0.0033
stmPedRampDetectableWarningCondition	0.0017	0.0017	0.0017	0.0017	0.0017	0.0033	0.0033	0.0033	0.0033	0.0033
stmPedRampDetectableWarningCondition	0.0017	0.0017	0.0017	0.0017	0.0017	0.0033	0.0033	0.0033	0.0033	0.0033

Variable Name	Some-LowVision	Device-LowVision	WChairM-LowVision	WChairE-LowVision	MScooter-LowVision	Some-Blind	Device-Blind	WChairM-Blind	WChairE-Blind	MScooter-Blind
stmPedRampDetectableWarningCondition	0.0017	0.0017	0.0017	0.0017	0.0017	0.0033	0.0033	0.0033	0.0033	0.0033
stmPedRampDetectableWarningCondition	0.0017	0.0017	0.0017	0.0017	0.0017	0.0033	0.0033	0.0033	0.0033	0.0033
stmCurbCutType	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
stmCurbCutType	0.0042	0.0042	0.0083	0.0042	0.0042	0.0042	0.0042	0.0083	0.0042	0.0042
stmCurbCutType	0.0000	0.0000	0.0042	0.0000	0.0000	0.0000	0.0000	0.0042	0.0000	0.0000
stmCurbCutType	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
stmCurbCutType	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
stmCurbCutWidthTop	0.0083	0.0083	0.0083	0.0083	0.0083	0.0083	0.0083	0.0083	0.0083	0.0083
stmCurbCutPassingWidth	0.0042	0.0042	0.0083	0.0083	0.0083	0.0042	0.0042	0.0083	0.0083	0.0083
stmCurbCutPassingWidth	0.0042	0.0042	0.0083	0.0083	0.0083	0.0042	0.0042	0.0083	0.0083	0.0083
stmCurbCutCrossSlope	0.0017	0.0033	0.0042	0.0017	0.0017	0.0033	0.0033	0.0042	0.0033	0.0033
stmCurbCutCrossSlope	0.0017	0.0033	0.0042	0.0017	0.0017	0.0033	0.0033	0.0042	0.0033	0.0033
stmCurbCutFlareSlopeLeft	0.0017	0.0017	0.0017	0.0017	0.0017	0.0017	0.0017	0.0017	0.0017	0.0017
stmCurbCutFlareSlopeLeft	0.0017	0.0017	0.0017	0.0017	0.0017	0.0017	0.0017	0.0017	0.0017	0.0017
stmCurbCutFlareSlopeRight	0.0017	0.0017	0.0017	0.0017	0.0017	0.0017	0.0017	0.0017	0.0017	0.0017
stmCurbCutFlareSlopeRight	0.0017	0.0017	0.0017	0.0017	0.0017	0.0017	0.0017	0.0017	0.0017	0.0017
stmCurbCutRampSlopeLeft	0.0042	0.0042	0.0083	0.0042	0.0042	0.0042	0.0042	0.0083	0.0042	0.0042

Variable Name	Some-LowVision	Device-LowVision	WChairM-LowVision	WChairE-LowVision	MScooter-LowVision	Some-Blind	Device-Blind	WChairM-Blind	WChairE-Blind	MScooter-Blind
stmCurbCutRampSlopeLeft	0.0042	0.0042	0.0083	0.0042	0.0042	0.0042	0.0042	0.0083	0.0042	0.0042
stmCurbCutRampCrossSlopeLeft	0.0017	0.0033	0.0042	0.0017	0.0017	0.0033	0.0033	0.0042	0.0033	0.0033
stmCurbCutRampCrossSlopeLeft	0.0017	0.0033	0.0042	0.0017	0.0017	0.0033	0.0033	0.0042	0.0033	0.0033
stmCurbCutRampSlopeRight	0.0042	0.0042	0.0083	0.0042	0.0042	0.0042	0.0042	0.0083	0.0042	0.0042
stmCurbCutRampSlopeRight	0.0042	0.0042	0.0083	0.0042	0.0042	0.0042	0.0042	0.0083	0.0042	0.0042
stmCurbCutRampCrossSlopeRight	0.0017	0.0033	0.0042	0.0017	0.0017	0.0033	0.0033	0.0042	0.0033	0.0033
stmCurbCutRampCrossSlopeRight	0.0017	0.0033	0.0042	0.0017	0.0017	0.0033	0.0033	0.0042	0.0033	0.0033
stmCurbCutDepressionSidewalkWidth	0.0042	0.0042	0.0083	0.0083	0.0083	0.0042	0.0042	0.0083	0.0083	0.0083
stmCurbCutDepressionSidewalkWidth	0.0042	0.0042	0.0083	0.0083	0.0083	0.0042	0.0042	0.0083	0.0083	0.0083
Crossing impedance logic updates pending										
stmCrossingSignalControlledIntersection	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
stmCrossingSignalControlledIntersection	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
stmCrossingStopControlledIntersection	0.0042	0.0042	0.0042	0.0042	0.0042	0.0042	0.0042	0.0042	0.0042	0.0042
stmCrossingStopControlledIntersection	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
stmCrossingCrosswalkPresent	0.0033	0.0033	0.0033	0.0033	0.0033	0.0033	0.0033	0.0033	0.0033	0.0033
stmCrossingCrosswalkPresent	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
stmCrossingCrosswalkComplete	0.0017	0.0017	0.0017	0.0017	0.0017	0.0017	0.0017	0.0017	0.0017	0.0017

Variable Name	Some-LowVision	Device-LowVision	WChairM-LowVision	WChairE-LowVision	MScooter-LowVision	Some-Blind	Device-Blind	WChairM-Blind	WChairE-Blind	MScooter-Blind
stmCrossingCrosswalkComplete	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
stmCrossingCrosswalkandRampsAligned	0.0017	0.0017	0.0017	0.0017	0.0017	0.0017	0.0017	0.0017	0.0017	0.0017
stmCrossingCrosswalkandRampsAligned	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
stmCrossingCrosswalkStyle	0.0017	0.0017	0.0017	0.0017	0.0017	0.0017	0.0017	0.0017	0.0017	0.0017
stmCrossingCrosswalkStyle	0.0008	0.0008	0.0008	0.0008	0.0008	0.0008	0.0008	0.0008	0.0008	0.0008
stmCrossingCrosswalkStyle	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
stmCrossingCrosswalkStyle	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
stmCrossingCrosswalkStyle	0.0083	0.0083	0.0083	0.0083	0.0083	0.0083	0.0083	0.0083	0.0083	0.0083
stmCrossingCrosswalkPaintConditions	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
stmCrossingCrosswalkPaintConditions	0.0008	0.0008	0.0008	0.0008	0.0008	0.0008	0.0008	0.0008	0.0008	0.0008
stmCrossingCrosswalkPaintConditions	0.0017	0.0017	0.0017	0.0017	0.0017	0.0017	0.0017	0.0017	0.0017	0.0017
stmCrossingNSRamp	0.0033	0.0033	0.0833	0.0833	0.0833	0.0033	0.0033	0.0833	0.0833	0.0833
stmCrossingNSLanding	0.0033	0.0033	0.0500	0.0500	0.0500	0.0033	0.0033	0.0500	0.0500	0.0500
stmCrossingNSPushButtonConditionAndAlignment	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
stmCrossingNSPushButtonConditionAndAlignment	0.0008	0.0008	0.0008	0.0008	0.0008	0.0008	0.0008	0.0008	0.0008	0.0008
stmCrossingNSPushButtonConditionAndAlignment	0.0017	0.0017	0.0017	0.0017	0.0017	0.0017	0.0017	0.0017	0.0017	0.0017
stmCrossingNSPushButtonConditionAndAlignment	0.0025	0.0025	0.0025	0.0025	0.0025	0.0025	0.0025	0.0025	0.0025	0.0025

Variable Name	Some-LowVision	Device-LowVision	WChairM-LowVision	WChairE-LowVision	MScooter-LowVision	Some-Blind	Device-Blind	WChairM-Blind	WChairE-Blind	MScooter-Blind
stmCrossingNSPushButtonVoiceSystem	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
stmCrossingNSPushButtonVoiceSystem	0.0042	0.0042	0.0042	0.0042	0.0042	0.0083	0.0083	0.0083	0.0083	0.0083
stmCrossingNSPushButtonVoiceSystem	0.0042	0.0042	0.0042	0.0042	0.0042	0.0083	0.0083	0.0083	0.0083	0.0083
stmCrossingNSPushButtonVoiceSystem	0.0042	0.0042	0.0042	0.0042	0.0042	0.0083	0.0083	0.0083	0.0083	0.0083
stmCrossingNSPushButtonHeightOK	0.0042	0.0042	0.0042	0.0042	0.0042	0.0042	0.0042	0.0042	0.0042	0.0042
stmCrossingNSPushButtonHeightOK	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
stmCrossingNSPushButtonReachOK	0.0042	0.0042	0.0042	0.0042	0.0042	0.0042	0.0042	0.0042	0.0042	0.0042
stmCrossingNSPushButtonReachOK	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
stmCrossingNSSigns	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
stmCrossingNSSigns	0.0008	0.0008	0.0008	0.0008	0.0008	0.0008	0.0008	0.0008	0.0008	0.0008
stmCrossingNSSigns	0.0017	0.0017	0.0017	0.0017	0.0017	0.0017	0.0017	0.0017	0.0017	0.0017
stmCrossingNSSigns	0.0017	0.0017	0.0017	0.0017	0.0017	0.0017	0.0017	0.0017	0.0017	0.0017
stmCrossingFSSignalHeadCondition	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
stmCrossingFSSignalHeadCondition	0.0008	0.0008	0.0008	0.0008	0.0008	0.0008	0.0008	0.0008	0.0008	0.0008
stmCrossingFSSignalHeadCondition	0.0017	0.0017	0.0017	0.0017	0.0017	0.0017	0.0017	0.0017	0.0017	0.0017
stmCrossingFSSignalHeadCondition	0.0017	0.0017	0.0017	0.0017	0.0017	0.0017	0.0017	0.0017	0.0017	0.0017
stmCrossingFSSignalHeadLampWorking	0.0042	0.0042	0.0042	0.0042	0.0042	0.0042	0.0042	0.0042	0.0042	0.0042

Variable Name	Some-LowVision	Device-LowVision	WChairM-LowVision	WChairE-LowVision	MScooter-LowVision	Some-Blind	Device-Blind	WChairM-Blind	WChairE-Blind	MScooter-Blind
stmCrossingFSSignalHeadLampWorking	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
stmCrossingFSSignalHeadVisible	0.0042	0.0042	0.0042	0.0042	0.0042	0.0042	0.0042	0.0042	0.0042	0.0042
stmCrossingFSSignalHeadVisible	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
stmCrossingFSRamp	0.0033	0.0033	0.0833	0.0833	0.0833	0.0033	0.0033	0.0833	0.0833	0.0833
stmCrossingFSLanding	0.0033	0.0033	0.0500	0.0500	0.0500	0.0033	0.0033	0.0500	0.0500	0.0500
stmCrossingFSPushButtonConditionAndAlignment	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
stmCrossingFSPushButtonConditionAndAlignment	0.0008	0.0008	0.0008	0.0008	0.0008	0.0008	0.0008	0.0008	0.0008	0.0008
stmCrossingFSPushButtonConditionAndAlignment	0.0017	0.0017	0.0017	0.0017	0.0017	0.0017	0.0017	0.0017	0.0017	0.0017
stmCrossingFSPushButtonConditionAndAlignment	0.0025	0.0025	0.0025	0.0025	0.0025	0.0025	0.0025	0.0025	0.0025	0.0025
stmCrossingFSPushButtonVoiceSystem	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
stmCrossingFSPushButtonVoiceSystem	0.0042	0.0042	0.0042	0.0042	0.0042	0.0083	0.0083	0.0083	0.0083	0.0083
stmCrossingFSPushButtonVoiceSystem	0.0042	0.0042	0.0042	0.0042	0.0042	0.0083	0.0083	0.0083	0.0083	0.0083
stmCrossingFSPushButtonVoiceSystem	0.0042	0.0042	0.0042	0.0042	0.0042	0.0083	0.0083	0.0083	0.0083	0.0083
stmCrossingFSPushButtonHeightOK	0.0042	0.0042	0.0042	0.0042	0.0042	0.0042	0.0042	0.0042	0.0042	0.0042
stmCrossingFSPushButtonHeightOK	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
stmCrossingFSPushButtonReachOK	0.0042	0.0042	0.0042	0.0042	0.0042	0.0042	0.0042	0.0042	0.0042	0.0042
stmCrossingFSPushButtonReachOK	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

Variable Name	Some-LowVision	Device-LowVision	WChairM-LowVision	WChairE-LowVision	MScooter-LowVision	Some-Blind	Device-Blind	WChairM-Blind	WChairE-Blind	MScooter-Blind
stmCrossingFSSigns	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
stmCrossingFSSigns	0.0008	0.0008	0.0008	0.0008	0.0008	0.0008	0.0008	0.0008	0.0008	0.0008
stmCrossingFSSigns	0.0017	0.0017	0.0017	0.0017	0.0017	0.0017	0.0017	0.0017	0.0017	0.0017
stmCrossingFSSigns	0.0017	0.0017	0.0017	0.0017	0.0017	0.0017	0.0017	0.0017	0.0017	0.0017
stmCrossingNSSignalHeadConditionAndAlignment	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
stmCrossingNSSignalHeadConditionAndAlignment	0.0008	0.0008	0.0008	0.0008	0.0008	0.0008	0.0008	0.0008	0.0008	0.0008
stmCrossingNSSignalHeadConditionAndAlignment	0.0017	0.0017	0.0017	0.0017	0.0017	0.0017	0.0017	0.0017	0.0017	0.0017
stmCrossingNSSignalHeadConditionAndAlignment	0.0017	0.0017	0.0017	0.0017	0.0017	0.0017	0.0017	0.0017	0.0017	0.0017
stmCrossingNSSignalHeadLampWorking	0.0042	0.0042	0.0042	0.0042	0.0042	0.0042	0.0042	0.0042	0.0042	0.0042
stmCrossingNSSignalHeadLampWorking	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
stmCrossingNSSignalHeadVisible	0.0042	0.0042	0.0042	0.0042	0.0042	0.0042	0.0042	0.0042	0.0042	0.0042
stmCrossingNSSignalHeadVisible	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
stmCrossingLinkVehicleVolumeRightA_B	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
stmCrossingLinkVehicleVolumeLeftA_B	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
stmCrossingLinkVehicleVolumeThroughA_B	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
stmCrossingLinkVehicleVolumeRightB_A	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
stmCrossingLinkVehicleVolumeLeftB_A	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

Variable Name	Some-LowVision	Device-LowVision	WChairM-LowVision	WChairE-LowVision	MScooter-LowVision	Some-Blind	Device-Blind	WChairM-Blind	WChairE-Blind	MScooter-Blind
stmCrossingLinkVehicleVolumeThroughB_A	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

Appendix F. Performance Measures and Metrics

Table 62 provides a comprehensive list of performance measures, associated metrics, and ingestion frequency with evaluation and data information. More comprehensive information is provided in the PMESP2.

Table 62. Performance Metrics and Ingestion Frequency

Metric ID	Performance Measure/Metric	Evaluation Question	Reporting Frequency
CT-PM-1	**Enhance Traveler Experience**		
CT-ME-1.1	1. The average survey response of travelers' complete trip travel experience. 2. The average survey response of how likely a user is to recommend G-MAP to other travelers.	Did the ST-CTN system enhance the travelers' complete trip travel experience?	Quarterly
CT-ME-1.2	The average survey response of travelers' rating of how the usability of the ST-CTN system enhanced their complete trip travel experience.	Did the usability (i.e. was the system easy to use, easy to configure, intuitive, etc.) of the ST-CTN system enhance the travelers' complete trip travel experience?	Quarterly
CT-ME-1.3	1. The average survey response of travelers' rating of how the ST-CTN system features and functions enhanced their complete trip travel experience. 2. Number of features and functions the traveler finds most valuable.	Did the ST-CTN system features and functions (i.e. alert and notification method, accessible route selection, remote stop request, automated ped actuation, etc.) enhance the travelers' complete trip travel experience?	Quarterly

Metric ID	Performance Measure/Metric	Evaluation Question	Reporting Frequency
CT-ME-1.4	1. Survey response to determine if the traveler has a trusted companion who uses G-MAP. 2. The average survey response, from those requiring caregiver support, of travelers' rating of how the ability to access support from their caregiver through the ST-CTN system during travel enhanced their complete trip travel experience.	Did access to the travelers' caregiver through the ST-CTN system enhance the travelers' complete trip travel experience?	Quarterly
CT-ME-1.5	1. Survey response to determine if the traveler has used G-MAP's call center support in the last three months. 2. The average survey response of travelers' rating of how access to the call center through the ST-CTN system enhanced their complete trip travel experience.	Did access to call center support through the ST-CTN system enhance the travelers' ability to complete their trip independently?	Quarterly
CT-ME-1.6	The average monthly number of call center support calls per user through the ST-CTN system.	Did access to call center support through the ST-CTN system allow the travelers to better understand the application and complete future trips without having to utilize the call center.	Quarterly/Manual
CT-ME-1.8	Variance between recommended ST-CTN system complete trip recommended routes and actual ST-CTN system travel routes that were taken.	Did travelers feel greater confidence and independence during their complete trip, including transitions, with the ST-CTN system or did they deviate from the ST-CTN system complete trip recommended routes?	Weekly

Metric ID	Performance Measure/Metric	Evaluation Question	Reporting Frequency
CT-ME-1.9	Number of destination types accessed by ST-CTN system users. If the traveler selects “other”, they will be prompted to specify the destination. The destination types will be defined based on data reviewed in Phase 3 of the ST-CTN project.	Did traveler’s access to new destinations increase with use of the ST-CTN system?	Quarterly
CT-ME-1.10	Number of complaints filed to Ride Gwinnett per month pertaining to lack of accessible routes to transit stops.	Did the accessible routes recommended by the ST-CTN system enhance the travelers' complete trip travel experience?	Quarterly/Manual
CT-ME-1.11	Number of unique ST-CTN system users per day.	Did the ST-CTN system enhance the travelers' complete trip travel experience?	Weekly
CT-ME-1.12	Number of trips planned and completed by unique ST-CTN system users per day.	Were travelers' satisfied with the ST-CTN system complete trip travel experience?	Weekly
CT-PM-2	**Improve Accessibility**		
CT-ME-2.2	1. The average survey response for if G-MAP gives back additional time in the traveler’s schedule. 2. The average survey response for if G-MAP reduces the traveler’s time and stress in travel planning. 3. The average survey response for if G-MAP increases the traveler’s awareness and confidence in traveling independently. 4. The average survey response for if G-MAP helps the traveler schedule trips more reliably. 5. The average survey response for the traveler’s quality of life rating	Did the ST-CTN system enhance the travelers' quality of life? Quality of life, in the context of this project, may include the following: • Additional time within their schedule, • Reduced time and stress to plan travel, • Increased awareness and confidence to travel independently, and • Ability to schedule more reliably.	Quarterly
CT-PM-3	**Enhance Complete Trip Pedestrian Safety**		

Metric ID	Performance Measure/Metric	Evaluation Question	Reporting Frequency
CT-ME-3.1	The average survey response of travelers' perception of safety while using the ST-CTN system.	Did the ST-CTN system enhance the travelers' perception of safety within the project study area?	Quarterly
CT-ME-3.2	Variance in geographic location between ST-CTN system complete trip recommended routes and actual ST-CTN system travel routes taken at signalized intersection crossings.	Did travelers deviate from the ST-CTN system complete trip recommended routes while crossing signalized intersections (i.e. are travelers receiving the benefits of the ST-CTN intersection crossing features)?	Weekly
CT-ME-3.3	1. The average survey response of taking a different route than the ST-CTN system complete trip recommended route. 2. Survey response to understand the variance between ST-CTN system complete trip recommended routes and actual ST-CTN system travel routes taken at signalized intersection crossings.	Why did travelers deviate from the ST-CTN system complete trip recommended routes while crossing signalized intersections (i.e. are travelers receiving the benefits of the ST-CTN intersection crossing features) and why?	1. Quarterly 2. Prompted/ Reported Quarterly
CT-PM-4	**Enhance Fixed-Route Transit**		
CT-ME-4.1	Average number of fixed-route aggregate riders within the ST-CTN project area.	Did the ST-CTN system impact fixed-route transit ridership?	Quarterly / Manual

Metric ID	Performance Measure/Metric	Evaluation Question	Reporting Frequency
CT-ME-4.3	1. Survey response of travelers' perception of fixed-route transit service while using the ST-CTN system (i.e., was service enhanced). 2. Survey response of travelers' perception of regular transit service while using the ST-CTN system (i.e., was service enhanced). 3. Survey response of travelers' perception of bus service while using the ST-CTN system (i.e., is it easier to ride the bus). 4. Survey response of travelers' perception of bus safety while using the ST-CTN system (i.e., did the traveler feel safer). 5. Survey response for the time associated with waiting for a bus while using the ST-CTN system (i.e., was waiting time decreased). 6. Survey response of travelers' perception of confidence while riding a bus using the ST-CTN system. 7. Survey response of travelers' perception of trip planning competence for trips with a bus using the ST-CTN system.	Did the ST-CTN system enhance fixed-route transit service?	Quarterly
CV-PM-1	**Enhance Safety and Awareness with Connected Vehicle**		
CV-ME-1.1	The average survey response of travelers' (end user of the ST-CTN system) rating of their perception of enhanced safety while using pedestrian crossing extensions through the ST-CTN system.	Did the ST-CTN system enhance the travelers' perception of safety while crossing signalized intersections within the project study area?	Quarterly

Metric ID	Performance Measure/Metric	Evaluation Question	Reporting Frequency
CV-PM-2	**Improve Transit Reliability**		
CV-ME-2.1	Average transit schedule adherence within the project area, measured by Ride Gwinnett as 0 minutes before / 5 minutes after scheduled time for on-time performance (OTP) for users who received enhanced TSP.	Did the ST-CTN system improve transit schedule adherence within the project area for users who received enhanced TSP?	Quarterly / Manual
CV-ME-2.2	Standard deviation of average OTP distribution by route when enhanced TSP is utilized.	Did the ST-CTN system improve transit schedule reliability within the project area when enhanced TSP was utilized?	Quarterly Manual
CV-ME-2.4	The average survey response of travelers' (end user of the ST-CTN system) rating of their perception of number of missed pickups with use of the ST-CTN system.	Did the ST-CTN system improve transit traveler missed pickups (i.e., the transit vehicle operator is aware of the traveler at the specific stop even if they are not able to access the stop)?	Quarterly

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