Phase 2 System Architecture Document (SAD)

Georgia Department of Transportation ITS4US Deployment Project

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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, sustainability, and accessibility. 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 accessibility for those with disabilities, older adults, and those with limited English proficiency.

This document presents the Systems Architecture Document (SAD) for the physical objects and applications identified in the Concept of Operations (ConOps) document and other systems engineering documents. The intent is to describe, at a high level, the architecture components of the ST-CTN and its respective interfaces. Development of the SAD leverages the Architecture Reference for Cooperative and Intelligent Transportation (ARC-IT) and is loosely based on the ISO/IEC/IEEE 42010 2011 Systems and Software Engineering – Architecture description. The architecture provides the framework to plan, define, and integrate ITS solutions.

Along with this document, the SAD will include a Standards Plan and Interface Control Document (ICD) Separate Document) that identify the nature of required interfaces to other systems that utilize existing networking or other standards when available.

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Table of Contents

Revision History ..... **i**

Table of Contents ..... **ii**

1 Introduction **1**

1.1 Document Purpose 1

1.1.1 Organization of this Document 1

1.2 Identifying Information 2

1.3 Project Scope 2

1.4 Approach 6

1.5 Rationale for Key Decisions 7

2 Stakeholders **9**

2.1 Introduction 9

2.2 Stakeholders 9

2.2.1 User Profiles 9

2.2.2 Other Involved Personnel 11

2.3 User Needs 12

2.3.1 End User Needs 12

2.3.2 Infrastructure Owner / Operator Needs 13

2.3.3 System Needs 15

2.4 Concerns 20

3 System of Interest (SOI) **21**

4 Architectural Viewpoints **25**

4.1 Enterprise View 25

4.1.1 Project Partners and Stakeholders 25

4.1.2 Resource Objects (Physical Objects) 27

4.1.3 Relationships 30

4.1.4 Enterprise View Diagrams 33

4.2 Physical View 36

4.2.1 Physical View – Layers 0 and 1 37

4.2.2 Service Package Diagrams 40

4.2.3 Functional Descriptions in Service Packages 47

4.3 Communications View 56

5 Functional Viewpoint **67**

5.1 Functional View 67

5.1.1 OTP for G-MAP Multimodal Trip Planner Subsystem 70

5.1.2 Space Time Memory Platform Subsystem 76
5.1.3 Connected Vehicle Subsystem 79
5.1.4 Performance Measurement Dashboard Subsystem 80
5.1.5 Data and Information Flow View 83
5.2 Relationship Between Functional and Physical Views 98
6 References 103
7 Definitions, Acronyms, and Abbreviations 107
7.1 Definitions 107
7.2 Acronyms and Abbreviations 109

List of Tables

Table 1. ST-CTN System User Profiles 9
Table 2. End User Needs 12
Table 3. Infrastructure Owner Operator Needs 13
Table 4. System Needs 15
Table 5. Project Partners and Stakeholders Included in the Enterprise Architecture 26
Table 6. Resources (Physical Objects) Included in the Enterprise Architecture 27
Table 7. Relationships and Agreements between Enterprise Objects 30
Table 8. Functions contained in Service Package Elements 48
Table 9. Communications Stack Types 56
Table 10. Information Flow Details 57
Table 11. Critical ST-CTN Information Flow Descriptions 69
Table 12. Functional Elements for G-MAP Trip Planner 72
Table 13. Functional Elements for the STM Platform Subsystem 77
Table 14. Functional Element of the Private PMD 81
Table 15. Functional Element of the Public PMD 83
Table 16. Relationship between Functional and Physical Information Flows 84
Table 17. Physical and Functional View Relationship 98
Table 18. Referenced Documents 103

List of Figures

Figure 1. Traveler's Complete Trip 3
Figure 2. ST-CTN High-Level Context Diagram 5
Figure 3. ST-CTN High-Level Context Diagram 21
Figure 4. ST-CTN System Enterprise View: Roles 34
Figure 5. ST-CTN System Enterprise View: Relationships 35
Figure 6. Physical Viewpoint Layer 0 for ST-CTN 38
Figure 7. Physical Viewpoint Layer 1 for ST-CTN Indoor Navigation 39
Figure 8. Physical Viewpoint Layer 1 for ST-CTN Performance Measurement Archives 40

Figure 9. DM02: Public Performance Monitoring Dashboard 41
Figure 10. DM02: Performance Monitoring 42
Figure 11. PT17: Transit Ride Request 43
Figure 12. SU04: Indoor Path Management 44
Figure 13. TI02: Personalized Traveler Information for Indoor Navigation 45
Figure 14. TI04: Infrastructure-Provided Trip Planning and Route Guidance 46
Figure 15. VS12: Pedestrian Mobility (PED-X) 47
Figure 16. Functional Architecture for ST-CTN System 68
Figure 17. Functional View of the G-MAP Subsystem 71
Figure 18. Functional View of the STM Platform Subsystem 76
Figure 19. Functional View of the Connected Vehicle Subsystem 80
Figure 20. Functional Architectural View – PMD Subsystem 81

1 Introduction

The Georgia Department of Transportation (GDOT) and Atlanta Regional Commission's (ARC) Safe Trips in a Connected Transportation Network (ST-CTN) project was selected by the U.S. Department of Transportation (USDOT) as a part of the ITS4US Deployment Program. The project seeks to enhance the traveler's complete trip travel experience by enhancing mobility, accessibility, reliability, and safety for system users, particularly for underserved communities, including people with disabilities, older adults, and users with limited English proficiency (LEP). This is done by leveraging innovative solutions, existing deployments and team collaboration such as integrating connected vehicle (CV) data with an open-source software-based trip planner that is used to provision web-based and mobile application user access. The trip planner will provide users with the ability to create a personalized trip plan with information regarding the navigation of physical infrastructure, the ability to resolve unexpected obstacles, and ensure users' visibility throughout the trip. The proposed deployment will provide targeted users with the ability to dynamically plan and navigate trips.

1.1 Document Purpose

The objective of the System Architecture Document (SAD) is to create the implementation architecture for the ST-CTN system that defines the structure, behavior, and viewpoints of the system. This architecture provides the framework to plan, define, and integrate the various intelligent transportation systems (ITS) solutions. A standalone Interface Control Document (ICD) which includes a Standards Plan will be developed to complement the Architecture Views and be a resource during the design and deployment activities during Phase 2.

1.1.1 Organization of this Document

The SAD includes the following sections which provide the foundation for the ST-CTN system design.

- **Section 2: Stakeholders** defines the stakeholders, user needs, and concerns for the proposed system found during Phase 1 that form the basis for system development. The relationship between stakeholders, user needs, and concerns are defined within the context of the System of Interest (SOI) as defined by ISO/IEC/IEEE 42010 standard.
- **Section 3: System of Interest (SOI)** provides a high-level description of the ST-CTN SOI. The context diagram developed in Phase 1 is provided and shows the interactions between the users and subsystems.
- **Section 4: Architectural Viewpoints** describes the physical, enterprise and communications views of the ST-CTN system as modeled in the Architecture Reference for Cooperative and Intelligent Transportation (ARC-IT) [ARC-IT v9.1]. Illustrations of these views are rendered by the Systems Engineering Tool for Intelligent Transportation (SET-IT) software application used to support high-level, planning architecture views. The following views are provided: enterprise, physical, and communications.

- **Section 5: Functional Viewpoint** provides a detailed view of the ST-CTN functions and information flows which extend the Phase 1 concepts. The functional view incorporates Phase 1 terminology and concepts to bridge the migration from concept to deployment.
- The **ICD** (Stand-alone) identifies the nature of required interfaces to other systems. In addition, the intended audience and their related information exchange needs and/or use cases are defined.
    - A **Standards Plan** is included in ICD. The Standards Plan will support the use of pre-existing ITS Standards (if possible) to support off-the-shelf interoperability rather than developing proprietary interfaces that restrict regional and national interoperability and typically increase life-cycle costs.

1.2 Identifying Information

The architecture name and SOI are provided below and will be used consistently throughout the remainder of this document.

Architecture Name: ST-CTN System Architecture

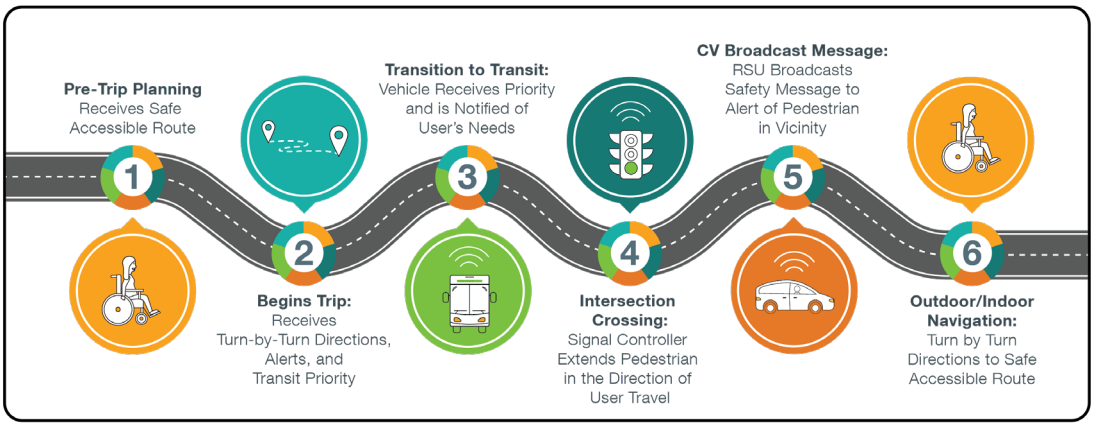
System-of-Interest: The ST-CTN system is composed of four major subsystems:

- OpenTripPlanner (OTP) for the Georgia – Mobility and Accessibility Planner (G-MAP) subsystem
- Connected Vehicle (CV) subsystem
- Space Time Memory (STM) Platform subsystem
- Performance Management Dashboard (PMD) subsystem

These subsystems are integrated with several external systems. Descriptions of the subsystems are included within the following subsection and the System-of-Interest is described further in Section 3.

1.3 Project Scope

The ST-CTN project aims to upgrade and integrate existing technologies and services to assist underserved populations with completing their complete trip successfully, safely, and reliably. The vision of the project is to provide users complete trip functionality 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 CV infrastructure to provide safer trips and more transportation network awareness. 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 abilities.
- **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) if the user requires additional time boarding or alighting a transit vehicle, is unable to stand for long periods, or is sensitive to weather conditions.
  - 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 for buses if the user requires additional time boarding or alighting a transit vehicle, is unable to stand for long periods, or is sensitive to weather conditions.
- **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 have accommodations 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 due to a user needing additional time to board or alight.
- **Step 4 Intersection Crossing.** When crossing a signalized intersection, the traveler indirectly interacts with the signal controller which extends the pedestrian phase in the direction of user travel.

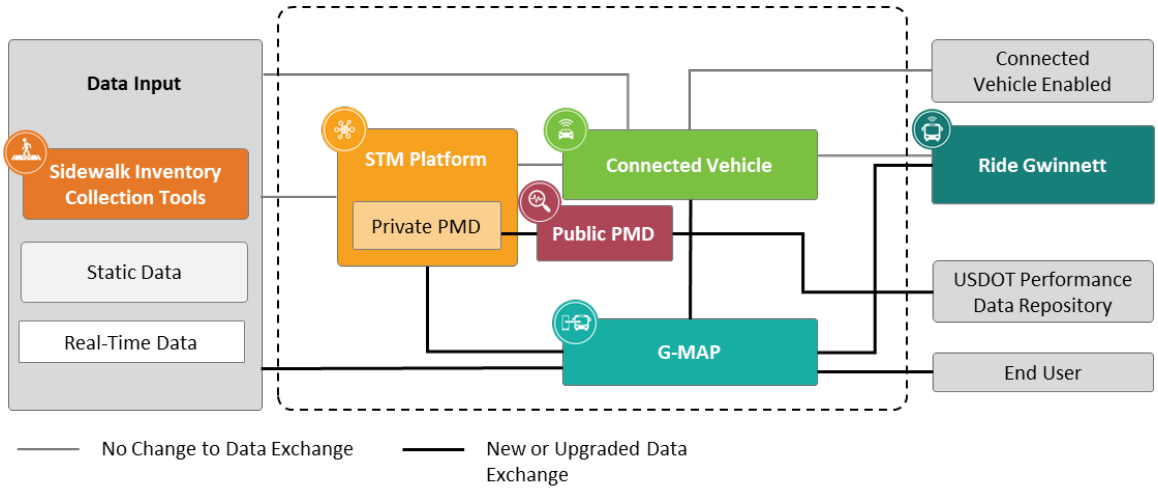
  - Allows the user to communicate with connected intersections if they are unable to reach or press the crosswalk button.
  - Provides the user with information about the intersection crossing and adds time to the crossing if needed.

- **Step 5 CV Broadcast Message.** Roadside units (RSUs) broadcast safety message to alert CVs of pedestrians/bicyclists in the vicinity.
  - Provides the ability for users to remotely request service from transit vehicles while waiting to board or alight.
  - Provides communications between CVs and users to make them aware of each other when crossing a roadway or waiting at a transit stop.
- **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 accessible channels (haptic, voice, text).
  - Alerts and dynamic rerouting in response to changes in path conditions.
  - Provides the user with accessible routes into and through transit hubs 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 will enable travelers – specifically those in the underserved community – to program 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 ST-CTN can be thought of as a *system of systems*; the scope of work required to develop, design, and deploy ST-CTN is focused on the expansion or enhancement of current systems and added connectivity between those systems. **Figure 2** provides a simplified context diagram of the proposed system – indicating the system of interest and added subsystem connectivity. Each subsystem is indicated by color and icon: Sidewalk Inventory Collection Tools is burnt orange; STM Platform is peach; CV is green; G-MAP is turquoise; Public PMD is maroon; and Ride Gwinnett (GCT) is teal. The STM Platform, ATL RIDES, and CV subsystems will each require expanded capability and added connectivity to support the proposed ST-CTN system. The Sidewalk Inventory Collection Tools and GCT existing independent systems will serve to support the proposed ST-CTN system. Data exchanges between subsystems are denoted by a gray or black line. A gray line indicates an existing and unchanged data exchange between subsystems. A black line indicates a new or upgraded data exchange between subsystems.



Source: GDOT, 2023

Figure 2. ST-CTN High-Level Context Diagram

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 will be developed specifically to support ST-CTN project evaluation. The icons and colors depicted below are used throughout the SAD 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 will be modified and enhanced based on ST-CTN project needs and leveraged to create a new, independent application which will be 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 ADA and inclusive design and condition data for use in pathway accessibility 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 accessible 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 will include the development of a Performance Measurement Dashboard (PMD) that is not currently in use.



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

1.4 Approach

The SAD describes the ST-CTN system architecture including four architectural views – physical, enterprise, communications and functional. This document applied ISO/IEC/IEEE 42010 practices to describe the systems architecture, views, models and relationships. The ST-CTN project team applied two frameworks for developing the four viewpoints – (1) Architecture Reference for Cooperative and Intelligent Transportation (ARC-IT) [ARC-IT] and (2) a functional flow model.

ARC-IT Framework. Section 4 Architectural Viewpoints which includes the Physical, Enterprise and Communications views use the ARC-IT v9.1 framework to build a set of planning viewpoints. The team used the USDOT Systems Engineering Tool for Intelligent Transportation (**SET-IT**) Version 9.1 (September 2022) [SET-IT] to create and render the Enterprise, Physical, and Communications views. The three views are consistent with ARC's Regional ITS Architecture such that the ST-CTN project will be able to be incorporated into the existing regional architecture and promote the eventual expansion of the system to other counties and municipalities in the region.

Functional Flow Framework. **Section 5 Functional View** starts where the Concept activities from Phase 1 commenced. The functional flow framework describes in more detail the functions and enumerates the flows from the Phase 1 concept to the Phase 2 design and development

activities and extends the functions and information flows detailed during Phase 1 of the ST-CTN project. The Functional View utilizes the same terminology, models, information flows, and constraints described in the Phase 1 documents particularly the ConOps, SyRS and Data Management Plan. The concepts developed during Phase 1 are mapped into the functional architecture to provide continuity and traceability into the deployment phase. Furthermore, user needs and requirements will be traced throughout the design and development process during Phase 2 and documented within the Systems Design Document (SDD).

Stakeholder names and descriptions are related to the high-level and more detailed views; however, more specific information is provided outside of the Regional ITS Architecture as would be expected at the design stage of an ITS project.

1.5 Rationale for Key Decisions

The ST-CTN SAD is based on an understanding of the existing subsystems and initiatives being leveraged throughout the region. The following key decisions led to the development of the SAD.

Leveraged ARC-IT. ARC-IT v9.1 was used to develop the architectural viewpoints of the system. By leveraging national ITS architecture tools, other agencies interested in deploying a similar system will be able to understand and efficiently apply this system architecture to their systems engineering process and concept development. For example, the use of ARC-IT framework has illuminated gaps in specific wayfinding and navigation service packages that are likely to be needed by others deploying similar technologies.

Maintained consistency with ARC's Regional ITS Architecture. The SAD provides a high-level description of the ST-CTN system architecture that is consistent with ARC's existing Regional ITS Architecture. This was done so that ARC can easily update the Regional ITS Architecture to incorporate the ST-CTN project architecture (as defined in Section 4).

Built on Phase 1 understanding. The team expended significant effort during Phase 1 Concept Development to understand programs that could be leveraged and enhanced to effectively meet stakeholder needs. The Functional Viewpoint (**Section 5**) extends the Phase 1 concepts to refine and further detail the functional elements and interfaces which will be used to guide the detailed design. A significant amount of high-level design work was developed during the Concept Phase. In order to include the engineering discussions and ensure consistency with previous work, the team decided to extend the concepts into this functional and information flow viewpoint.

Incorporated Phase 2 Design and Solution Elements. The as-built version of this architecture has incorporated design constraints and solution elements into an updated system architecture. These elements are consistent with the Phase 2 updates of the ST-CTN Concept of Operations (2024) and System Requirements Specification (2024) .

Terminology and descriptions of system elements are consistent with the updated Phase 1 Concept Development documents such as the Concept of Operations (ConOps), System Requirements Specification (SyRS), and the Phase 2 Data Management Plan (DMP). Where terminology including stakeholder names differ within the ARC Regional ITS Architecture, we added detail to clarify traceability. In addition, we were specific when the details were known.

2 Stakeholders

2.1 Introduction

This section defines the stakeholders, user needs, and concerns of the ST-CTN system as was defined during Phase 1 to document the interactions of these groups with system and with each other. The concerns provided at the end of this section describe the stakeholders concerns of the System of Interest (SOI) as defined by ISO/IEC/IEEE 42010 standard.

2.2 Stakeholders

The following sections provide a summary of stakeholders expected to interact with the proposed ST-CTN system. Information pertaining to user profiles and other involved personnel relevant to the ST-CTN system architecture are provided below. For a comprehensive list of stakeholders including advocacy groups, training partners, and outreach support, reference the Phase 1 Updated ConOps.

2.2.1 User Profiles

Table 1 provides a summary of user profiles that are expected to be impacted by the ST-CTN system.

Table 1. ST-CTN System User Profiles

User Group	Subsystem / Component	Description	ST-CTN Responsibility
USDOT	ST-CTN	ST-CTN project sponsor. USDOT Performance Data Repository owner, operator, and maintainer.	Assist ST-CTN system deployment by providing funds, direction, and technical support. Own, operate, and maintain the USDOT Performance Data Repository.
GDOT	ST-CTN and Connected Vehicle	ST-CTN project lead and Connected Vehicle subsystem owner, operator, and maintainer. GDOT Traffic Management Center (TMC) and statewide ATMS (NaviGAtor) infrastructure owner, operator, and maintainer.	Manage ST-CTN project funds. Own, operate, and maintain Connected Vehicle subsystem at GDOT maintained traffic signal locations. Own, operate, and maintain TMC and NaviGAtor infrastructure.

User Group	Subsystem / Component	Description	ST-CTN Responsibility
ARC	ST-CTN and G-MAP	ST-CTN project manager and ST-CTN system owner and maintainer. G-MAP subsystem owner and maintainer. Manages Call Center for expansion. Operates Public PMD. Owns Call Center for expansion, Indoor Navigation subsystem, and Public PMD.	Manage ST-CTN project delivery. Own and maintain ST-CTN, G-MAP subsystem, Call Center, Indoor Navigation subsystem, and Public PMD subsystem during Phase 3 and during the 5-year post deployment phase.
Gwinnett County – Traffic and Operations	Connected Vehicle	CV subsystem owner, operator, and maintainer.	Own, operate, and maintain Connected Vehicle subsystem at Gwinnett County maintained traffic signal locations. Own, operate, and maintain Gwinnett County Traffic Control Center (TCC), traffic signal management, and transit signal priority. Own, operate, and maintain the Gwinnett County communications network including communications to traffic signals and ATMS devices and maintaining server infrastructure within the Gwinnett County TCC.
Ride Gwinnett (previously known as the Gwinnett County Transit or GCT)	Connected Vehicle	CV subsystem operator.	Operate CV subsystem on Gwinnett County transit vehicles. Integrate and operate CV subsystem including TSP and ride request with existing Gwinnett County transit computer aided dispatch (CAD) system. Own, operate, and maintain Gwinnett County Transit system including bus fleet, stop, station, signage, and service information (i.e., GTFS).
The ATL	ATL RIDES (relevant for potential future expansion)	Existing, independent ATL RIDES system owner and maintainer.	Own and maintain ATL RIDES application.

User Group	Subsystem / Component	Description	ST-CTN Responsibility
Arcadis (aka IBI Group, G-MAP Vendor)	ST-CTN and G-MAP	ST-CTN system and G-MAP subsystem developer and operator.	Develop and operate ST-CTN system and G-MAP subsystem.
Georgia Tech / GTRI (GA Tech)	ST-CTN, SidewalkSim, STM Platform, and Private PMD	ST-CTN system developer and operator. STM Platform, and Private PMD subsystems operator and maintainer.	Develop and operate ST-CTN system. Develop, operate and maintain SidewalkSim, STM Platform, and Private PMD subsystems.
ICF (Public PMD Developer)	ST-CTN and Public PMD	ST-CTN system engineering lead and public PMD developer and software maintainer.	Develop and operate ST-CTN system. Develop and maintain Public PMD.
End User / Traveler / Traveler Companion	Traveler personal web or mobile devices	Traveler leveraging the ST-CTN system to support their complete, safe, accessible trip.	Create user profile and trip planning request and follow turn-by-turn directions provided by the ST-CTN system and/or G-MAP application. Provide feedback on performance and system use.

2.2.2 Other Involved Personnel

Stakeholders involved with the proposed system in a passive or supportive role include:

- Avail Technologies (Avail). Gwinnett County DOT – Transit computer-aided dispatch (CAD) provider and ride request module integrator.
- 360 Network Solutions, LLC (360ns). GDOT Regional Connected Vehicle Smart Corridor deployment lead in Gwinnett County. Responsible for the deployment of connected vehicle infrastructure and implementation of TSP.
- Gwinnett County Transit Vehicle Operators. Utilize TSP and ride request within the ST-CTN project area. Receives on-board connected vehicle notifications.
- Indoor Navigation (beacons) Vendor. Developer and integrator of indoor navigation subsystem that will facilitate indoor turn-by-turn directions for two facilities within the ST-CTN project area.
- Gwinnett County Support Services – Operations and Maintenance Division. Responsible for the **Gwinnett Justice and Administration Center (GJAC)** and **Norcross OneStop f**acility operations and maintenance.
- Call Center. Gwinnett County personnel are responsible for call center operations for the project duration. ARC personnel are responsible for call center operations following the call center's regional expansion.

2.3 User Needs

Identifying user needs is one of the first steps taken when beginning the systems engineering process. Well written user needs provide a foundation for all subsequent systems engineering processes and are of critical importance to the success of the ST-CTN project. System needs, system requirements, and design elements are traced to identified user needs, so developing a thorough list of user needs at the onset of the project allows all subsequent processes to flow smoothly. User needs also provide future stakeholders, IOOs, and System Developers (SD) with the rationale for decisions that were made previously in the systems engineering process.

The ST-CTN project team conducted stakeholder engagement in the form of user needs interviews with advocacy groups and representatives from underserved communities. User needs were identified based on the findings of this engagement as well as literature research and were documented within the Phase 1 ConOps in the form of need statements.

To help organize the user needs, a parent child relationship was identified in which child needs have a hierarchal relationship to parent needs. Parent needs are summarized in the following sub-sections for end users, infrastructure owner/operators (IOO), and system needs. All user needs have been given a unique ID associated by trip segment or step, as defined in **Section 1.3**: Step 1 Pre-Trip Planning, Step 2 Begin Trip, Step 3 Transition to Transit, Step 4 Intersection Crossing, Step 5 CV Broadcast Message, Step 6 Outdoor/Indoor Navigation, Reporting, and Future Development (FT). This identification convention will allow for traceability throughout the project. The Phase 1 ConOps document provides a comprehensive list of parent and child needs as well as a full description of the process used to develop need statements.

2.3.1 End User Needs

Table 2 provides a summary of the end user parent needs, associated justification for those needs, and priority (where E=essential, D=desired, and O=optional). A full list of end user parent and child needs may be found in Section 4.2.2 of the Phase 1 ConOps.

Table 2. End User Needs

Need ID	End User Need Statement	Priority
Pre-Trip Planning (PT) PT-EU-1.1	Travelers need personalized trip information that accommodates their preferences and abilities.	E
PT-EU-1.2	Travelers need the ability to customize their App accessibility features to accommodate their abilities.	E
Begin Trip (BT) BT-EU-2.1	Travelers need support services during trip planning and traveling based on their preferences and abilities.	E
BT-EU-2.2	Travelers need to receive personalized information and alerts during their trip in a way that is accessible to them.	E

Need ID	End User Need Statement	Priority
Transition to Transit (TT) TT-EU-3.1	Travelers need the ability to communicate with transit infrastructure and transit vehicle operators to ensure adequate time to board or alight a transit vehicle based on their abilities.	E
Intersection Crossing (IC) IC-EU-4.1	Travelers need the ability to communicate with infrastructure and CVs at signalized crosswalks beyond the currently existing push buttons.	D
Connected Vehicle Broadcast Message (CV) CV-EU-5.1	Travelers need the ability to remotely request transit service while waiting or traveling to a transit stop.	D
Indoor/Outdoor Navigation (NV) NV-EU-6.1	Travelers need accurate information to successfully navigate indoor spaces.	D
Reporting (RP) RP-EU-7.1	Travelers need the ability to provide feedback on infrastructure and services.	D

2.3.2 Infrastructure Owner / Operator Needs

Table 3 provides a summary of the IOO parent needs, associated justification for those needs, and priority (where E=essential, D=desired, and O=optional). These needs are primarily driven by existing county and regional plans as well as identified end user needs. IOO interviews were held to discuss existing infrastructure and systems; during this time, key end user needs were shared and IOO needs were identified. A full list of IOO parent and child needs may be found in Section 4.2.3 of the Phase 1 ConOps.

Table 3. Infrastructure Owner Operator Needs

Need ID	IOO Need Statement	Priority
Pre-Trip Planning (PT) PT-OO-1.1	Gwinnett County Department of Transportation (GCDOT) and Gwinnett County Transit (GCT) need to provide all travelers real-time, secure, and reliable travel information to support safe, complete trip planning and navigation, especially for underserved communities. [GCTP-4]	E
PT-OO-1.2	Infrastructure Owner Operators need to protect travelers' personal information by ensuring that any PII data is safe, secure, and private.	E

Need ID	IOO Need Statement	Priority
Transition to Transit (TT) TT-OO-3.1	Transit operators need more information about their riders' preferences and abilities to better serve them; particularly people with disabilities and people with limited English proficiency (LEP).	D
TT-OO-3.2	To support the use of transit, GCT needs to improve travel time reliability, including bus speeds and reliability for several transit routes. [CVTMP]	D
TT-OO-3.3	To improve pedestrian safety hailing an approaching transit vehicle, or boarding or alighting a transit vehicle, a connected vehicle (CV) application needs to notify the connected bus and infrastructure about a person with a disability currently boarding or alighting the vehicle. [CVTMP] (related CV applications include: Transit Vehicle at Station/Stop Warnings, Transit Stop Request)	D
Intersection Crossing (IC) IC-OO-4.1	Connected intersections need to improve safety and mobility of vulnerable road users as they approach and cross the intersection. The Gwinnett County CVTMP (CVTMP) describes near-term application deployments to achieve this near-term need including: Mobile Accessible Pedestrian Signal System (PED-SIG) as well as long-term applications such as Pedestrian Mobility, and Pedestrian in Signalized Crosswalk Warning.	E
IC-OO-4.2	To improve pedestrian safety at crosswalks, a CV application needs to create a more detailed alert to communicate the presence of pedestrian activities at crosswalks including information such as crosswalk occupancy, direction of travel, speed, and whether the crosswalk is clear of pedestrians. [CVTMP, p., 35] (related CV applications include: PED-SIG, Pedestrian in Signalized Crosswalk Warning, and Pedestrian Mobility)	E
CV-OO-5.1	To communicate the location of intersections that support the connected vehicle safety strategies for pedestrians and transit, the County needs to inventory and disseminate the locations of intersections that support Multimodal Intelligent Traffic Signal System (MMITSS) applications including PED-SIG, Transit Signal Priority (TSP), and other related CV applications.	E
Connected Vehicle Broadcast Message (CV) CV-OO-5.2	An optimized signal system needs to accommodate signal priority for transit movement through a signalized intersection based on conditional criteria such as vehicle loads or schedule adherence in order to improve operating performance of the transit vehicles. Related CV applications include Intelligent Traffic Signal System (I - SIG), MMITSS and TSP. [CVTMP]	D

Need ID	IOO Need Statement	Priority
Indoor/Outdoor Navigation (NV) NV-OO-6.2	To generate personalized and accessible indoor and outdoor trip plans and event notifications, Gwinnett County needs to manage static and dynamic information on pathway assets, conditions and states that include accessible entrance, indoor navigable routes, elevator and escalator status, and signalized intersections with pedestrian crossing signals.	E
Reporting (RP) RP-OO-7.1	Gwinnett County needs to collect current bus stop accessibility and shelter conditions and make that information accessible to travelers.	E
Future Development (FT) FT-OO-8.1	Gwinnett County and GDOT CV infrastructure needs to establish guidelines for deploying new and evolving technology to support leveraging advances in technology while balancing scalability and use of existing and future applications.	D
FT-OO-8.2	Gwinnett County and GDOT CV infrastructure and strategy implementation must be compatible with one another and set a standard approach for replicating similar applications by local agencies across the state. The purpose of the ST-CTN project is to be replicable throughout the region and the implementation of conflicting strategies or technologies would degrade its ability to be replicable.	D

2.3.3 System Needs

Table 4 provides a summary of the parent system needs, justification for those needs, priority (where E=essential, D=desired, and O=optional), and associated end user and IOO needs. The end user needs, along with the IOO needs drive the system needs.

System needs were developed through an iterative process in which a technical team of ST-CTN executive management team (EMT) and system developers considered end user needs, IOO needs, and actions of the proposed system that would be required to support the end user and IOO needs. System needs were derived to support these actions, end user, and IOO needs. A full list of end user parent and child needs may be found in Section 4.2.3 of the Phase 1 ConOps.

Table 4. System Needs

Need ID	System Need Statement	Priority	Associated End User and IOO Need
Pre-Trip Planning (PT) PT-SY-1.1	The system needs to protect traveler safety and privacy by ensuring tracking services are optional (opt-in) and any PII is secure.	E	PT-EU-1.1.8 BT-EU-2.1.2 BT-EU-2.2.5 BT-EU-2.2.6 PT-OO-1.2
PT-SY-1.2	The system needs to provide support services to all travelers during their journey, including those who do not have access to data (e.g., cellular connection or access to the internet) during travel.	E	BT-EU-2.1.2 BT-EU-2.2.1 BT-EU-2.2.5 BT-EU-2.2.6 PT-OO-1.1
PT-SY-1.3	The system needs to generate a framework to transform values assigned to travel preferences into impedance values for the simulation models (e.g., SidewalkSim).	E	PT-EU-1.1.1 PT-EU-1.1.2 PT-EU-1.1.3 PT-EU-1.1.4 PT-EU-1.2.5 PT-EU-1.2.6 PT-EU-1.2.9 BT-EU-2.2.3
PT-SY-1.4	The system needs to allow travelers to customize the UI of the application based on their abilities or preferences.	E	PT-EU-1.2.1 PT-EU-1.2.2 PT-EU-1.2.3 PT-EU-1.2.4 PT-EU-1.2.5 BT-EU-2.2.1 PT-OO-1.1
PT-SY-1.5	The system needs to have an option of adding additional travelers and their accessibility needs when planning a trip.	D	PT-EU-1.1.7 BT-EU-2.1.1 BT-EU-2.1.2 BT-EU-2.1.3
PT-SY-1.6	The system needs to allow travelers to practice their turn-by-turn directions before the trip with their preferred notifications, device, or methods to reduce disorientation and discomfort during the trip.	D	PT-EU-1.2.8
Begin Trip (BT) BT-SY-2.1	The complete trip system functions (STM and G-MAP) need to be scalable to generate and accommodate multiple personalized trip plans and journeys for travelers simultaneously in order to be reliable and responsive to traveler requests and preferences.	E	-

Need ID	System Need Statement	Priority	Associated End User and IOO Need
BT-SY-2.2	The G-MAP Mobile App needs to be capable of providing hands-free, turn-by-turn directions based on user preferences and abilities to meet user needs.	E	BT-EU-2.2.1 BT-EU-2.2.2
BT-SY-2.3	The system needs to be compatible with open standards that are embedded or used in devices including mobile phones and connected assistive devices.	D	PT-EU-1.2.1 PT-EU-1.2.2 PT-EU-1.2.3 PT-EU-1.2.4 PT-EU-1.2.5
BT-SY-2.4	The system needs to be designed such that travelers will be able to customize how notifications are received based on their abilities or preferences.	E	PT-EU-1.2.1 PT-EU-1.2.2 PT-EU-1.2.3 PT-EU-1.2.4 PT-EU-1.2.5 BT-EU-2.2.1 BT-EU-2.2.2 BT-EU-2.2.5 PT-OO-1.1
BT-SY-2.5	The system needs to be able to track travelers who opt-in to provide more support during their trip through a call center or their caregiver.	E	BT-EU-2.1.2 BT-EU-2.1.3

Need ID	System Need Statement	Priority	Associated End User and IOO Need
BT-SY-2.6	The system needs to activate automated messages and alerts, as well as re-routing based on real-time information consistent with the traveler's preferences while the traveler is executing their travel.	E	PT-EU-1.1.1 PT-EU-1.1.2 PT-EU-1.1.3 PT-EU-1.1.4 BT-EU-2.1.3 BT-EU-2.1.4 BT-EU-2.2.1 BT-EU-2.2.2 BT-EU-2.2.3 BT-EU-2.2.4 BT-EU-2.2.5 BT-EU-2.2.6 TT-EU-3.1.1 TT-EU-3.1.2 TT-EU-3.1.3 TT-EU-3.1.4 TT-EU-3.1.5 TT-EU-3.1.6 TT-EU-3.1.7 CV-EU-5.1.1 CV-EU-5.1.2 NV-EU-6.1.1 NV-EU-6.1.2 NV-EU-6.1.3 PT-OO-1.1
Transition to Transit (TT) TT-SY-3.1	The system needs to provide a method for a traveler to send a stop request to an approaching transit vehicle. The stop request may also identify special needs of the traveler.	E	TT-EU-3.1.1 TT-EU-3.1.3 TT-EU-3.1.5 CV-EU-5.1 TT-OO-3.2 CV-OO-5.2
TT-SY-3.2	The system needs to confirm receipt and status of the request for a transit stop request so that the traveler knows that their request has been received by the system.	E	-
Intersection Crossing (IC) IC-SY-4.1	The system needs to connect to traffic signal system infrastructure to enable travelers to activate crosswalk signals using a hands-free method, or automatically using their trip plan and location so that the traveler is able to complete their trip based on their preferences and abilities.	E	IC-OO-4.2 IC-EU-4.1 CV-EU-5.1.1 CV-EU-5.1.2 CV-OO-5.2

Need ID	System Need Statement	Priority	Associated End User and IOO Need
IC-SY-4.2	The system needs to confirm receipt and status of the request for a pedestrian crossing request so that the traveler knows that their request has been received by the system.	E	IC-OO-4.1
Connected Vehicle Broadcast Message (CV) CV-SY-5.1	The system needs to connect travelers to the connected infrastructure to increase safety.	E	IC-OO-4.1 IC-OO-4.2 CV-OO-5.1
Indoor/Outdoor Navigation (NV) NV-SY-6.1	The system needs to ingest static and real-time data about indoor and outdoor assets and conditions (e.g., sidewalk blockages, elevator/ escalator outages) to ensure accuracy in the accessibility of routes.	E	PT-EU-1.1.3 PT-EU-1.1.4 BT-EU-2.2.3 NV-EU-6.1.1 NV-EU-6.1.2 NV-EU-6.1.3 PT-OO-1.1 NV-OO-6.2 RP-OO-7.1
NV-SY-6.2	The system needs to interface with facility or third-party communications assets using protocols available on smartphones (e.g., near-field communication (NFC), Bluetooth, Wi-Fi) and also use standardized navigation or wayfinding messages to communicate with travelers.	D	PT-EU-1.1.3 PT-EU-1.1.4 NV-EU-6.1.2 NV-EU-6.1.3
Reporting (RP) RP-SY-7.1	The system needs to store and provide access to a G-MAP account holder about their trip histories so that the traveler or the traveler's guardian is able to review their trip history for verification and safety purposes.	D	RP-EU-7.1 RP-OO-7.1
RP-SY-7.2	The system needs to collect input about disruptions and obstructions to their travel during or after their travel.	D	RP-EU-7.1 RP-OO-7.1
RP-SY-7.3	The system needs to provide anonymized information about trip performance to the performance monitoring module (in the STM subsystem) that details traveler behavior to help improve trip plan customization for users.	E	RP-EU-7.1 RP-OO-7.1

Need ID	System Need Statement	Priority	Associated End User and IOO Need
Future Development (FT) FT-SY-8.1	The system needs to allow for future scalability or development in order to address user needs that are not within the scope of this project and will not be implemented in the initial roll out.	D	FT-OO-8.1 FT-OO-8.2

2.4 Concerns

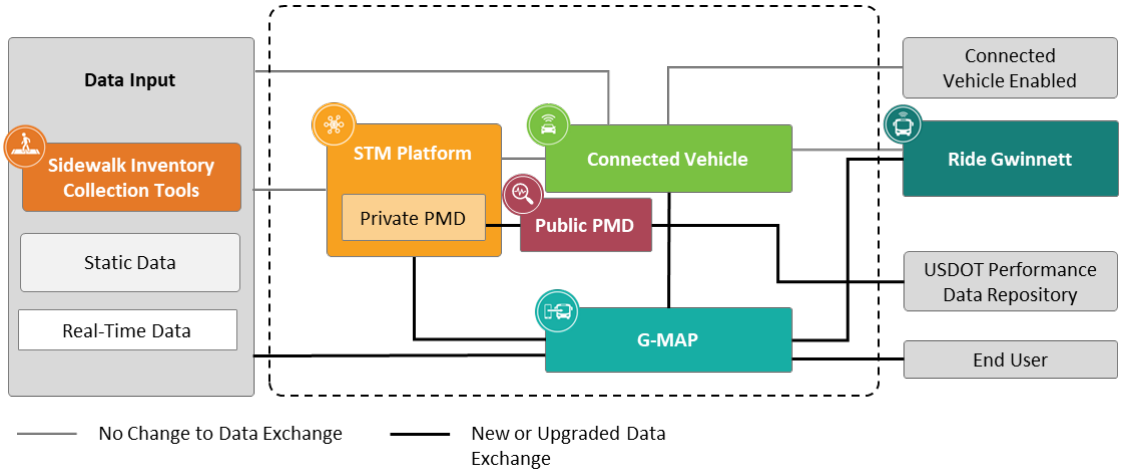
The ARC-IT viewpoints and modifications used to supplement existing functions and objects within this document address all relevant concerns. As such, the ARC-IT viewpoints can reference the ARC-IT viewpoint definition pages as needed.

Other concerns may arise during the design, deployment, or evaluation stages of the project which may require modifications to the architecture based on redefined roles and responsibilities. It is understood that this is an evolving project and that roles and responsibilities may change post Phase 3.

Other concerns arose during the design deployment and evaluation which resulted in changes in the architecture. These changes are documented in the as-built version of this document. It helped redefine roles and responsibilities as well as some physical resources and functionalities. Regardless, it is understood that this is an evolving project, as a result roles and responsibilities may continue to change in Phase 3.

3 System of Interest (SOI)

This section provides a high-level description of the proposed System of Interest (SOI). The context diagram presented in **Figure 3** 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 architectural views presented in **Sections 4** and **5**.



Source: ARC, 2024

Figure 3. ST-CTN High-Level Context Diagram

The scope of the project will expand and enhance 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 is being developed with the support of FTA's 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 will extend 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, such as real-time transit data, work zone impacts, and impedance calculations based traffic conditions. The extended capabilities will be branded as G-MAP. It should be noted that during Phase 1, 'ATL RIDES' was used to describe the trip planning and user interface subsystem. However, the subsystem naming convention has been refined to be described as G-MAP herein to clarify the distinct systems.

The G-MAP will include 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 will use the GCT Transit 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** -- Mobile Accessible Pedestrian Signal System is an application that allows for an automated request via a center to center (C2C) information flow from G-MAP to the signal controller via a proxy server also known as the Secure Mobile Unit Gateway (SMUG) (part of the CV Subsystem) to request the pedestrian signal (PED-X) at a specific intersection crossing and extend the pedestrian walk time as needed. The PED-X signal at the intersection provides confirmation of the request.

- **Indoor Navigation** – The indoor navigation function will be 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 will be installed in the Gwinnett Justice Administration Center and Norcross OneStop, both facilities operated and maintained by the Gwinnett County Facilities Department.



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 will leverage 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 ITS Hub connected through GDOT communications network. The GDOT communication network also consists of a SMUG that allow for information exchange between the G-MAP system and the signal controllers. The roadside components consist of traffic signal systems owned and operated by GDOT and Gwinnett County. The subsystem allows for the broadcast of pedestrian safety messages (PSMs) when pedestrians are in the vicinity or crossing at an intersection. The subsystem also provide TSP via the OBE on the transit vehicle to the signal controller via the RSE. The equipment and operations of the subsystems will not be changed 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 will include sidewalks and all local roads and will correspond 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 is envisioned 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. The PMD subsystem is comprised of private and public components where the private PMD manages and performs analytics on private data, including 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.

4 Architectural Viewpoints

This section describes three architectural viewpoints of the proposed system. The three viewpoints – Enterprise, Physical, and Communications use the methodology as defined in ARC-IT v9.1 [ARC-IT v9.1]. The viewpoints including the elements contained therein are consistent with the existing Atlanta Regional Commission Regional ITS Architecture (https://itsarchitecture.atlantaregional.org/).

The Functional view is provided in **Section 5**. As mentioned in our Approach (**Section 1.4**) the Functional viewpoint is based on the detailed functions and information flows defined in Phase 1 and serves as a bridge from the high-level architectural views to the design of the system.

4.1 Enterprise View

The Enterprise View describes how Enterprise Objects (stakeholders and personnel) interact with Physical Objects (or resources) by assigning roles – owners, operators, developers, etc. The interactions between Enterprise Objects are defined as Relationships. The relationships between Enterprise Objects and Physical Objects are largely determined by the roles.

There are four object types that are defined by ARC-IT and will be represented in the Enterprise View (as defined by ARC-IT 9.0).

1. **Enterprise Object:** An organization or individual that interacts with other Enterprise Objects and/or Physical objects. An Enterprise Object may be a component of another larger Enterprise Object, which may in turn be a component of a third, even larger, Enterprise Object. Enterprise Objects may participate wholly or in part in other Enterprise Objects.

2. **Resource:** An asset that can support the achievement of Enterprise Objects. This may be a physical or virtual element and may be of limited availability. All Physical Objects are resources, but other resources may include policies and documents.

3. **Relationship:** Formal or informal coordination between Enterprise Objects; e.g., agreements, contracts, funding, and expectations.

4. **Role:** The way in which an object participates in a relationship; an object's set of behaviors and actions associated with a resource.

4.1.1 Project Partners and Stakeholders

Project Partners and Stakeholders are described in **Section 2.2** as relevant for the ST-CTN project. The Enterprise Objects – stakeholder names have been updated to be consistent with ARC Regional ITS Architecture and are referenced below in **Table 5** with their corresponding role and resource / physical object as denoted in the SET-IT model. The table includes the name of each stakeholder (column 1) as described within the architecture views and the user profile

stakeholder name as identified in **Section 2.2**, their profile stakeholder name (column 2), and their role with respect to Resources / Physical Objects (columns 3 and 4). The table uses standard architecture roles for the relationship between stakeholder and Resource / Physical Object – manages and owns. Owns assumes a financial relationship to the resource while manages assumes a planning, operations and/or maintenance role with the resource. In addition, a stakeholder may have a relationship with personnel resources such as administrators, operators, etc. We assigned the role of "has a" to those relationships.

Table 5. Project Partners and Stakeholders Included in the Enterprise Architecture

Enterprise View Stakeholder	User Profile Stakeholder Name	Role	Resource / Physical Object
Atlanta Regional Commission	ARC	Manages	Call Center for Expansion
Atlanta Regional Commission	ARC	Owns	Call Center for Expansion, Facility Path Update System, Public PMD, STM Platform, and G-MAP Trip Planner
Connected Vehicle Vendor	360ns (CV Vendor)	Manages	Connected Vehicle System
GA Tech	GA Tech	Has a	Private PMD System Administrator
GA Tech	GA Tech	Manages	Private PMD and STM Platform
GA Tech	GA Tech	Owns	Private PMD
Georgia Department of Transportation	GDOT	Manages	CV Vendor
G-MAP Vendor	Arcadis	Has a	G-MAP System Administrator
G-MAP Vendor	Arcadis	Manages	G-MAP Mobile App, and G-MAP Trip Planner
Gwinnett County	Gwinnett County – Transit – Traffic and Operations – Facility	Has a	GCT Dispatch Operator, GCT Operator, and Gwinnett Facility Personnel
Gwinnett County	Gwinnett County – Transit – Traffic and Operations – Facility	Manages	GCT Bus, GCT Bus OBE, Gwinnett Facility, Gwinnett County Roadway Signal System, Gwinnett County RSE, Gwinnett County TCC, Gwinnett Transit Management Center, and Call Center throughout project duration

Enterprise View Stakeholder	User Profile Stakeholder Name	Role	Resource / Physical Object
Gwinnett County	Gwinnett County – Transit -- Traffic and Operations -- Facility	Owns	GCT Bus, GCT Bus OBE, Gwinnett Facility, Gwinnett County Roadway Signal System, Gwinnett County RSE, Gwinnett County TCC, and Gwinnett Transit Management Center, Call Center throughout project duration
Indoor Navigation Vendor	Indoor Navigation (beacon) Vendor	Manages	Facility Map Update System
Public PMD Developer	ICF (Public PMD Developer)	Has a	Public PMD System Administrator
Public PMD Operator	ARC	Operates	Public PMD
Traveler		Is a	Traveler or Trusted Companion
Traveler		Owns	G-MAP Mobile App
USDOT		Has a	Independent Evaluator
USDOT		Manages, Owns	USDOT Performance Data Repository

4.1.2 Resource Objects (Physical Objects)

The element inventory (e.g., resources) included in the ST-CTN project architecture are listed in **Table 6**. The table includes a list of the resources, their descriptions and the stakeholder that has a relationship (role) associated with the resource. Personnel are included in **Table 5** as resources and are associated with a resources / physical object and have not been included as a resource in this table.

Table 6. Resources (Physical Objects) Included in the Enterprise Architecture

Resource Name	Resource Description	Stakeholder
Call Center	Call Center that includes G-MAP call taker module. Used to support travelers and travel companions with planning and navigating their G-MAP trip plans.	ARC for expansion Gwinnett County for project duration
Facility Map Update System	Facility Map Update System used to support travelers with accurate indoor routing and navigation.	ARC, Indoor Navigation Vendor
GCT Bus	GCT Bus.	Gwinnett County DOT - Transit

Resource Name	Resource Description	Stakeholder
GCT Bus OBE	GCT Bus OBE used to transmit a signal to the RSE located at enabled CV traffic signals for the purposes of providing TSP. Receives messages and alerts which are communicated to the transit operator.	Gwinnett County DOT - Transit
Gwinnett Facility	Gwinnett Justice and Administration Center (GJAC) and Norcross OneStop to be outfitted with indoor navigation system to support traveler routing and navigation within the facility.	Gwinnett County
G-MAP Mobile App	Mobile App that a traveler will access to provide profile needs and preferences to receive personalized trip plans.	G-MAP vendor, Traveler
G-MAP Trip Planner	Trip Planner that provides turn-by-turn directions based on traveler's needs and preferences.	ARC, G-MAP Vendor
Gwinnett County Roadway Signal System	Gwinnett County advanced traffic signal system configured to provide TSP and pedestrian crossing extension when required.	Gwinnett County–Traffic and Operations
Gwinnett County RSE	GC CV Roadside Equipment used to broadcast alerts and safety messages to enabled CVs in the vicinity. Receives messages from GCT Bus OBE to support TSP.	Gwinnett County–Traffic and Operations
Gwinnett County TCC	GC Traffic Control Center houses the operations and management of GC traffic signal system including central communications network, data, and video systems.	Gwinnett County–Traffic and Operations
Gwinnett Transit Management Center	Gwinnett Transit Management Center houses the central operations and management systems used to support GC transit services. This includes the computer aided dispatch (CAD) and GTFS data.	Gwinnett County-Transit
Private PMD	Private performance management dashboard (data pipe and storage) for system archived data. Secure storage for private and PII datasets.	GA Tech

Resource Name	Resource Description	Stakeholder
Public PMD	Public facing dashboard summarizing the performance of the ST-CTN system.	ARC, Public PMD Developer/ Maintainer
STM Platform	Platform to support generating prediction, personalization of trip planning.	ARC, GA Tech
Traveler, Trusted Companion (e.g., Caregiver)	The traveler (and trusted companion) represents any individual who uses transportation services. The interfaces to the traveler provides general pre-trip and en-route information supporting trip planning, personal guidance, and requests for assistance in an emergency that are relevant to all transportation system users. It also represents users of a public transportation system and addresses interfaces these users have within a transit vehicle or at transit facilities such as roadside stops and transit centers. In addition, within the context of the ST-CTN system, traveler refers to pedestrians as well, where a traveler participates in ITS services that support safe, shared use of the transportation network by motorized and non-motorized transportation modes. Representing those using non-motorized travel modes, pedestrians provide input (e.g., a call signal requesting right of way at an intersection) and may be detected by ITS services to improve safety. This object also includes travelers in special motorized conveyances, which travel at slow speed through portions of the transportation network and interact with ITS. The Trusted Companion is provided with the same access to information and system capabilities as the Traveler. The Traveler will have the capability to access the Trusted Companion through their G-MAP User Interface (UI). The Trusted Companion will be notified of the Traveler's trip.	Traveler
USDOT Performance Data Repository	USDOT Performance Data Repository used to store anonymized data relevant for ST-CTN performance.	USDOT

4.1.3 Relationships

In this section, a table of the Relationships for this deployment including service agreements, contracts, and expectations are included. A separate formal agreement or informal expectation is made between each source and destination pair, e.g., the source and destination of an information flow. **Table 7** describes the relationship number, relationship (or agreement), relationship type, relationship description, source and destination of the relationship. Note that the relationship numbers are not sequential due to updates that resulted in the removal of several agreements from this version of the enterprise architecture. Relationships are shown in numerical order. Any relationships not shown in the table below were removed due to changes in the system design as follows: The GA Tech / ARC Information Provision Agreement (relationship 9) was removed because ARC is not responsible for the GTFS feeds for this project. The GTFS feeds for the project are represented in relationship 10, Ride Gwinnett GTFS. The remaining relationships (12, 14, 15, and 18) were removed because MARTA is not a project partner, and the indoor navigation location is no longer at Doraville MARTA station.

Table 7. Relationships and Agreements between Enterprise Objects

Relationship Number	Relationship	Relationship Type / Description	Source Stakeholder	Destination Stakeholder
1	ARC / GA Tech Operations Agreement	Operations Agreement between Atlanta Regional Commission and GA Tech to operate and maintain the STM and private PMD during the project.	Atlanta Regional Commission	GA Tech
2	ARC / GA Tech Information Provision Agreement	Information Provision Agreement between Atlanta Regional Commission and GA Tech to exchange information to support the STM and evaluate the system.	Atlanta Regional Commission	GA Tech
3	ARC / Gwinnett County Information Exchange Agreement	Information Exchange Agreement between Atlanta Regional Commission and Gwinnett County	Atlanta Regional Commission	Gwinnett County

Relationship Number	Relationship	Relationship Type / Description	Source Stakeholder	Destination Stakeholder
4	ARC / Gwinnett County Information Provision Agreement	Information Provision Agreement between Atlanta Regional Commission and Gwinnett County	Atlanta Regional Commission	Gwinnett County
5	GDOT / Indoor Navigation Vendor Operations Agreement	Operations Agreement between GDOT and Indoor Navigation vendor per contract.	Georgia Department of Transportation	Indoor Navigation vendor
6	ARC / Public PMD Developer/Maintainer Operations Agreement	Operations Agreement between Atlanta Regional Commission and Public PMD Developer/Maintainer	Atlanta Regional Commission	Public PMD Developer/Maintainer
7	ARC / G-MAP Vendor Operations Agreement	Operations Agreement between Atlanta Regional Commission and G-MAP Vendor	Atlanta Regional Commission	G-MAP Vendor
8	ARC / Traveler Information Exchange Agreement	Information Exchange Agreement between Atlanta Regional Commission and Traveler	Atlanta Regional Commission	Traveler
10	Gwinnett County / GA Tech Information Provision Agreement	Information Provision Agreement between Gwinnett County and GA Tech to provide accurate and timely transit information including GTFS and GTFS real time data feeds.	Gwinnett County	GA Tech
11	Gwinnett County / Traveler Information Exchange Agreement	Information Exchange Agreement between Gwinnett County and Traveler	Gwinnett County	Traveler

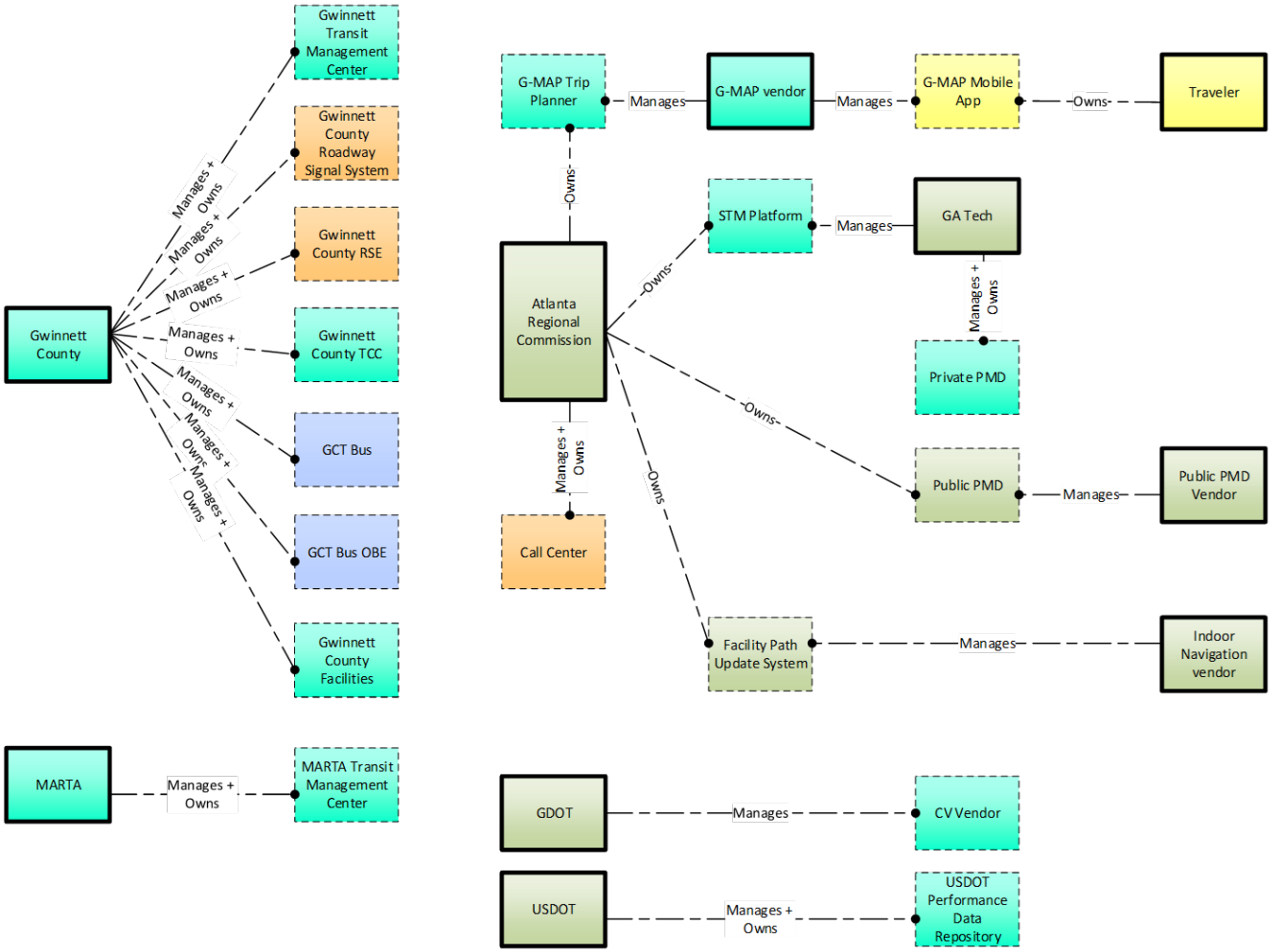
Relationship Number	Relationship	Relationship Type / Description	Source Stakeholder	Destination Stakeholder
13	MARTA / ARC Information Provision Agreement	Information Provision Agreement between MARTA and Atlanta Regional Commission	MARTA	Atlanta Regional Commission
16	Traveler / ARC Information Exchange and Action Agreement	Information Exchange and Action Agreement between Traveler and Atlanta Regional Commission	Traveler	Atlanta Regional Commission
17	Traveler / Gwinnett County Information Exchange and Action Agreement	Information Exchange and Action Agreement between Traveler and Gwinnett County	Traveler	Gwinnett County
19	Traveler / G-MAP Vendor Operations Agreement	Operations Agreement between Traveler and G-MAP Vendor	Traveler	G-MAP Vendor
20	USDOT / GDOT Information Exchange Agreement	Information Exchange Agreement between USDOT and GDOT	USDOT	GDOT
21	Traveler/ G-MAP Vendor Consent / Recruitment Agreement	Consent / Recruitment Agreement between Traveler and G-MAP Vendor	G-MAP Vendor	Traveler
22	GDOT/ ARC Information Exchange Agreement	Information Exchange Agreement between GDOT and Atlanta Regional Commission	GDOT	Atlanta Regional Commission
23	GDOT/ CV Vendor Operations Agreement	Operations Agreement between GDOT and CV Vendor	GDOT	CV Vendor

4.1.4 Enterprise View Diagrams

The following two diagrams in this section present the Enterprise View. The diagrams have been segmented such that the information is easier to view. Enterprise View diagrams have been created consistent with SET-IT notation, where:

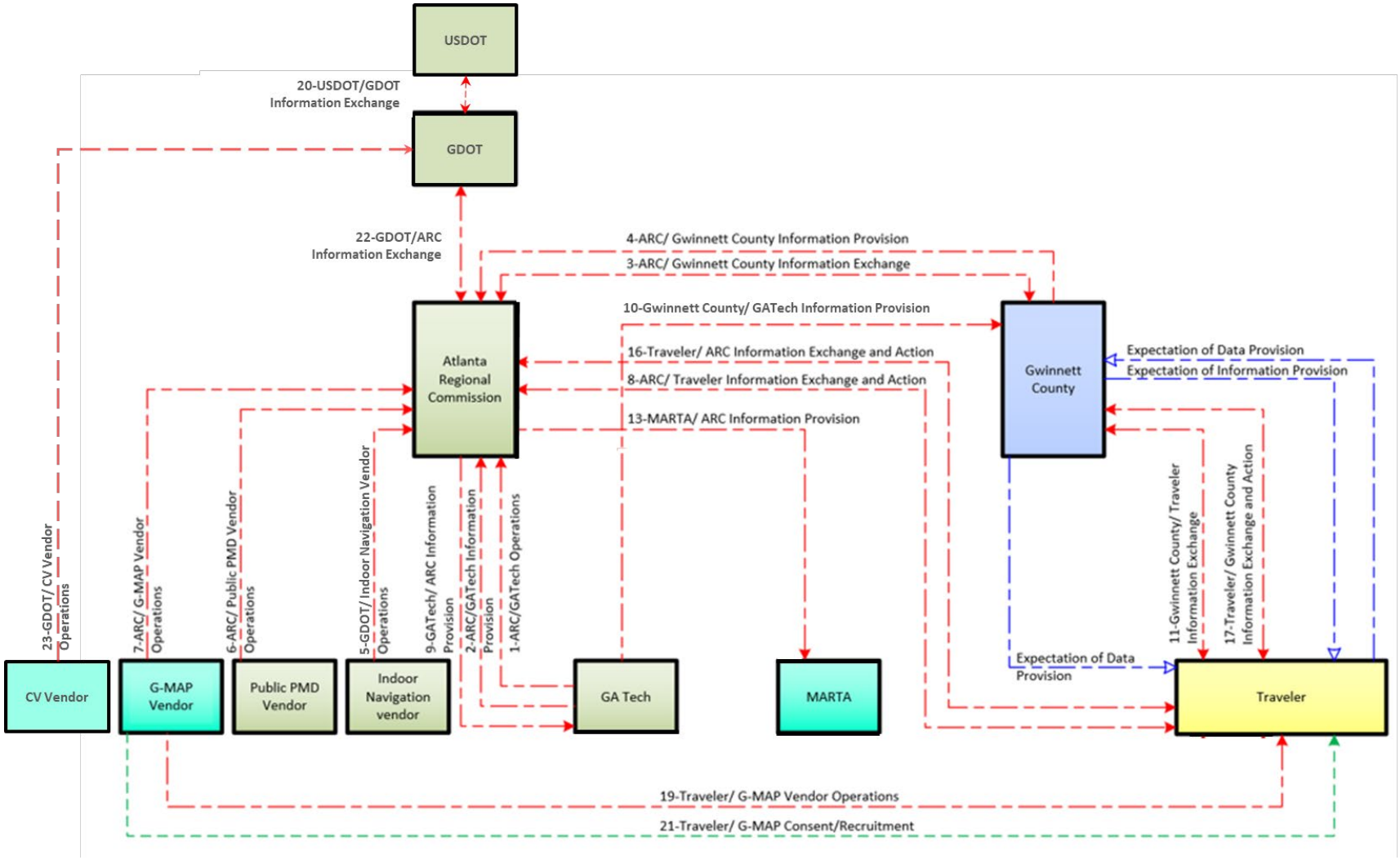
- Enterprise objects are shown as rectangular boxes with bold outlines,
- Resources (physical objects) are represented as rectangular boxes with dashed outlines,
- Enterprise object roles are depicted with black dashed lines between Enterprise and Resource objects,
- Enterprise object formal agreements are shown as red dashed lines between Enterprise objects where the arrow/dot indicates the party who receives the benefit of the agreement,
- Enterprise object informal agreements are shown as blue dashed lines between Enterprise objects where the arrow/dot indicates the party who receives the benefit of the agreement, and
- Enterprise object consent/recruitment agreements are shown as green dashed lines between Enterprise objects where the arrow/dot indicates the party who receives the benefit of the agreement.
- Two-way arrows represent contractual agreements or information exchanges.
- One-way arrows represent information and service provisions and/or expectations or recruitment agreements.

Figure 4 displays the roles associated between the Enterprise objects and resources during the 5-year maintenance period and is associated with **Table 6** in **Section 4.1.2**. **Figure 5** displays the relationships between Enterprise Objects and is associated with **Table 7** in **Section 4.1.3**.



Source: GDOT, 2024

Figure 4. ST-CTN System Enterprise View: Roles



Source: GDOT, 2024

Figure 5. ST-CTN System Enterprise View: Relationships

4.2 Physical View

The Physical view describes the transportation system and the information flows. It represents the engineering viewpoint of the system by incorporating the physical objects that operate in the field and the back office. It contains the functionality within those objects, the roles these objects play in delivering user services, and the connections between them within the context of ARC-IT service packages.

In accordance with the ARC-IT methodology, the following objects are defined in the Physical Viewpoint [1].

1. **Physical Object (P-Object):** Person, place, or thing that participates in ITS. Physical Objects are defined in terms of the applications they support, the processing they include, and their interfaces with other physical objects. They are grouped into five classes: Center, Field, Support, Personal and Vehicle. Physical Objects are defined with scope such that they are under the control of a single Enterprise Object.
    i. **Center:** An element that provides application, management, administrative, and support functions from a fixed location not in proximity to the road network. The terms "back office" and "center" are used interchangeably. Center is traditionally a transportation-focused term, evoking management centers to support transportation needs, while back office generally refers to commercial applications. In the architecture figures, the center elements are designated as green boxes.
    ii. **Field:** Infrastructure proximate to the transportation network which performs surveillance (e.g., traffic detectors, cameras), traffic control (e.g., signal controllers), information provision (e.g., Dynamic Message Signs (DMS)) and local transaction (e.g., tolling, parking) functions. Typically governed by transportation management functions running in centers. Field also includes connected vehicle roadside equipment and other wireless communications infrastructure that provides communications between mobile elements and fixed infrastructure. In the architecture figures, the field elements are designated as orange boxes.
    iii. **Support:** A center that provides a non-transportation specific service. Typically, these are enabling functions, such as communications facilitation, security or management. In the architecture figures, the support elements are designated as grey boxes.
    iv. **Personal:** Equipment used by travelers to access transportation services pre-trip and en-route. This includes mobile/handheld as well as desktop equipment owned and operated by the traveler. In the architecture figures, the personal elements are designated as yellow boxes.
    v. **Vehicle:** Vehicles, including driver information and safety systems applicable to all vehicle types. In the architecture figures, the vehicle elements are designated as blue boxes.

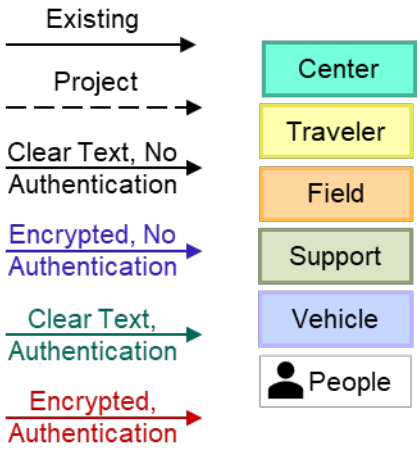
2. **Functional Object:** The building blocks of the physical objects of the physical view. Functional objects group similar processes of a particular Physical Object together into an "implementable" package. The grouping also takes into account the need to accommodate various levels of functionality. Since Functional Objects are both the most detailed components of the physical view and tied to specific service packages, they provide the common link between an interface-oriented architecture definition and deployment-oriented applications. Functional Objects provide the functionality defined by P-Specs in the Functional View. Functional elements are designated as light grey boxes embedded in physical objects.

3. **Information Flow:** Information that is exchanged between physical objects in the physical view. Information flows and their associated communication requirements provide the highest-level definition of interfaces. Information flows are related to entity relationships in the Enterprise View and are more fully detailed in the Communications View. Information Flows are characterized by Flow Characteristics, which imply various communications protocol standards. They are always accompanied by a provision agreement relationship. Such relationships are formal if both participants are centers, support, or field equipment. They are nearly always informal if between two mobile objects. If between mobile and fixed, the relationship may be formal if personalized or individually targeted information is exchanged. Black flows indicate native ARC-IT information flows while red lines identify customized flows defined by this project.
4. **Triple:** The combination of P-Object source, Information Flow and P-Object destination. The Triple is the foundational structure used to define an interface.
5. **Service Package (Physical) Diagram:** A summary diagram illustrating all of the P-Objects, Functional Objects and Information Flows likely needed to support the Service Package. Service Package diagrams may support more than one use case. **The Service Package Diagram will be covered in Section 4.2.2 of this document.**

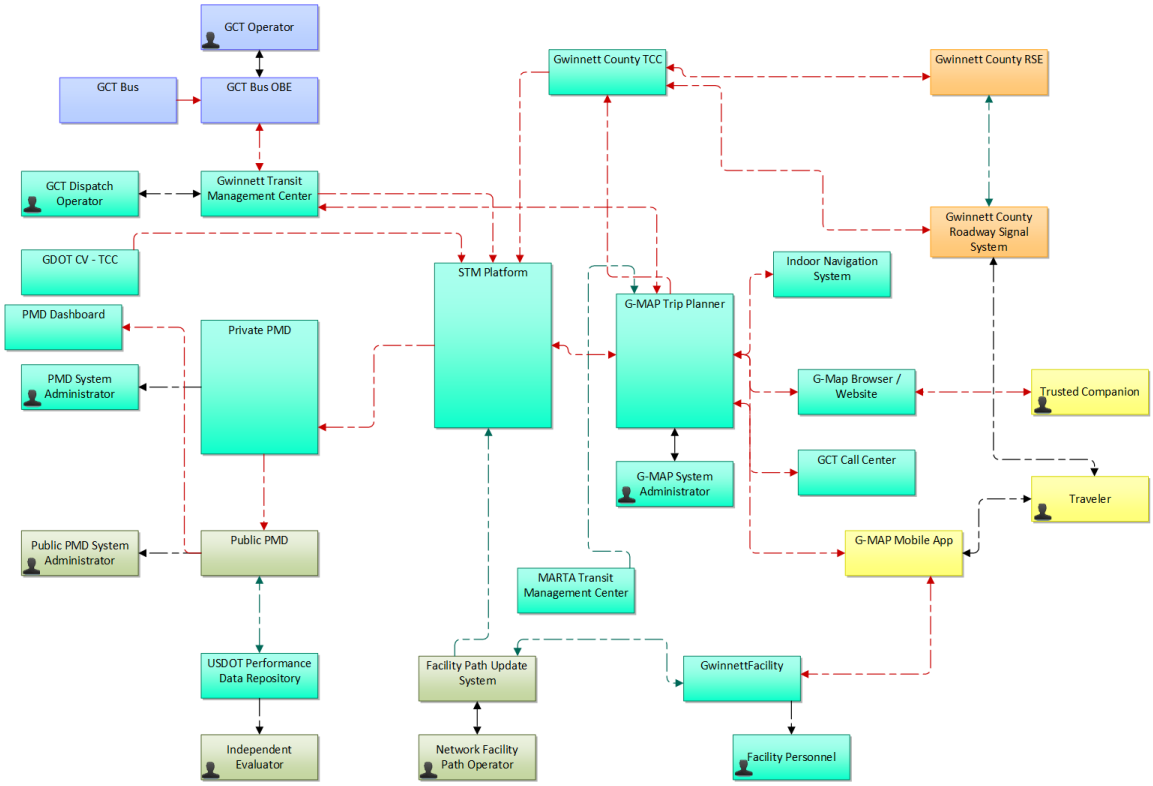
4.2.1 Physical View – Layers 0 and 1

There are several layers of varying details that represent the Physical View. Physical View diagrams have been created consistent with SET-IT notation, where:

- Physical objects are shown as rectangular boxes,
- People are designated with a silhouette inside of the rectangular box,
- Functional objects are shown as white rectangular boxes inside of a larger Physical object box,
- Flow security is designated by color where, black = no security specified; blue = encrypted without source authentication; green = no encryption, but sender authentication; and red = both encryption and authentication of the source.



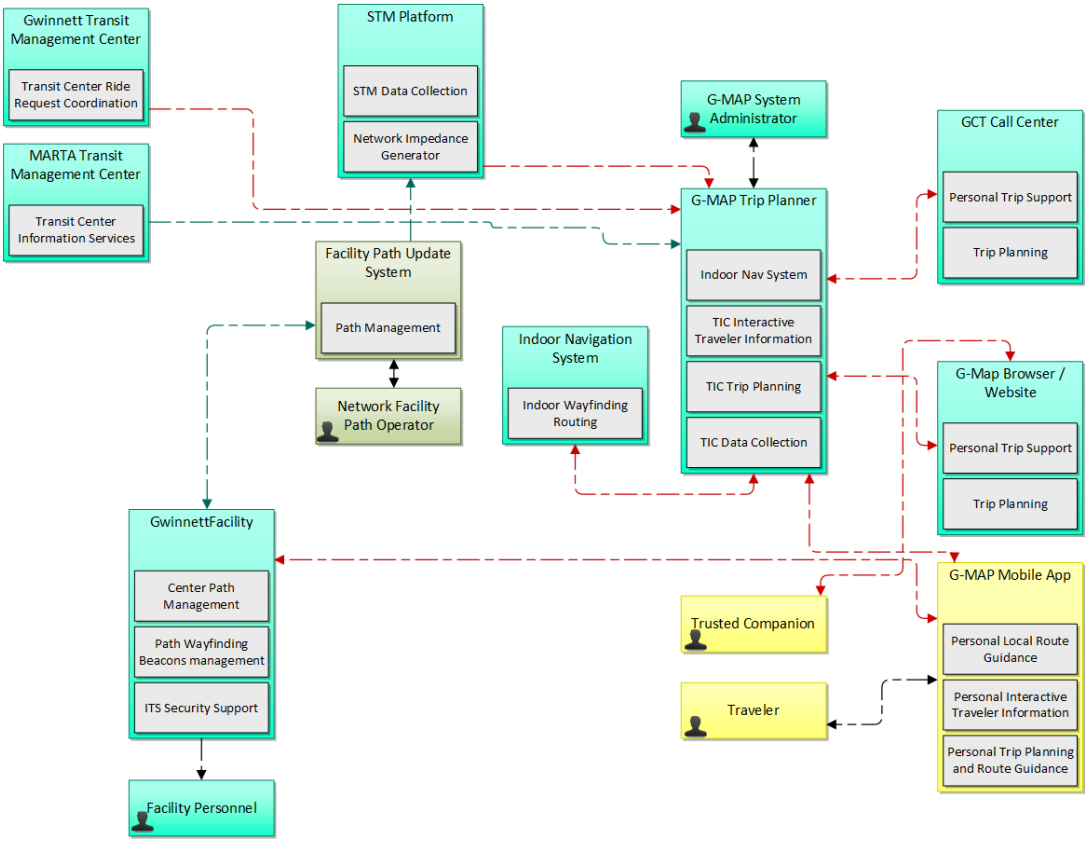
The Layer 0 diagram (**Figure 6**) encompasses all the physical objects and their related information flows. Layer 1 diagrams aggregate more than one service package to complete an end-to-end business process. For the ST-CTN system, two layer 1 diagrams are defined: (1) indoor navigation and (2) PMD (private/public) subsystems. The Layer 1 diagrams consist of the Indoor Navigation elements **(Figure 7**) and the Performance Management Archiving functions (**Figure 8**). The individual service packages are covered in **Section 4.2.2**.



Source: GDOT, 2024

Figure 6. Physical Viewpoint Layer 0 for ST-CTN

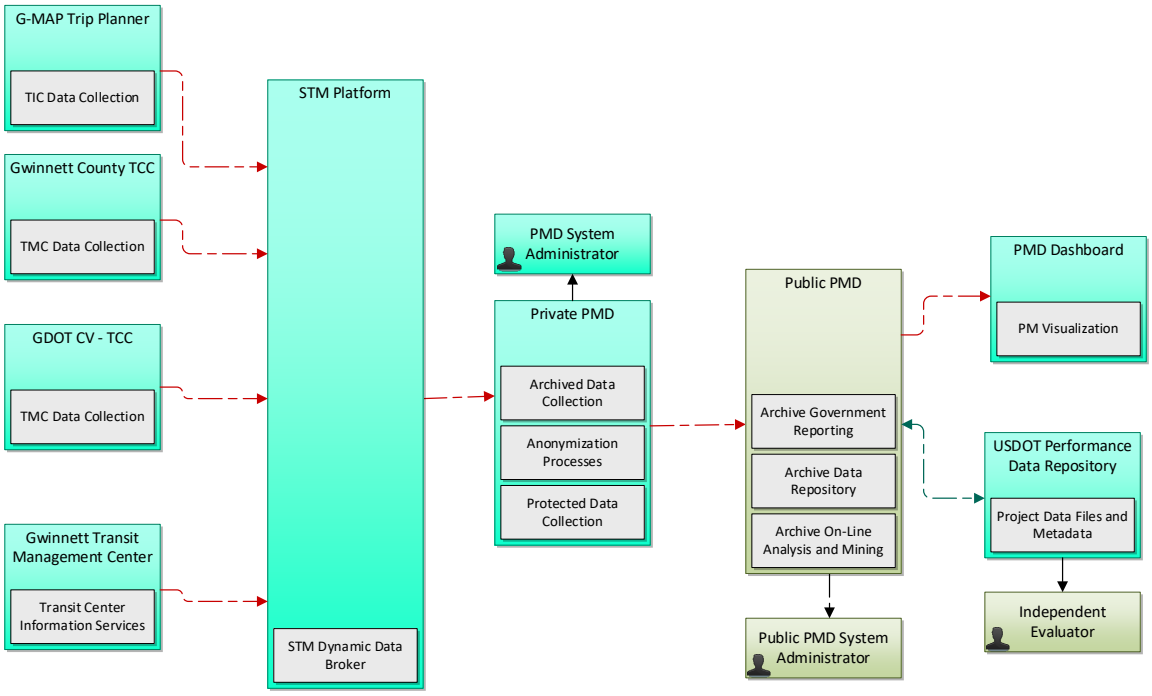
The Level 1 Physical View for indoor navigation is illustrated in **Figure 7**. The indoor navigation functions are part of the G-MAP subsystem. The component includes the Facilities Map Update elements for GJACand Norcross OneStop, provisioning of the data to the STM Platform for integrating into the network impedances as well as the G-MAP Trip Planner for integrating into the trip plan. The Level 1 architecture also includes the use of the G-MAP mobile app by the traveler to communicate with the beacons (path waypoints) at the facilities to aid navigation and wayfinding to their destination or transition point.



Source: GDOT, 2024

Figure 7. Physical Viewpoint Layer 1 for ST-CTN Indoor Navigation

The PMD subsystem is composed of the Private and Public segments of the PMD as shown in **Figure 8**. Operational and performance information flows through the private PMD to the public PMD. The public PMD provisions the anonymized and aggregated performance metrics to the Public PMD for presentation and distribution to the public and the USDOT Performance Data Repository (and Independent Evaluators).



Source: GDOT, 2024

Figure 8. Physical Viewpoint Layer 1 for ST-CTN Performance Measurement Archives

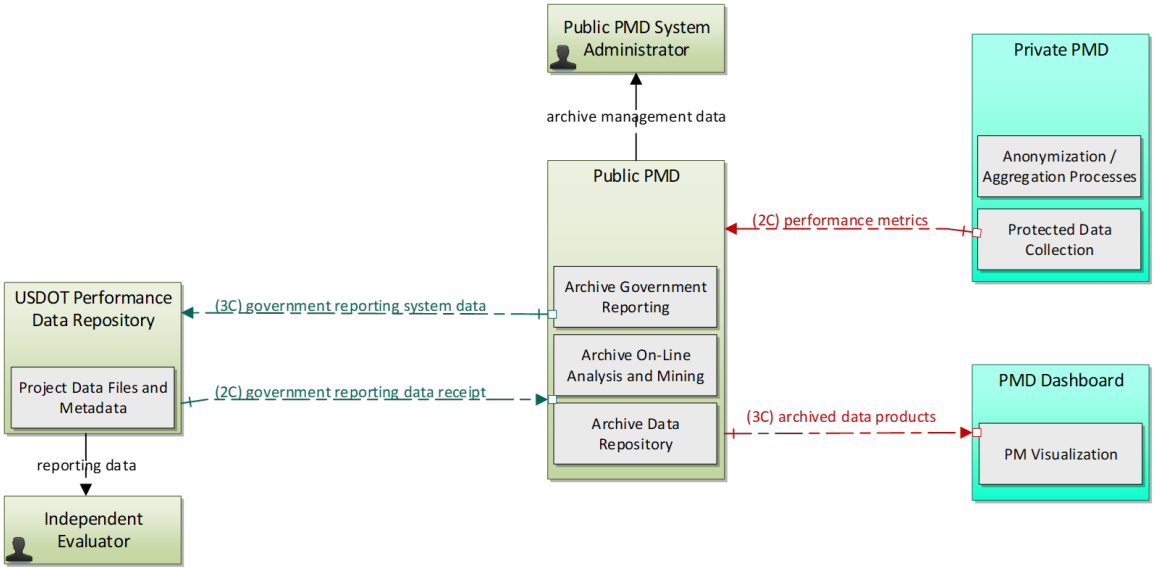
4.2.2 Service Package Diagrams

There are seven service packages represented in the ST-CTN physical architecture (layer 2 diagrams). The service packages are defined below. The four-character naming nomenclature (i.e., DM02) is consistent with the ITS Architecture name associated with the diagram that has been modified for this project:

- DM02: Public Performance Monitoring Dashboard (**Figure 9**)
- DM02: Performance Monitoring (**Figure 10**)
- PT17: Transit Ride Request (**Figure 11**)
- SU04: Map Management (**Figure 12**)
- TI02: Personalized Traveler Information for Indoor Navigation (**Figure 13**)
- TI04: Infrastructure-Provided Trip Planning and Route Guidance (**Figure 14**)

- VS12: Pedestrian Mobility (**Figure 15**)

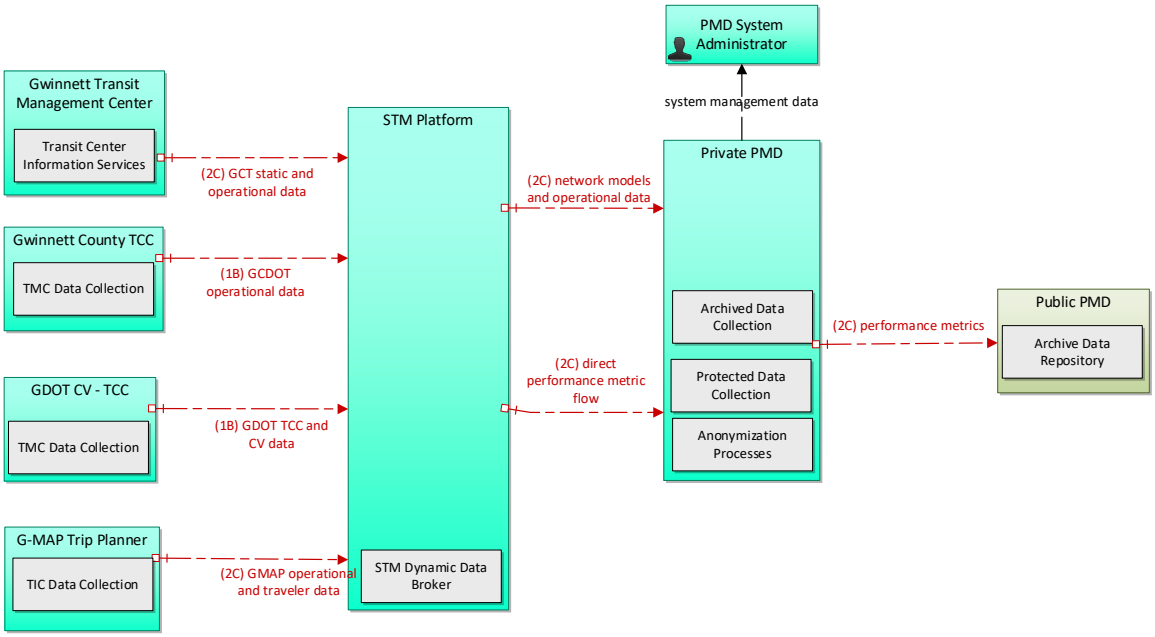
The Service Package DM02: Public Performance Monitoring Dashboard (**Figure 9**) covers the activities of the Public PMD. Anonymized and aggregated performance metrics and planned data are transmitted from the Private PMD to the Public PMD. The Public PMD generates the data files for the USDOT Performance Data Repository, provides access to and presents data in a dashboard to the public.



Source: GDOT, 2023

Figure 9. DM02: Public Performance Monitoring Dashboard

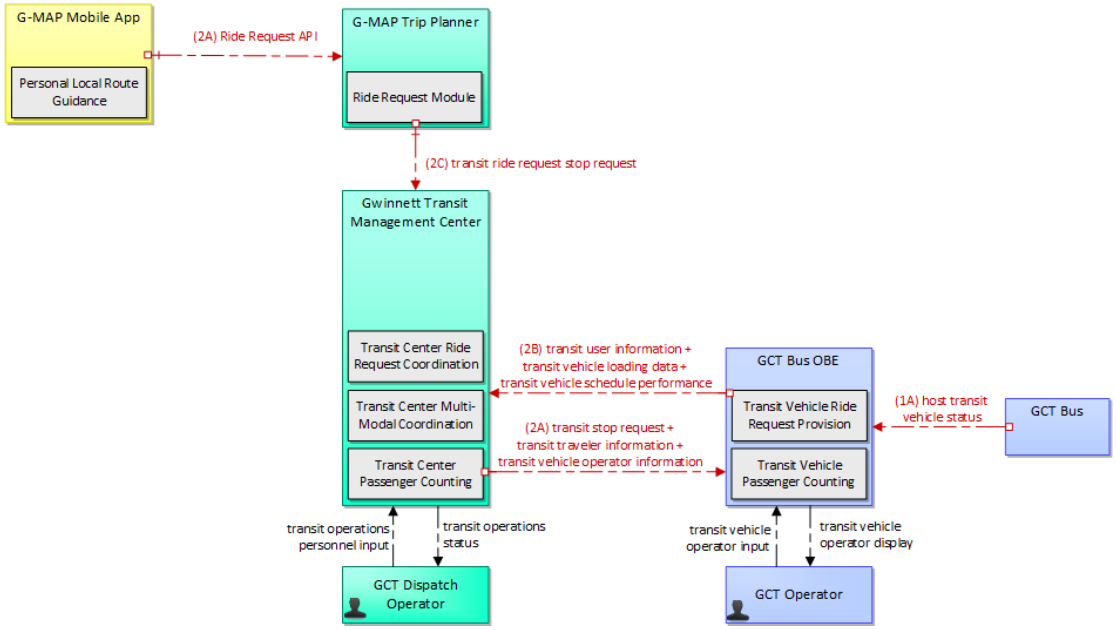
The DM02: Performance Monitoring Service Package (**Figure 10**) shows the information flows from the subsystems and external data sources to the Private PMD. Information to the Private PMD will be ingested, checked for quality with metadata, stored in secured data stores, and transformed to formats needed by downstream users. Transformation processes include anonymization, aggregation, and formatting for performance measures. Data is stored in a GA Tech on-premises data storage system that is access controlled. Only anonymized data will be sent to the Public PMD.



Source: GDOT, 2024

Figure 10. DM02: Performance Monitoring

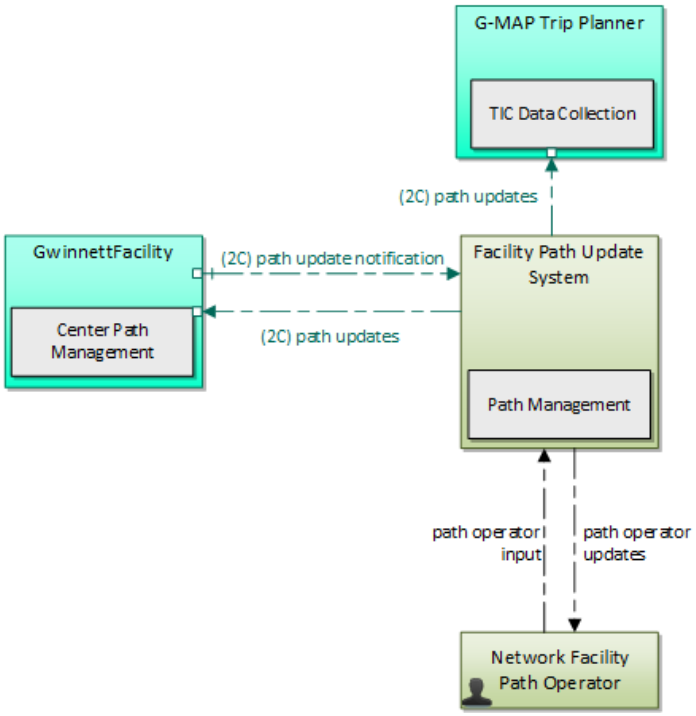
The PT17: Transit Ride Request Service Package (**Figure 11**) shows the ride request application that is integrated with the G-MAP Trip Planner. When G-MAP issues the trip plan to the traveler, the mobile app tracks the traveler as they approach their transit stop. When they are close, the mobile app will alert the G-MAP Trip Planner which then alerts the GCT Ride Request module (via the transit management system) of the traveler near or awaiting the bus at the stop. A notification is sent to the bus operator of the presence of the traveler and their needs.



Source: GDOT, 2024

Figure 11. PT17: Transit Ride Request

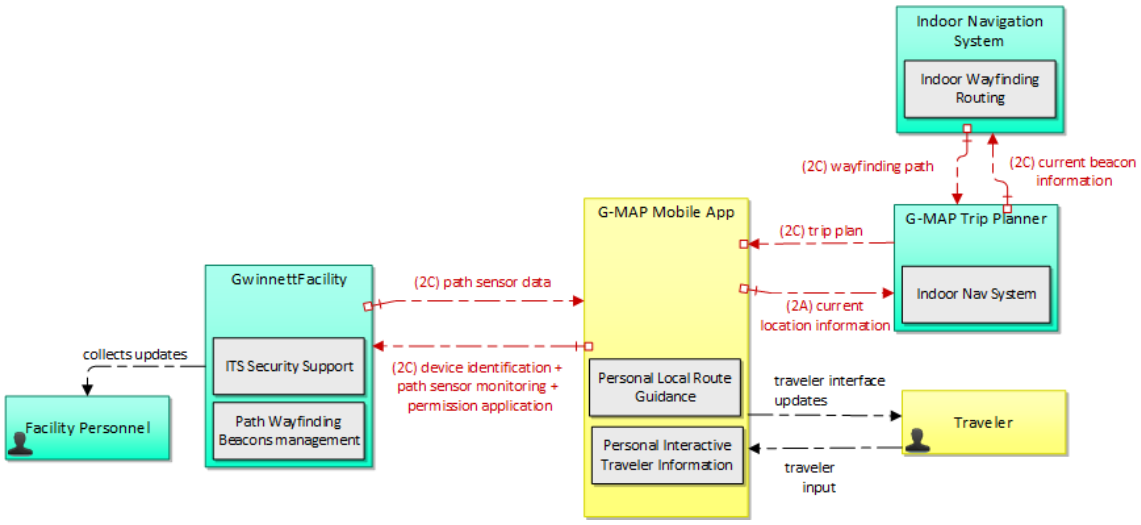
The SU04: Map Management Service Package (**Figure 12**) shows the facility map update system that manages and disseminates updates to indoor facility paths and beacon locations. The Gwinnett County facility personnel will alert the update system of any changes to the network path. The updates will be provided to the G-MAP Trip Planner. The G-MAP data collection function will be used for updating the map provided to the G-MAP Mobile App, which generates trip plans and alerts travelers to obstacles (see Infrastructure-Provided Trip Planning and Route Guidance Service Package).



Source: GDOT, 2024

Figure 12. SU04: Indoor Path Management

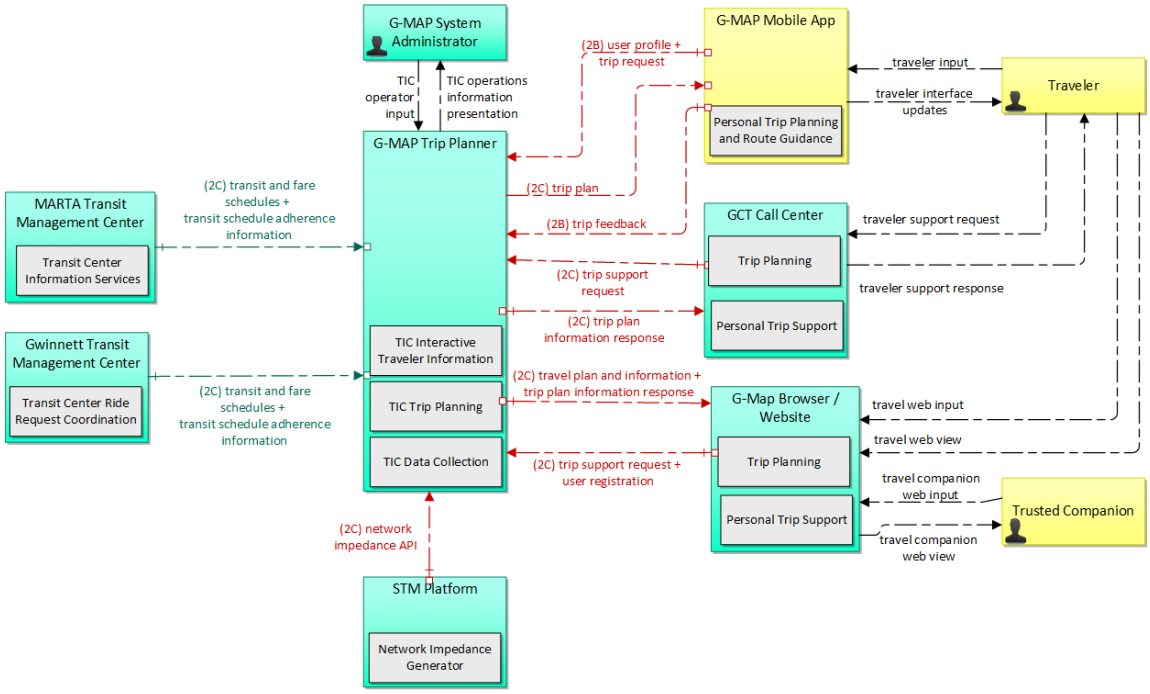
The TI02: Personalized Traveler Information for Indoor Navigation Service Package (**Figure 13**) shows the functions and information flows for using the beacons as an aid for wayfinding and navigation through indoor facilities (or outdoor facilities with low GPS signals). The GJAC and Norcross OneStop facilities will include beacons that broadcast identification signals that are available to any mobile handset. The mobile app will monitor the beacon signal and use it as a waypoint to locate a traveler's position in each facility. A support center (cloud services) which includes the beacon locations and infrastructure functions is managed by the Indoor Navigation vendor. This support center will provide wayfinding information based on beacon locations and wayfinding algorithms.



Source: GDOT, 2024

Figure 13. TI02: Personalized Traveler Information for Indoor Navigation

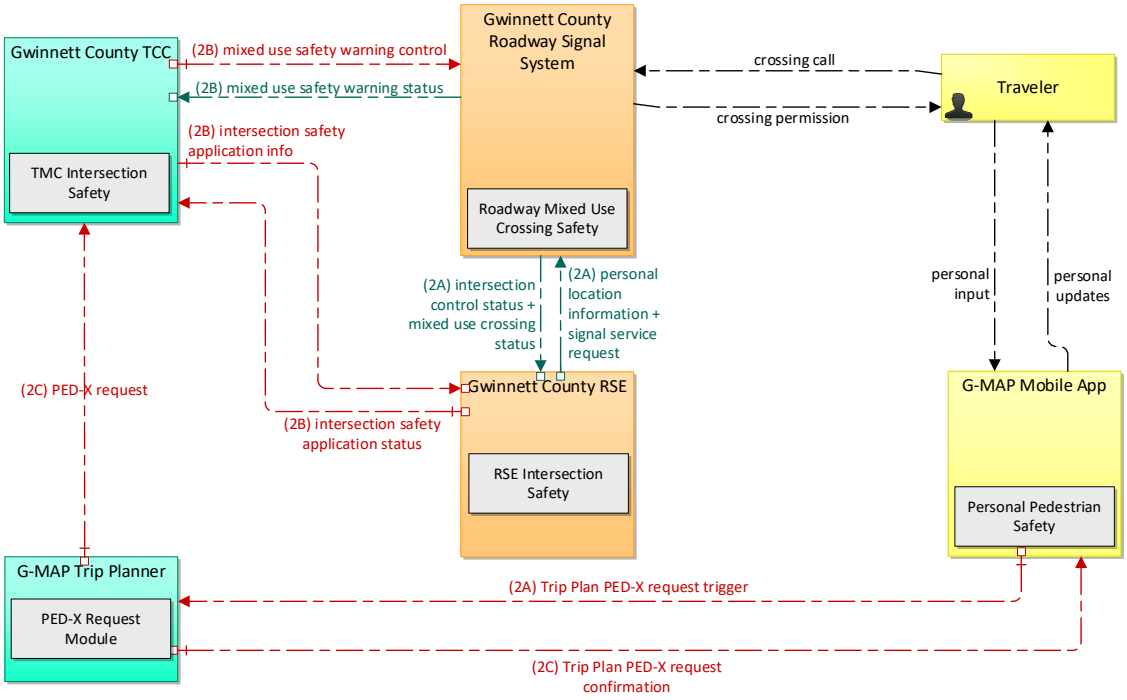
The TI04: Infrastructure-Provided Trip Planning and Route Guidance Service Package (**Figure 14**) shows the pre-planned trip planning and en-route route guidance functions provided by the G-MAP Trip Planner and supportive tools provided by the system including the trip planner web site, mobile app, and call center. In addition, the traveler's information will be available to a trusted companion through the G-MAP Trip Planner. Information about current planned and real time information flow into the G-MAP Trip Planner from MARTA, GCT, and STM Platform (including roadside situational information. The GTFS and GTFS real-time data will be obtained directly from the transit agencies.



Source: GDOT, 2024

Figure 14. TI04: Infrastructure-Provided Trip Planning and Route Guidance

The VS12: Pedestrian Mobility Service Package (**Figure 15**) shows the Mobile Accessible Pedestrian Signal System operations. The G-MAP mobile app triggers a hands-free walk request through the G-MAP and flows to the Gwinnett County TCC (part of the CV Subsystem) and roadside equipment to the PED-X at the crosswalk. The interface between the G-MAP Trip Planner and Gwinnett County TCC is part of a VPN that will be strictly controlled to allow only certain messages through a firewall.



Source: GDOT, 2022

Figure 15. VS12: Pedestrian Mobility (PED-X)

4.2.3 Functional Descriptions in Service Packages

The functions included in the Service Packages are described in **Table 8**. Most of the functional descriptions are adapted from the ARC-IT v. 9.1. Several are project-defined functions. Project-defined functions are identified by the bolded Function Names. In some cases, project defined function names such as Network Impedance Generator and Path Wayfinding Beacon Management (indicated as 'yes' in the Project Defined column), were required to be created for this project and may be considered for future inclusion of the national ITS Architecture. The related information flows are listed in **Table 10** with the communication profiles.

Table 8. Functions contained in Service Package Elements

Element	Function Name	Functional Description (adapted from ARC-IT v 9.1)	Project Defined
Private PMD	Anonymization and Aggregation Processes	Processes used to strip personally identifiable information and spatially and temporally aggregate data as needed to prevent derived public performance data results, taken alone or in combination with external data, from revealing personally identifiable information.	Yes
Public PMD	Archive Data Repository	Archive Data Repository collects data and data catalogs from one or more data sources and stores the data in a focused repository that is suited to a particular set of ITS data users. It includes capabilities for performing quality checks on the incoming data, error notification, and archive to archive coordination. It includes the capability to define a data registry that allows registration of data identifiers or data definitions for interoperable use throughout a region. It supports a broad range of implementations, ranging from simple data marts that collect a focused set of data and serve a particular user community to large-scale data warehouses that collect, integrate, and summarize transportation data from multiple sources and serve a broad array of users within a region. Repositories may be established to support operations planning, performance monitoring and management, and policy and investment decisions.	No
Public PMD	Archive Government Reporting	Archive Government Reporting selects and formats data residing in an ITS archive to facilitate local, state, and federal government data reporting requirements. It provides transportation system statistics and performance measures in required formats to support investment and policy decisions.	No

Element	Function Name	Functional Description (adapted from ARC-IT v 9.1)	Project Defined
Public PMD	Archive On-Line Analysis And Mining	Archive On-Line Analysis and Mining provides advanced data analysis, summarization, and mining features that facilitate discovery of information, patterns, and correlations in large data sets. Multidimensional analysis, selective summarization and expansion of data details, and many other advanced analysis services may be offered. Complex performance measures that are derived from multiple data sources may also be produced.	No
Public PMD	Archived Data Collection	See Archived data repository function.	Yes
Gwinnett Facilities	Center Path Management	Center Path Management provides the map functionality necessary to support facility pathway updates. It manages path data for the facility and provides pathway data to center applications that use the paths.	Yes
G-MAP Trip Planner	Ride Request Module	Ride Request is a module that sends a request to the Transit Management Center to alert a GCT bus via on-board equipment to connect with a traveler at a specific transit stop.	Yes
G-MAP Trip Planner	Indoor Nav System	System to generate non-motorized routing within indoor facilities.	Yes
Gwinnett Facilities	ITS Security Support	ITS Security Support provides communications and system security functions to the ITS Object, including privacy protection functions. It may include firewall, intrusion management, authentication, authorization, profile management, identity management, cryptographic key management. It may include a hardware security module and security management information base. With respect to this function, the ITS Security Support provides the handshaking between the beacon (waypoint) and traveler's handset.	Yes

Element	Function Name	Functional Description (adapted from ARC-IT v 9.1)	Project Defined
Facility Path Update System	Path Management	Map Management provides the GIS functionality necessary to support map data creation and management. It provides an operator interface that supports management of the map data and rendering of the maps under operator control and interfaces to external data sources, including the connected vehicle environment.	Yes
STM Platform	Network Impedance Generator	The Network Impedance Generator assigns a cost to network nodes and links based on the accessibility levels. The network impedances are matched to the targeted network (Open Street Map) and transformed to the Network Impedance API.	Yes
Gwinnett Facilities	Path Wayfinding Beacon Management	The Path Wayfinding Beacon Management function interfaces with the equipment / beacons installed at the Gwinnett facilities that support Path Routing and Wayfinding	Yes
G-MAP Trip Planner	PED-X Request Module	PED-X Request Module triggers a request when a traveler is near a planned intersection crossing to actuate a pedestrian crossing signal from the Gwinnett County Traffic Signal System via the Gwinnett County TCC.	Yes
G-MAP Mobile App	Personal Interactive Traveler Information	Personal Interactive Traveler Information provides traffic information, road conditions, transit information, yellow pages (traveler services) information, special event information, and other traveler information that is specifically tailored based on the traveler's request and/or previously submitted traveler profile information. It also supports interactive services that support enrollment, account management, and payments for transportation services. The interactive traveler information capability is provided by personal devices including personal computers and personal portable devices such as smart phones.	No

Element	Function Name	Functional Description (adapted from ARC-IT v 9.1)	Project Defined
G-MAP Mobile App	Personal Local Route Guidance	Personal Local Route Guidance provides multi-modal route planning and transition by transition route guidance capabilities that are self-contained on the personal device. It provides autonomous route guidance in the absence of real-time information or factors in real-time information provided by the infrastructure into its route selection and guidance algorithms if available. It also includes truly autonomous systems that are not configured to receive or process any external data. The route guidance capabilities are hosted on personal devices including smart phones, tablets, and personal computers.	No
G-MAP Mobile App	Personal Pedestrian Safety	Personal Pedestrian Safety improves pedestrian, (cyclist), and other non-motorized user safety by providing personal location information to the infrastructure that can be used to avoid collisions involving non-motorized travelers (e.g., PED-X actuation). The information provided and the user interface delivery mechanism (visual, audible, or haptic) can also be tailored to the needs of the user that is carrying or wearing the device that hosts the application.	No
G-MAP Mobile App	Personal Trip Planning And Route Guidance	Personal Trip Planning and Route Guidance provides a personalized trip plan to the traveler. The trip plan is calculated based on preferences and constraints supplied by the traveler and provided to the traveler for confirmation. Coordination may continue during the trip so that the route plan can be modified to account for new information. Many equipment configurations are possible including systems that provide a basic trip plan to the traveler as well as more sophisticated systems that can provide transition by transition guidance to the traveler along a multi-modal route with transfers. Devices represented by this functional object include desktop computers at home, work, or at major trip generation sites, plus personal devices such as tablets and smart phones.	No

Element	Function Name	Functional Description (adapted from ARC-IT v 9.1)	Project Defined
GCT Call Center, G-MAP	Personal Trip Support	Personal Trip Support provides support for the traveler through G-MAP, i.e., all of the functions supported by G-MAP other than trip planning.	Yes
PMD Dashboard	PM Visualization	PM Visualization is a virtual dashboard used to visualize performance measures of the ST-CTN system.	Yes
USDOT Performance Data Repository	Project Data Files And Metadata	Project Data Files and Metadata collects ST-CTN data files and metadata and stores the data in a repository that is suited to the USDOT's independent evaluator.	Yes
Private PMD	Protected Data Collection	Protected Data Collection collects and stores PII data in a separate, secured data store that are maintained for handling PII data at GA Tech. Additionally, the PII servers reside on a separate secure network that restricts access to other networks even within the GA Tech Civil Engineering network.	Yes
Gwinnett County Roadway Signal System	Roadway Mixed Use Crossing Safety	Roadway Mixed Use Crossing Safety is an advanced infrastructure application that [alerts] pedestrians, cyclists, and other non-motorized users and provides active safety warnings to drivers when crosswalks or other intersecting mixed-use paths are occupied.	No
Gwinnett County RSE	RSE Intersection Safety	RSE Intersection Safety uses CV communications to support connected vehicle applications that improve intersection safety. It communicates with approaching vehicles and ITS infrastructure to alert and warn drivers of potential stop sign, red light, and non-motorized user crossing conflicts or violations.	No

Element	Function Name	Functional Description (adapted from ARC-IT v 9.1)	Project Defined
STM Platform	STM Data Collection	STM Data Collection collects transportation-related data from other centers, performs data quality checks on the collected data and then consolidates, verifies, and refines the data and makes it available in a consistent format to applications that support operational data sharing between centers and deliver traveler information to end-users. A broad range of data is collected including traffic and road conditions, transit data, emergency information and advisories, special event information, traveler services, parking, and multimodal data. It also shares data with other transportation information centers.	Yes
G-MAP Trip Planner	TIC Data Collection	TIC Data Collection collects transportation-related data from other centers, performs data quality checks on the collected data and then consolidates, verifies, and refines the data and makes it available in a consistent format to applications that support operational data sharing between centers and deliver traveler information to end-users. A broad range of data is collected including transit data, traveler services, and multimodal data. It also shares data with other transportation information centers.	No
G-MAP Trip Planner	TIC Interactive Traveler Information	TIC Interactive Traveler Information disseminates personalized traveler information including transit information, multimodal information, and event information. Tailored information is provided based on the traveler's request in this interactive service.	No

Element	Function Name	Functional Description (adapted from ARC-IT v 9.1)	Project Defined
G-MAP Trip Planner	TIC Trip Planning	TIC Trip Planning provides pre-trip and enroute trip planning services for travelers. It receives origin, destination, constraints, and preferences and returns trip plan(s) that meet the supplied criteria. Trip plans may be based on the network impedances and transit operational information collected through multiple sources including the STM network impedance API, GTFS, and GTFS-real-time. Candidate trip plans are multimodal and may include vehicle, transit, and alternate mode segments based on traveler preferences. It also confirms the trip plan for the traveler. The trip plan includes specific routing information and instructions for each segment of the trip.	No
Gwinnett County TCC	TMC Data Collection	TMC Data Collection collects and stores information that is created in the course of traffic operations performed by the Traffic Management Center (e.g., NaviGator, central signal operations). This data can be used directly by operations personnel or it can be made available to other data users and archives in the region. For example, this data is provided to the STM Platform to generate impedance values.	No
Gwinnett County TCC	TMC Intersection Safety	TMC Intersection Safety controls and monitors RSEs that support stop sign, red light, and mixed-use crossing violations. It configures the RSEs for the current intersection geometry and traffic signal control equipment at the intersection. Information that is currently being communicated to passing vehicles and the operational status of the field equipment is monitored by this application. The operational status of the field equipment is reported to operations personnel.	No
Gwinnett Transit Management Center	Transit Center Ride Request Coordination	Transit Center Ride Request Coordination supports the capability for an individual traveler to alert transit bus operators as they approach a transit stop to pickup a passenger on a transit trip and if they require assistance with boarding or alighting.	Yes

Element	Function Name	Functional Description (adapted from ARC-IT v 9.1)	Project Defined
Gwinnett Transit Management Center	Transit Center Information Services	Transit Center Information Services collects the latest available information for a transit service (e.g., GTFS, GTFS realtime) and makes it available to the G-MAP for further distribution.	No
MARTA Transit Management Center	Transit Center Information Services	Transit Center Information Services collects the latest available information for a transit service (e.g., GTFS and GTFS realtime) and makes it available to the G-MAP for further distribution.	No
Gwinnett Transit Management Center	Transit Center Multi-Modal Coordination	Transit Center Multimodal Coordination supports transit service coordination between transit properties and coordinates with other surface and air transportation modes. As part of service coordination, it shares schedule and trip information, as well as transit transfer cluster (a collection of stop points, stations, or terminals where transfers can be made conveniently) and transfer point information between Multimodal Transportation Service Providers, Transit Agencies, and Information Service Providers (ISP).	No
Gwinnett Transit Management Center	Transit Center Passenger Counting	Transit Center Passenger Counting receives and processes transit vehicle loading data using two-way communications from equipped transit vehicles.	No
GCT Bus OBE	Transit Vehicle On-Board Ride Request Provision	Transit Vehicle On-Board Ride Request Provision monitors vehicle schedule performance and provides it to the transit center for ride request processing. It receives operator instructions relating to managing ride request and recognizes individual travelers who have arranged for ride request and provides ride request information to the transit center.	No
GCT Bus OBE	Transit Vehicle Passenger Counting	Transit Vehicle Passenger Counting collects transit vehicle loading data and makes it available to the center.	No

Element	Function Name	Functional Description (adapted from ARC-IT v 9.1)	Project Defined
GCT Call Center, G-Map Browser / Website	Trip Planning	Traveler Trip Planning provides a personalized trip plan to the traveler. The trip plan is calculated based on preferences and constraints supplied by the traveler and provided to the traveler for confirmation.	Yes
Indoor Navigation System	Indoor Wayfinding Routing	Indoor wayfinding routing engine providers personalized indoor trip pathway information based on traveler preference (destination and accessibility) and location within the facility based on nearby beacon information	Yes

4.3 Communications View

Except for the Gwinnett traffic and transit management systems, the communications view is composed of several communications protocol stacks that use internet protocol suite (also called TCP/IP model) via commercial Broadband Integrated Services Digital Networks or cellular networks. The lower level of the TCP/IP suite are operated by the commercial providers and are out of scope of the project. The middle layers will follow the TCP/IP internet protocols. The Application layer will be secured by the secure Hypertext Transfer Protocol (HTTPs) and appropriate encoding methods such as REST, JSON, Open API and other standardized messaging formats. Typical communication protocol stack types are described in **Table 9**.

Table 9. Communications Stack Types

Solution	Standard Name
Secure Internet (ITS)	Bundle: SNMP MIB, Development needed, Internet Subnet Alternatives, Internet Transport Alternatives, IP Alternatives, Secure Session Alternatives
Secure Wireless Internet (ITS)	Bundle: SNMP MIB, Development needed, Internet Transport Alternatives, IP Alternatives, Secure Session Alternatives, Wireless Internet Alternatives (NA)
GTFS real-time - Secure Internet (ITS)	Bundle: SNMP MIB, GTFS Realtime, IETF RFC 7230 HTTP, Internet Subnet Alternatives, Internet Transport Alternatives, IP Alternatives, ISO 21320-1 ZIP, Secure Session Alternatives
GTFS static - Secure Internet (ITS)	Bundle: SNMP MIB, General Transit Feed Specification, IETF RFC 4180 CSV Files, IETF RFC 7230 HTTP, Internet Subnet Alternatives, Internet Transport Alternatives, IP Alternatives, Secure Session Alternatives

Solution	Standard Name
NTCIP Traffic Signal -SNMPv3/TLS	Bundle: ISO 15784-2, Bundle: SNMP MIB, Field SubNet Alternatives, IETF RFC 6353 TLS for SNMP, Internet Transport Alternatives, IP Alternatives, NTCIP Global Objects, NTCIP Signal Controller Objects

Each information flow is associated with a source and destination and associated communication protocol stack. The details of the flow and the specific communications protocols associated with the flow will be detailed in the ICD. **Table 10** lists each flow from the architecture by name, description, communication protocol stack, and source and destination elements.

Table 10. Information Flow Details

Flow Name	Description	Communication Stack	Source	Destination
Archived data products	Aggregated, anonymized performance measures.	Security Internet (ITS)	Public PMD	PMD Dashboard
Current Beacon Information	Information about beacons (e.g., locations, strength) and traveler information	Secure Internet (ITS)	G-MAP Trip Planner	Indoor Navigation System
Device Identification	An identifier and device type designation that is used to uniquely identify a device in the Connected Vehicle Environment.	Secure Internet (ITS)	G-MAP App	Gwinnett Facilities
GMAP operational and traveler data	Detailed traveler trip trace data and planned data. Daily transfer.	Secure Internet (ITS)	G-MAP Trip Planner	STM
Government Reporting Data Receipt	The acknowledgement of satisfactory receipt of information used as input to government data systems or a report identifying problems or issues with the data submittal.	Secure Internet (ITS)	USDOT Performance Data Repository	Public PMD
Government Reporting System Data	Information provided by an ITS archive, formatted as appropriate, that can be used as input to government data reporting systems.	Secure Internet (ITS)	Public PMD	USDOT Performance Data Repository

Flow Name	Description	Communication Stack	Source	Destination
Intersection Control Status	Status data provided by the traffic signal controller including phase information, alarm status, and priority/preempt status.	NTCIP Traffic Signal - SNMP3/TLS	Gwinnett County Roadway Signal System	Gwinnett County RSE
Intersection Safety Application Info	Intersection and device configuration data, including intersection geometry, and warning parameters and thresholds. This flow also supports remote control of the application so the application can be taken offline, reset, or restarted.	Secure Internet (ITS)	Gwinnett County TCC	Gwinnett County RSE
Intersection Safety Application Status	Infrastructure safety application status reported by the RSE. This includes current operational state and status of the RSE and a record of intersection safety issues identified and alerts and warnings issued.	Secure Internet (ITS)	Gwinnett County RSE	Gwinnett County TCC
Mixed Use Crossing Status	Current pedestrian and other mixed use crossing information including an indication of whether the call button has been activated, the current state of the mixed- use crossing signal, and information indicating whether non-motorized users are currently occupying the cross walk.	NTCIP Traffic Signal - SNMP3/TLS	Gwinnett County Roadway Signal System	Gwinnett County RSE
Mixed Use Safety Warning Control	Configuration and control of equipment that monitors and manages mixed use crossings and provides visual displays and warnings to drivers when non-motorized users are occupying a cross walk or other mixed- use path crossing.	NTCIP Traffic Signal - SNMP3/TLS	Gwinnett County TCC	Gwinnett County Roadway Signal System

Flow Name	Description	Communication Stack	Source	Destination
Mixed Use Safety Warning Status	Current operational status and state of pedestrian crossings and other mixed- use path crossing warning systems.	NTCIP Traffic Signal - SNMP3/TLS	Gwinnett County Roadway Signal System	Gwinnett County TCC
Network Impedance API	A network impedance API associated with the links and nodes of the trip planning graph contain different levels of accessibility based on personal needs and preferences.	Secure Internet (ITS)	STM Platform	G-MAP Trip Planner
Network Models and Operational Data	Various network models and operational data that compose operational information that may include PII.	Secure Internet (ITS)	STM Platform	Private PMD
Operational Data and Metrics	Situational operational data and metrics collected from the CV and TCC that are used to evaluate performance of the network and ST-CTN tools.	Secure Internet (ITS)	Gwinnett County TCC	Private PMD
Operational Performance	Operational performance data collected from the G-MAP Trip Planner that may contain PII.	Secure Internet (ITS)	G-MAP Trip Planner	Private PMD
Path Sensor Data	Signals broadcast about a sensor serving as a waypoint that is installed in facility.	Secure Wireless Internet (ITS)	Gwinnett Facilities	G-MAP Mobile App
Path Sensor Monitoring	Signal monitoring of sensor/beacon broadcasted data.	Secure Wireless Internet (ITS)	G-MAP Mobile App	Gwinnett Facilities

Flow Name	Description	Communication Stack	Source	Destination
Path Update Notification	Notification of maintenance, construction, and other activities that will result in medium to long term changes to path location and configuration that may impact navigable maps. This flow includes the timing of the changes and precise enumeration of the location and configuration changes. It also includes updated static characteristics and default travel times.	Secure Internet (ITS)	Gwinnett Facility	Facility Path Update System
Path Updates	Map update that could include a new underlying static or real-time path or map layer(s) update. Map layers can include path, topography, points of interest, and conveyance information including escalator directions and status.	Secure Internet (ITS)	Facility Path Update System	Gwinnett Facilities, G-MAP Trip Planner
PED-X Request	Request to actuate PED crossing at intersection with extended walk time.	Secure Internet (ITS)	G-MAP Trip Planner	Gwinnett County TCC
Performance Metrics	Performance metrics that are ready for public consumption.	Secure Internet (ITS)	Private PMD	Public PMD
Permission Application	A request for permission to access a beacon signals in a facility.	Secure Internet (ITS)	G-MAP Mobile App	Gwinnett Facilities
Personal Location Information	Pedestrian user locations at an intersection as detected and reported by an RSE.	Secure Internet (ITS)	Gwinnett County RSE	Gwinnett County Roadway Signal System
Ride Request API	The message that is triggered when a traveler with a transit trip enters the area around their planner transit stop.	Secure Internet (ITS)	G-MAP Mobile App	G-MAP Trip Planner

Flow Name	Description	Communication Stack	Source	Destination
Signal Service Request	A call for service or extension for a signal control phase that is issued by the RSE for connected vehicles approaching an intersection and/or pedestrians at a crosswalk. This flow identifies the desired phase and service time.	NTCIP Traffic Signal - SNMP3/TLS	Gwinnett County RSE	Gwinnett County Roadway Signal System
Transit and Fare Schedules	Transit service information including routes, schedules including GTFS static files.	GTFS static - Secure Internet (ITS)	Gwinnett Transit Management Center, MARTA Transit Management Center	G-MAP Trip Planner
Transit schedule adherence information	Dynamic transit schedule adherence and transit vehicle location information.	GTFS real-time - Secure Internet (ITS)	Gwinnett Transit Management Center	G-MAP Trip Planner
Transit Traveler Information	Transit information prepared to support transit users and other travelers. It contains transit schedules, real-time arrival information, alerts and advisories, and general transit service information.	GTFS - Secure Wireless Internet (ITS)	Gwinnett Transit Management Center	GCT Bus OBE
Transit Traveler Request	Request by a transit traveler to summon assistance, request transit information, or request any other transit services.	Secure Wireless Internet (ITS)	GCT Bus OBE	Gwinnett Transit Management Center
Transit User Information	Information about individual transit users boarding a transit vehicle, used to track a user's progress on a scheduled transit trip.	Secure Wireless Internet (ITS)	GCT Bus OBE	Gwinnett Transit Management Center

Flow Name	Description	Communication Stack	Source	Destination
Transit Vehicle Loading Data	Data collected on board the transit vehicle relating to passenger boarding and alighting.	Secure Wireless Internet (ITS)	GCT Bus OBE	Gwinnett Transit Management Center
Transit Vehicle Operator Information	Transit service instructions, wide area alerts, traffic information, road conditions, and other information for transit operators.	Secure Wireless Internet (ITS)	Gwinnett Transit Management Center	GCT Bus OBE
Transit Vehicle Schedule Performance	Estimated times of arrival and anticipated schedule deviations reported by a transit vehicle.	GTFS real-time - Secure Wireless Internet (ITS)	GCT Bus OBE	Gwinnett Transit Management Center
Trip Confirmation – Call Center	Acknowledgement by the G-MAP of acceptance of a trip plan and the request to save the trip plan or download it to the mobile app. Conversely, this flow may also reject the proposed trip plan. Confirmations include the selected route and subsequent trip confirmation messages will be issued for route changes.	Secure Internet (ITS)	Call Center	G-MAP Trip Planner
Trip Confirmation – G-MAP App	Acknowledgement by the G-MAP of acceptance of a trip plan and the request to save the trip plan or download it to the mobile app. Conversely, this flow may also reject the proposed trip plan. Confirmations include the selected route and subsequent trip confirmation messages will be issued for route changes.	Secure Wireless Internet (ITS)	G-MAP App	G-MAP Trip Planner

Flow Name	Description	Communication Stack	Source	Destination
Trip Feedback	Information provided at the conclusion of a trip that supports performance monitoring and system optimization. Information provided may include a record of the trip including trip plan usage and user provided feedback at the conclusion of the trip.	Secure Wireless Internet (ITS)	G-MAP App	G-MAP Trip Planner
Trip Plan – Call Center	A travel itinerary identifying a route and associated traveler information and instructions identifying recommended modes, transfer information, and transit information. This flow also includes intermediate information that is provided as the trip plan is interactively created, including identification of alternatives, requests for additional information.	Secure Internet (ITS)	G-MAP Trip Planner	Call Center
Trip Plan – G-MAP App	A travel itinerary identifying a route and associated traveler information and instructions identifying recommended modes, transfer information, and transit information. This flow also includes intermediate information that is provided as the trip plan is interactively created, including identification of alternatives, requests for additional information.	Secure Wireless Internet (ITS)	G-MAP Trip Planner	G-MAP App
Trip Plan PED-X Request Trigger	A request to trigger PED crossing request to actuate walk signal at intersection.	Secure Wireless Internet (ITS)	G-MAP App	G-MAP Trip Planner

Flow Name	Description	Communication Stack	Source	Destination
Trip Plan Stop Request	Alert sent to transit vehicle via G-MAP and Transit Management Center to request GCT bus wait at stop based on traveler's proximity to transit stop.	Secure Wireless Internet (ITS)	G-MAP App	G-MAP Trip Planner
Trip Support Request (Call Center)	Request for trip planning services that identifies the trip origin, destination(s), timing, preferences, and constraints. The request may also include the requestor's location or a request for transit associated with the trip. The trip request also covers requests to revise a previously planned trip and interim updates that are provided as the trip is interactively planned.	Secure Internet (ITS)	Call Center	G-MAP Trip Planner
Trip Request (G-MAP App)	Request for trip planning services that identifies the trip origin, destination(s), timing, preferences, and constraints. The request may also include the requestor's location or a request for transit associated with the trip. The trip request also covers requests to revise a previously planned trip and interim updates that are provided as the trip is interactively planned.	Secure Wireless Internet (ITS)	G-MAP App	G-MAP Trip Planner
User Performance Metrics	Information on travelers' adherence to their trip itinerary and other operational data associated with their journey. The information flow includes PII.	Secure Internet (ITS)	G-MAP Trip Planner	Private PMD

Flow Name	Description	Communication Stack	Source	Destination
User Profile	Information provided to register for a travel service and create a user account. The provided information includes personal identification, traveler preferences (e.g., maximum transfer wait time, maximum walking distance, mode preferences, special needs), device information, a user ID and password, and other personal information.	Secure Wireless Internet (ITS)	G-MAP Mobile App	G-MAP Trip Planner
Wayfinding Path	Path (trip) information from current location to destination in an indoor facility	Secure Internet (ITS)	Indoor Navigation System	G-MAP Trip Planner

5 Functional Viewpoint

This section provides an overview of the Functional Viewpoint based on the detailed functions and information defined in Phase 1 and updated based on as-built functionality. The ST-CTN project team is utilizing this view as a bridge from the high-level architectural views described in **Section 4** to the design of the system during Phase 2.

5.1 Functional View

The Functional Viewpoint describes the functions (the 'what') and their interactions between the major subsystems and with external systems. As described in the Approach (**Section 1.4**), the Functional View is the bridge between the Phase 1 concept and the Phase 2 deployment. Detailed functions and interfaces, described in the ConOps, Phase 1 DMP, and SyRS are traced to the architecture elements and information flows shown in the following figures. In addition, system requirements will be tracked throughout the design, testing, and deployment stages of the project and will support development of the System Design, Phase 2 DMP, and link the system engineering processes such that stakeholders will be able to clearly ensure that the deployment meets their needs and requirements. Phase 1 documentation will be updated throughout the life of the project to ensure consistency is maintained.

The Functional View focuses on the subsystems – existing and those that require expanded functionality and additional connectivity than is available within its current state. As highlighted in **Section 3**, 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 11**. 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 **Section 1.3**, 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 16 provides the ST-CTN high-level functional and information flow diagram in more detail and corresponds with the flows described in **Table 11**. These flows are shown throughout the subsystem Functional View diagrams and are consistent with the definitions provided in Table 11. The flows are further described in **Section 5.1.5**.

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.

Sidewalk Inventory Collection Tools is burnt orange

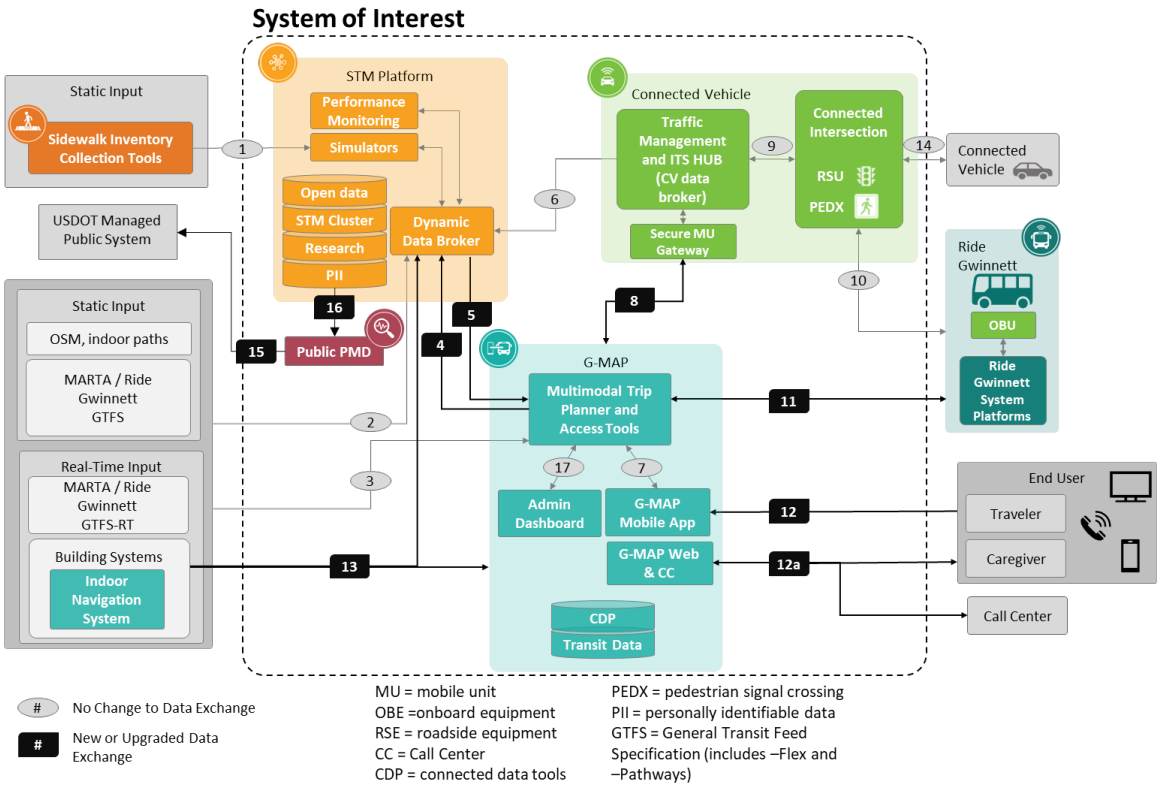
STM is peach

CV is green

OTP for G-MAP is turquoise

Gwinnett County Transit is teal

PMD is red



Source: GDOT, 2024

Figure 16. Functional Architecture for ST-CTN System

The system information flows are identified by number in the functional diagram above and described in **Table 11**. The grey oval labels indicate existing data exchanges that will be utilized with no change to the current data exchange. Black rectangular labels indicate data exchanges that will be 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 11. 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 STM Platform dynamic data broker and G-MAP multimodal trip planner	External	G-MAP, STM
4	G-MAP Mobile App logs and trip feedback	G-MAP	STM
5	STM Network Impedance API	STM	G-MAP
6	CV and Traffic Operations Messages: signal phasing and timing NaviGAtor ITS, road characteristics, traffic data	CV	STM
7	Open Trip Planner (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 MU gateway)
9	CV messages	CV	CV Connected Intersection
10	Transit signal priority (TSP) and other CV application messages	GCT 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.	G-MAP	G-MAP Mobile App
12a	Similar data flows to Data Exchange ID 12 with restrictions on viewing and changing certain data.	G-MAP	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 Mobile App
14	CV data	CV OBU	CV RSU
15	Project data for USDOT-managed Public System	Public PMD	USDOT Managed Public System

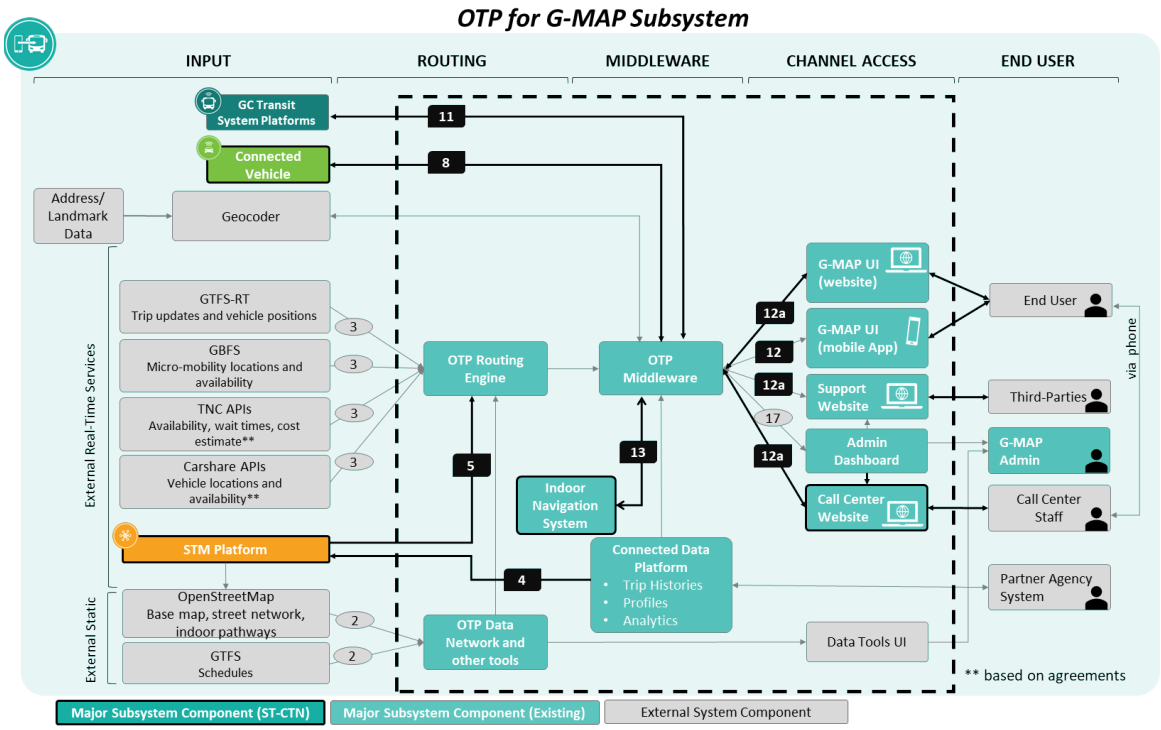
Information Flow ID	Description	Source	Destination
16	Public facing data and visualizations for reporting on system operations and performance	Private PMD (STM)	Public PMD
17	G-MAP Administration Tool configuration and control message exchanges	G-MAP	G-MAP

5.1.1 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 utilizes the region's transit services. G-MAP is the ATL RIDES instance with enhancements for the ST-CTN program.

As described in **Section 3**, the G-MAP will be 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 will connect with the PDM for evaluation purposes.

Figure 17 shows the functional view of G-MAP subsystem with associated existing and extensions proposed for the ST-CTN. The G-MAP UI exists but will be enhanced as part of the ST-CTN deployment project.



Source: GDOT, 2024

Figure 17. 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 12** provides a summary of functional elements for the G-MAP Trip Planner.

Table 12. 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. 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 (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. • Notifications to additional recipient(s) such as trusted companions (e.g., arrived at destination). • Synchronizing with user device(s). • Notifications to users based on their preferences (e.g., voice, text, haptic). • Triggering settings to connect to infrastructure and transit assets (pedestrian crossing request, bus stop request) as well as sending notifications to a specified asset when approach / arrive at transition point. 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 User Interfaces:** Current web-based user interfaces 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 User Interfaces:** The Mobile app will provide user interfaces that support similar functionality as the web-based version for registration, profiling, trip planning and report summaries as the web user interface. In addition, the mobile app will track and monitor traveler trip plans, receive notifications related to their preferences, trigger events based on geolocation (including Ride Request and PED-X requests), and interact with the indoor environment and will incorporate an API or service to

Function Name	Function and Feature Descriptions
	provide navigation instructions to travelers of indoor facilities. Specifically for the indoor navigation function, the mobile handset interface will monitor the environment for indoor beacon signals and use 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 user interfaces. 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 computer aided dispatch system) to exchange messages with the Ride Request module.
	
	The following new data information flows will be 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 Performance Measurement Dashboard

Routing	Incorporate OSM graph for sidewalks and roadways using updated impedances from STM network. This new feature will incorporate the information from the STM Network Impedance API and use that network for routing in the OTP routing module.
Connected Data Platform 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 will not be augmented as part of this project except for generating and accessing new performance measures which will be shared with the STM Platform to generate evaluation measures. Performance measures will be derived through the data collected and stored in the Connected Data Platform, including trip histories, profiles, and analytics.

Operating Environment

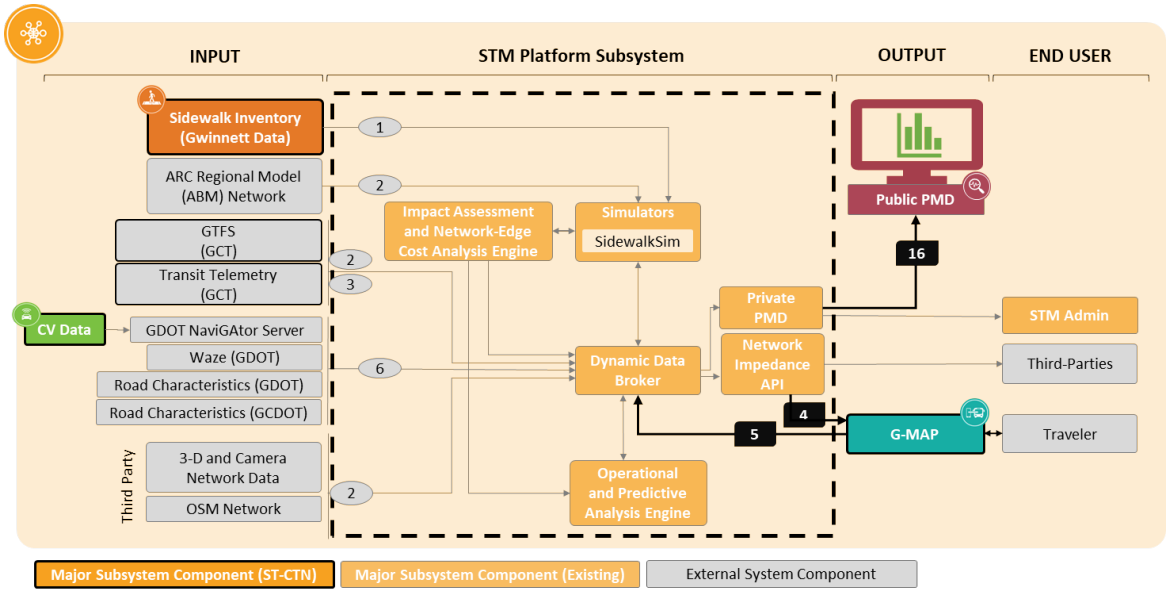
Given the production needs of the G-MAP, the infrastructure will be hardened to ensure subsystem reliability, scalability, and availability. The G-MAP routing engine and middleware are cloud hosted on Amazon Web Services and sit behind a load balancer, allowing for scaling of resources to match level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

The G-MAP mobile app will be 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.

5.1.2 Space Time Memory Platform Subsystem

As mentioned in Chapter 3, 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 will be 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 will be updated to increase the origin-destination shortest path query response speed and will be integrated with new real-time data streams (e.g., information flow ID “5”, Table 11). **Figure 18** provides the STM Platform Functional View diagram with functions and information.



Source: GDOT, 2024

Figure 18. Functional View of the STM Platform Subsystem

Table 13 provides a summary of the functional elements for the STM Platform subsystem.

Table 13. Functional Elements for the STM Platform Subsystem

Function Name	Function and Feature Descriptions
Dynamic Data Broker	The dynamic data broker will be extended to ingest additional data sources. The expanded data sources include the following: • GTFS and 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 will manage generation and publication of two new information flows including: **OSM updates** – The STM will transform 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 will include 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 will be at a rate and location available for G-MAP to consume. **STM Network Impedance API** – The STM Network Impedance API will 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.

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 will be capable of including indoor navigation features such as locating the most appropriate accessible entrance, navigating to operating elevators, and more. The graphs will depend on the information available to generate the graphs. To ensure compatibility with the G-MAP app, the OSM network will be 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 will include: • The simulator will update sidewalk network changes using construction permit final inspection reports generated by Gwinnett County, regular Sidewalk Inventory tools, and agency field inspections. • The simulator will associate and update Sidewalk infrastructure conditions with sidewalk links, ramps, curb cuts, and other elements that are explicitly tracked. These elements will be 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 will calculate the customized impedance values for traveling on a segment of the trip. Different penalties will be associated to 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 will score high impedances for people with mobility challenges. Permanent protrusions (i.e., architectural features) and temporary protrusions (i.e., low hanging branches) will narrow the walking path and score high impedance values for people with vision loss. Permanent protrusions will be documented during the sidewalk inventory. The algorithms will 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 will be worked out in the design phase of this project and will be highly adaptive, allowing GA Tech to specify any set of impedance functions for various disabilities and ranges, mode, or sub-mode.

Function Name	Function and Feature Descriptions
Operational and Prediction Analysis Engine	The Operational and Prediction Analysis Engine serves as the machine learning 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 will be to interpret planned versus actual travel of various user classes.
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 monitoring engine will track performance characteristics, such as volume and frequency of requests, response speeds, and data throughput. Comprehensive performance monitoring metrics will be developed and included in the Performance Measurement Plan.

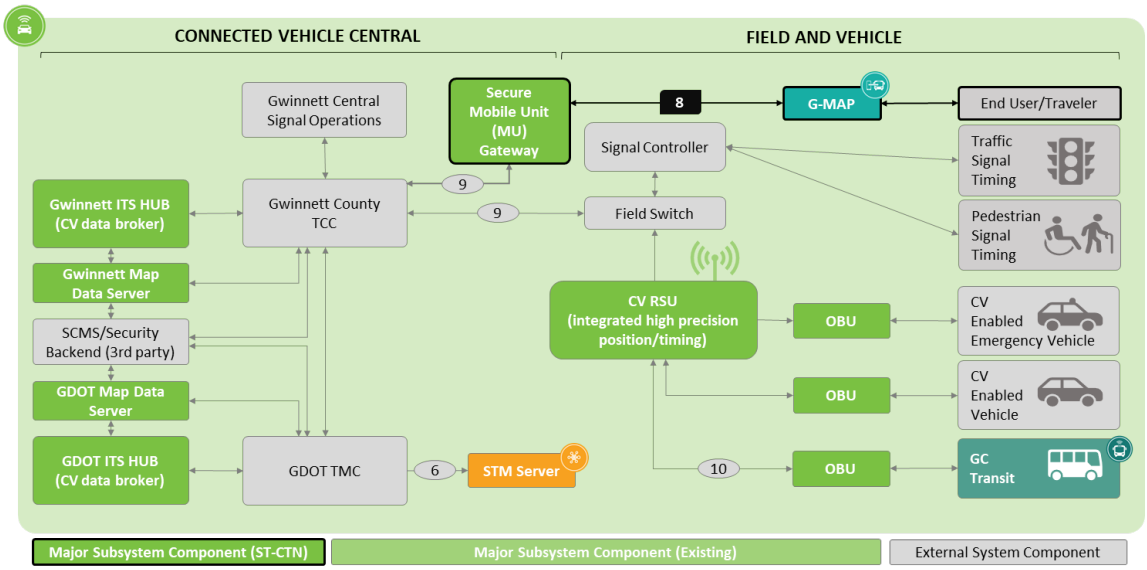
Operating Environment

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

5.1.3 Connected Vehicle 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 CV subsystem will leverage 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 will be 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 will 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 will be channeled through the G-MAP (server). A secure, firewalled network connection will be 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) will be unidirectional from the ITS Hub or GDOT TMC to the destination platform. Note that this service will not interfere with existing operations of the pedestrian requests actuated by travelers pressing the physical pedestrian push button.



Source: GDOT, 2024

Figure 19. Functional View of the Connected Vehicle Subsystem

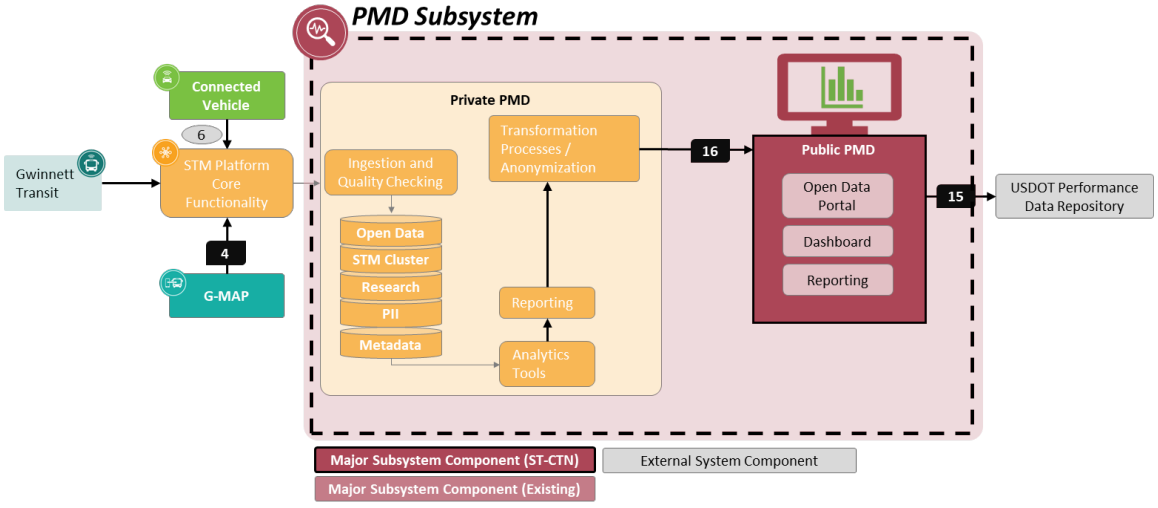
The existing system only requires minor configuration updates to accommodate the Pedestrian Signal Request (information flow from Interface #8 to pedestrian signal via Interface #9) and to update the frequency of information from the GDOT.

In addition, the SMUG will be configured to enable the G-MAP to transmit pre-defined PED-X messages to the Gwinnett County TCC.

5.1.4 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 will ingest, quality check, and curate the data. The PMD will perform 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 20**. The PMD subsystem is comprised of private and public components where the private PMD manages and performs analytics on private data, including 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 20. Functional Architectural View – PMD Subsystem

Table 14 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 14. 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 will be 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 will be 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 user interfaces for the open data portal will be undertaken during design. Note: although most of the datasets originate in the GDOT/GCDOT ITS Data Hub, they are not archived.
PII Server	STM; Operational

Function Name	Function Description
	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 will be stored on research server.
Research Server	STM (subset on STM Cluster); Operational Multiple high-resource computers (e.g., 96 cores, 512 GB RAM) are used for the development, training and execution of the Machine Learning 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 Georgia 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 will store and process STM network and Network Impedance data.
Metadata	Information about the datasets stored on the data storage systems.
Analytic Tools	Performance metrics data will be processed and analyzed.
Reporting	Performance metrics data will be reported in a manner that is capable of being transformed.
Transformation Process/ Anonymization	Reported data will be transformed and anonymized and made available for public consumption. Additional transformation and aggregation will be applied to meet performance measurement and analytic requirements.
Interfaces	See **Section 5.1.5**

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 15 provides a summary of functional elements of the Public PMD. The Public PMD will be developed and provide a public facing dashboard to display the evaluation of the ST-CTN performance measures.

Table 15. 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**

The operating environment will use a web server.

5.1.5 Data and Information Flow View

Since the physical and functional architecture views are depicted using different methodologies and terminology, **Table 16** shows how the physical and functional information flow align and differ. The Functional Architecture View does not show systems, information flows and elements that are already implemented, whereas the physical architecture identifies the reference information flows that are pre-requisites to enable end-to-end processes.

Table 16. Relationship between Functional and Physical Information Flows

Physical Flow Name	Physical Flow Description	Physical Source to Destination Pair	Func Flow ID	Functional Flow Description	Functional Source: Destination Pair
Archived data products	Aggregated, anonymized performance measures.	Public PMD to PMD Dashboard	15	Project data for USDOT-managed Public System	Public PMD: Public
Current Beacon Information	Information about beacons (e.g., locations, strength) and traveler information	G-MAP Trip Planner to Indoor Navigation System (INS)	13	Dynamic information from building facilities (including beacons to the G-MAP mobile app) and INS vendor cloud software development kit (SDK)	Indoor Navigation System: G-MAP
Device Identification	An identifier and device type designation that is used to uniquely identify a device in the Connected Vehicle Environment.	G-MAP App to GJAC Facility G-MAP App to Norcross OneStop	2	Static data from various existing sources to the STM Platform dynamic data broker	External: G-MAP External: STM
GMAP operational and traveler data	Detailed traveler trip trace data and planned data. Daily transfer.	G-MAP Trip Planner to STM	4	G-MAP Mobile App logs and trip feedback	G-MAP:STM
Government Reporting Data Receipt	The acknowledgement of satisfactory receipt of information used as input to government data systems or a report identifying problems or issues with the data submittal.	USDOT Performance Data Repository to Public PMD	15	Project data for USDOT-managed Public System (Note: this will be implemented as pull from the USDOT Managed Public System)	USDOT Managed Public System: Public PMD

Physical Flow Name	Physical Flow Description	Physical Source to Destination Pair	Func Flow ID	Functional Flow Description	Functional Source: Destination Pair
Government Reporting System Data	Information provided by an ITS archive, formatted as appropriate, that can be used as input to government data reporting systems.	Public PMD to USDOT Performance Data Repository	15	Project data for USDOT-managed Public System	Public PMD: USDOT Managed Public System
Intersection Control Status	Status data provided by the traffic signal controller including phase information, alarm status, and priority/preempt status.	Gwinnett County Roadway Signal System to Gwinnett County RSE	9	CV messages	Connected Intersection: Traffic Management and ITS Hub
Intersection Safety Application Info	Intersection and device configuration data, including intersection geometry, and warning parameters and thresholds. This flow also supports remote control of the application so the application can be taken offline, reset, or restarted.	Gwinnett County TCC: to Gwinnett County RSE	9	CV messages	Connected Intersection: Traffic Management and ITS Hub
Intersection Safety Application Status	Infrastructure safety application status reported by the RSE. This includes current operational state and status of the RSE and a record of intersection safety issues identified and alerts and warnings issued.	Gwinnett County RSE to Gwinnett County TCC	9	CV messages	Connected Intersection: Traffic Management and ITS Hub

Physical Flow Name	Physical Flow Description	Physical Source to Destination Pair	Func Flow ID	Functional Flow Description	Functional Source: Destination Pair
Path Update Notification	Notification of maintenance, construction, and other activities that will result in medium to long term changes to path location and configuration that may impact navigable maps. This flow includes the timing of the changes and precise enumeration of the location and configuration changes. It also includes updated static characteristics and default travel times.	Gwinnett Facility to Facility Path Update System	2	Static data from various existing sources to the STM Platform dynamic data broker	External: G-MAP External: STM
Path Updates	Map update that could include a new underlying static or real-time path or map layer(s) update. Map layers can include path, topography, points of interest, and conveyance information including escalator directions and status.	Facility Path Update System to Gwinnett Facilities	2	Static data from various existing sources to the STM Platform dynamic data broker	External: G-MAP External: STM

Physical Flow Name	Physical Flow Description	Physical Source to Destination Pair	Func Flow ID	Functional Flow Description	Functional Source: Destination Pair
Mixed Use Crossing Status	Current pedestrian and other mixed use crossing information including an indication of whether the call button has been activated, the current state of the mixed use crossing signal, and information indicating whether non-motorized users are currently occupying the cross walk.	Gwinnett County Roadway Signal System to Gwinnett County RSE	9	CV messages	Connected Intersection: Traffic Management and ITS Hub
Mixed Use Safety Warning Control	Configuration and control of equipment that monitors and manages mixed use crossings and provides visual displays and warnings to drivers when non-motorized users are occupying a cross walk or other mixed use path crossing.	Gwinnett County TCC to Gwinnett County Roadway Signal System	9	CV messages	Connected Intersection: Traffic Management and ITS Hub
Mixed Use Safety Warning Status	Current operational status and state of pedestrian crossings and other mixed use path crossing warning systems.	Gwinnett County Roadway Signal System to Gwinnett County TCC	9	CV messages	Connected Intersection: Traffic Management and ITS Hub

Physical Flow Name	Physical Flow Description	Physical Source to Destination Pair	Func Flow ID	Functional Flow Description	Functional Source: Destination Pair
Network Impedance API	A network impedance API associated with the links and nodes of the trip planning graph contain different levels of accessibility based on personal needs and preferences.	STM Platform to G-MAP Trip Planner	5	STM Network Impedance API	STM: G-MAP
Network Models and Operational Data	Various network models and operational data that compose operational information that may include PII.	STM Platform to Private PMD	n/a	Internal to STM. See **Figure 18** for Network Operational Condition, CV, System Customer Performance, System Performance Logs, Incident Data, and Energy / Emissions Datasets	Internal to STM
Operational Data and Metrics	Situational operational data and metrics collected from the CV and TCC that are used to evaluate performance of the network and ST-CTN tools.	Gwinnett County TCC to Private PMD	6	CV and Traffic Operations Messages: , NaviGAtor ITS, road characteristics, traffic data	CV:STM
Operational Performance	Operational performance data collected from the G-MAP Trip Planner that may contain PII.	G-MAP Trip Planner to Private PMD	4	G-MAP Mobile App logs and trip feedback	G-MAP:STM

Physical Flow Name	Physical Flow Description	Physical Source to Destination Pair	Func Flow ID	Functional Flow Description	Functional Source: Destination Pair
Path Sensor Data	Signals broadcast about a sensor serving as a waypoint that is installed in facility.	Gwinnett Facilities to G-MAP Mobile App	13	Dynamic information from building facilities (including beacons to the G-MAP Mobile App) and INS vendor cloud SDK	Building System (external): G-MAP Mobile App
Path Sensor Monitoring	Signal monitoring of sensor/beacon broadcasted data.	Gwinnett Facilitiesto G-MAP Mobile App	13	Dynamic information from building facilities (including beacons to the G-MAP Mobile App) and INS vendor cloud SDK	Building System (external): G-MAP Mobile App
PED-X Request	Request to actuate PED crossing at intersection with extended walk time.	G-MAP Trip Planner: to Gwinnett County TCC	**8**	Mobile Accessible Pedestrian Signal System (PED-SIG)	G-MAP: CV (Secure MU gateway)
Performance Metrics	Performance metrics that are ready for public consumption.	Private PMD to Public PMD	**16**	Public facing data and visualizations for reporting on system operations and performance	Private PMD (STM): Public PMD
Personal Location Information	Pedestrian user locations at an intersection as detected and reported by an RSE.	Gwinnett County RSE: to Gwinnett County Roadway Signal System	n/a	Internal to the physical pedestrian signal actuation equipment	

Physical Flow Name	Physical Flow Description	Physical Source to Destination Pair	Func Flow ID	Functional Flow Description	Functional Source: Destination Pair
Signal Service Request	A call for service or extension for a signal control phase that is issued by the RSE for connected vehicles approaching an intersection and/or pedestrians at a crosswalk. This flow identifies the desired phase and service time.	Gwinnett County RSE to Gwinnett County Roadway Signal System	9	CV messages	Connected Intersection: Traffic Management
Transfer Request	A traveler request for a transfer between transit routes, services, or modes. The request may also include preferences such as a need for extra connection time or ride request in the event of a delay.	GCT Bus OBE to Gwinnett Transit Management Center	**10**	Transit signal priority (TSP) and other CV application messages	GCT OBE: CV Connected Intersection
Transfer Status	Information indicating whether a requested transfer can be confirmed including specific information about the connection including fare payment information. Real-time updates are provided if the transfer status changes up to and including a reminder just prior to the transfer.	Gwinnett Transit Management Center: to GCT Bus OBE	n/a	Internal to the Gwinnett Transit Computer Aided Dispatch (CAD) and vehicle Automated Vehicle Location (AVL) system	GCT: GCT

Physical Flow Name	Physical Flow Description	Physical Source to Destination Pair	Func Flow ID	Functional Flow Description	Functional Source: Destination Pair
Transit and Fare Schedules	Transit service information including routes, schedules including GTFS static files.	Gwinnett Transit Management Center to G-MAP Trip Planner MARTA Transit Management Center to G-MAP Trip Planner	2	Static data from various existing sources to the STM Platform dynamic data broker	External: STM External: G-MAP
Ride Request API	A traveler ride request -- for transit to stop for pick up at a stop by a transit vehicle.	G-MAP Trip Planner to Gwinnett Transit Management Center	**11**	Ride Request messages	G-MAP Mobile App via G-MAP: Gwinnett Transit
Transit schedule adherence information	Dynamic transit schedule adherence and transit vehicle location information.	Gwinnett Transit Management Center to G-MAP Trip Planner MARTA Transit Management Center to G-MAP Trip Planner	3	Static and dynamic data from various existing sources to the STM Platform dynamic data broker	External: STM External: G-MAP
Transit Traveler Information	Transit information prepared to support transit users and other travelers. It contains transit schedules, real-time arrival information, alerts and advisories, and general transit service information.	Gwinnett Transit Management Center to GCT Bus OBE	n/a	External to architecture	Internal to MARTA and GCT

Physical Flow Name	Physical Flow Description	Physical Source to Destination Pair	Func Flow ID	Functional Flow Description	Functional Source: Destination Pair
Transit Traveler Request	Request by a transit traveler to summon assistance, request transit information, or request any other transit services.	GCT Bus OBE: to Gwinnett Transit Management Center	n/a	Internal to GCT. Will be aggregated and provided as performance data via information flow #3	Internal to GCT
Transit User Information	Information about individual transit users boarding a transit vehicle, used to track a user's progress on a scheduled transit trip.	GCT Bus OBE: to Gwinnett Transit Management Center	n/a	Internal to GCT. Will be aggregated and provided as performance data via information flow #3	Internal to GCT
Transit Vehicle Loading Data	Data collected on board the transit vehicle relating to passenger boarding and alighting.	GCT Bus OBE to Gwinnett Transit Management Center	n/a	Internal to GCT. Will be aggregated and provided as performance data via information flow #3	Internal to GCT
Transit Vehicle Operator Information	Transit service instructions, wide area alerts, traffic information, road conditions, and other information for transit operators.	Gwinnett Transit Management Center to GCT Bus OBE	n/a	Internal to GCT. Will be aggregated and provided as performance data via information flow #3	Internal to GCT
Transit Vehicle Schedule Performance	Estimated times of arrival and anticipated schedule deviations reported by a transit vehicle.	GCT Bus OBE to Gwinnett Transit Management Center	n/a	Internal to GCT. Will be aggregated and provided as performance data via information flow #3	Internal to GCT

Physical Flow Name	Physical Flow Description	Physical Source to Destination Pair	Func Flow ID	Functional Flow Description	Functional Source: Destination Pair
Trip Confirmation – Call Center	Acknowledgement by the G-MAP of acceptance of a trip plan and the request to save the trip plan or download it to the mobile app. Conversely, this flow may also reject the proposed trip plan. Confirmations include the selected route and subsequent trip confirmation messages will be issued for route changes.	Call Center to G-MAP Trip Planner	12a	G-MAP Mobile App APIs and Traveler exchange – profile, trip plan, settings, notifications, feedback, etc. with restrictions on viewing and changing certain data.	G-MAP: Website, Call Center, Trusted Companion device
Trip Confirmation – G-MAP App	Acknowledgement by the G-MAP of acceptance of a trip plan and the request to save the trip plan or download it to the mobile app. Conversely, this flow may also reject the proposed trip plan. Confirmations include the selected route and subsequent trip confirmation messages will be issued for route changes.	G-MAP App to G-MAP Trip Planner	12a	G-MAP Mobile App APIs and Traveler exchange – profile, trip plan, settings, notifications, feedback, etc. with restrictions on viewing and changing certain data.	G-MAP: Website, Call Center, Caregiver device

Physical Flow Name	Physical Flow Description	Physical Source to Destination Pair	Func Flow ID	Functional Flow Description	Functional Source: Destination Pair
Trip Feedback	Information provided at the conclusion of a trip that supports performance monitoring and system optimization. Information provided may include a record of the trip including trip plan usage and user provided feedback at the conclusion of the trip.	G-MAP App to G-MAP Trip Planner	12, 12a	12- G-MAP Mobile App APIs and Traveler exchange – profile, trip plan, settings, notifications, feedback, etc. 12A- Similar data flows to Data Exchange ID 12 with restrictions on viewing and changing certain data.	G-MAP: Channel Access methods
Trip Plan – Call Center	A travel itinerary identifying a route and associated traveler information and instructions identifying recommended modes, transfer information, and transit information. This flow also includes intermediate information that is provided as the trip plan is interactively created, including identification of alternatives, requests for additional information.	G-MAP Trip Planner to Call Center	12a	G-MAP Mobile App APIs and Traveler exchange – profile, trip plan, settings, notifications, feedback, etc. with restrictions on viewing and changing certain data.	G-MAP: Website, Call Center, Caregiver device

Physical Flow Name	Physical Flow Description	Physical Source to Destination Pair	Func Flow ID	Functional Flow Description	Functional Source: Destination Pair
Trip Plan – G-MAP App	A travel itinerary identifying a route and associated traveler information and instructions identifying recommended modes, transfer information, and transit information. This flow also includes intermediate information that is provided as the trip plan is interactively created, including identification of alternatives, requests for additional information.	G-MAP Trip Planner to G-MAP App	12	G-MAP Mobile App APIs and Traveler exchange – profile, trip plan, settings	G-MAP: G-MAP mobile app
Trip Plan PED-X Request Trigger	A request to trigger PED crossing request to actuate walk signal at intersection.	G-MAP App to G-MAP Trip Planner	12	G-MAP Mobile App APIs and Traveler exchange – profile, trip plan, settings	G-MAP: G-MAP mobile app
Trip Plan Stop Request	Alert sent to transit vehicle via G-MAP and Transit Management Center to request GCT bus wait at stop based on traveler's proximity to transit stop.	G-MAP App to G-MAP Trip Planner	12	G-MAP Mobile App APIs and Traveler exchange – profile, trip plan, settings	G-MAP: G-MAP mobile app

Physical Flow Name	Physical Flow Description	Physical Source to Destination Pair	Func Flow ID	Functional Flow Description	Functional Source: Destination Pair
Trip Support Request (Call Center)	Request for trip planning services that identifies the trip origin, destination(s), timing, preferences, and constraints. The request may also include the requestor's location or a request for transit associated with the trip. The trip request also covers requests to revise a previously planned trip and interim updates that are provided as the trip is interactively planned.	Call Center to G-MAP Trip Planner	12a	G-MAP Mobile App APIs and Traveler exchange – profile, trip plan, settings, notifications, feedback, etc. with restrictions on viewing and changing certain data.	G-MAP: Website, Call Center, Caregiver device
Trip Request (G-MAP App)	Request for trip planning services that identifies the trip origin, destination(s), timing, preferences, and constraints. The request may also include the requestor's location or a request for transit associated with the trip. The trip request also covers requests to revise a previously planned trip and interim updates that are provided as the trip is interactively planned.	G-MAP App to G-MAP Trip Planner	12a	G-MAP Mobile App APIs and Traveler exchange – profile, trip plan, settings, notifications, feedback, etc. with restrictions on viewing and changing certain data.	G-MAP: Website, Call Center, Caregiver device
User Performance Metrics	Information on travelers' adherence to their trip itinerary and other operational data associated with their journey. The information flow includes PII.	G-MAP Trip Planner to Private PMD	4	G-MAP Mobile App logs and trip feedback	G-MAP: STM

Physical Flow Name	Physical Flow Description	Physical Source to Destination Pair	Func Flow ID	Functional Flow Description	Functional Source: Destination Pair
User Profile	Information provided to register for a travel service and create a user account. The provided information includes personal identification, traveler preferences (e.g., maximum transfer wait time, maximum walking distance, mode preferences, special needs), device information, a user ID and password, and other personal information.	G-MAP App to G-MAP Trip Planner	12, 12a	12- G-MAP Mobile App APIs and Traveler exchange – profile, trip plan, settings, notifications, feedback, etc. 12a- Similar data flows to Data Exchange ID 12 with restrictions on viewing and changing certain data.	G-MAP: Channel Access methods
Wayfinding Path	Path (trip) information from current location to destination in an indoor facility	Indoor Navigation System to G-MAP Trip Planner	13	Dynamic information from building facilities (including beacons to the G-MAP mobile app) and INS vendor cloud SDK	Indoor Navigation System: G-MAP

5.2 Relationship Between Functional and Physical Views

The ST-CTN system is an innovative ITS project with complex relationships and reliance on existing systems, open-source applications, and *multi-modal and accessible traveler applications* which are not yet represented by ARC-IT. As mentioned previously, the SAD depicts the various viewpoints of the project architecture and is the basis for design. The relationship between the Physical and Functional Views are presented in **Table 17** where each Physical View name and diagram is cross-referenced with the Functional View name and diagram it is associated with.

Table 17. Physical and Functional View Relationship

Physical View – Function Name	Physical Architecture Diagram	Functional View – Function Name	Functional View Diagram
Anonymization / Aggregation Processes	DM02: Performance Monitoring (Copy 2), DM02: Public Performance Monitoring Dashboard (Copy 1), Performance Management Archives	Transformation Processes/Anonymization	PMD Subsystem
Archive Data Repository	DM02: Performance Monitoring (Copy 2), DM02: Public Performance Monitoring Dashboard (Copy 1), Performance Management Archives	Open Data (private PMD)	PMD Subsystem
Archive Government Reporting	DM02: Public Performance Monitoring Dashboard (Copy 1), Performance Management Archives	Open Data Portal	PMD Subsystem
Archive On-Line Analysis and Mining	DM02: Public Performance Monitoring Dashboard (Copy 1), Performance Management Archives	Reporting	PMD Subsystem
Archived Data Collection	DM02: Performance Monitoring (Copy 2), Performance Management Archives	Set of Data Storage (open data, STM cluster, research, PII, metadata)	PMD Subsystem
Center Path Management	Indoor Navigation - Layer 1, SU04: Map Management (Copy 1)	External Static Data (OSM)	G-MAP Subsystem

Physical View – Function Name	Physical Architecture Diagram	Functional View – Function Name	Functional View Diagram
Ride Request Module	PT17: Transit Ride Request (Copy 1)	Configured as a trigger that is part of existing SW in G-MAP	G-MAP Subsystem
Indoor Nav System	Indoor Navigation - Layer 1, TI02: Personalized Traveler Information for indoor navigation (Copy 1)	Indoor Navigation System	G-MAP Subsystem
ITS Security Support	Indoor Navigation - Layer 1, TI02: Personalized Traveler Information for indoor navigation (Copy 1)	Data Broker	G-MAP Subsystem
Network Impedance Generator	Indoor Navigation - Layer 1, TI04: Infrastructure-Provided Trip Planning and Route Guidance (Copy 1)	Impact Assessment and Network Edge Cost Analysis Engine	STM Platform Functional Architecture
Path Management	Indoor Navigation - Layer 1, SU04: Map Management (Copy 1)	TBD (external system provided by vendor)	Not Included
Path Wayfinding Beacons management	Indoor Navigation - Layer 1, TI02: Personalized Traveler Information for indoor navigation (Copy 1)	Data Broker	G-MAP Subsystem
PED-X Request Module	VS12: Pedestrian Mobility (Copy 1)	GC TCC	CV Functional View
Personal Interactive Traveler Information	Indoor Navigation - Layer 1, TI02: Personalized Traveler Information for indoor navigation (Copy 1)	G-MAP UI	G-MAP Subsystem
Personal Local Route Guidance	Indoor Navigation - Layer 1, PT17: Transit Ride Request (Copy 1), TI02: Personalized Traveler Information for indoor navigation (Copy 1)	G-MAP UI (OTP routing engine)	G-MAP Subsystem
Personal Pedestrian Safety	VS12: Pedestrian Mobility (Copy 1)	G-MAP UI (middleware)	G-MAP Subsystem

Physical View – Function Name	Physical Architecture Diagram	Functional View – Function Name	Functional View Diagram
Personal Trip Planning and Route Guidance	Indoor Navigation - Layer 1, TI04: Infrastructure-Provided Trip Planning and Route Guidance (Copy 1)	G-MAP (CDP + routing)	G-MAP Subsystem
Personal Trip Support	Indoor Navigation - Layer 1, TI04: Infrastructure-Provided Trip Planning and Route Guidance (Copy 1)	G-MAP (CDP + routing+call center)	G-MAP Subsystem
PM Visualization	DM02: Public Performance Monitoring Dashboard (Copy 1), Performance Management Archives	Dashboard	PMD Subsystem
Project Data Files and Metadata	DM02: Public Performance Monitoring Dashboard (Copy 1), Performance Management Archives	USDOT Performance Data Repository	PMD Subsystem
Protected Data Collection	DM02: Performance Monitoring (Copy 2), DM02: Public Performance Monitoring Dashboard (Copy 1), Performance Management Archives	Private PMD (PII, research)	PMD Subsystem
Roadway Mixed Use Crossing Safety	VS12: Pedestrian Mobility (Copy 1)	Switch, Controller, Traffic Signal Timing	CV Functional View
RSE Intersection Safety	VS12: Pedestrian Mobility (Copy 1)	Pedestrian Signal Timing, Traffic Signal Timing	CV Functional View
STM Dynamic Data Broker	DM02: Performance Monitoring (Copy 2), Indoor Navigation - Layer 1, Performance Management Archives, SU04: Map Management (Copy 1)	Dynamic Data Broker	STM Platform Functional Architecture

Physical View – Function Name	Physical Architecture Diagram	Functional View – Function Name	Functional View Diagram
TIC Data Collection	DM02: Performance Monitoring (Copy 2), Indoor Navigation - Layer 1, Performance Management Archives, TI04: Infrastructure-Provided Trip Planning and Route Guidance (Copy 1)	G-MAP	G-MAP Subsystem
TIC Interactive Traveler Information	Indoor Navigation - Layer 1, TI04: Infrastructure-Provided Trip Planning and Route Guidance (Copy 1)	G-MAP UI	G-MAP Subsystem
TIC Trip Planning	Indoor Navigation - Layer 1, TI04: Infrastructure-Provided Trip Planning and Route Guidance (Copy 1)	Routing Engine, OTP Middleware	G-MAP Subsystem
TMC Data Collection	DM02: Performance Monitoring (Copy 2), Performance Management Archives	GC ITS Hub; GDOT ITS Hub	CV Functional View
TMC Intersection Safety	VS12: Pedestrian Mobility (Copy 1)	Controller, Pedestrian Signal Timing	CV Functional View
Transit Center Ride Request	Indoor Navigation - Layer 1, PT17: Transit Ride Request (Copy 1), TI04: Infrastructure-Provided Trip Planning and Route Guidance (Copy 1)	Ride Request (added to CAD)	GCT Platform
Transit Center Information Services	DM02: Performance Monitoring (Copy 2), Indoor Navigation - Layer 1, Performance Management Archives, TI04: Infrastructure-Provided Trip Planning and Route Guidance (Copy 1)	External Systems in Overall Functional Architecture (flows 2 and 3)	Overall
Transit Center Multi-Modal Coordination	PT17: Transit Ride Request (Copy 1)	External Systems in Overall Functional Architecture (flows 2 and 3)	Overall

Physical View – Function Name	Physical Architecture Diagram	Functional View – Function Name	Functional View Diagram
Transit Center Passenger Counting	PT17: Transit Ride Request (Copy 1)	CAD	GCT Platform
Transit Vehicle On-Board Ride Request	PT17: Transit Ride Request (Copy 1)	AVL / OBU	GCT Platform
Transit Vehicle Passenger Counting	PT17: Transit Ride Request (Copy 1)	AVL / OBU	GCT Platform
Trip Planning	Indoor Navigation - Layer 1, TI04: Infrastructure-Provided Trip Planning and Route Guidance (Copy 1)	edit G-MAP UI and Call Center Module	G-MAP Subsystem

6 References

Table 18 lists the documents that were used to support the development of the ST-CTN SAD. References to these documents are identified with the acronym provided in brackets.

Table 18. Referenced Documents

ID	Referenced Documents
[CVTMP]	AECOM. "Gwinnett County Connected Vehicle Technology Master Plan (CVTMP)." Duluth: Gwinnett County Department of Transportation. (2019).
[ARCRTP]	Atlanta Regional Commission. (2021). “The Atlanta Region’s Plan: Regional Transportation Plan” Atlanta: Atlanta Regional Commission.
[UNIRP]	Atlanta Regional Commission. Deliverable Task 1.B User Needs Identification and Requirements Planning. Atlanta: U.S Department of Transportation. (2021).
[SRCRP]	Atlanta Regional Commission. Deliverable Task 2.1 Stakeholder Registry and ConOps Review Panel Roster. Atlanta: U.S Department of Transportation. (2021).
[NS]	Atlanta Regional Commission. Deliverable Task 2.2 Needs Summary. Atlanta: U.S Department of Transportation. (2021).
[CPACS]	Center for Pan Asian Community Services. Transportation. Atlanta: Center for Pan Asian Community Services, Inc. (2021).
[BCS]	Ferrel, Christopher E. The Benefits of Transit in the United States: A Review and Analysis of Benefit-Cost Studies. San Jose: Mineta Transportation Institute. (2015).
[CV1K]	Georgia Department of Transportation. "The Regional Connected Vehicle Program Scope of Work." Atlanta: Georgia Department of Transportation.
[GBFS]	GitHub. General Bikeshare Feed Specification. Washington D.C.: GTFS. (2019).
[GTFS-Flex]	GitHub. GTFS Flex. Washington D.C.: GTFS (2019).
[GTFS-RT]	GTFS Realtime. GTFS Realtime Reference v2. Washington D.C.: GTFS Realtime. (2019)
[GTFSP]	GTFS. General Transit Feed Specification Pathway. Washington D.C.: GTFS. (2019).

ID	Referenced Documents
[GTFS]	GTFS. General Transit Feed Specification Reference. Washington D.C.: GTFS. (2019).
[CGCT]	Gwinnett County Department of Transportation. Connect Gwinnett Transit Plan - Existing Conditions Technical Memorandum. Duluth: Gwinnett County Government. (2017).
[PSRG]	Gwinnett County Transit. Paratransit Service Rider's Guide. Duluth: Gwinnett County Government. (2018).
[MARTA4GC]	Gwinnett County Transit. The Plan - MARTA for Gwinnett. Duluth: Gwinnett County Government. (2021).
[SS-GC]	Gwinnett County. Senior Services. Duluth: Gwinnet County Government. (2021).
[API]	IBM Cloud Education. Application Programming Interface (API). Armonk: IBM. (2020).
[CI]	ICF, Wyoming Department of Transportation. Connected Intersection - Concept of Operations. Cheyenne: USDOT (2018).
[IEEE-1362]	IEEE. Guide for Information Technology - System Definition - Concept of Operations (ConOps) Document. IEEE. IEEE Std 1362-1998
[IEEE-1028]	IEEE. Guide for Software Reviews and Audits. IEEE. IEEE Standard 1028-2008.
[IEEE-29148]	IEEE. ISO/IEC/IEEE International Standard - Systems and Software Engineering -- Life Cycle Processes -- Requirements Engineering, IEEE/ISO/IEC 29148-2018
[IEEE-1609]	IEEE. Wireless Access in Vehicular Environment. IEEE. IEEE Standard 1609.2-2016.
[GCTP-1]	Kimley-Horn, Bleakly Advisory Group, Pond, Sycamore, VHB, & Debra Semans. (2017). Gwinnett County Destination 2040 - Gwinnett's Comprehensive Transportation Plan - Executive Summary. Atlanta: Gwinnett County.
[GCTP-2]	Kimley-Horn, Bleakly Advisory Group, Pond, Sycamore, VHB, & Debra Semans. (2017). Gwinnett County Destination 2040 - Gwinnett's Comprehensive Transportation Plan - Existing Conditions. Atlanta: Gwinnett County.
[GCTP-3]	Kimley-Horn, Bleakly Advisory Group, Pond, Sycamore, VHB, & Debra Semans. (2017). Gwinnett County Destination 2040 - Gwinnett's Comprehensive Transportation Plan - Needs Assessment. Atlanta: Gwinnett County.
[GCTP-4]	Kimley-Horn, Bleakly Advisory Group, Pond, Sycamore, VHB, & Debra Semans. (2017). Gwinnett County Destination 2040 - Gwinnett's Comprehensive Transportation Plan - Recommendations Report. Atlanta: Gwinnett County.

ID	Referenced Documents
[NTCIP-1211]	National Transportation Communications for ITS Protocol 1211 Object Definitions for Signal Control and Prioritization. (2014) Washington, D.C.: AASHTO, ITE, NEMA.
[NOBLIS]	Noblis, Inc. (2017). Applying Scrum Methods to ITS Projects. Washington D.C.: U.S. Department of Transportation.
[OSM]	OpenStreetMap Foundation. Open Street Map. Washington D.C.: UCL, ByteMark. (2021).
[CAV]	Park, Hyungjun; Khattak, Zulqarnain; Smith, Brian. Glossary of Connected and Automated Vehicle Terms *Version 1.0*. Charlottesville.: University of Virginia Center for Transportation Studies. (2018).
[ICS]	Rusnak, Sean. (2019). How an Insufficient Public Transportation System Decelerates Economic Mobility. Washington D.C.: Institute for Child Success.
[OSEP]	Ryen, Ed. (2008). Overview of the System Engineering Process. Bismarck: North Dakota Department of Transportation.
[PSWPCCS]	Saad, Wasan Kadhim; Hashim, Yasir; Jabbar, Waheb A. (2020). Design and Implementation of Portable Smart Wireless Pedestrian Crossing Control System. Najab: IEEEAccess.
[SAE-J2735]	SAE J2735-2020 C2X Message Set. Warrendale: SAE International.
[SAE-J2945]	SAE J2945-2017 On-Board System Requirements for V2V Safety Communications. Warrendale: SAE International.
[DW]	Schrade, Brad. (2014). Deadly walk: a spike in Georgia's pedestrian deaths. Atlanta: The Atlanta Journal-Constitution.
[CV SAD]	M. Talas, D. Benevelli, R. Rausch, and S. Sim. (2021). Connected Vehicle Pilot Deployment Program Phase 2, System Architecture - New York City. no. FHWA-JPO-17-451, Apr. 2021, [Online]. Available: https://rosap.ntl.bts.gov/view/dot/61190
[IMISOW]	The ATL. (2020). Integrated Mobility Innovation Statement of Work - Atlanta-Region Rider Information and Data Evaluation System. Atlanta: Federal Transit Administration.
[IVR]	TTEC. (2021). Interactive Voice Response (IVR). Englewood: TTEC.
[CONOPS]	U.S Department of Transportation, Federal Highway Administration, California Division. (2016). Concept of Operations Template. Washington D.C.: Federal Highway Administration.

ID	Referenced Documents
[FAST]	U.S. Department of Transportation Federal Highway Administration. (2015). Fixing America's Surface Transportation Act.
[ARC-IT v9.1]	U.S. Department of Transportation Federal Highway Administration. (2022). Architecture Reference for Cooperative and Intelligent Transportation, ARC-IT v9.1. https://www.arc-it.net/index.html (accessed May 10, 2022).
[SE-ITS]	U.S. Department of Transportation, Federal Highway Administration, Federal Transit Administration. (2007). Systems Engineering for Intelligent Transportation Systems - An Introduction for Transportation Professionals. Washington D.C.: Department of Transportation, Office of Operations.
[BAA]	U.S. Department of Transportation, Federal Highway Administration. (2020). ITS4US Broad Agency Announcement. Washington D.C.: U.S. Department of Transportation.
[ACS]	United States Census Bureau. (2017). American Community Survey. Washington D.C.: U.S. Department of Commerce.
[QF]	United States Census Bureau. (2019). QuickFacts - Fulton County, Georgia; DeKalb County, Georgia; Gwinnett County, Georgia. Washington D.C.: U.S. Department of Commerce.
[ADA]	United States Department of Justice, Civil Rights Division. (2009). Americans with Disabilities Act of 1990. Washington D.C.: United States Government.

7 Definitions, Acronyms, and Abbreviations

This section provides definitions, acronyms, and abbreviations used throughout the SAD.

7.1 Definitions

Americans with Disability Act (ADA) – An act to “provide a clear and comprehensive national mandate for the elimination of discrimination against individuals with disabilities.” The act provides enforceable standards to address discrimination against individuals with disabilities and requires public facilities to be readily accessible and usable by individuals with disabilities [ADA].

Application Programming Interface (API) – Enables companies to make available the data of their products and services to external developers and business partners. This allows multiple services and products from different companies to communicate and leverage each other’s data for improved collaboration, innovation, and added security [API].

Artificial Intelligence (AI) – Intelligence that is learned, displayed, and carried out by machines. An "intelligent" machine perceives its environment and then takes actions that maximize its chance of success at some goal. Examples that we know include human speech recognition, which turns spoken words into the contents of a text document or email, and autonomous driving, where the vehicle has a learning element to recognize its environment including other vehicles, pedestrians and the infrastructure. Intelligence and decision-making that come from a machine and an autonomous vehicle is known as artificial intelligence. Deep learning and machine learning are mainly included in AI. [CAV]

Basic Safety Message (BSM) – Data content that is broadcasted through V2V or V2I at a 10 Hz frequency. The data elements are vehicle position (latitude, longitude, elevation) and motion (heading, speed, acceleration). [CAV]

Cellular – Vehicle to Everything (C-V2X) – A connected vehicle platform that utilizes the cellular network to provide vehicle-to-vehicle, vehicle-to-infrastructure, and vehicle-to-pedestrian communication. Unlike DSRC and LTE-V2X which enable direct communication between participants, C-V2X utilizes the cellular network to transmit and receive data [CVTMP].

Cellular V2X – Cellular V2X (C-V2X) is a 3GPP specification, release 3GPPr14, describing a technology to achieve the V2X requirements. C-V2X is an alternative to 802.11p, the IEEE specified standard for V2V and other forms of V2X communications.

Connected Vehicle (CV) – A vehicle (car, truck, bus, etc.) that is equipped with a wireless communication device (1). A CV uses any of the available wireless communication technologies to communicate with other cars on the road (vehicle-to-vehicle [V2V]), roadside infrastructure (vehicle-to-infrastructure [V2I]), and other travelers and the cloud. [CAV]

Dedicated Short-Range Communication (DSRC) – A protocol for communication between vehicles and between moving vehicles and fixed roadside access points. The protocol addresses safety critical issues associated with sending and receiving data. The protocol provides low-latency data-only V2V and V2I communications. [CAV]

General Transit Feed Specification (GTFS) – A data specification that allows public transit agencies to publish their data to be consumed by a variety of transit-related applications. This data includes schedule, fare, and vehicle position which can be used to predict arrival times and display real-time information [GTFS].

High Precision Positioning/Timing Source -- Source data service which could be a base station or a satellite allowing the system to calculate positioning and UTC for system processes or provide position corrections. An example of a High Precision Positioning/Timing Source is a GNSS receiver. [CI]

Intelligent Traffic Signal System (I-SIG) – A traffic signal system that controls signals and maximizes flows in real time by collecting data from vehicles through V2V, V2P, and V2I communications. [CAV]

Interactive Voice Response (IVR) – Automated phone system that allows users to access information using a voice response system of pre-recorded messages to convey information without having to speak to an agent. [IVR].

MAP – MAP data provides intersection and roadway lane geometry data for one or more locations (e.g., intersections and fragments of maps) based on the SEA JS2735 message set standards. [CAV]

Mobile Unit (MU) – [A device that] performs the data exchange between the infrastructure and a road user. MUs may be integrated with cellular phones or otherwise be carried by pedestrians, cyclists, other travelers, or workers in the roadway. [CI]

Onboard Unit (OBU) – An ITS related hardware that performs the connected vehicle data exchange between the infrastructure and a vehicle and installed in a vehicle (includes an after-market device). An OBU may contain applications that process the data received from the infrastructure and other sources such as another OBU. [CI] Note that Onboard Equipment (OBE) refers to all the equipment onboard a vehicle and refers to ARC-IT v9.1 onboard equipment.

Personally Identifiable Information (PII) – Information on an individual's identity such as name, address, identifying number, telephone number, email address, etc.

Privacy – The ability of an individual or group to seclude themselves or seclude information about themselves, thereby revealing themselves selectively. [CAV]

Roadside Unit (RSU) -- A transportation field device that performs the data exchange between OBUs, MUs, and other infrastructure elements. [CI] Similar to the OBE, Roadside Equipment (RSE) refers to any field equipment including Connected Vehicle roadside units.

Signal Phase and Timing (SPaT) – The signal state of the intersection and how long this state will persist for each approach and lane that is active, according to the SPaT Benefits Report. The SPaT message sends the current state of each phase, with all-red intervals not transmitted.

Movements are given to specific lanes and approaches by use of the lane numbers present in the message. In a connected vehicle environment, the message is sent from the roadway infrastructure to approaching vehicles. [CAV]

SCMS/Security Backend -- A system that provides and manages security certificates to support trust within the CI system. [CI]

Transit Signal Priority (TSP) – A part of a signal system that allows transit agencies to manage service by prioritizing buses and granting their right of way based on schedule adherence or passenger loads. [CAV]

7.2 Acronyms and Abbreviations

ABM - Activity-based Model

ACS – American Community Survey

ADA – Americans with Disability Act

API – Application Programming Interface

ARC – Atlanta Regional Commission

ARC-IT – Architecture Reference for Cooperative and Intelligent Transportation

ATL – Atlanta-Region Transit Link Authority

ATL RIDES – Atlanta-Region Rider Information and Data Evaluation System

ATMS – Advanced Transportation Management System

AVL – Automatic Vehicle Location

CAD – Computer-Aided Dispatch

CC – Call Center

CCTV – Closed Circuit Television

CDP – Connected Data Platform

CMAQ – Congestion Mitigation and Air Quality Program

CO – Coordinator

ConOps – Concept of Operations

CPACS – Center for Pan Asian Community Services

CTP – Comprehensive Transportation Plan

CV – Connected Vehicle

CV1K – Regional Connected Vehicle Infrastructure Deployment Program

C-V2X – Cellular – Vehicle to Everything

CVTMP – Connected Vehicle Technology Master Plan

DBHDD – Georgia Department of Behavioral Health and Developmental Disabilities

DOE – Department of Energy

DOEd – Department of Education

DSRC – Dedicated Short-Range Communication

EMT – Executive Management Team

EVP – Emergency Vehicle Preemption

FCC – Federal Communication Commission

FHWA – Federal Highway Administration

FTA – Federal Transit Administration

GA Tech – Georgia Institute of Technology

GBFS – General Bikeshare Feed Specification

GCCV – Gwinnett County Connected Vehicles

GCDOT – Gwinnett County Department of Transportation

GCIT – Gwinnett County Information Technology

GCT – Gwinnett County Transit

GCTO – Gwinnett County Traffic and Operations

GDOT – Georgia Department of Transportation

GIS – Geographic Information System

G-MAP – Georgia Mobility and Accessibility Planner

GOSystems – GO Systems and Solutions

GPS – Geographic Positioning System

GRTA – Georgia Regional Transit Authority

GTFS – General Transit Feed Specification

I2P – infrastructure to person

ICD - Interface Control Document

IEEE – Institute of Electrical and Electronic Engineers

IMI – Integrated Mobility Innovation

IOO – Infrastructure Owner/Operator

I-SIG – Intelligent Traffic Signal System

IT – information technology

ITS – Intelligent Transportation Systems

IVR – Interactive Voice Response

JPO – Joint Program Office

LEP – Limited English proficiency

MAP – Map Data

MARTA – Metropolitan Atlanta Regional Transit Authority

MDC – Major Desired Capability

MMITSS – Multimodal Intelligent Traffic Signal System

MPO – Metropolitan Planning Organization

MU – Mobile Unit

NFC – Near-Field Communication

NIST – National Institute of Standards and Technology

NOAA – National Oceanic and Atmospheric Administration

OBE – Onboard Equipment

OBU – Onboard Unit

OSM – OpenStreetMap

OSS – Open Source Software

OST – Office of the Secretary

OTP – Open Trip Planner

PACE – Partnership for an Advanced Computing Environment

P2I – Person to Infrastructure

P2V – Person to Vehicle

PED-SIG – Mobile Accessible Pedestrian Signal System

PED-X – Pedestrian Crossing Signal

PII – Personally Identifiable Information

PMD – Performance Management Dashboard

PRG – Priority Request Generator

PRS – Priority Request Service

PSM – Personal Safety Message

RITIS – Regional Integrated Transportation Information System

RAD-IT – Regional Architecture Development for Intelligent Transportation

RSE – Roadside Equipment (also referred to as RSU)

RTP – Regional Transportation Plan

SAD – System Architecture Document

SCMS – Security Credential Management System

SDD – Systems Design Document

SET-IT - Systems Engineering Tool for Intelligent Transportation

Sidewalk MV – Sidewalk Machine Vision

SILCGA – Statewide Independent Living Council of Georgia

SLA – Service Level Agreement

SPaT – Signal, Phasing, and Timing

SRM – Signal Request Message

SSM – Signal Status Message

SRTA – State Road and Tollway Authority

STBGP – Surface Transportation Block Grant Program

ST-CTN – Safe Trips in a Connected Transportation Network

STM – Space Time Memory

SyRS – System Requirements Specification

TAP – Transportation Alternatives Program

TBD – To Be Determined

TCC – Traffic Control Center

TI – Traveler Information

TIC – Transportation Information Center

TIP – Transportation Improvement Program

TMC – Traffic Management Center

TNC – Transportation Network Company

TrMC – Transit Management Center

TSP – Transit Signal Priority

TTY – Text Telephone system

UI – User Interface

UPWP – Unified Planning Work Program

USDOT – U.S. Department of Transportation

V2P – Vehicle to Person

VLAN – Virtual Local Area Network

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