Phase 2 Concept of Operations (ConOps)

GDOT ITS4US Deployment Project

www.its.dot.gov/index.htm

Final Report — June 28, 2021

Phase 2 Update — January 20, 2025

FHWA-JPO-21-857

ITS4US

IT'S TRANSPORTATION FOR ALL OF US

U.S. Department of Transportation

Produced by Atlanta Regional Commission (ARC) and Georgia Department of Transportation (GDOT)
U.S. Department of Transportation
Office of the Assistant Secretary for Research and Technology
Intelligent Transportation Systems (ITS) Joint Program Office (JPO)
Office of the Secretary of Transportation (OST)
Federal Highway Administration (FHWA)
Federal Transit Administration (FTA)

Notice

This document is disseminated under the sponsorship of the Department of Transportation in the interest of information exchange. The United States Government assumes no liability for its contents or use thereof.

The U.S. Government is not endorsing any manufacturers, products, or services cited herein and any trade name that may appear in the work has been included only because it is essential to the contents of the work.

Technical Report Documentation Page

1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.
FHWA-JPO-21-857		

4. Title and Subtitle	5. Report Date
Phase 2 Concept of Operations (ConOps) GDOT ITS4US Deployment Project	January 20, 2025
	6. Performing Organization Code 075863845

7. Author(s)	8. Performing Organization Report No.
Kofi Wakhisi (ARC), Maria Roell (ARC), Polly Okunieff (Go Systems and Solutions), Natalie Smusz-Mengelkoch (Kimley-Horn & Associates), Tom Glueckert (Kimley-Horn & Associates), and Poonam Patel (Kimley-Horn & Associates)	

9. Performing Organization Name and Address	10. Work Unit No. (TRAIS)
Atlanta Regional Commission – Georgia Ste Gov Atlanta RGL COM 229 Peachtree St NE, Ste 100 Atlanta, GA 30303-1601	
	11. Contract or Grant No. 693JJ321C000008

12. Sponsoring Agency Name and Address	13. Type of Report and Period Covered
U.S. Department of Transportation ITS Joint Program Office 1200 New Jersey Avenue, SE Washington, DC 20590	Final Report
	14. Sponsoring Agency Code 693JJ3

15. Supplementary Notes

Elina Zlotchenko (Program Manager), Amalia Rodezno (Contracting Officer), Karen Timpone (Phase 1 Contracting Officer Representative), Norah Ocel (Agreement Officer Representative), Sarah Tarpgaard (Agreement Officer)

16. Abstract

The GDOT 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 serves as the Concept of Operations (ConOps) for the deployment project. This ConOps is the initial step in the systems engineering process whose goal is to lay the groundwork for a successful deployment of the ST-CTN project. The ConOps helps build consensus among stakeholders regarding project components, roles and responsibilities, and operations. The ConOps provides a foundation for more detailed analyses that will follow.

17. Keywords	18. Distribution Statement
Concept of Operations (ConOps); Safe Trips in a Connected Transportation Network; ITS4US; Complete Trip; Deployment	Phase I – Final Concept of Operations (ConOps)

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of Pages	22. Price
None	None	149	N/A

Form DOT F 1700.7 (8-72) **Reproduction of completed page authorized**

Revision History

Name	Date	Version	Summary of Changes	Approver
EMT / Subsystem Developers	19 May 2021	0.1	Initial Draft	JD Schneeberger
EMT / Subsystem Developers	21 May 2021	0.1	Draft Final	Maria Roell
EMT / Subsystem Developers	18 June 2021	0.2	Initial Final	Maria Roell
EMT	28 June 2021	1	Final	Maria Roell
EMT	30 August 2024	2	Final – Update for Phase 2	Polly Okunieff
EMT	20 January 2025	2.1	Final – Update for Phase 2	Natalie Smusz-Mengelkoch

PAGE INTENTIONALLY LEFT BLANK

Table of Contents

1. Scope 1

1.1 Project Background 2

1.2 Acronyms and Glossary 4

1.3 Document Overview 4

1.4 Sponsors, Project Team, and Intended Audience 5

1.5 System Scope 6

2. Referenced Documents 11

3. Current System and Situation 15

3.1 Background and Scope 15

3.1.1 Project Study Area 15

3.1.2 Objectives 16

3.1.3 Scope 17

3.2 Description of the Current System and Situation 18

3.2.1 ATL RIDES Multimodal Trip Planner 18

3.2.2 Space Time Memory (STM) Platform 20

3.2.3 Sidewalk Inventory Collection Tools 24

3.2.4 Gwinnett County and GDOT Connected Vehicle 27

3.2.5 Gwinnett County Transit 31

3.3 Current System Stakeholders and User Groups 33

3.4 Support Environment 38

3.5 Modes of Operation for Current System 39

3.6 Operational Policies and Constraints 40

4. Justification for and Nature of Changes 41

4.1 Justification of Changes 41

4.1.1 Transit 41

4.1.2 Trip Planning 42

4.1.3 CV Infrastructure 42

4.1.4 Data 43

4.1.5 Expectations of the Proposed Concept 43

4.2 Description of Desired Changes 45

4.2.1 Priorities Among Changes 47

4.2.2 End User Needs 48

4.2.3 Infrastructure Owner / Operator Needs 55

4.2.4 System Needs 57

4.3 Changes Considered but Not Included 62
4.4 Assumptions and Constraints 64
5. Concepts for the Proposed System 67
5.1 Background and Scope 67
5.2 Description of the Proposed System 68
5.2.1 G-MAP Multimodal Trip Planner Subsystem 70
5.2.2 Space Time Memory Platform Subsystem 72
5.2.3 Connected Vehicle Subsystem 75
5.2.4 System Interfaces and Interoperability 77
5.2.5 External System Interfaces 81
5.3 Stakeholders and Actors of the Proposed System 83
5.3.1 Stakeholder Roles 83
5.3.2 Other Involved Personnel 84
5.3.3 Roles and Responsibilities 85
5.3.4 Interactions Among System Stakeholders 88
5.4 Support Environment 89
5.5 Modes of Operations for Proposed System 89
5.6 Operational Policies and Constraints 91
5.6.1 Funding and Resources 91
5.6.2 Information Technology and Communications 92
6. Operational Scenarios 93
6.1 Use Case Structure 93
6.2 Use Case 1: Traveler's Complete Trip with ST-CTN 94
6.3 Use Case 2: Connected Vehicle 110
7. Summary of Impacts 119
7.1 Operational Impacts 119
7.1.1 Gwinnett County Transit Operational Impacts 119
7.1.2 GCDOT Operational Impacts 120
7.1.3 GDOT Operational Impacts 120
7.1.4 G-MAP Operational Impacts 120
7.1.5 Transit Users Operational Impacts 121
7.2 Organizational Impacts 121
7.2.1 Gwinnett County Transit Organizational Impacts 121
7.2.2 GCDOT Organizational Impacts 121
7.2.3 GDOT Organizational Impacts 122
7.2.4 ARC Organizational Impacts 122
7.2.5 SILCGA Organizational Impacts 122

7.3 Impacts During Development 123

8. Analysis of the Proposed Systems 125

8.1 Analysis of the Proposed System 125

8.1.1 Expected Benefits 125

8.1.2 Limitations and Disadvantages 129

8.2 Alternatives and Trade-Offs Considered 131

Appendix A. Acronyms 133

Appendix B. Glossary 137

List of Tables

Table 1. Referenced Documents 11
Table 2. ATL RIDES Milestone Schedule 20
Table 3. STM Platform Milestones Schedule 24
Table 4. Sidewalk Inventory Milestones Schedule 27
Table 5. CV Milestone Schedule 30
Table 6. CTP Needs Assessment Transit Speeds (Average Travel Speed by GCT Route) 32
Table 7. Gwinnett County Transit Milestones Schedule 33
Table 8. Current System Stakeholders and User Groups 34
Table 9. System Users' Expected Benefits 44
Table 10. End User Needs 49
Table 11. IOO Needs 55
Table 12. System Needs 58
Table 13. Considered Changes Not Included 63
Table 14. Critical ST-CTN Connection Descriptions 69
Table 15. ST-CTN System Interfaces and Interoperability 78
Table 16. External System Interfaces – Inputs 81
Table 17. External System Interfaces – Outputs 83
Table 18. Stakeholders and Roles in the ST-CTN System 83
Table 19. Roles and Responsibilities for the G-MAP Subsystem 85
Table 20. Roles and Responsibilities for the STM Subsystem 87
Table 21. Roles and Responsibilities for the CV Subsystem 88
Table 22. Critical ST-CTN Connection Descriptions 98
Table 23. Use Case 1: End User's Complete Trip with ST-CTN Operational Flow 100
Table 24. CV Application Descriptions 110
Table 25. Critical ST-CTN Use Case 2 CV Connection Descriptions 112
Table 26. Use Case 2: Connected Vehicle Application Operational Flows 115
Table 27. Proposed System Expected Benefits 125

List of Figures

Figure 1. The “Vee” Systems Engineering Process (Source: FHWA) 2
Figure 2. Phases of the Complete Trip – ITS4US Deployment Program (Source: USDOT) 3
Figure 3. ST-CTN Deployment Site Map (Source: ARC) 4
Figure 4. Traveler’s Complete Trip (Source: ARC) 6
Figure 5. ST-CTN High-Level Context Diagram (Source: ARC) 8
Figure 6. Current ATL RIDES Context Diagram (Source: ARC) 19
Figure 7. Current STM Context Diagram (Source: ARC) 22
Figure 8. Current Sidewalk Inventory Collection Tools (Source: ARC) 25
Figure 9. Sidewalk Sentry Wheelchair (Source: GA Tech) 26
Figure 10. Sidewalk Scout User Interface (Source: GA Tech) 26
Figure 11. Gwinnett County CV Program RSU Deployment Locations (Source: Gwinnett County) 28
Figure 12. Gwinnett County and GDOT CV Program Context Diagram (Source: ARC) 29
Figure 13. Ride Gwinnett Local Route Service Map (Source: Gwinnett County) 31
Figure 14. Ride Gwinnett Current Bus and Operational Technology (Source: ARC) 32
Figure 15. Needs Priority Survey Introduction (Source: ARC) 48
Figure 16. Safe Trip in a Connected Transportation Network Simplified Context Diagram (Source: ARC) 68
Figure 17. Safe Trip in a Connected Transportation Network Data Exchange Flow Diagram (Source: ARC) 69
Figure 18. Proposed G-MAP Subsystem Extension (Source: ARC) 71
Figure 19. Proposed STM Subsystem Extension (Source: ARC) 73
Figure 20. Proposed CV Subsystem Extension (Source: ARC) 76
Figure 21. End User’s Complete Trip with ST-CTN (Source: ARC) 95
Figure 22. Use Case #1 Information Flow in the ST-CTN System (Source: ARC) 97
Figure 23. Use Case 2 Connected Vehicle Applications Information Flow in the ST-CTN System (Source: ARC) 111

1. Scope

This document serves as the Concept of Operations (ConOps) for the Safe Trips in a Connected Transportation Network (ST-CTN) project led by the Georgia Department of Transportation (GDOT) in Gwinnett County, Georgia as part of U.S. Department of Transportation's (USDOT's) Complete Trip – ITS4US Deployment Program. The ST-CTN concept is comprised of an integrated set of advanced transportation technology solutions – connected vehicles (CV), transit signal priority (TSP), machine learning, and predictive analytics – to support safe and complete trips. The project seeks to enhance accessibility for travelers in underserved communities including those with disabilities, older adult populations, low-income communities, and limited English proficiency (LEP) communities.

This ConOps is the initial step in the systems engineering process whose goal is to lay the groundwork for a successful deployment of the ST-CTN project. The ConOps helps build consensus among stakeholders regarding project components, roles and responsibilities, and operations. This helps minimize risks of conflict or change later in the project development process. The ConOps provides a foundation for more detailed analyses that will follow. Key objectives of the ConOps include:

- Identification of user needs and system capabilities in terms that all project stakeholders can understand
- Stakeholder agreement on interrelationships and roles and responsibilities for the system
- Shared understanding by system owners, operators, maintainers, and developers of how the system will operate under different scenarios
- Agreement on key performance measures and a basic plan for how the system will be validated at the end of project development

Systems engineering focuses on defining customer needs and required functionality early in the development cycle; documenting requirements; and then proceeding with design synthesis and system validation while considering the complete problem. The "Vee" Diagram, shown in **Figure 1**, illustrates the systems engineering process beginning with a focus of defining user needs and required functionality early in the development cycle, documenting requirements, and then tracing those decisions throughout the implementation process.

As the ST-CTN project progresses from concept definition (and planning) to design and testing, most components of the project will follow the systems engineering process outlined in **Figure 1**. As such, the needs and desired capabilities identified in this ConOps will serve as the basis for requirements and design later in the process. Other components of the ST-CTN project will follow an agile development process where requirements and solutions evolve through collaboration between self-organizing cross-functional teams. For agile projects, needs and desired capabilities developed in the ConOps will ultimately drive subsystem's user story roadmaps for developers implementing an agile development process.

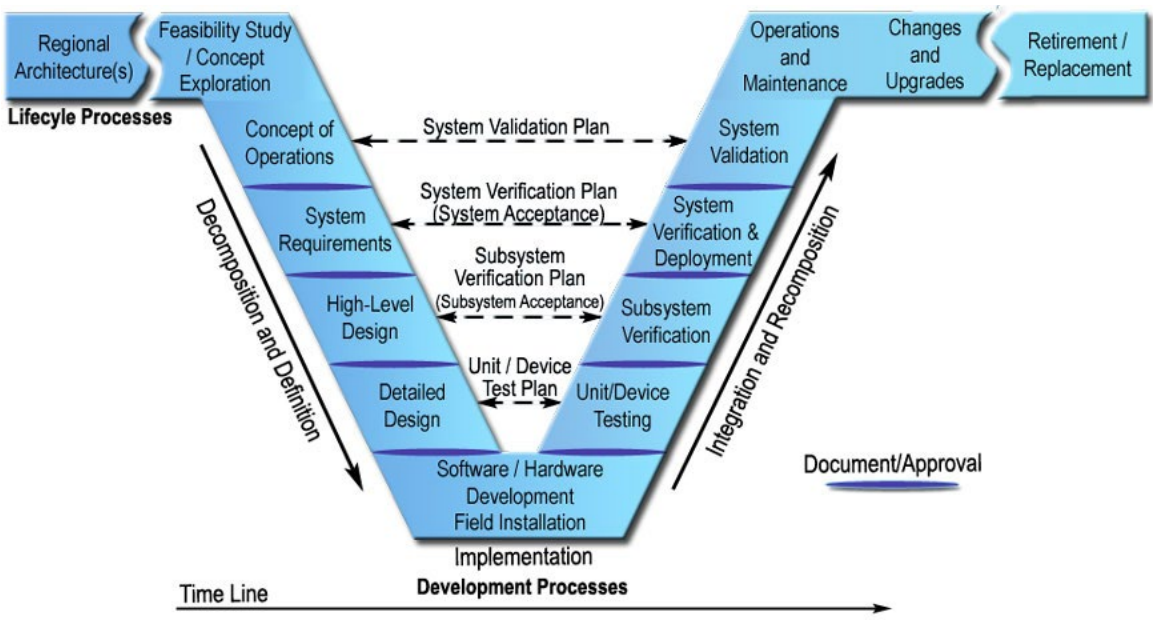

Figure 1. The "Vee" Systems Engineering Process (Source: FHWA)

1.1 Project Background

The Complete Trip - ITS4US Deployment Program is a multimodal effort – led by the Intelligent Transportation Systems (ITS) Joint Program Office (JPO) – and supported by the Office of the Secretary (OST), Federal Highway Administration (FHWA), and Federal Transit Administration (FTA) – to identify ways to provide more efficient, affordable, and accessible transportation options for underserved communities that often face greater challenges in accessing essential services. The program aims to solve mobility challenges for all travelers with a specific focus on underserved communities, including people with disabilities, older adults, low-income individuals, and LEP travelers. This program seeks to enable communities to build local partnerships, develop and deploy integrated and replicable mobility solutions to achieve complete trips for all travelers.

The Complete Trip – ITS4US Deployment Program will be executed in three phases. As depicted in **Figure 2**, deployment sites are expected to go through three phases:

- **Phase 1.** Concept Development
- **Phase 2.** Design and Testing
- **Phase 3.** Operations and Evaluation

Post deployment, sites are expected to sustain operations for a minimum period of five years without supplementary federal funds.

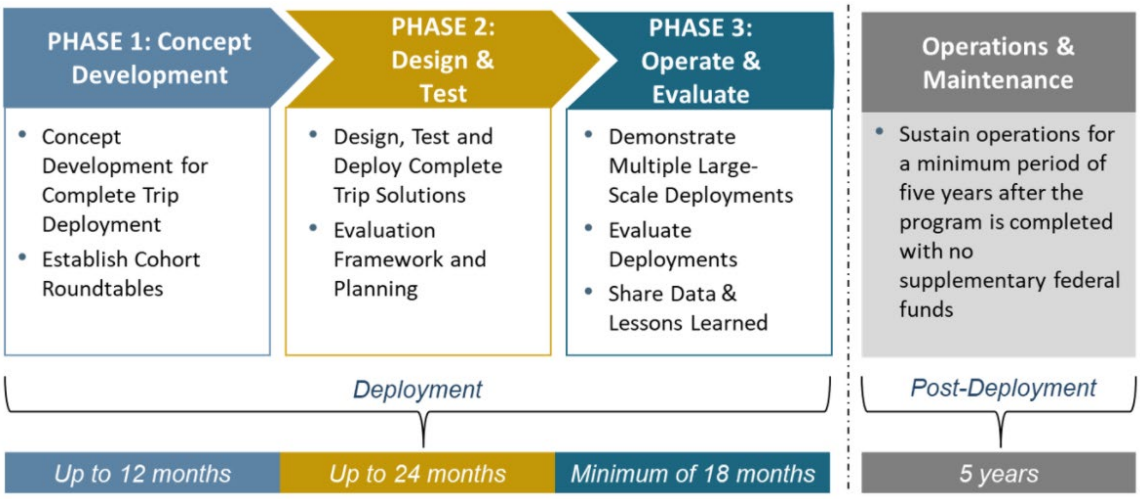

Figure 2. Phases of the Complete Trip – ITS4US Deployment Program (Source: USDOT)

ARC was selected by USDOT as one of the Phase 1 projects to showcase innovative business partnerships, technologies, and practices that promote independent mobility for all travelers regardless of location, income, or disability. The project team intends to address multiple aspects of the Complete Trip by integrating multiple technological innovations. The ST-CTN system will integrate CV data with an open-sourced web-based and mobile application. The application 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. Underserved communities of interest include:

- **People with Disabilities.** Persons with a physical disability may be unable to, or have trouble, performing specific tasks (i.e., boarding a bus, navigating a sidewalk, or hearing specific broadcast messages or alerts) without the use of a device such as a wheelchair, crutches, hearing aid, or white cane. A disability is the state in which an individual has a limitation in independent, purposeful physical movement of the body or of one or more extremities, and substantially limits one or more major life activities.
- **Older Adults.** Older adults may have trouble performing specific tasks within a set time period (e.g., crossing a road or boarding a transit vehicle) or standing for an extended period of time. Older adults are people (typically 60 years of age or older) who may have limited mobility that impacts their ability to perform daily activities.
- **Limited English Proficiency (LEP) Communities.** A person with LEP refers to a person who is not fluent in the English language. Users who have LEP may have trouble understanding directions and alerts when delivered in their non-native language, may have different cultural norms that make it difficult to follow directions others would feel are standard, or may have difficulty understanding wayfinding signs.
- **Low Income Communities.** Users who fall into the low-income category may be single or no-vehicle households, may have trouble accessing different forms of technology (i.e., cellphone or personal computer), may be on reduced payment or fixed payment transit plans, may be unbanked (e.g., not have access to a bank account or credit card), or may use transit as their sole means of transportation. A person who has low income has a median household income that is at or below the Department of Health and Human

Services poverty guidelines. Poverty guidelines designate $26,500 as the threshold for a household of four in the state of Georgia in 2021.

The ST-CTN project will be implemented in Gwinnett County. The project area is home to a significant portion of the underserved communities that reside in Gwinnett County. Over 50% of the disabled population, LEP population, and zero vehicle household population in Gwinnett County is located within the project area. Approximately 50% of the low-income population and approximately 25% of the older adult population in Gwinnett County is located within the project area. It also faces many of the same challenges as much of Metro Atlanta, including suburban land-uses; wide, high-speed roadways; and inconsistent pedestrian infrastructure. This area also was chosen to leverage its implementation readiness and the planning work recently completed at the County level on CVs, as well as transit needs and expansion. A map of the project area can be found in **Figure 3**.

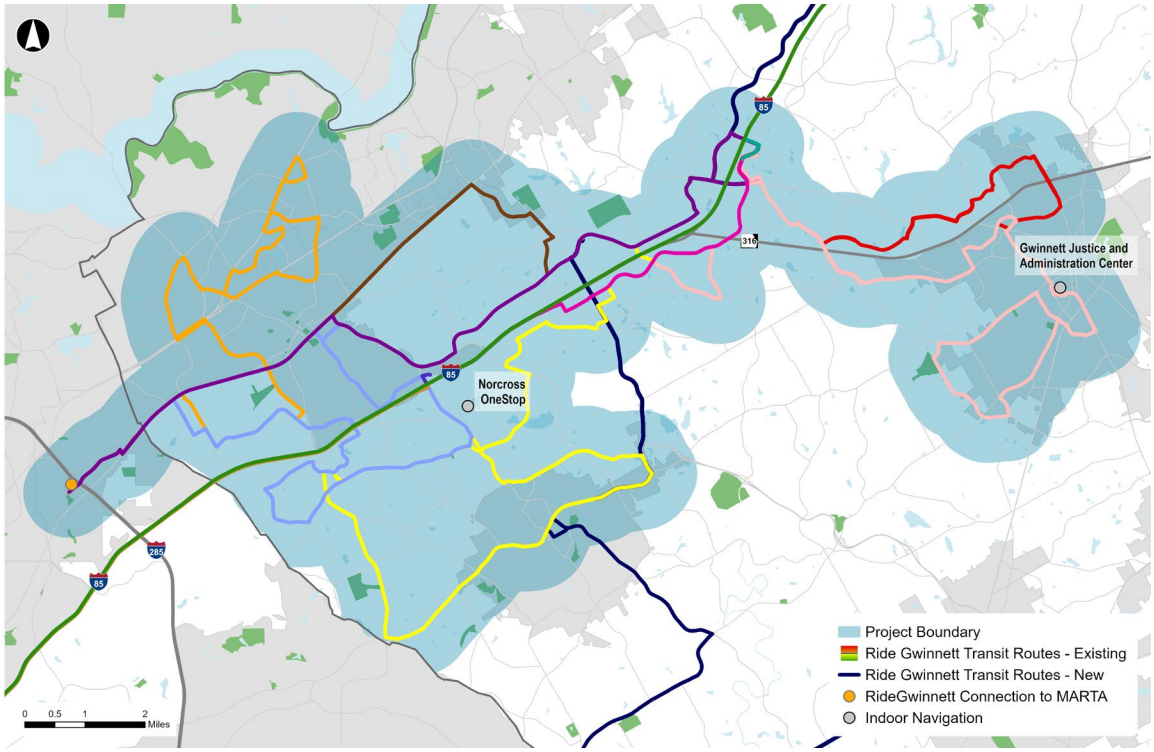

Figure 3. ST-CTN Deployment Site Map (Source: ARC)

1.2 Acronyms and Glossary

A list of acronyms can be found in **Appendix A** and the glossary of terms is provided in **Appendix B**.

1.3 Document Overview

This ConOps document is based on the ConOps template provided by the USDOT for the ITS4US-Complete Trip program and adapted from the Institute of Electrical and Electronic

Engineers (IEEE) Guide for information Technology – System Definition – Concept of Operations (ConOps Document, IEEE Standard 1362, 1998). The remainder of this document consists of the following sections and content:

- **Section 2** (Referenced Documents) identifies external documents referenced throughout the ConOps document.
- **Section 3** (Current System and Situation) describes the existing system from the standpoint of the project stakeholders.
- **Section 4** (Justification for and Nature of Changes) describes the shortcomings of the current system from the standpoint of the project stakeholders. It also provides the user needs – or desired capabilities – for the proposed system.
- **Section 5** (Concepts for the Proposed System) describes the proposed system and subsystem functionality required to meet the user needs identified in **Section 4**. This section also describes the key features, the users, and their interaction with the system.
- **Section 6** (Operational Scenarios) documents the user-oriented use cases for how the proposed system should operate.
- **Section 7** (Summary of Impacts) describes the operational and organizational impacts of the new system on the users, developers, maintainers, and other agencies or organization involved with the ST-CTN system.
- **Section 8** (Analysis of the Proposed Systems) provides an analysis of the benefits, limitations, advantages, disadvantages, and alternatives considered for the proposed system.

1.4 Sponsors, Project Team, and Intended Audience

The ST-CTN project is being led by GDOT in Gwinnett County, GA. The project team intends to address multiple aspects of the Complete Trip through the development of the ST-CTN concept. The ST-CTN project team includes the following partners and their respective roles on the project:

- **Georgia Department of Transportation (GDOT).** Project management, concept development, concept collaboration lead, and CV integration lead
- **ARC.** Project management, concept development, and concept collaboration lead
- **Gwinnett County Department of Transportation (GCDOT).** System development and local agency deployment lead
- **Ride Gwinnett (GCT).** System development and local agency deployment lead
- **Atlanta-Region Transit Link Authority (ATL).** Atlanta-Region Rider Information and Data Evaluation System (ATL RIDES) integration lead
- **Statewide Independent Living Council of Georgia (SILCGA).** Community coordinator lead
- **Georgia Institute of Technology (GA Tech).** Technical innovation lead
- **GO Systems and Solutions (GOSystems).** System development lead

- **Arcadis IBI Group.** Georgia Mobile Accessibility Planner (G-MAP) system and mobility app development lead
- **Kimley-Horn and Associates, Inc. (KHA).** Concept development and production management leads

The intended audience of this ConOps includes the stakeholders who will use, develop, and manage the software and infrastructure that will be deployed as a part of the ST-CTN system. These stakeholders include: underserved communities within the program limits, GCDOT personnel involved with transportation systems management and operations and CV systems, GCT personnel involved with fleet management and operations, GDOT personnel involved with transportation systems management and operations and CV systems, and the ATL personnel involved with the ATL RIDES system. Additionally, USDOT personnel and future deployment teams will find this document useful for developing assessment documents and understanding the context of the ST-CTN system.

1.5 System Scope

The ST-CTN project aims to upgrade and integrate existing technologies and services to assist underserved populations with completing their 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. As an illustration of how the ST-CTN system will be used, transit-based trips were delineated into six segments (as depicted in **Figure 4**) to allow for easier understanding and a greater breakdown of priorities and goals.

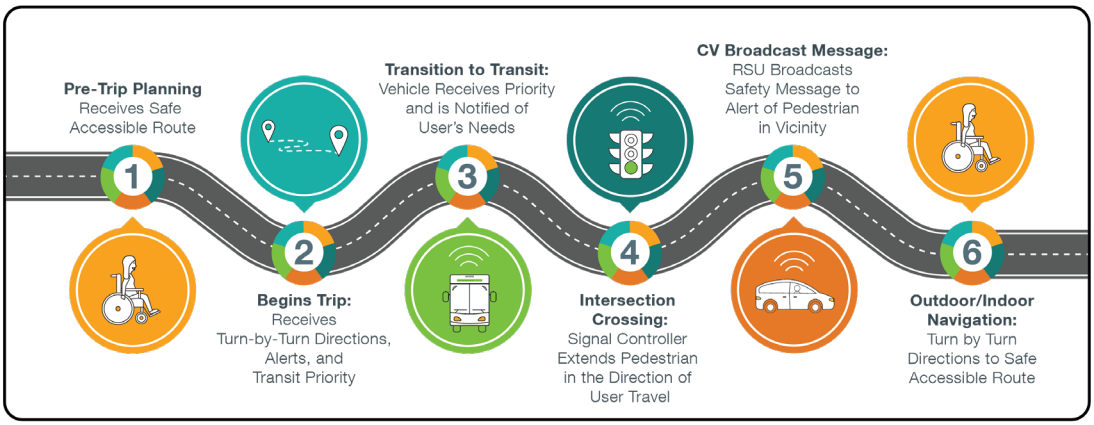

Figure 4. Traveler's Complete Trip (Source: ARC)

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 TSP if the user requires additional time boarding or alighting a transit vehicle or is unable to stand for long periods.
    - 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 or is unable to stand for long periods.
- **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 interacts with the signal controller in that an authorized system call is made to the controller which extends the pedestrian phase in the direction of user travel.
    - Allows the user to communicate with connected intersections if they are unable to reach or press the crosswalk button.
    - Provides the user with information about the intersection crossing and adds time to the crossing if needed.
- **Step 5 CV Broadcast Message.** Roadside units (RSUs) broadcast safety message to alert connected vehicles of pedestrians in the intersection.
    - Provides the ability for users to remotely request service from transit vehicles while waiting to board or alight.
    - Provides communications to CVs from pedestrian cross signal systems (via RSUs) to make them aware of pedestrians crossing a roadway.
    - Provides communications between transit vehicles and travelers waiting at a transit stop to make them aware of each other.
- **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.

Additionally, user reporting will be available through the application to allow users to provide feedback on infrastructure that is currently out of service (elevators, escalators, etc.) or not accessible due to temporary or permanent obstructions (sidewalks, shared use-paths, etc.). This feature will help users avoid becoming delayed or stranded because of unforeseen outages. Transit providers, city, county, and/or construction crews currently flag outages into the system. New features being proposed as part of the project will allow users to flag infrastructure that has not already been flagged by public agency staff. System development and system integrations completed within the scope of this pilot 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; and use crowdsourced data collection to update infrastructure conditions.

The ST-CTN project will use open source software (OSS) tools allowing for the results to be replicable across the region and sidewalk inventory innovations will reduce the costs of managing pedestrian assets in any community.

The conceptual diagram presented in **Figure 5** illustrates the concept, including the software, hardware, communications, and services planned for ST-CTN as shown.

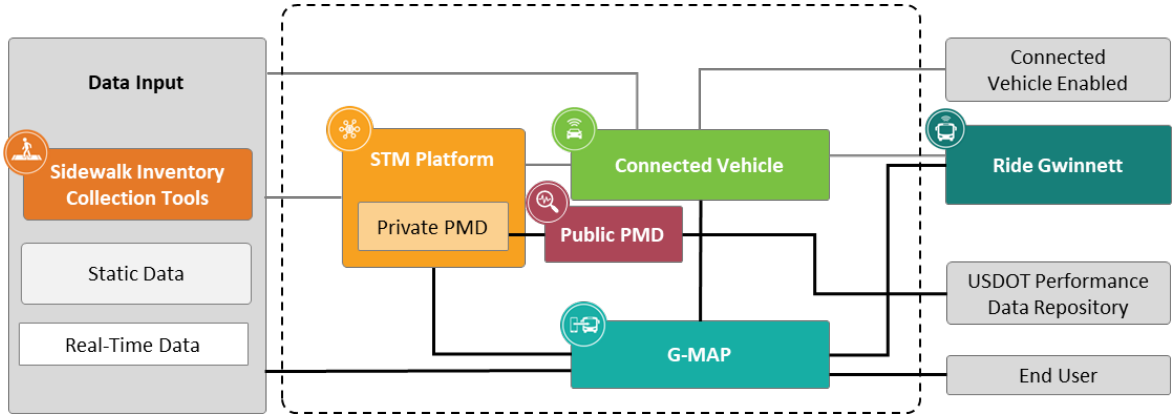

Figure 5. ST-CTN High-Level Context Diagram (Source: ARC)

The scope of the project is limited to development of interfaces between existing programs that expand the capabilities of these programs. The existing initiatives that are being leveraged to support the proposed ST-CTN system are described below. Each system is associated with an icon and color. These icons and colors are used throughout the ConOps document to clearly identify the critical components of ST-CTN.

OTP for G-MAP. ATL RIDES includes an 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 ap turn-by-turn

directions. The Open Trip Planner (OTP) architecture facilitates integration with additional OSS tools including a data analytics engine, call center 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 Americans with Disability Act (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 will be 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 costs 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. The PMD will include a public PMD for the public to access open data presented on an interactive dashboard to the public.

2. Referenced Documents

Table 1 lists the documents that were used to support the development of the ST-CTN ConOps document. References to these documents are identified with the acronym provided in brackets.

Table 1. 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. (2024).
[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
[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.
[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.
[FAST]	U.S. Department of Transportation Federal Highway Administration. (2015). Fixing America's Surface Transportation Act.
[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.

ID	Referenced Documents
[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.

3. Current System and Situation

This section describes the multimodal transportation network within the project study area as it currently exists and highlights the problems and challenges that motivated the development of the proposed system. It defines how the region currently operates regarding transportation for underserved communities and the stakeholders, systems, and other components that are currently in place.

3.1 Background and Scope

Access to a robust multimodal transportation system is crucial to providing equitable access for all communities within the Metro Atlanta region and around the United States. Housing, employment, education, and healthcare choices are all dictated by access to a transportation system that allows users to make complete trips [ICS]. A complete trip is defined by an individual's ability to go from origin to destination reliably, spontaneously, confidently, independently, safely, and efficiently without gaps in the travel chain regardless of location, income, or disability [BAA]. Stakeholders, particularly those within underserved communities, need more traveler information and support to complete their trips safely, reliably, and efficiently.

3.1.1 Project Study Area

The project study area is an example of a transportation network that needs to provide complete trips for its population. Even though the project study area only contains 30% of Gwinnett County's total population, it contains over 50% of the population of people with disabilities, over 50% of LEP households, over 50% of zero-vehicle households, and nearly 50% of households that classify as low income [ACS].

The population in Gwinnett County has grown by over 16% between 2010 and 2019 estimates, outpacing surrounding counties including DeKalb County and Fulton County which had a growth rate over the same period of 9.7% and 15.6% respectively [QF]. According to the Gwinnett County's Destination 2040 Comprehensive Transportation Plan (CTP), the majority of the population growth is occurring within the ST-CTN project study area [GCTP-2].

The mean travel time to work for Gwinnett County between the years of 2015 and 2019 is 34.1 minutes. This is higher compared to its neighboring counties where the mean travel time to work in DeKalb and Fulton Counties are 32.3 minutes and 28.8 minutes, respectively. Several major roadways cut through the project area, including Buford Highway, Peachtree Industrial Boulevard, and Interstate 85 (I-85). Buford Highway is a well-known destination in the region for having the city's largest collection of authentic ethnic restaurants, a source of pride in its community. However, Buford Highway is notoriously dangerous for pedestrians [DW]. Peachtree Industrial Boulevard is also a major roadway through the project area, handling significant amounts of commuter travel and freight traffic volumes. I-85 bisects the project area, creating a boundary that interrupts accessibility between communities. As of this submittal Gwinnett County has not

completed an ADA Transition Plan. Inventory of sidewalks within the project limits is not published.

A robust transit system exists in the project study area including GCT fixed route and on-demand paratransit service and Center for Pan Asian Community Services (CPACS) mobility on-demand service. Major destinations connected to the area's bus service include, Northside Hospital at Gwinnett, Sugarloaf Mills Shopping Center, the Gwinnett Place Mall, the Gwinnett Justice and Administration Center (GJAC), OneStop Norcross, a health and human services center, the Gwinnett Civic Center and Arena, and HomeFirst Gwinnett Initiative, a nonprofit addressing homelessness in Gwinnett County. There are several important transit connections and transfer points within the project area. Metropolitan Atlanta Regional Transit Authority's (MARTA) Doraville Station provides a crucial connection between GCT and MARTA rail destinations, which includes direct service to the airport and downtown Atlanta. Ride Gwinnett Transit Center also is a major transfer point between GCT transit lines and CPACS mobility on-demand transit services.

The project study area is based on the GCT on-demand paratransit service area which is provided within ¾ mile on either side of the existing fixed route system. This encompasses seven fixed route lines with connections to MARTA heavy rail. CPACS-Mobility is an on-demand bus service that operates within Gwinnett County and offers expanded transportation services to immigrant and refugee LEP seniors above 65 years old, disabled persons 19 and older, and transportation disadvantaged users [CPACS]. The goal of CPACS-Mobility is to increase access to transportation for refugees, immigrant seniors, and disabled persons providing quality of life trips such as shopping, recreation, religious, civic, and for social purposes. CPACS-Mobility buses also provide late-night, weekend, shuttle, demand-responsive van, and ridesharing/carpool/vanpool services.

3.1.2 Objectives

One of the main goals for GDOT, ARC, and the region, as stated in The Atlanta Region's Plan Policy Framework, is to ensure a comprehensive transportation network, incorporating regional transit and 21st century technology. GDOT and ARC have identified many means to achieve this goal including promoting an accessible and equitable transportation system and fostering the application of advanced technologies to the transportation system. Many areas in the Atlanta region have infrastructure and land use challenges that make getting to transit difficult and reduce access to jobs and services. It is vital to maintain and expand the comprehensive transportation system to ensure equal access for everyone. Technology has already changed the way residents live and travel in the Atlanta region. New technologies can provide travelers with real-time data to inform decisions and will continue to shape the way residents and goods move in the future. The Atlanta Region supports the development and further application of existing technologies, such as user friendly, accessible smart phone apps, to improve the travel experience.

Many agencies and advocates are already working toward these goals in ways that ST-CTN will be able to leverage. The Atlanta region is home to one of the largest CV deployments in the United States – CV1K. CV1K program's aim is to increase safety by deploying interoperable CV technologies at signalized intersections throughout the Atlanta region. The program provides support to configure, operate, and maintain CV infrastructure and applications, including TSP. Gwinnett County is the largest recipient of the first phase of CV1K in keeping with the priorities stated in the CVTMP [CVTMP]. The CVTMP's goals are 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 set the standard for implementing CVs.

Among the high priorities identified is establishing a mobile accessible safety program and alternative strategies for TSP in Gwinnett County.

ATL is currently in development of ATL RIDES. The system is a multi-modal trip planner and mobile application with integrated mobile fare payment options and a Connected Data Platform (CDP) using regional GTFS feeds. The goal of this project is to give all travelers easier access to consolidated transit information, making it easier to use transit. The tool supports multi-agency context, multilingual support, and live-tracking capabilities using GTFS feeds. The OTP architecture facilitates integration with additional OSS tools including a data analytics engine, call center, and account management system.

GA Tech researchers have created an asset management system and shortest path routing tool for pedestrian pathways, SidewalkSim. 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 any user-specified needs. Also, part of GA Tech's research is a python platform, STM, which 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. The STM output allows routing decisions to incorporate travel time, safety, and other impedance values into path selection. Both of these tools have been created to give all travelers better access to accurate data when they plan their trip.

3.1.3 Scope

The current systems relevant to the ST-CTN project regarding transportation for underserved communities are comprised of disparate systems, projects, and initiatives, including ATL RIDES, STM Platform, Sidewalk Inventory Collection Tools, GC and GDOT CV Program, and GCT. These systems each serve their current stakeholders within the scope of their respective systems.

- **ATL RIDES.** This effort supports multimodal trip planning for regional travelers, but has limited features to support the underserved communities that are the focus of the ST-CTN project.

- **STM Platform.** This research-grade model is used to predict trajectories through the regional network as congestion evolves in time and space and to provide users with more realistic estimates of commute duration, impedance value, and energy use across alternative departure times, routes, and transportation modes.

- **Sidewalk Inventory Collection Tools.** These tools are used to inventory pedestrian facilities and the current asset characteristics, including accessibility and obstruction features. Gwinnett County data does not currently exist.

- **GC and GDOT CV Program.** This initiative provides CV infrastructure to support the future development and testing of CV applications, original equipment manufacturers (OEM), and third parties. Gwinnett County existing applications under development include emergency vehicle preemption (EVP) and TSP.

- **GCT.** GCT currently provides commuter, local, and on-demand transit service to all, including the underserved community, within the GCT service area.

3.2 Description of the Current System and Situation

The following sections provide an overview of the current systems relevant to the ST-CTN project and their respective current operational environments; capabilities, functions, and features; major system components; inputs, outputs, and data flows; performance characteristics; and system schedules.

3.2.1 ATL RIDES Multimodal Trip Planner

The ATL was awarded funding through FTA's Integrated Mobility Innovation (IMI) Demonstration program in March 2020 to create ATL RIDES. It is a journey planning application using a connected data environment to improve the experience of multi-modal trip planning, increase transit ridership, provide coordinated information across the region's multiple transit operators, and demonstrate using a connected data environment to support transportation decision making. ATL RIDES is being created to provide more reliable and easier to access transit data to all travelers making it easier for them to utilize the region's transit services.

Operational Environment. ATL RIDES platform is an OSS multimodal trip planning and mobile application, integrated mobile fare payment options, and a CDP using regional GTFS feeds. The trip planning platform is built on the latest version of OTP with a web application and mobile app.

Capabilities, Functions, and Features. The tool supports multi-agency context, multilingual support, and live-tracking capabilities. The responsive web application and native mobile apps provide the tools and functions for making trip search requests, updating preferences and settings, viewing map-based and itinerary views of trip results and managing a user's account, including saved preferences, favorite locations, and stored trips for monitoring.

Major System Components. ATL RIDES consists of four primary modules: (i) the core OTP routing engine, (ii) OTP-middleware, (iii) responsive web app user interface (UI), and native mobile apps for iOS and Android smartphones. **Figure 6** provides the current ATL RIDES system context diagram.

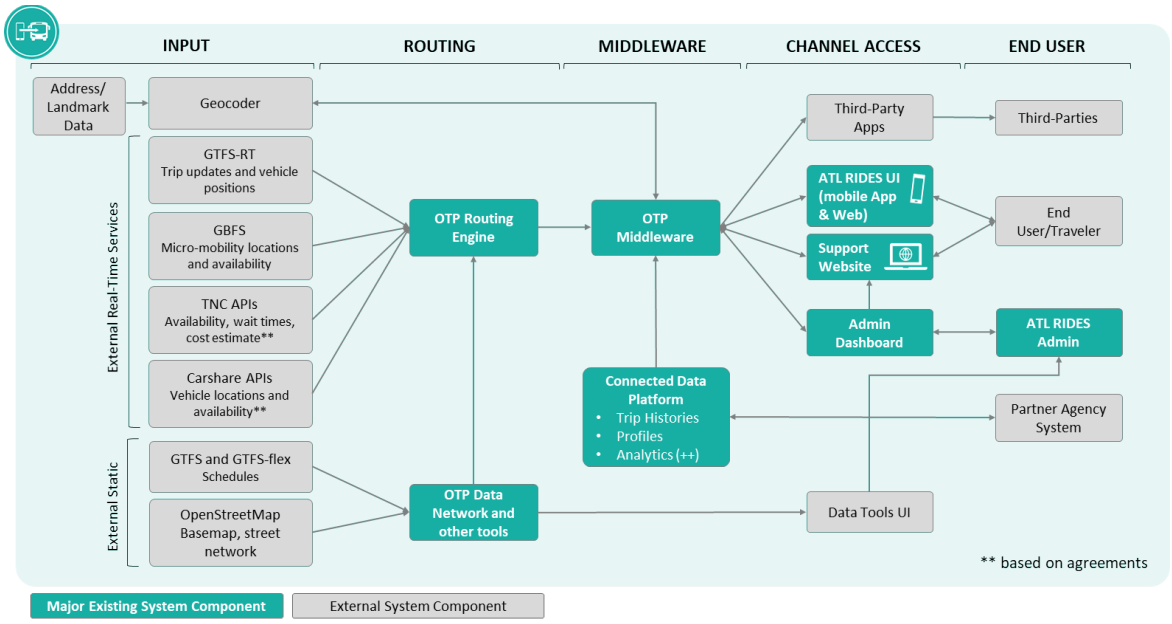

Figure 6. Current ATL RIDES Context Diagram (Source: ARC)

Inputs, Outputs, and Data Flow. The ATL RIDES system currently interfaces with a number of real-time data services and static data sets. The core OTP routing engine receives data from a range of real-time and static sources, including:

- **Real-Time Services**
  - Transit real-time updates for service alerts, vehicle positions, and arrival/departure predictions – General Transit Feed Specification-Real Time (GTFS-RT)
  - Micro-mobility (bikeshare and e-scooter) locations and availability – General Bikeshare Feed Specification (GBFS)
  - Transportation Network Company (TNC) availability, wait time, and cost estimates via provider APIs
  - Carshare vehicle locations and availability via provider APIs
- **Static Data Sets**
  - Transit schedule information (GTFS for fixed route and GTFS-Flex for demand responsive and flexible schedules)
  - Road and sidewalk network – OpenStreetMap (OSM)

When a trip search request is passed from the middleware to the routing engine, the routing engine returns a range of multimodal trip options based on the origin, destination, time preferences and mode preferences that were made in the user's trip search request. These trip itinerary options are passed back to the web app or mobile app where the user made the search and displayed in the app for the user to filter, sort, and compare in order to select their preferred trip option.

The ATL RIDES system relies on the external Geocode.earth geocoding API service when a user makes a trip request to translate addresses and placenames into latitude/longitude values that can be understood by the routing engine. That request is then passed on to the OTP-middleware.

The OTP-middleware coordinates between the system modules, passing the request on to the core routing engine, but also is responsible for storing user account data and monitoring saved trips for service alerts, delays, or other disruptions that would trigger a notification to the user. The OTP-middleware also includes the CDP, which allows anonymized trip plan requests, trip itineraries and other data generated by the ATL RIDES system to be available for analysis and/or partner agency use.

Performance Characteristics. Performance of the ATL RIDES platform consists of availability to customers, speed of trip plan response, and quality/reliability of information. The system's routing engine is cloud hosted behind a load balancer, allowing the system to be scaled to meet demand. This also provides redundancy in the event there is an issue with the routing engine server. Regular performance testing of trip plan response time ensures adequate compute resources are dedicated at any given time. In addition, regular audits of input data quality, and spot checking of trip plan results help ensure high quality, reliable trip plan information.

For system security, ATL RIDES relies on the Auth0 user authentication service for username/ password and system permissions management. To protect user privacy, trip plan request and results data are only archived for analysis if the user has opted-in to trip plan logging, and their logged data is only made available for analysis in an anonymized format. In addition, if a user later chooses to opt-out of data logging, all of their records are purged from the system.

System Schedule. The ATL RIDES system is currently being developed by the ATL through the FTA's IMI Program. The project is committed to be completed in May of 2022 with the following milestones scheduled for completion as shown below in **Table 2**.

Table 2. ATL RIDES Milestone Schedule

Project Item	Completion Date
Regional Data Assessment Support and Policy Recommendations	Completed Spring 2021
Conceptual and Detailed Design	Completed Spring 2021
Modifications to the OTP Routing Engine and React-User Interface	September 2021
CDP and OTP Middleware Development	September 2021
Mobile Application Development and Mobile Ticketing Integration	September 2021
User Testing and Evaluation	September 2022
Data Analysis from the CDP	September 2022
Customer Education and Outreach	September 2022

3.2.2 Space Time Memory (STM) Platform

The regional STM, as currently deployed, is a research-grade model developed by GA Tech from 2016-2018 for the Department of Energy (DOE) Advanced Research Projects Agency-Energy (ARPA-E) Traveler Response Architecture using Novel Signaling for Network Efficient in Transportation (TRANSNET) Atlanta project. The current regional STM is being used by GA Tech in shortest path modeling for research and data analysis and outputs. The STM stores historic

traffic condition data for every link in the modeled transportation system at 5-minute temporal resolution, along with more than 100 infrastructure parameters, for use in deep learning applications. The system can use current traffic conditions to predict the shortest path from any origin to destination on the network using traditional Dijkstra processes, and is designed to predict shortest paths based upon congestion formation and dissipation projected over the short term (within one hour) using machine learning processes. The system finds the shortest paths by moving vehicles through space-time trajectories, where the link speeds encountered by the vehicle along each path is the projected speed at the time the vehicle arrives at each link. The goal of this system is to predict trajectories through the network as congestion evolves in time and space and to provide users with more realistic estimates of commute duration, impedance value, and energy use across alternative departure times, routes, and transportation modes.

Operational Environment. The STM platform is an OSS application that 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. It is currently comprised of a dynamic data broker which manages the operational and predictive analysis engine.

Capabilities, Functions, and Features. The STM platform is designed to ingest data from a wide variety of sources, including GDOT NaviGAtor data feeds, GTFS data feeds from GCT and MARTA, ARC's planning network, National Oceanic and Atmospheric Administration (NOAA), and any third-party system capable of providing real-time feeds for roadway traffic conditions, as shown in **Figure 7**. The STM attaches data to the network as link attributes in five-minute time bins through a process of data transformation and data fusion. The data transformation includes steps for data verification, validity checking, imputation of missing data, and network conflation.

The STM platform projects trip trajectories through the transportation network, as network conditions change in space and time. The Python system can currently project through a roadway and transit network once the data is provided. That projection is used to find the shortest path, allowing routing decisions to incorporate travel time, safety, and other impedance values into path selection. Outputs are provided through the use of a Commute Advisor Application Programming Interface (API).

Major System Components. The STM system consists of a wide range of data inputs, the STM data broker, system simulators, operational and performance analysis engine, network-edge cost computing engine, performance monitoring dashboard, and commute advisor API and UI. **Figure 7** provides the STM system context diagram.

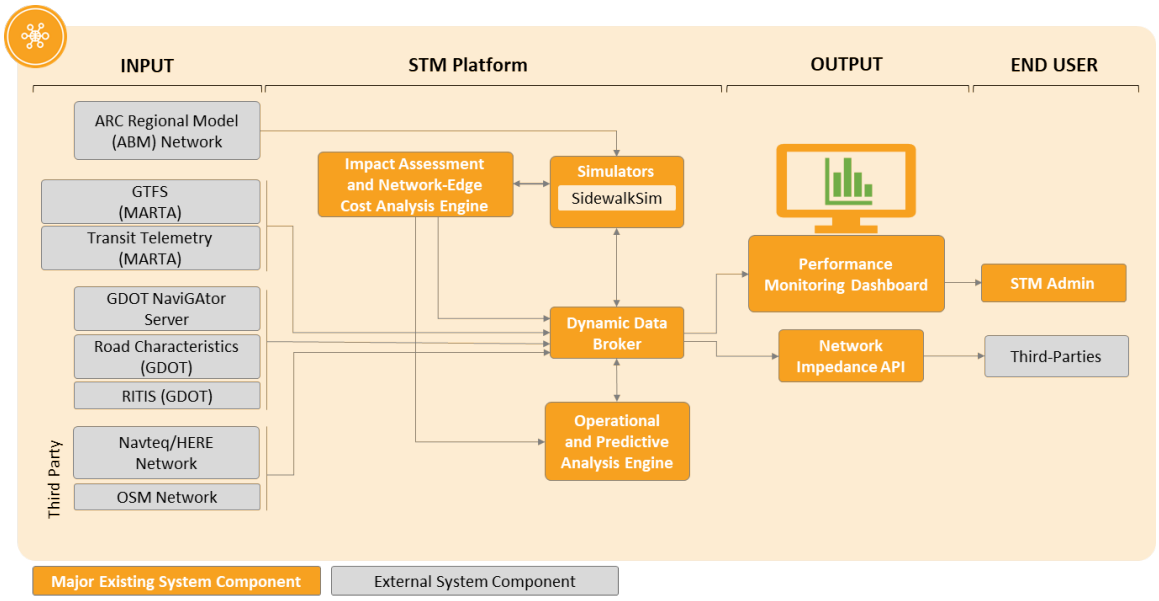

Figure 7. Current STM Context Diagram (Source: ARC)

The system simulators are part of the Python-based modeling suite which calculates the preferred route based on network information and Dijkstra's shortest path (lowest impedance value) algorithms where users can optimize path selection to minimize travel distance, travel time, energy use, or any specified user impedance function. For example, impedance penalties can be applied for wheelchair travel when ramps are absent or do not meet ADA slope or cross-slope standards.

- *RoadwaySim* – uses a 203,000-link roadway network from multiple static and dynamic resources which is updated every 5-minutes. The roadway network is independent from the other networks but is connected.
- *TransitSim* – currently includes all MARTA fixed rail routes, 90 MARTA bus routes, and Georgia Regional Transit Authority (GRTA) express bus routes (speeds derived from schedules). Connectivity between the transit simulation model and the distributed network simulation model supports the integration of transit and carpool park-and-ride options.
- *SidewalkSim* – uses a pedestrian pathway network that is independent from, but connected to, the surrounding roadway and transit networks. SidewalkSim network links represent sidewalks, pathways, roadway crossings, and grade-separated pedestrian pathways in the pedestrian network. Connection nodes represent the locations where pedestrians transition from link to link and enter/egress roadway, rail, and other crossings. The system also tracks relevant sidewalk and pathway elements that affect mobility (e.g., curb ramps, curb cuts, signal heads, push button controls, etc.). This allows GA Tech to track mobility-relevant features associated with each element.

  Sidewalk networks have been inventoried throughout the region for the GA Tech campus, Midtown area, City of Atlanta, East Point, Sandy Springs, Cobb County, and Clayton County. Sidewalk networks have been inventoried outside of the region in Yarmouth (ME) and Northampton (MA).

Inputs, Outputs, and Data Flow. The STM system ingests data from a range of sources, uses the data to model and identify optimum routes, and then provides this information to users.

The STM system and data broker receive and manage the following data input:

- *Roadway Networks* – ARC's Activity-based Model (ABM) and HERE's (formerly, Navteq) network are confirmed and utilized as the primary roadway network. Given the higher accuracy levels of the ABM and accuracy and completeness of the HERE network, the system simulator networks used by the STM start with reconciling these two network data sources, eliminating unnecessary nodes, and adding nodes as needed to complete minor road pathways.
- *Open Street Map Network* – The team regularly updates the OSM network to reflect changes in static network elements identified with the sidewalk inventory tools described in **Section 3.2.3** (Sidewalk machine vision (Sidewalk MV), Sidewalk Sentry, Sidewalk Scout, etc.) and as machine-learning processes identify network refinements that can increase route efficiency.
- *Transit Data* – GTFS data feeds and transit telemetry from MARTA and others as available are pulled into the STM and leveraged by the system simulators to identify routing for transit.
- *Roadway Characteristics* – GDOT's NaviGAtor advanced transportation management system (ATMS) software, GDOT roadway information, and GDOT's access to Regional Integrated Transportation Information System (RITIS) data is used to define the existing conditions of the roadway within the STM system.
    - The NaviGAtor system monitors and archives data for monitored freeway and arterial links at 20-second, lane-by-lane resolution. In addition, this connectivity also gives the STM platform access to the GDOT CV Program described in **Section 3.2.4**. The STM currently processes NaviGAtor data feeds to system simulators at 5-minute resolution.
    - The STM is capable of carrying real-time network data from any external data source, provided that the source can deliver link-level data at 5-minute temporal resolution. The STM retains all attributes provided by every data source.
    - The STM currently carries more than 100 roadway-related parameters from the various data sources for use in its deep learning processes. A significant number of these parameters are design-related and considered static in nature, such as facility class, link length, number of lanes, lane width, engineering capacity, design speed, posted speed limit, surface type, etc.
    - A road grade dataset from 2019 has been prepared by the team at high resolution for the entire metro area and can be applied at any spatial scale.
    - Lighting conditions by time of day are also used to support safe, efficient routing.

The STM dynamic data broker receives the data and disseminates appropriate data sets to the system simulators, operational and predictive analysis engine, and the impact assessment and network-edge cost analysis engine. The network-edge cost engine calculates the impedance value or level of inconvenience of a route to a traveler taking into consideration multiple parameters including time, monetary cost, and comfort. The data is analyzed and assessed and sent back to the data broker to be distributed to the appropriate output channel. In the ARPA-E

research project, the STM system provided the following output within the production environment:

- *Commute Advisor API Version 1.0* – The commute advisor API provides STM near-real-time updates to transportation network impedances compatible with OSM network data feeds.

Performance Characteristics. The STM dynamic data broker currently receives network performance data and disseminates appropriate data sets to the system simulators, operational and predictive analysis engine, and the impact assessment and network-edge cost analysis engine at a five-minute temporal resolution. Stress testing performed in the ARPA-E project established that a single-server solution is capable of considering origin-destinations within a regional area from more than 20,000 users simultaneously.

Currently data and impedances are reviewed manually to ensure quality and integrity of the data. In the event of communication outages within the system, the default mode is to use the OTP with no impedances updated.

The STM system is currently in a research environment and does not contain any encryption features that would be implemented within a production environment. However, structure to support a production environment is built and able to be migrated with additional enhancements.

System Schedule. The research-grade STM system currently exists. The system will be expanded and enhanced to a production grade system in Phase 2. The Northwest Region Project is a parallel effort developing tools to be used across the entire region but will not include any local roads. **Table 3** provides the milestones schedule for the STM platform.

Table 3. STM Platform Milestones Schedule

Project	Milestone	Completion Date
Northwest Region Project	Network Reconciliation (OSM and ABM) Tool Development	October 2021

3.2.3 Sidewalk Inventory Collection Tools

The sidewalk inventory collection tools provide enhanced pedestrian infrastructure data that is currently integrated within the SidewalkSim simulators referenced above in the STM system. SidewalkSim will be an integral element of the production grade STM, providing the pedestrian pathway network that is independent from, but connected to, the surrounding roadway and transit networks used in multi-modal path processing. The SidewalkSim network links represent sidewalks, pathways, roadway crossings, and grade-separated pedestrian pathways in the pedestrian network. The system also tracks relevant sidewalk and pathway elements that affect mobility (e.g., curb ramps, curb cuts, signal heads, push button controls, etc.). This allows GA Tech to track mobility-relevant features associated with each element. GA Tech has already developed a number of systems to inventory and collect sidewalk asset condition and ADA design compliance data. The purpose and goal of the development of these inventory collection tools is to be able to efficiently and accurately inventory pedestrian pathways and initial conformance with ADA design standards such that the data may be leveraged to support better traveler information and safety applications.

Operational Environment. The Sidewalk Scout, Sidewalk Sentry, and Sidewalk MV tools together create an enhanced sidewalk inventory system that collects and records sidewalk infrastructure, conditions, and obstructions. Enhanced sidewalk data collection and accessibility inventory using these systems has been completed in several areas around the region including Midtown Atlanta, East Point, Sandy Springs, Cobb County, and Clayton County, as well as other locations nationally.

Capabilities, Functions, and Features. Taken together, these three systems are used to inventory pedestrian pathway assets (sidewalks, crossings, pedestrian curb ramps, driveway curb cuts, etc.) and to assess element conditions for use in asset management tracking, to guide investment prioritization, and/or to inform travelers about path conditions.

Major System Components. The sidewalk inventory system is comprised of the Sidewalk Scout, Sidewalk Sentry, and Sidewalk MV data collection tools. **Figure 8** provides the sidewalk inventory system context diagram.

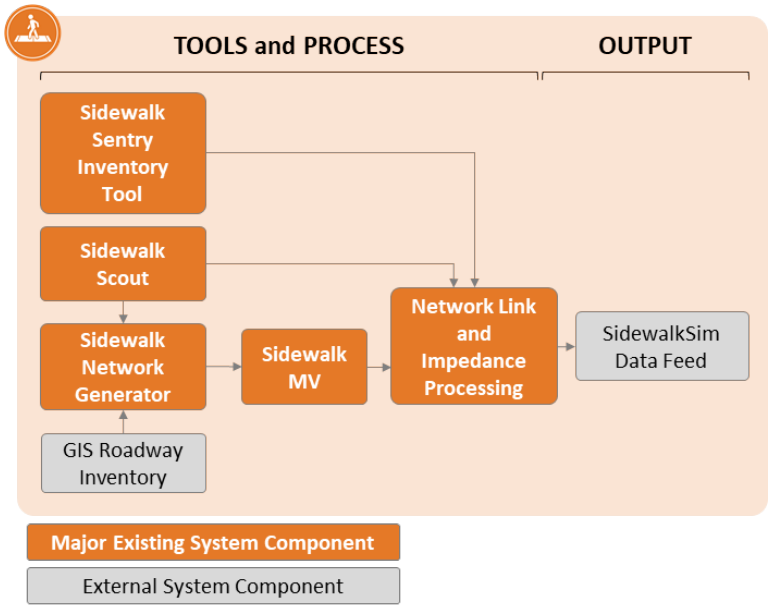

Figure 8. Current Sidewalk Inventory Collection Tools (Source: ARC)

Sidewalk Sentry is a tablet-based Android application used to collect sidewalk roughness data and a video inventory of sidewalks, crossings, ramps, and curb cuts. As shown in **Figure 9**, the tablet is attached to a non-motorized wheelchair and the data collector walks through the network at 2-3 mph collecting rolling ground level video, geographic position system (GPS) data, and accelerometer/gyroscope data from internal sensors. The GPS data is made more accurate by pre-processing location data before collecting field data – data used to support a non-safety critical application. The system uses the GPS and video data to create Geographic Information System (GIS) based sidewalk inventories. A web-based application is used by inspectors to playback video and record deviations from ADA design standards and condition defects (e.g., presence of potholes, obstructions, pavement disjoints, width narrowing, debris, ponded water, etc.).



Figure 9. Sidewalk Sentry Wheelchair (Source: GA Tech)

Sidewalk Scout™ is an Android app as shown in **Figure 10**, that allows registered users to record photos of individual sidewalk elements and report specific defects in sidewalk conditions or pedestrian amenities, including sidewalk obstruction, inadequate sidewalk width, improper slope and cross-slope, pavement discontinuities, broken walk signal heads, etc. The Sidewalk Scout™ app feeds data directly into the GA Tech sidewalk inventory system, with proper user training, Sidewalk Sentry can be used as a crowdsourced data collection app.

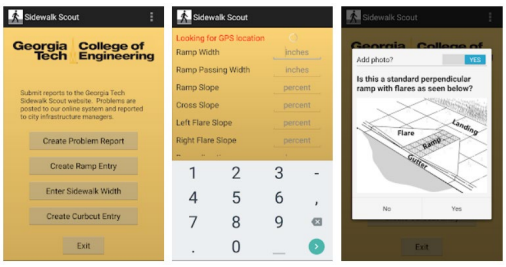

Figure 10. Sidewalk Scout User Interface (Source: GA Tech)

The team at GA Tech has been developing Sidewalk MV tools designed to process video and automatically identify the presence and position of sidewalk assets from the inventory videos and identify defects from the inspection videos. Enhanced machine vision processes are expected to improve sidewalk data granularity and accuracy at lower labor costs.

Inputs, Outputs, and Data Flow. Sidewalk inventories are developed through a series of processes that ingest data, processes the data and output a network that is compatible with SidewalkSim shortest path calculator.

The sidewalk inventory system receives and manages the following data input:

- Parcel-level land use data and roadway centerline data are used to create pedestrian pathways. The resulting pedestrian network represents all sidewalks, pathways, roadway crossings, and grade-separated pedestrian pathways as links.
- Sidewalk Sentry video data are used to verify asset spatial placement and to video-inspect sidewalk elements for deviations from ADA design standards and condition defects that are likely to increase route impedance.
- Sidewalk Scout inspection data are used during field inspections of sidewalk assets to identify deviations from ADA design standards and condition defects that are likely to increase route impedance.

Performance Characteristics. The sidewalk inventory network accuracy is assessed during the spatial reconciliation process. Networks are tested through origin-destination path analysis in which broken links are discovered and reconciled. Shortest path performance is tested and is a function of network density (links involved in path calculations).

Schedule. Table 4 provides the milestones schedule for the sidewalk inventory system. Minor system updates and refinements are completed during use of the sidewalk inventory tools. The Sidewalk MV tool is currently being developed by the GA Tech team as a research investment for use in future research and will be employed in support of ST-CTN to the extent that the tools have been field-demonstrated to provide efficiency and accuracy benefits. This tool is not required for ST-CTN implementation.

Table 4. Sidewalk Inventory Milestones Schedule

Milestone	Completion Date
Sidewalk MV Tool	Continued Development

3.2.4 Gwinnett County and GDOT Connected Vehicle

Gwinnett County operates and maintains 745 traffic signals, 328 closed circuit television (CCTV) cameras, and 244 miles of fiber throughout the county with a robust advanced traffic signal system. Gwinnett County works closely with GDOT who is responsible for traffic signals along state-owned roadways within the county. The CV system will rely on and work with the established traffic signal system.

Gwinnett County is a leader in deployment of CV infrastructure, having approximately 100 existing RSUs deployed along key corridors and currently participating in the GDOT CV1K deployment program. Gwinnett County is currently deploying interoperable CV technologies at signalized intersections throughout the Atlanta region to deliver safety and mobility-based applications. The program provides support to configure, operate, and maintain CV infrastructure and applications, including TSP. The goal of the program is to provide CV infrastructure to support the future development and testing of CV applications by agencies, original equipment manufacturers (OEM), and third parties.

Operational Environment. Gwinnett County will be one of the largest recipients of the first phase of the GDOT CV1K deployment program with approximately 400 planned C-V2X RSUs

throughout the county (see **Figure 11**). In addition, Gwinnett County is in the process of selecting a vendor to supply onboard units (OBUs) for county vehicles and support application development. Gwinnett County's CV operational environment relies on infrastructure and support from GDOT.

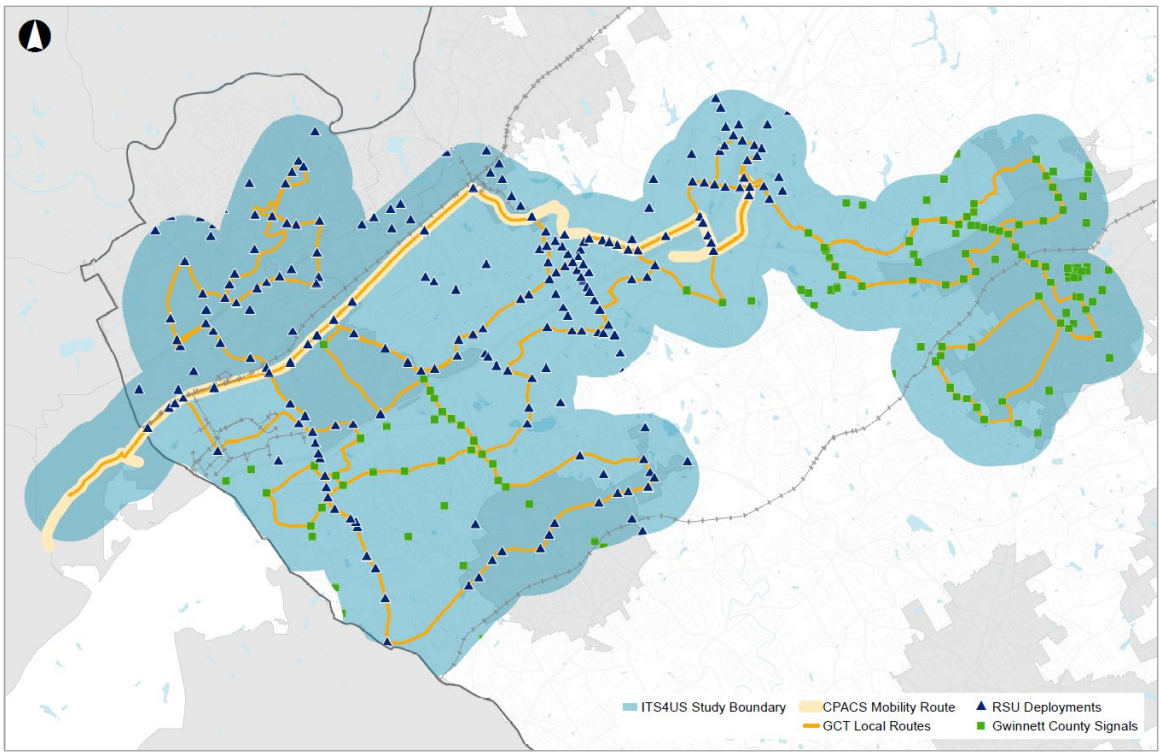

Figure 11. Gwinnett County CV Program RSU Deployment Locations (Source: Gwinnett County)

Capabilities, Functions, and Features. Gwinnett County is currently broadcasting signal, phasing and timing (SPaT) and Map Data (MAP) from signalized intersections along key corridors throughout the county. The county is working towards the deployment of EVP and TSP through a separate project (referred to as the Smart Corridor project) and will purchase OBUs for emergency and transit vehicles prior to deployment of ST-CTN. EVP is a priority application for the County and will be deployed with the Smart Corridor project. Transit signal priority hardware components will be purchased, deployed, and configured through the Smart Corridor project.

Major System Components. The CV program is comprised of field and central CV equipment and supporting infrastructure. **Figure 12** provides the Gwinnett County CV program context diagram.

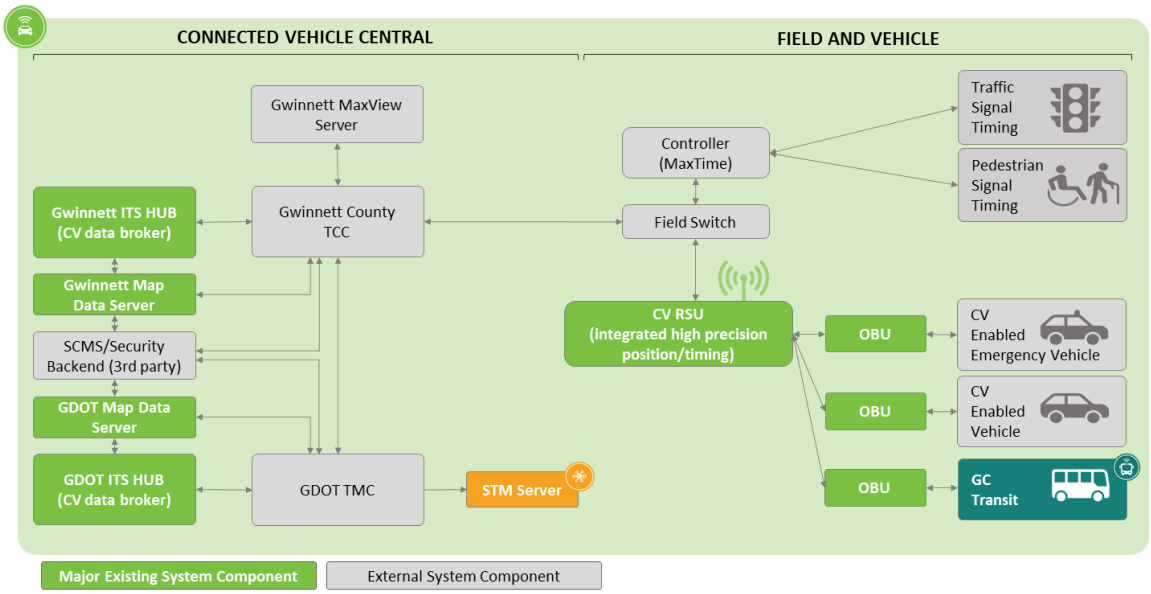

Figure 12. Gwinnett County and GDOT CV Program Context Diagram (Source: ARC)

The central components of the CV program consist of the ITS Hub or CV data broker, and ATMS servers (NaviGAtor and MaxView). The ITS Hub is responsible for receiving data from the field, processing the information, developing messaging, and monitoring CV infrastructure. The ATMS servers manage, operate, and monitor the traffic signal equipment and interface with the traffic management center (TMC). The central ITS Hub is replicated from the GDOT TMC to the Gwinnett County traffic control center (TCC) for resiliency and data preservation. The MAP Server stores and provides information on road configuration using the MAP standards (in the SAE J2735 standard). The MAP data server, with the security credentialing service, provides signed MAP messages that are sent to the RSUs. RSUs are configured with a high precision positioning and timing source that synchronizes RSU and OBU equipment.

The field components of the CV program primarily consist of RSUs which broadcast SPaT and MAP messages. County vehicles equipped with OBUs and connected consumer vehicles can receive and broadcast basic safety messages (BSM) and receive MAP and SPaT data from the RSUs.

Inputs, Outputs, and Data Flow. The CV system receives input from traffic signals, including signal phasing and timing data. The data flows as described below.

- GDOT-Owned Signals
    - Data is communicated from the field controller through the field hardened Ethernet switch, to the GDOT NaviGAtor server located in Gwinnett.
    - Data is replicated and sent to the Gwinnett ITS hub.
    - Data is sent from the GDOT NaviGAtor server located in Gwinnett to the GDOT NaviGAtor server located at GDOT.
    - The GDOT NaviGAtor server located at GDOT sends the data to the GDOT ITS hub for processing.

  - The GDOT ITS hub data is sent back through the communication path to the field hardened ethernet switch, to the RSU and broadcasted to be received by CV enabled devices. Data can also be sent from the GDOT ITS hub to modify timing and phasing in the traffic signal controller.

- Gwinnett-Owned Signals
  - Data is communicated from the field controller through the field hardened Ethernet switch, to the GDOT NaviGAtor server located in Gwinnett.
  - Data is sent to the Gwinnett ITS hub for processing.
  - The Gwinnett ITS hub data is sent back through the communication path to the field hardened ethernet switch, to the RSU and broadcasted to be received by CV enabled devices. Data can also be sent from the Gwinnett ITS hub to modify timing and phasing in the traffic signal controller.

Performance Characteristics. Performance characteristics, including quality and security, are being defined by the Smart Corridor project. The existing GDOT infrastructure includes a Security Credential Management System (SCMS) which is a third-party system that provides and manages security certificates to support trust for components that interface with the CV system. The SCMS being used is IEEE 1609.2 conforming and will be implemented with TSP requests during configuration and deployment.

System Schedule. Table 5 provides a brief overview of the CV milestones for the CV1K and Smart Corridor projects that will both be leveraged for the implementation of the ST-CTN system.

Table 5. CV Milestone Schedule

Project	Milestone	Completion Date
CV1K	400 RSUs ordered	June 2021
Smart Corridor	Vendor/Consultant selection	May 2021
Smart Corridor	OBUs for Transit Buses ordered	January 2022
CV1K	RSU deployment	February 2022
Smart Corridor	OBU installation	May 2022
Smart Corridor	TSP deployment	Summer 2022

3.2.5 Gwinnett County Transit

The Gwinnett County transit system currently provides commuter, local, and on-demand (paratransit) services throughout Gwinnett County, Georgia.

Operational Environment. Local, fixed-route service is the primary focus for the ST-CTN project and is operated with a fleet of 38 transit vehicles within the County. GCT currently operates seven local service bus lines. These bus lines reach the communities of Doraville, Norcross, Lawrenceville, Lilburn, Peachtree Corners, and Duluth. Route 10A, 10B, 20, and 35 all provide access to the Doraville MARTA Station. A map of GCT's Local Service Routes is provided in **Figure 13**. Outside of the Gwinnett Place Transit Center at the Gwinnett Place Mall, access to these bus lines is provided through roadside bus stops at fixed locations. The infrastructure at the bus stops varies from no infrastructure to sheltered locations with seating. Transit vehicles utilize automatic vehicle location (AVL) and a central computer-aided dispatch (CAD) system for service operations and management. In addition, transit vehicles are outfitted with cellular routers that provide free Wi-Fi to riders.

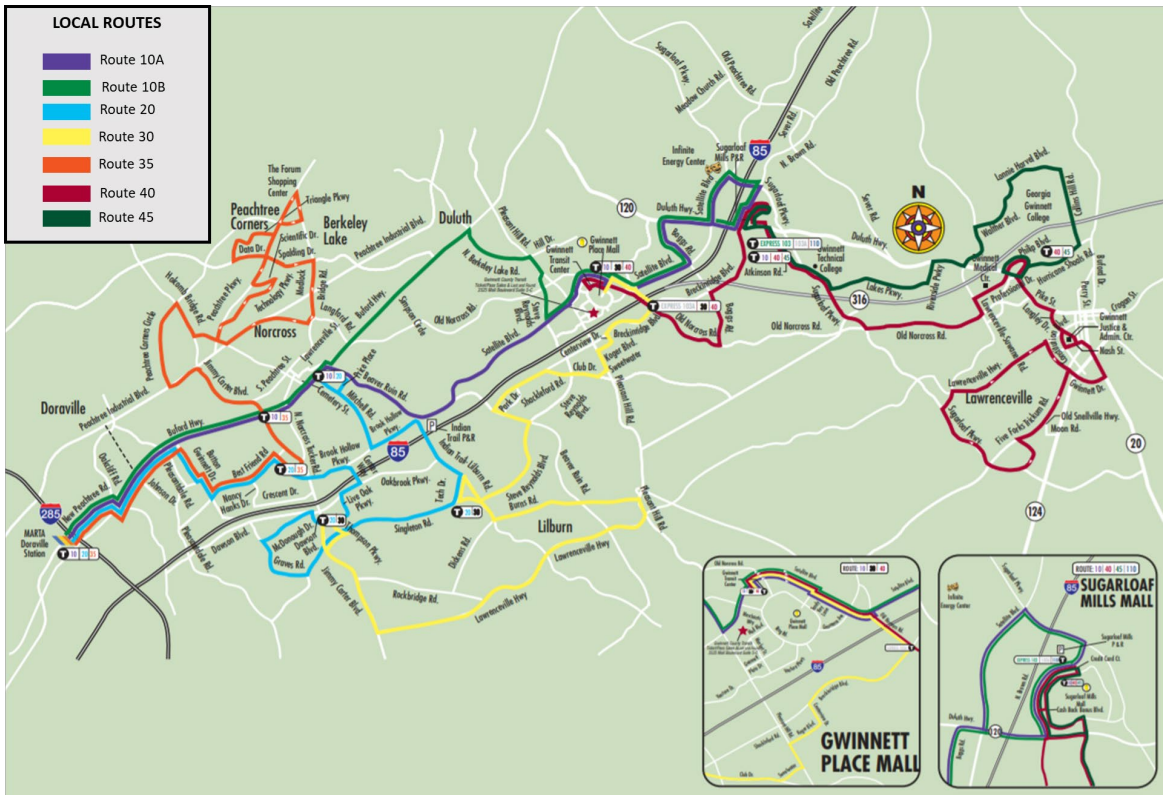

Figure 13. Ride Gwinnett Local Route Service Map (Source: Gwinnett County)

Transit speeds from the CTP Needs Assessment (2018) are included in **Table 6**. Route 45 is not included in the table as that route was added after the CTP was published. As noted in the CTP Needs Assessment, 25% of riders transfer twice on their one-way trip.

Table 6. CTP Needs Assessment Transit Speeds (Average Travel Speed by GCT Route)

Direction	10A	10B	20	30	35	40
Inbound	12.5 mph	14.9 mph	16.7 mph	18.1 mph	15.9 mph	19.9 mph
Outbound	13.7 mph	15.1 mph	15.6 mph	18.8 mph	15.2 mph	16.9 mph

Capabilities, Functions, and Features. The GCT system is capable of sharing transit schedule information, both in static and real-time. The system currently provides real-time ridership, route information, and service alerts information, which is available to travelers through a third-party app, myStop Mobile. Transit vehicles have onboard passenger counters (not specific by seat type, i.e., there are no sensors that track if wheelchair tie-downs are utilized), dynamic signs, operator mobile displays, and free passenger Wi-Fi. The GCT system will operate TSP with completion of the Smart Corridor project.

Major System Components. The GCT system is comprised of central system platforms, call center, and support website and developer portal. **Figure 14** provides the GCT system context diagram.

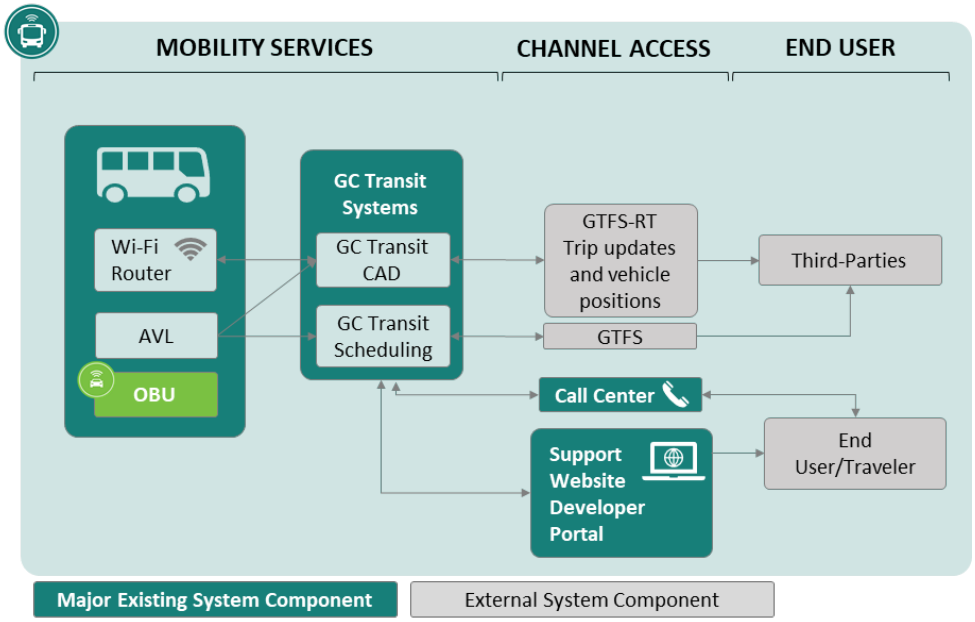

Figure 14. Ride Gwinnett Current Bus and Operational Technology (Source: ARC)

Central system platforms manage the GCT CAD and scheduling applications. These applications process static and real-time information including, transit vehicle locations, scheduling, routes, and ridership. The processed information is available to support a call center, support website developer portal, and GTFS feeds.

The GCT call center and support website developer portal provides information and direct support to customers. Customer service is available through the call center Monday through Friday from 6:00am to 8:00pm and Saturday from 7:00am to 8:00pm. Customers can access the website anytime and view routes, track vehicle status, plan trips, set alerts, and view messages.

Inputs, Outputs, and Data Flow. The GCT system receives input from transit vehicle onboard AVL devices and routers. This data is processed by the GCT system platforms which provide GTFS-RT and GTFS data feeds as well as operational and performance data. The GTFS-RT and GTFS data feeds are provided for third-party use and application. The operational and performance data is utilized by the call center and website which is then provided for customer consumption.

Performance Characteristics. The GCT system components have the following performance characteristics, including quality and security:

- Onboard Wi-Fi routers offer free access to all riders within the GCT system. These will be upgraded in Fall of 2021 to Sierra Wireless MG90 Gigabit Wi-Fi routers.
- Automated vehicle location devices currently provide vehicle location and availability data approximately every 30 seconds. The current system has noticeable float but provides the quality and accuracy that is required to meet the needs of the GCT system.
- Security upgrades are being completed to support the upgraded Wi-Fi routers to include virtual local area networks (VLAN) which will partition the network and allow for added security and quality.
- Deployed OBUs will get security certificates from the SCMS through the RSUs.

System Schedule. The GCT schedule of milestones that are pertinent to the ST-CTN proposed concept are shown below in **Table 7**.

Table 7. Gwinnett County Transit Milestones Schedule

Milestone	Completion Date
Router Upgrades	Q1 2022
System Platform Consolidation	Q1 2022
ATL RIDES Data Integration and Verification	Q2 2022
TSP Implementation	Q3 2022

3.3 Current System Stakeholders and User Groups

The current system stakeholders are those user groups and actors involved in the usage, management, operation, and maintenance of the current system. User groups and actors are distinguished by the way in which the user groups interact with the system. In this context, a user is anyone who interacts with the system including end users, operational users, subsystem developers and operators, and system maintainers.

User groups have been identified within three user classifications based on the general nature in which they interact with the current system. It is anticipated that the current system stakeholders will be maintained and migrate to the proposed system once available.

- **End Users (EU).** These users directly interact with the front end of the system. This user classification includes the user groups that represent the underserved populations that are the primary focus of the ST-CTN project.
- **Infrastructure Owner Operators (IOO).** These users represent infrastructure owners and operators within the project area. This includes transit infrastructure, communications infrastructure, CV infrastructure, signal infrastructure, and information technology infrastructure.
- **System Developers (SD).** These users represent system and subsystem developers who develop, update, and maintain the subsystems that support the ST-CTN project.

Table 8 provides a brief description of current system stakeholders by user groups and their current roles and responsibilities.

Table 8. Current System Stakeholders and User Groups

User Group	Abbreviation	Description
End User Classification		
Disability	EU-PD	End users with a physical disability may be unable to, or have trouble, performing specific tasks (i.e., boarding a bus, navigating a sidewalk, or hearing specific broadcast messages or alerts) without the use of a device such as a wheelchair, crutches, hearing aid, or white cane. A disability is the state in which an individual has a limitation in independent, purposeful physical movement of the body or of one or more extremities, and substantially limits one or more major life activities. **Role:** End user of the system. **Responsibility:** Interact with the system through the provided UI; provides preferences and abilities; provides feedback and input to enhance the functionality and accuracy of the system.
Older Adult	EU-AA	End users who are older adults may have trouble performing specific tasks within a set time (i.e., crossing a road or boarding a transit vehicle), standing for an extended period of time, or be more sensitive to the elements (i.e., waiting for transit in excessive heat). Older adults are people (typically 60 years of age or older) who may have limited mobility that impact their ability to perform daily activities. They may also have difficulty understanding how to use certain assistive technology. **Role:** End user of the system. **Responsibility:** Interact with the system through the provided UI; provides preferences and abilities; provides feedback and input to enhance the functionality and accuracy of the system.

User Group	Abbreviation	Description
Limited English Proficiency	EU-LEP	End users who have LEP may have trouble understanding directions and alerts when delivered in their non-native language, may have different culture norms that make it difficult to follow directions others would feel are standard, or may have difficulty understanding wayfinding signs. A person with LEP refers to a person who is not fluent in the English language. **Role:** End user of the system. **Responsibility:** Interact with the system through the provided UI; provides preferences and abilities; provides feedback and input to enhance the functionality and accuracy of the system.
Low Income	EU-LI	End users who fall into the low-income category may be single or no-vehicle households, may have trouble accessing different forms of technology (i.e., cellphone or personal computer), may be on reduced payment or fixed payment transit plans, may be unbanked (i.e., not have access to a bank account or credit card), or may use transit as their sole means of transportation. A person who has low income has a median household income that is at or below the Department of Health and Human Services poverty guidelines. Poverty guidelines designate $26,500 as the threshold for a household of four in the state of Georgia in 2021. **Role:** End user of the system. **Responsibility:** Interact with the system through the provided UI; provides preferences and abilities; provides feedback and input to enhance the functionality and accuracy of the system.
Infrastructure Owner Operator Classification		
Ride Gwinnett	IOO-GCT	The Ride Gwinnett user group includes the administrative staff, maintenance staff, drivers, and operators that work with the Ride Gwinnett organization. **Role:** Owner / operator of the current Ride Gwinnett system. **Responsibility:** Operates routes; monitors and maintains schedule; facilities planning and operations. Bus operations and maintenance. Provides transit data generation (GTFS, GTFS-RT).
Gwinnett County Traffic and Operations	IOO-GCTO	The Gwinnett County Traffic and Operations user group includes administrative staff, engineering staff, Traffic Control Center operators, and technicians who work with the Gwinnett County Traffic and Operations organization.

User Group	Abbreviation	Description
Gwinnett County Traffic and Operations (cont.)	IOO-GCTO	**Role:** Owner / operator of the current Gwinnett County traffic operations, including Gwinnett County TCC, traffic signal and CV infrastructure. **Responsibility:** Manages and operates infrastructure to support efficient traffic operations, including TCC; traffic signal system (Maxtime and Maxview); field traffic signal equipment; CV infrastructure – RSUs; GDOT NaviGAtor server located at Gwinnett County.
The Atlanta-Region Transit Link Authority (The ATL)	IOO-ATL	The ATL user group includes administrative staff, engineering staff, operators, and support personnel who work with the ATL organization. **Role:** Owner / operator of the current ATL RIDES application. **Responsibility:** Manages and operates ATL RIDES application and supporting infrastructure.
Georgia Department of Transportation (GDOT)	IOO-GDOT	The GDOT user group includes administrative staff, engineering staff, Traffic Management Center (TMC) operators, and technicians who work with the GDOT organization. **Role:** Owner / operator of the GDOT TMC, statewide ATMS (NaviGAtor), existing CV infrastructure. **Responsibility:** Collaborates with Gwinnett County to manage and operate infrastructure to support efficient traffic operations including, traffic signal system (Maxtime and Maxview); field traffic signal equipment; CV infrastructure – RSUs; GDOT NaviGAtor server located at GDOT TMC; ITS Hub. Potentially will own and operate subsystem component infrastructure.
Gwinnett County Information Technology	IOO-GCIT	The Gwinnett County Information Technology user group includes administrative staff, engineering staff, IT support staff, and programmers who work with the Gwinnett County Information Technology organization. **Role:** Owner / operator of the current Gwinnett County Information Technology Department. **Responsibility:** Manages and operates the Gwinnett County communications, security, data management and all server systems.
Atlanta Regional Commission (ARC)	IOO-ARC	The ARC user group includes administrative staff, engineering staff, operators, and support personnel who work with the ARC organization.

User Group	Abbreviation	Description
Atlanta Regional Commission (ARC) (cont.)	IOO-ARC	**Role:** Owner / operator of the current Atlanta Regional Commission. **Responsibility:** Responsible for encouraging and coordinating regional expansion of the ST-CTN concept and potentially owning and operating subsystem component infrastructure.
System Developer Classification		
Georgia Institute of Technology	SD-GAT	The Georgia Institute of Technology user group includes engineering staff, IT support staff, and operators from the Georgia Institute of Technology. **Role:** System developer at the Georgia Institute of Technology for the STM and sidewalk inventory tools. **Responsibility:** Responsible for the STM processing, operations, and maintenance. Responsible for the operations, processing of data collection with the sidewalk inventory tools, Sidewalk Scout, Sidewalk Sentry, and Sidewalk MV.
Gwinnett County Information Technology	SD-GCIT	The Gwinnett County Information Technology user group includes administrative staff, engineering staff, and IT staff who work with the Gwinnett County Information Technology organization. **Role:** Systems developer for Gwinnett County Information Technology. **Responsibility:** Responsible for the Gwinnett County Information Technology network operations, maintenance, uptime, and security.
Gwinnett County Connected Vehicles	SD-GCCV	The Gwinnett County Connected Vehicles user group includes administrative staff and engineering staff who work with the Gwinnett County Department of Transportation. **Role:** Systems developer for Gwinnett County Connected Vehicles. **Responsibility:** Responsible for the Gwinnett County Connected Vehicle functions and technologies.
Gwinnett County Transit	SD-GCT	The Gwinnett County Transit user group includes the administrative staff, maintenance staff, drivers, and operators that work with the Gwinnett County Transit organization. **Role:** Systems developer for Gwinnett County Transit.

User Group	Abbreviation	Description
Gwinnett County Transit (cont.)	SD-GCT	**Responsibility:** Responsible for the Gwinnett County Transit elements.
ATL RIDES	SD-ATLR	The ATL RIDES user group includes administrative staff, engineering staff, operators, developers, and support personnel who work with the ATL organization. **Role:** Systems developer, operator, and maintenance for ATL RIDES. **Responsibility:** Responsible for data management, application function and processing, application, and mobile app for the ATL RIDES subsystem.
Georgia Department of Transportation	SD-GDOT	The GDOT user group includes administrative staff, engineering staff, TMC operators, and technicians who work with the GDOT organization. They will be responsible for the GDOT CV elements. **Role:** Systems developer, operator, and maintenance for GDOT CV system and GDOT traffic signal system. **Responsibility:** Responsible for the GDOT CV elements, including ITS Hub, signal RSUs at GDOT maintained intersections, ATMS software (NaviGAtor), and MaxView.

3.4 Support Environment

The existing systems that will be leveraged to develop the ST-CTN system rely on critical components that will support the future system as well. The current system is supported by the following systems, infrastructure, and capabilities that are relevant to the proposed ST-CTN system:

- **Communications Network Infrastructure.** This infrastructure supports communication to the traffic signals, detection systems, traffic cameras, and field CV equipment. This allows system operators to monitor and actively manage signal timing, monitor field conditions and incidents, and monitor and manage CV messaging.
- **Centralized Traffic Signal System.** The system supports the efficient movement of vehicular and pedestrian traffic throughout Gwinnett County. The traffic signal system is integrated with the current CV system to broadcast SPaT and receive BSM messages at connected intersections.
- **Gwinnett County TCC.** The management and operation of Gwinnett County advanced transportation systems are accomplished from the Gwinnett County TCC which is the central location for housing system applications and servers, as well as operators. Relevant systems managed and operated from the Gwinnett County TCC include MaxView/MaxTime traffic signal system, digital video system, and CV system.

- **GDOT TMC.** The management and operation of the GDOT advanced transportation systems are accomplished from the GDOT TMC which is the central location for housing system applications and servers, as well as operators. Relevant systems managed and operated from the GDOT TMC include MaxView/MaxTime traffic signal system, digital video system, 511 Open Portal and CV system.
- **CV Supporting Infrastructure.** This infrastructure includes the field Ethernet switch, traffic signal controller, and SCMS / security backend support. These external system components are referenced in **Figure 12** and support the Gwinnett County and GDOT CV Program deployments.
- **Data.** Real-time and static data is critical to the current systems. Data inputs include GTFS-RT, GBFS, GTFS-Flex, GTFS-Pathways, OpenStreetMap base map, GA 511 Open Portal, etc.
- **Traveler App or Application Device.** These devices are required to facilitate the connectivity between the ATL RIDES application and the end user / traveler.

3.5 Modes of Operation for Current System

This section describes the normal operation, degraded, and failure modes of operation for the current systems described above.

Normal Operation. During normal operations, the respective systems, as described in **Section 3.2**, are functional and available to front facing and backend stakeholders. All objects in the environment are functioning normally and are being monitored by specified personnel.

Degraded Modes. In degraded mode, the systems are not functioning as intended. Several degraded modes are explained below.

- If the **ATL RIDES** front end interface experiences a loss in functionality, the end user may not be able to access their user profile, plan a trip, or navigate a trip. If the ATL RIDES backend interfaces lose connectivity or functionality, data will not update and static data and conditions will apply until functionality may be reestablished.
- If the **STM Platform** experiences a loss of functionality, the current research environment will potentially lose data and the ability to process multimodal trip plans. This currently has minimal consequence because the STM Platform is not in production mode.
- If communication between the **Sidewalk Inventory** and the STM Platform is interrupted, accurate, real-time, travel impedances will not be processed within the STM simulators. This currently has minimal consequence because the STM Platform is not in production mode.
- If the Gwinnett County and GDOT CV system experiences a loss in functionality, the RSUs will be unable to broadcast or receive messages. Therefore, TSP requests and pedestrian signal requests will not be received or responded to. In addition, if a communication failure is present within the network, local messages will be able to be broadcasted (SPaT), however, TSP will not be functional and connectivity with pedestrians will not be possible.
- If the GCT System Platforms experience a loss in functionally, GTFS data, scheduling, and real-time bus status will not be accessible by other dependent systems.

Failure Mode. In failure mode, the current systems are not available to provide outputs or serve end users.

3.6 Operational Policies and Constraints

Currently each system described follows the guidelines set by its lead agency. The IT policies for each system are based on similar standards that serve to protect the integrity and security of their networks. No system is currently using proprietary data or information that would impact this project. Additionally, all agencies have budgeted funding for maintenance of the current systems as described including staffing. This does not include GA Tech's STM and Sidewalk Inventory systems, which is addressed in further detail in **Section 7.2.4**.

Following Phase 1, the current project and proposed system underwent the following changes:

- Award owner and manager of the contract changed from ARC to GDOT.
- The proposed application was previously named ATL RIDES but is now called OpenTripPlanner for Georgia Mobility and Accessibility Planner (OTP for G-MAP).
- Gwinnett County Transit (GCT) underwent a name change to Ride Gwinnett. The acronym GCT has been maintained throughout the document.
- The ATL is no longer a stakeholder for Phase 2 although they are aware of the progress.
- The function, Connection Protection, has been adapted to only remotely request that an operator stop the transit vehicle at certain stops for boarding and alighting. The operator will also be notified if the traveler needs additional time to board or alight. This functionality is now called Ride Request.
- The indoor navigation locations will be the Gwinnett Justice and Administration Center (GJAC) and Norcross OneStop.
- Sidewalk inventory tools, Sidewalk Scout and Sidewalk Sentry, have evolved into what is now referred to as the enhanced pedestrian data collection.

4. Justification for and Nature of Changes

Access to affordable and reliable multimodal transportation affords people with disabilities and people in underserved communities flexibility to successfully complete trips. This access is critical to reaching essential services like healthcare, but also expands everyone's opportunities in education, employment, housing, and community life. This section describes the shortcomings of the current system and sheds light on the motivation for the modification of the existing system to integrate solutions that allow all users to successfully make complete trips.

4.1 Justification of Changes

Providing the underserved community with tools that allow them to successfully plan and complete multimodal transportation trips increases their mobility, thereby increasing their economic, housing, and social integration potential. Without the ability to complete trips in an accessible network, underserved users may have limited alternative options or not be able to complete the trip at all. These options can be costly and sometimes unreliable for underserved communities and can place them at a disadvantage when engaging in economic or social relationships. Additionally, information on whether a trip is completable given a user's abilities and preferences is not available from any singular source. Without confidence in their ability to complete a trip, it is likely they will choose not to make a trip at all.

The ST-CTN project study area is made up of many underserved communities including people with disabilities, older adults, people with limited English proficiency, and low-income individuals. It also encompasses the entirety of the GCT local fixed route transit network. With the technology advances being made through the Gwinnett County CV and CV1K initiatives, ST-CTN is seizing the opportunity to better accommodate accessibility needs through technology.

4.1.1 Transit

The current transit system within Gwinnett County provides accommodations to underserved communities in the form of accessible transit vehicles, reduced fare options, and transit on-demand services. However, it does not offer full accessibility information to travelers such as bus stop accommodations and does not connect transit operators with information about a traveler's needs such as the need for additional boarding time. Buses may also not always effectively announce their arrival at bus stops, which greatly affects individuals with visual disabilities. It is also difficult for some travelers to request a stop once on the bus or to know when to request their stop.

Travelers using transit can also have much longer trip times, not only from the necessity of an indirect route, but also from poor reliability of buses in mixed traffic. According to Connect Gwinnett Transit Plan, GCT's on-time performance is below 80% for local bus routes [CGCT].

The current transit system also has a high percentage of riders transferring between transit services.

Many of these challenges will be solved through ST-CTN. Travelers will have much more information about their trip in much greater detail. They will be able to program the system to alert them when the bus arriving, that their stop is next, and will be able to request service to board or alight a bus automatically, based on their programmed trip plan, or remotely, through their mobile device. ST-CTN can also connect the traveler to the transit operator to deliver information about their disability or needs. TSP technologies will help ensure on-time arrivals for those travelers who need additional time boarding or alighting the transit vehicle or are unable to stand for long periods, increasing the on-time performance of the system. Additionally, TSP could be activated post boarding to catch up to the schedule if the user requires additional time to board or alight the transit vehicle. An increase in on-time performance through the use of TSP, would also ensure that users who require a transfer are able to arrive at their designated transfer point on-time. Remote service requests would be able to inform drivers that a passenger is planning on completing a transfer if their current service is running behind schedule.

4.1.2 Trip Planning

The ATL RIDES application supports enhanced multimodal mobility for regional travelers. ATL RIDES allows users to create personal profiles and store general preferences, such as mode choice, traveled facility type, preferred route, and notification types. The development of ATL RIDES provides an opportunity for disseminating more transit travel information regionally. However, the application does not currently provide travelers with full accessibility features for alerts and hands-free use. It is also not integrated with the necessary data sets to provide users routing information based on their abilities and does not have the ability to communicate with connected vehicle infrastructure.

The underserved communities that ST-CTN is seeking to support have identified a range of travel needs to create a fully accessible application. These needs include connection to a call center, sharing user location with a care giver, audio alerts, haptic feedback alerts, personalized landmark navigation, personalized verbal cues, and more. Currently, ATL RIDES does not have as robust of a personalization platform necessary to accommodate the needs of people with disabilities, older adults, and LEP communities outside of Spanish, Chinese, Korean and Vietnamese speakers. These features must be created to help underserved communities gain independence and access throughout the deployment area.

The ATL RIDES application needs to integrate with more data sets in order to provide detailed trip accessibility information and routing. ST-CTN will integrate these data sets through GA Tech's STM and SidewalkSim platforms. Additionally, ST-CTN will integrate ATL-RIDES with connected vehicle infrastructure to enable the traveler to access the safety and reliability benefits of that technology including holding pedestrian signals at crosswalks, triggering TSP for better transit reliability, and sending and receiving personal safety messages to and from nearby connected vehicles.

4.1.3 CV Infrastructure

In the Atlanta region, 69% of crashes occur on roadway with less than 4 lanes [ARCRTP]. These are the same streets that are more likely to be used by pedestrians. In fact, bicycle and

pedestrian fatalities, as a percent of all fatalities, grew to 20% in 2018, without a significant increase in mode share [ARCRTP]. While this is both a regional and national issue, in the ST-CTN project study area there are many intersections with twice the regional average of crashes. The installation of CV applications is one way to increase safety as more auto manufacturers include CV devices in their vehicles. However, to ensure all travelers have the ability to benefit from this technology, applications must be created. ST-CTN will enable all travelers regardless of their vulnerable road user class, to take advantage of Gwinnett County's investment in connected infrastructure and increase their safety. It will also support transit riders by enabling TSP and increasing transit reliability.

One of the ways the ST-CTN system will enhance the Gwinnett County CV infrastructure is the inclusion of remote (hands free) pedestrian signal actuation. This is currently not included in the Gwinnett County CVTMP due to several constraints including the inability to discern intent when a user is approaching an intersection. Since the ST-CTN application is providing routing guidance to the user, the intent to cross a road at a signalized crossing is established, making this feature possible. Additionally, the ST-CTN application will understand the user's ability to cross a road within the given timeframe and be able to request an extension for the user if needed.

The ST-CTN system will use the G-MAP app to actuate the pedestrian signal system which activates the personal safety messages to connected vehicles. The Gwinnett County CVTMP identifies safety messages that will be broadcast when a pedestrian phase is active to nearby vehicles. The ST-CTN application will also be able to receive messages if a connected transit vehicle is approaching the user. These features will improve the current system and provide a safer environment for vulnerable road users.

4.1.4 Data

One of the most consistent issues faced by travelers, especially those with disabilities, is a lack of information on the accessibility of their trip. ST-CTN will give travelers much more data about their trip to make the best decision for them. GA Tech's STM and SidewalkSim will be critical in this area. Detailed information about sidewalk conditions is not readily available over much of the region and at all in the project area. Creating a system for collecting this data efficiently will enable all areas in the region to have a more complete sidewalk and asset data set.

The data collected through ST-CTN is critical for the success of the project. Particularly for people with disabilities and older adults, information regarding the infrastructure along a trip route can give travelers a higher level of confidence that they will be able to complete their trip. Without this information travelers may encounter an obstacle that forces them to take a long detour or force them to return home. Providing as much information to the traveler is the crux of the ST-CTN system and key to a flexible transportation system that serves all.

4.1.5 Expectations of the Proposed Concept

The proposed system offers an opportunity to better support underserved communities with increased mobility, safety, and information about their trips; expand the existing infrastructure asset management system that is available to Gwinnett County through crowdsourced data collection options; and increase the reliability of transit service within the project study area. By having additional information about their trip options, the underserved community will be able to increase their safety and mobility, thereby increasing their economic and social opportunities. By

crowdsourcing data collection, Gwinnett County will be able to better manage their infrastructure assets within the project study area. By increasing the deployed technology within GCT's network, an increase in on-time performance and service is expected.

Table 9 provides a summary of the expected benefits for the systems users.

Table 9. System Users' Expected Benefits

User Classification	Expected Benefits of Proposed Concept
End User	• Improved trip planning capability. • Turn by turn directions that consider user's preferences and abilities. • Real-time information on transit vehicle status. • Accessibility features within application including haptic feedback, hands free mode, and sensory adjustments. • TSP activation if a bus is running behind while a person with a disability or older adult is waiting for service. • TSP activation to catch up to schedule if an end user needs additional time to board or alight a bus. • Adequate time provided when boarding and alighting transit vehicles. • Pedestrian phase time extension at signal crossings. • Increased visibility near roadways through CV technology. • Ability to automatically request transit service, based on the programmed trip plan, to board or alight a bus. • Ability to remotely request transit service, through a mobile device, to board or alight a bus. • Indoor space navigation information.
Gwinnett County Department of Transportation	• Enhanced asset management of pedestrian infrastructure from initial mapping and crowdsourced data collection.
Ride Gwinnett	• TSP activation if a bus is running behind while a person with a disability or older adult is waiting for service. • TSP activation to catch up to schedule if an end user needs additional time to board or alight a bus. Enhanced asset management of transit infrastructure through crowdsourced data collection. • Transit operators have enhanced situational awareness in case of emergency by knowing if a transit user requires additional support.

4.2 Description of Desired Changes

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 SDs with the rationale for decisions that were made previously in the systems engineering process.

IEEE 1362-1998 Guide for Information Technology – System Definition – Concept of Operations Document defines a user need as: "a user requirement for a system that a user believes would solve a problem experienced by the user," noting that the use of word "requirement" here does not imply system requirements. A user need is an expression of a required capability of the system, expressed in general (i.e., non-solution oriented) terms. To ensure that user needs are well written, the following criteria are applied to each user need:

- **Uniquely Identifiable.** Each need must be uniquely identified (i.e., each need shall be assigned a unique number and title).
- **Major Desired Capability (MDC).** Each need shall express an MDC in the system, regardless of whether the capability exists in the current system or situation or if there is a gap.
- **Solution Free.** Each need shall be solution free, thus giving designers flexibility and latitude to produce the best feasible solution.
- **Capture Rationale.** Each need shall capture the rationale or intent as to why the capability is needed in the system.

The ST-CTN project team conducted stakeholder engagement in the form of user needs interviews with advocacy groups and representatives from underserved communities to:

- Gain insight and an understanding of mobility and technology challenges and needs that are experienced during travel
- Understand the priorities and greatest obstacles facing stakeholders related to travel
- Learn about existing solutions and activities that individuals use to address their challenges and needs today

Through the process of identifying user needs, the ST-CTN team identified what project stakeholders, specifically those from the underserved community, need from the proposed system. Stakeholders were introduced to the Complete Trip – ITS4US Deployment Program; provided with a high-level description of the ST-CTN concept; given a brief summary of existing known challenges; and then asked to identify challenges within their typical trips. To ensure that the entire trip was discussed, discussions occurred around the distinct segments or steps of a complete trip, including:

Step 1 **Pre-Trip Planning.** The traveler will interact with the trip plan and receive turn by turn directions based on their user profile. The route can avoid obstacles such as

rough sidewalks, curbs without adequate ramps, and inadequate drop-off/pickup points.

Step 2 **Begins Trip.** The traveler will begin their trip and follow turn by turn directions along their safe and accessible route.

Step 3 **Transition to Transit.** The traveler's transit vehicle and driver will be notified of the travel request and given priority along the route if conditions require, such as a traveler needing additional time to board the bus. The traveler will be alerted to estimated wait times and any trip modifications.

Step 4 **Intersection Crossing.** When a traveler is required to cross an intersection, a message will be placed to the signal controller to extend the pedestrian phase in the direction of travel.

Step 5 **CV Broadcast Message.** The traveler will be recognized by the CV infrastructure located at signalized intersections and the RSU will broadcast BSMs to alert of pedestrian/bicyclist in vicinity.

Step 6 **Outdoor/Indoor Navigation.** The traveler will be provided with turn by turn directions along a safe and accessible route. This includes navigating the closest, accessible paths for outdoor navigation. Accessible building entrances and indoor navigation information such as building entrances, elevators, escalators, and connecting paths will be provided for key facilities within the ST-CTN project area.

Underserved communities were represented by members of advocacy groups such as the SILCGA, ARC's Aging and Independence Service Group, CPACS, and others. Hour long user needs interviews were conducted with groups of 3 to 7 stakeholders (not counting ST-CTN team members). To focus appropriately on the needs of the end users, the interview sessions were separated into mobility challenged groups (including physical disability and older adults) and LEP groups. The challenges and needs of low-income communities were discussed during all user needs interviews, understanding that these underserved populations sometimes overlap in nature and that the stakeholders were able to provide insight related to low-income communities as well. Interviews were led by trained, local facilitators who have experience engaging underserved communities and have an ongoing relationship with regional and national advocacy groups that represent them.

The user needs interviews and a review of the literature were used to outline existing challenges and needs. This information was captured and categorized within the anticipated relevant trip segment that was described. Based on inputs, needs statements were defined. As needs were reviewed and consolidated, the project team identified that there was a relationship between many of the needs. To help organize the user needs, a parent child relationship was identified in which child needs have a hierarchal relationship to parent needs. Each need statement has been given a unique identifier with the following nomenclature:

AB-CD-E.F.G, where:

- AB = Need Area / Trip Segment
    - PT = Pre-Trip Planning

    - BT =Begin Trip
    - TT = Transition to Transit
    - IC = Intersection Crossing
    - CV = Connected Vehicle Broadcast Message
    - NV = Indoor/Outdoor Navigation
    - RP = Reporting
    - FT = Future Development
- CD = User Classification
    - EU = End User
    - OO = Owner / Operator
    - SY = System
- E = Need Area Number
- F = Need Statement Number
- G = Child Statement Number (if applicable)

Child statement numbers were applied to needs that were similar in nature to one another and were grouped under a need statement number. An example of this is the need statement "Travelers need personalized trip information that accommodates their preferences and abilities." Child needs include the need for information that considers the dimensions of the infrastructure, the need for information that considers temporary or permanent obstructions of the infrastructure, and the need for information that considers the dimensions of infrastructure within buildings. The child needs help define the scope of each need statement they are applied to.

The next sections present the identified user needs – end user needs, IOO needs, and system needs. All user needs have been given a unique ID to allow for traceability throughout the project. The user needs will dictate the proposed concepts discussed in this ConOps document. The user needs documented herein will be used to drive the system requirements and validate the system design after deployment. It is anticipated that user needs will continue to be refined over the life of the concept development phase; the ConOps document will be a living document and will be updated to reflect need refinements and additions. Safety needs were developed, documented and maintained in the Safety Management Plan (SMP). User needs and safety needs will drive the Systems Requirements Document (SyRS).

4.2.1 Priorities Among Changes

End User, IOO, and System needs have been classified as essential, desirable, or optional in their respective tables in **Section 4.2.2, Section, 4.2.3** and **Section 4.2.4**. The essential, desirable, and optional priorities are defined as such:

- **Essential Needs.** Needs that shall be provided by the new system.
- **Desirable Needs.** Needs that should be provided by the new system.
- **Optional Needs.** Needs that might be provided by the new system.

User needs interviews with end users and advocacy groups who represent underserved communities were conducted to gain insight on mobility and technology needs and challenges experienced throughout a persons' complete trip. After the completion of the user needs interviews and development of the end user need statements, the participants of the user needs interviews were asked to review the end user need statements in the form of a survey, shown in **Figure 15**. Survey participants were asked to provide feedback regarding whether the needs were accurately depicted and to prioritize them based on their experience.

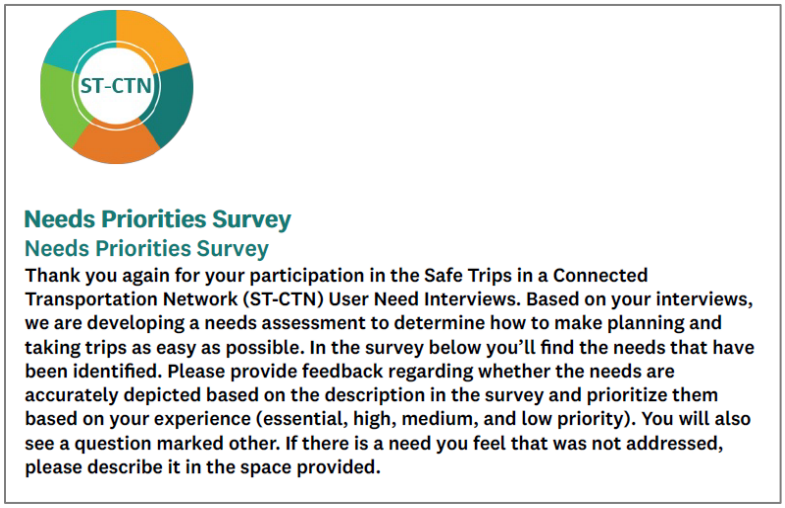

Figure 15. Needs Priority Survey Introduction (Source: ARC)

Upon receiving the results of the survey, a meeting was held with the ST-CTN technical team which included the EMT, system developers, and IOOs to discuss the survey results and finalize the end user need statements and need priorities. The end user need priorities guided the priorities of the IOO and system needs.

Needs that were classified as essential were deemed critical to the operation of the application or safety of the end user by the stakeholders and technical team. If these needs are not accounted for in the final system, the possibility of application failure increases and the level of safety of the end user decreases.

Needs that were classified as desirable were deemed as quality of life improvements or marginal increases to the safety of end users by the stakeholders. In some cases, these needs are outside of the scope of the project or will be included in future updates. If these needs are not accounted for in the final system, the application will run as intended and the level of safety of the end user will not decrease.

4.2.2 End User Needs

Table 10 provides a summary of the end user needs, associated justification for those needs, and priority (essential, desired, and optional). More information regarding the prioritization process is provided in **Section 4.2.1**. These needs are based on the literature review and a series of user needs interviews with end users and advocacy groups who represent underserved communities.

Any modifications to end user needs will be reflected in this ConOps document through the life of the project.

Table 10. 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-1.1.1	Travelers need personal trip information that considers the dimensions, conditions, and status of outdoor facilities and physical infrastructure. Travelers using public right of ways such as shared use paths and sidewalks need to ensure that the planned trip considers the dimensions, safe intersections (curb cuts, traffic and pedestrian signals, etc.), conditions, and status to ensure that the traveler can complete the trip based on their preferences and abilities.	E
PT-EU-1.1.2	Travelers need personal trip information that considers obstructions (e.g., cafes, store signs) along their planned trip that limit their access along public right of ways. Travelers using public right of ways such as shared use paths and sidewalks need to ensure that the planned trip considers permanent obstructions such as protrusions from the surface, side of buildings or above, broken and undulating paths, and temporary detours and pop-up obstructions to ensure that the traveler can complete the trip based on their preferences and abilities.	E
PT-EU-1.1.3	Travelers need personal trip information that considers the dimensions, conditions, and status of facilities and physical infrastructure within buildings and public spaces along their planned trip. Travelers accessing public buildings and spaces need to ensure that the planned trip considers the dimensions, conditions, and status of facilities within buildings and public spaces to ensure that the traveler can complete the trip based on their preferences and abilities.	D
PT-EU-1.1.4	Travelers need personal trip information that considers the Americans with Disabilities Act (ADA) compliance of building entrances along their planned trip. Travelers accessing public buildings need to ensure that the planned trip considers the ADA compliance of building entrances to ensure that the traveler is rerouted to an accessible entrance or that the traveler is able to complete the trip based on their preferences and abilities.	E

Need ID	End User Need Statement	Priority
PT-EU-1.1.6	Travelers need personalized trip information to consider the accessibility features (i.e. chair lift, ramp, internal widths) that transit vehicles have which will accommodate their needs/preferences. For example, Travelers with mobility disabilities and older adults using assistive devices, such as wheelchairs, walkers, etc. or travelers with support attendants (including service animals) need to ensure that vehicles can accommodate their preferences.	E
PT-EU-1.1.7	Travelers traveling in a group need the ability to set preferences to group travel. Travelers who are traveling with a group of people that have different abilities and preferences need to be able to temporarily augment their own abilities and preferences to ensure that the group of travelers can complete the trip based on the group preferences and abilities. Temporary needs would remain active until the user disables them.	D
PT-EU-1.1.8	Travelers need their personally identifiable information (PII) to be secure and private.	E
PT-EU-1.1.9	Travelers need, when traveling on fixed route or transit on-demand services separate from Gwinnett County Transit, personalized trip information to consider the accessibility features (i.e. chair lift, ramp, internal widths) that vehicles have that accommodate their needs/preferences. For example, travelers with mobility disabilities and older adults using assistive devices (e.g., wheelchairs, walkers, etc. or travelers with support attendants including service animals) need to ensure that vehicles can accommodate their needs.	O
PT-EU-1.2	Travelers need the ability to customize their App accessibility features to accommodate their abilities.	E
PT-EU-1.2.1	Travelers with vision loss need the ability to customize their App accessibility features to accommodate their abilities. Travelers need the App to be able to provide audio, audio-described graphics, and haptic feedback or audio alerts to assist them in navigating a complete trip.	E
PT-EU-1.2.2	Travelers with hearing loss need the ability to customize their App accessibility features to accommodate their abilities. Travelers need the App to be able to provide text based or haptic feedback alerts to assist them in navigating a complete trip.	E
PT-EU-1.2.3	Travelers need the ability to receive alerts from the App on their preferred device or tool including wearable devices, hearing device, connected canes, etc. This allows travelers to access information from the App using devices and/or tools that the traveler is familiar using when navigating the trip.	E
PT-EU-1.2.4	Travelers with sensory sensitivity, including sensitivity to vibration, sounds, or lights need the ability to customize their App accessibility features to accommodate their preferences. This allows travelers with sensory sensitivity to access the App in a way that accommodates their preferences and abilities to assist them in navigating a complete trip.	E

Need ID	End User Need Statement	Priority
PT-EU-1.2.5	Travelers need the ability to access the app in a hands-free mode if they are unable to hold or manipulate the cell phone during the entire trip. This allows travelers to update their trip configuration or preferences using hands free features in a way that accommodates their preferences and abilities to assist them in navigating a complete trip.	E
PT-EU-1.2.6	Travelers with low reading levels need to be able to customize their App accessibility features to accommodate their abilities. Travelers need to be able to receive information from the App that does not require a high reading level. Potential means for conveying this information might include image-based instructions and routing descriptions, pictures of landmarks to guide their routing decisions, or visualizations of boarding or alighting locations in a way that accommodates their preferences and abilities to assist them in navigating a complete trip.	E
PT-EU-1.2.8	Travelers need the ability to preview route choices, location information, all entrances to their destination building, and potentially practice routing choices or entire trip segments in order to be able to make new and unfamiliar trips.	E
PT-EU-1.2.9	Travelers with LEP need information regarding the route provided through visualizations or landmarks, mapping, or turn by turn directions. Travelers need to be able to receive information from the App that does not require a high level of proficiency with the English language such that they can understand the directions and navigate their complete trip. Potential means for conveying this information might include image-based instructions and routing descriptions, pictures of landmarks to guide their routing decisions, or visualizations of boarding or alighting locations.	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-2.1.1	Travelers need the ability to talk or interact with support personnel during their trip to help them if they have difficulties processing information, are unfamiliar with the App, or get easily disoriented during routing.	E
BT-EU-2.1.2	Travelers need to be able to share their location with support personnel or caregivers during their trip who can help them if they become disoriented or require assistance while completing their planned trip.	E
BT-EU-2.1.3	Some travelers with disabilities, need to have the transit vehicle operator know about their conditions in case of an incident. The transit vehicle operator will be able to assist the traveler better by having traveler information available to them through onboard device or through a dispatcher.	E

Need ID	End User Need Statement	Priority
BT-EU-2.1.4	Travelers need to have additional information including stop announcements, provided to them through the use of the App.	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
BT-EU-2.2.1	Travelers need the App to be able to provide real-time, turn-by-turn updates to trip progress and routing choices. Some travelers required specific feedback about their trip progress and path and require additional time to understand routing changes. These alerts need to be personalized for each traveler and will ensure that travelers are safely able to navigate their trip.	E
BT-EU-2.2.2	Travelers need to be able to receive alerts while executing their trip that alerts them to situations where they are off their route, alerts them when they are getting close to a landmark, or alerts them if they are going the wrong way. These alerts need to be personalized for each traveler and will ensure that travelers are safely able to navigate their trip.	E
BT-EU-2.2.3	Travelers need the App to be able to provide real-time updates on route conditions that may prevent the traveler from completing their trip. Sidewalk, path, transit service, and indoor infrastructure (e.g., out-of-order elevators or escalators) can change during the course of travel; the App needs to be able to provide this information, when available, to travelers who are currently navigating their trip based on their personalized information to ensure they are able to successfully complete it.	D
BT-EU-2.2.4	Travelers need to receive information from the App based on their personalized information prior to boarding or alighting a transit vehicle that conveys information about the transit vehicle and informs the travelers that they are getting on the right transit vehicle or alighting at the right stop. Some travelers may have difficulty or be unable to recognize the correct transit vehicle or the correct departure point without additional information being provided by the App, ensuring that they are able to complete their trip successfully.	E
BT-EU-2.2.5	Travelers need personalization options for notifications and alerts that are sent to the traveler. Allowing the travelers to personalize the messages they receive will ensure that they are able to successfully navigate their trip.	D
BT-EU-2.2.6	Travelers need the ability to opt-in to functions on the app such as preferred mobile device or method of communications, alerts, automated requests, tracking, off-line navigation, notifications to third-parties, support types, etc. so that they may manage and receive information in a manner that is safe and comfortable for them during their travel.	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
TT-EU-3.1.1	Travelers need to communicate with transit infrastructure, including transit vehicle operators, if they require additional time to board or alight a transit vehicle based on their abilities.	E
TT-EU-3.1.2	Travelers need to communicate with transit infrastructure, including transit vehicle operators, if they require assistance to board or alight a transit vehicle (e.g., transit ramp or lift) based on their abilities.	E
TT-EU-3.1.3	Travelers need to communicate with transit infrastructure, including transit vehicle operators, if they require additional time to pay for transit vehicle services after boarding a vehicle.	D
TT-EU-3.1.4	Travelers need to communicate with transit infrastructure, including transit vehicle operators, if they require priority access to designated areas of seating within the bus such as areas with wheelchair tie downs or priority seating at the front of the bus.	E
TT-EU-3.1.5	Travelers need to communicate with transit infrastructure, including transit vehicle operators, if they require additional time to navigate the interior of the transit vehicle to get to a seat or alight the vehicle.	D
TT-EU-3.1.6	Travelers need to communicate with transit infrastructure, including transit vehicle operators, if they have difficulty operating mobility assistance devices on the transit vehicle and need support and assistance from the transit vehicle operator.	D
TT-EU-3.1.7	Travelers need the ability to remotely request service from a transit vehicle while waiting to alight. Some travelers may have difficulty operating transit vehicle equipment, such as a stop request cord or button, to notify the operator that a stop is required, and therefore need the ability to do so through the App.	D
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
IC-EU-4.1.1	Travelers need the ability to communicate with connected intersections at signalized crosswalks when they require additional time to cross the road.	D
IC-EU-4.1.2	Travelers need the ability to communicate with connected intersections at signalized intersections to receive additional information about the crossing time and other characteristics of the signalized crossing.	D
IC-EU-4.1.3	Travelers need the ability to communicate “hands-free” with signalized crosswalk infrastructure requesting the appropriate crossing signal if they are not able to reach or press a crosswalk push button.	D

Need ID	End User Need Statement	Priority
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
CV-EU-5.1.1	Travelers need the ability to remotely request service from a transit vehicle while waiting at a stop. Some travelers may have difficulty indicating to an approaching transit vehicle that they require service, and therefore need to be able to submit a request through the App.	D
CV-EU-5.1.2	Travelers need the ability to remotely request service from a bus while traveling to a stop internally in a transit hub. Some travelers may need additional time transferring between modes or transit services in a given amount of time and the ability to request service in route and would ensure that travelers are able to complete their trip.	D
CV-EU-5.2.2	Travelers need the ability to be notified of approaching vehicles while navigating through their complete trip. Some travelers may have difficulties seeing and identifying oncoming vehicles and need additional feedback from the App when one is approaching.	D
Indoor/Outdoor Navigation (NV) NV-EU-6.1	Travelers need accurate information to successfully navigate indoor spaces.	D
NV-EU-6.1.1	Travelers with physical disabilities need information about accessible building entrances in order to successfully navigate new spaces.	D
NV-EU-6.1.2	Travelers need assistance navigating through indoor spaces they are unfamiliar with or that may be under changing conditions such as construction or service outages, and therefore need accurate information to successfully navigate indoor spaces.	D
NV-EU-6.1.3	Travelers need to know when buildings are open to the public, so they are able to determine if an accessible path, sometimes with access to elevators or escalators, is available, and therefore 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
RP-EU-7.1.1	Travelers need to have the ability to provide feedback on infrastructure and services if they notice an elevator or escalator service outage that is not currently identified through the App.	D

Need ID	End User Need Statement	Priority
RP-EU-7.1.2	Travelers need to have the ability to provide feedback on infrastructure and services if they notice inaccessible sidewalks due to construction, grades, vegetation, or other obstructions that are not currently identified through the App.	D
RP-EU-7.1.3	Travelers need to have the ability to provide feedback on infrastructure and services if they notice transit service outages that are not currently identified through the App.	D
RP-EU-7.1.4	Travelers need to have the ability to provide feedback on infrastructure and services if they notice issues with the App that have not been previously identified and addressed.	D

4.2.3 Infrastructure Owner / Operator Needs

Table 11 provides a summary of the IOO needs, associated justification for those needs, and priority (essential, desired, and optional). More information regarding the prioritization process is provided in **Section 4.2.1**. 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. Any modifications to IOO needs will be reflected in this ConOps document through the life of the project.

Table 11. IOO 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
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.	D

Need ID	IOO Need Statement	Priority
TT-OO-3.3 (cont.)	[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
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
RP-OO-7.1.1	Gwinnett County needs to collect inventory on bus stops/shelter assets' condition including accessibility for boarding and alighting transit vehicles at stop locations and accessible approaches to bus stop and station / hub locations and share with travelers who need updated information on the condition of transit stops in order to make a complete trip based on their preferences and abilities.	E

Need ID	IOO Need Statement	Priority
RP-OO-7.1.2	Gwinnett County needs to disseminate information on bus stops and shelter assets and condition including accessibility for boarding and alighting transit vehicles at stop locations such that travelers may use updated information on the condition of transit stops in order to make a complete trip based on their preferences and abilities.	E
RP-OO-7.1.3	Gwinnett County needs to disseminate information to inform travelers about accessible approaches to bus stop and station / hub locations such that travelers may use updated information on the condition of transit stops in order to make a complete trip based on their preferences and abilities.	E
RP-OO-7.1.4	Gwinnett County needs to complete the Gwinnett County ADA Transition Plan and replace, repair, upgrade inadequate transit infrastructure (i.e., sidewalks, county building entrances, bus stops and shelters) as outlined in their plan so that all travelers may complete trips safely throughout the county.	D
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

4.2.4 System Needs

The following table provides a summary of the system needs, justification for those needs, priority (essential, desired, and optional), and associated end user and IOO needs. More information regarding the prioritization process is provided in **Section 4.2.1**. 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. Some system needs are not mapped directly to a user need or IOO need; rational has been included for these system needs to explain the process behind their development. System needs are summarized in **Table 12**.

The system needs identified below will drive the development of the system requirements. Traceability of system requirements will be ensured during the concept development, design, and deployment phases of the ST-CTN project. Any modifications to system needs will be reflected in this ConOps document through the life of the project.

Table 12. 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-2.1.1	G-MAP needs to be accessed simultaneously by all travelers who are interested in planning a trip so as not to lose or drop their requests or notifications.	E	-
BT-SY-2.1.2	G-MAP needs to respond and regenerate trip plans for all travelers simultaneously based on their trip routing and mode preferences, notification preferences, and accessibility preferences in order to be reliable and responsive to their requests.	E	-
BT-SY-2.1.3	STM needs to respond and generate updates based on the G-MAP routing engine needs to the predictive networks (e.g., SidewalkSim), and produce an appropriately formatted network that can be ingested for trip planning and journeying purposes.	E	-
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-IOO-4.2 IC-EU-4.1 CV-EU-5.1.1 CV-EU-5.1.2 CV-OO-5.2
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-IOO-4.1

Need ID	System Need Statement	Priority	Associated End User and IOO Need
Connected Vehicle Broadcast Message (CV) CV-SY-5.1	The system needs to connect travelers to the connected infrastructure to increase safety.	E	IC-IOO-4.1 IC-IOO-4.2 CV-IOO-5.1
CV-SY-5.1.1	The system needs to identify and communicate traveler presence at RSU-deployed signalized intersections to nearby connected vehicles for the safety of the traveler(s).	E	IC-IOO-4.1 IC-IOO-4.2 CV-IOO-5.1
CV-SY-5.1.2	The system needs to detect that a traveler needs additional crossing time at a signalized intersection.	E	IC-IOO-4.1 IC-IOO-4.2 CV-IOO-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 an 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
FT-SY-8.1.1	The system needs to be scalable to accommodate future growth, modifications, or integration with multiple services, including those that may be needed to buy transit tickets or passes from public agencies.	D	FT-OO-8.1 FT-OO-8.2
FT-SY-8.1.2	The system needs to be scalable such that other geographic areas may be included in the future.	D	FT-OO-8.1 FT-OO-8.2
FT-SY-8.1.3	The system needs to be scalable such that transit or other mobility on demand services may be integrated in the future – this includes the ability to book transit/mobility on demand trips less than 24 hours in advance.	D	FT-OO-8.1 FT-OO-8.2
FT-SY-8.1.4	The system needs to be scalable such that it can support future functionalities such as subsidized trip costs across multiple mobility options.	D	FT-OO-8.1 FT-OO-8.2
FT-SY-8.1.5	The system needs to be scalable to accommodate future growth, modifications, or integration with multiple services, including those that may be mobility service access rights from private sector agencies such as bikeshare, ridehaling, microtransit services or others.	O	FT-OO-8.1 FT-OO-8.2

4.3 Changes Considered but Not Included

The majority of the desired changes identified by stakeholders were included in the user needs. In some cases, desired changes identified by stakeholders were outside the scope of the project or were not related to the proposed system. System developer and IOO needs were generated from the end user needs that were included in the Needs Summary Document, therefore, there are no desired changes identified by the IOO or System Developers that were not included.

Table 13 provides a summary of changes that were considered based on end user feedback but were excluded from the proposed system.

Table 13. Considered Changes Not Included

Need Area / Trip Segment	Need Statement	Reason for Omission
Pre-Trip Planning	Travelers with hearing loss need the ability to generate messages using graphical sign language.	The production team determined that it would be too difficult to generate all application outputs in this format. Additionally, it was determined that this feature would be underutilized, and that text could be used instead.
Pre-Trip Planning	Travelers need an expanded schedule of transit service hours.	It is outside of the scope of this project to expand the service hours or route configuration of existing fixed route and on-demand transit services.
Pre-Trip Planning	Travelers need the ability to customize application and maps based on their comfort level using mobile applications and maps.	The ATL RIDES application uses base mapping from OSMs. Although some features are customizable, the effort required to provide additional and on-demand customization is outside the scope of work for this program. Application customization features such as haptic feedback and alternative languages are covered in other needs.
Begin Trip	Travelers need better street lighting to complete their trip safely.	It is outside of the scope of this project to install or modify street lighting.
Transition to Transit	Transit vehicle operators need more training on the use of accessibility features and how to recognize and respond to users with mobility challenges.	It is outside of the scope of this project to provide training on accessibility features installed on transit vehicles or to provide training on how to recognize and respond to user specific mobility challenges.
Transition to Transit	CPACS microtransit vehicles need to have OBUs installed to allow for TSP or CV applications.	It is outside of the scope of this project to install OBUs on CPACS microtransit vehicles.
Transition to Transit	Providing information to operators on customers with disabilities.	It is outside of the scope of this project to provide training to bus drivers on how to recognize and respond to user specific mobility challenges.

Need Area / Trip Segment	Need Statement	Reason for Omission
Intersection Crossing	Travelers need safe intersections and interchanges constructed within the project area.	It is outside of the scope of this project to modify the entirety of an intersection. This project will identify areas of concern such as missing curb cuts or ramps.
Indoor/Outdoor Navigation	Travelers need doorway thresholds reduced and non-automatic door pressure to be reduced.	It is outside of the scope of this project to modify building entries. This project will identify areas of concern such as those listed.
Indoor Navigation	The addition of “talking signs” inside facilities to help travelers navigate.	It is outside the scope of this project to modify or install infrastructure within public or private indoor spaces.
Future Development	Transit stations need to be expanded to provide additional shelter and restrooms.	It is outside of the scope of this project to expand existing transit facilities.
Future Development	The application should include public amenities and partner with private companies to provide discounts or benefits for using the application.	It is outside of the scope of this project to provide these additional services.

4.4 Assumptions and Constraints

Some key assumptions were made when defining the features of the proposed system, including the following:

- During the testing period, there will be enough testers from the underserved communities to ensure that functionality exists for users of all abilities.
- The CV1K and Gwinnett County CVTMP goals, such as RSU and OBU deployment, are accomplished as described in order for the ST-CTN project to utilize these assets.
- The network edge impedance algorithm processing time can be managed in an environment with changing characteristics, such as road or sidewalk closures, curb cut or ADA ramp changes, etc.
- Existing field devices, infrastructure, and key systems that will interact with the new system will remain operational in the project limits.
- No significant changes to transit service/routes.
- Existing project progress as planned and on-schedule with all the capabilities needed to support the ST-CTN project.

- All connected vehicle infrastructure and applications will adhere to GDOT's Security Credential Management System (SCMS) which is compliant with IEEE 1609.2.
- All institutional Review Board Human Use and PII rules will be followed.

The following constraints have been identified during the development of the proposed system and will need to be addressed prior to or during the deployment.

- The ST-CTN application shall abide by agency IT policies.
- The deployment of the ST-CTN project will not require additional agency staff to operate and maintain the system.
- Too many preferences will reduce the options for trip planning. Some restrictions on preference choices may need to be put in place to address the end user's major accommodations yet still provide options for travel. Even if end user preferences are included in the scenarios, the priority for implementing them will be driven by ensuring that the data to address the preferences can be economically collected and a complete trip plan can be generated.
- CV technologies shall adhere to the Federal Communication Commission (FCCs) rules for the use of the Safety Band.

5. Concepts for the Proposed System

The proposed ST-CTN system is being developed to address the needs and challenges that have been expressed by end users, particularly those representing underserved communities. The new system is a result of end user, IOO, and system needs and desired capabilities as described in **Section 4**.

5.1 Background and Scope

The ST-CTN concept will integrate six programs currently existing or underway with regional commitments into a single system. These programs are leading the Atlanta region towards providing all travelers with a suite of innovative mobility solutions, which will be leveraged to support the ST-CTN system. ST-CTN will merge these separate initiatives through data fusion and communications network integration. ARC intends to leverage the successes of the infrastructure, tools, and capabilities of these programs and apply them to support trip planning and wayfinding for all travelers, particularly underserved communities.

*The goal of the ST-CTN system is to leverage existing advanced transportation technology solutions to support **safe, reliable, accessible, complete** trips for all, particularly undeserved communities, including people with disabilities, older adults, people with limited English proficiency, and low-income travelers.*

ST-CTN system aims to upgrade and integrate existing technologies and services to assist underserved populations with completing their 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.

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 16** 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; Ride Gwinnett is teal; and Public PMD is maroon. The STM Platform, G-MAP, CV, and Public PMD subsystems will each require expanded capability and added connectivity to support the proposed ST-CTN system. The Sidewalk Inventory Collection Tools and Ride Gwinnett 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.

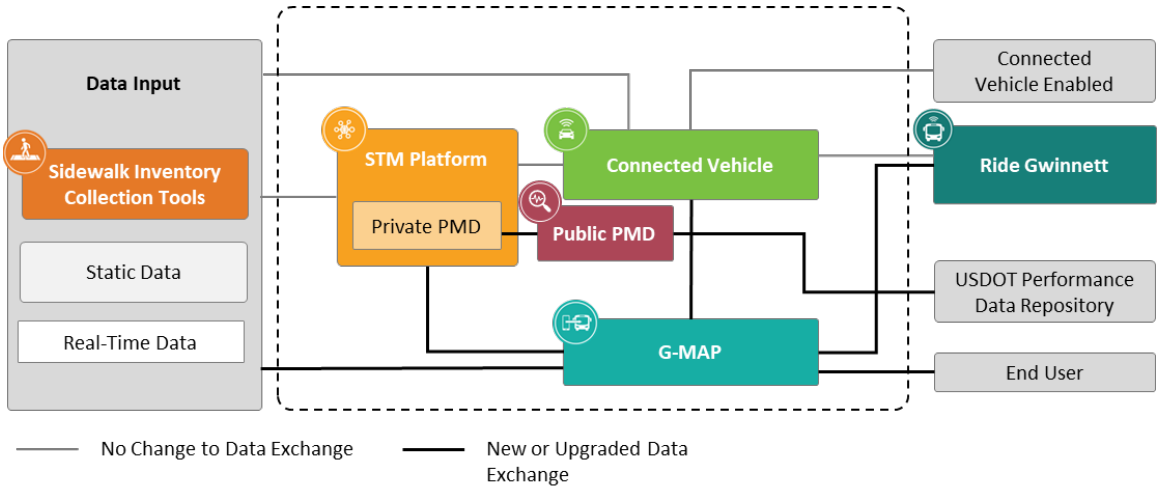

Figure 16. Safe Trip in a Connected Transportation Network Simplified Context Diagram (Source: ARC)

5.2 Description of the Proposed System

The following section provides an overview of all the major aspects of the new system, focusing on those subsystems that will require expanded functionality and additional connectivity – G-MAP, STM Platform, CV Program, and Public PMD. In addition, system interfaces and interoperability as well as 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 14**. 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 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 17** provides the ST-CTN context diagram in more detail.

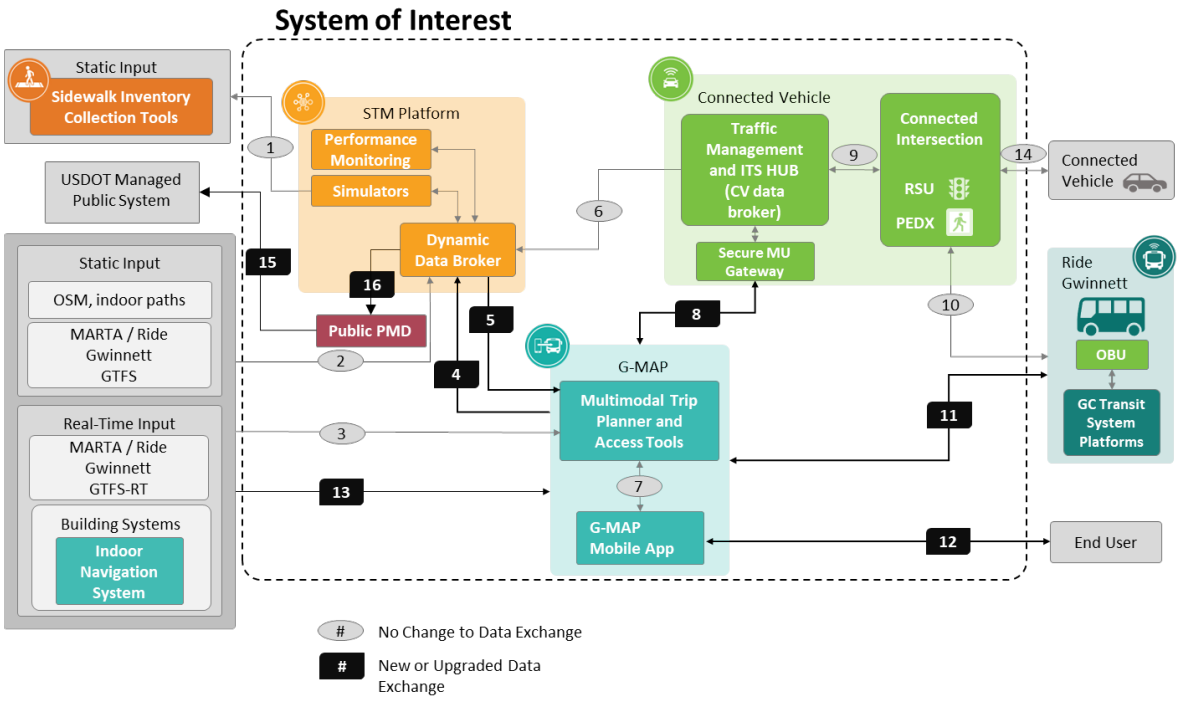

Figure 17. Safe Trip in a Connected Transportation Network Data Exchange Flow Diagram (Source: ARC)

Critical ST-CTN data exchanges are identified by number in the context diagram above and described in **Table 14**. 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.

Table 14. Critical ST-CTN Connection Descriptions

Data Exchange ID	Description
1	Sidewalk inventory data, including accessibility features to the STM Platform simulators
2	Static and dynamic data from various existing sources to the STM Platform dynamic data broker
3	Static and dynamic data from various existing sources to the G-MAP multimodal trip planner and access tools
4	G-MAP Mobile App logs and trip feedback
5	STM Network Impedance API
6	CV and Traffic Operations Messages: NaviGAtor ITS, road characteristics, traffic data

Data Exchange ID	Description
7	OTP APIs and G-MAP APIs
8	Mobile Accessible Pedestrian Signal System (PED-SIG)
9	CV messages
10	TSP and other CV application messages
11	Ride Request messages
12	G-MAP Mobile App APIs and Traveler exchange – profile, trip plan, settings, notifications, feedback, etc.
13	Dynamic information from building facilities (including beacons to the G-MAP mobile app) and INS vendor cloud SDK
14	CV data
15	Project data for USDOT-managed Public System
16	Public facing data and visualizations for reporting on system operations and performance
17	G-MAP Administration Tool configuration and control message exchanges (exchange 17 is internal to G-MAP Multimodal Trip Planner and Access Tools)

Expansions and enhancements required to support the ST-CTN system within the G-MAP, STM Platform, and CV Program subsystems are described in the following sections.

5.2.1 G-MAP Multimodal Trip Planner Subsystem

ATL RIDES is being developed with the support of FTA's IMI Grant program and is a journey planning application to provide more reliable and easier to access transit data to all travelers, making it easier to utilize the region's transit services.

Description. As described in **Section 3.2.1**, the ATL RIDES context diagram will be augmented to support more infrastructure features, user routing and accessibility preferences and notifications, and ingest dynamic information from the STM platform and output PII-free and performance measures to the STM for evaluation purposes.

Functions. Figure 18 provides the current ATL RIDES architecture major subsystem components along with the proposed augmentations that will be required to address system needs as described in **Section 4.2.4**. Existing data exchanges are displayed with a grey line, a grey oval shape, and normal, black text. New data exchanges are displayed with a thick black

line, a black rectangular shape, and bolded, white text. The current functionality will continue to operate, and these extensions will drive additional fields, configurations, and algorithms already implemented in the software. Specifically, the extensions are listed by functional components in this section.

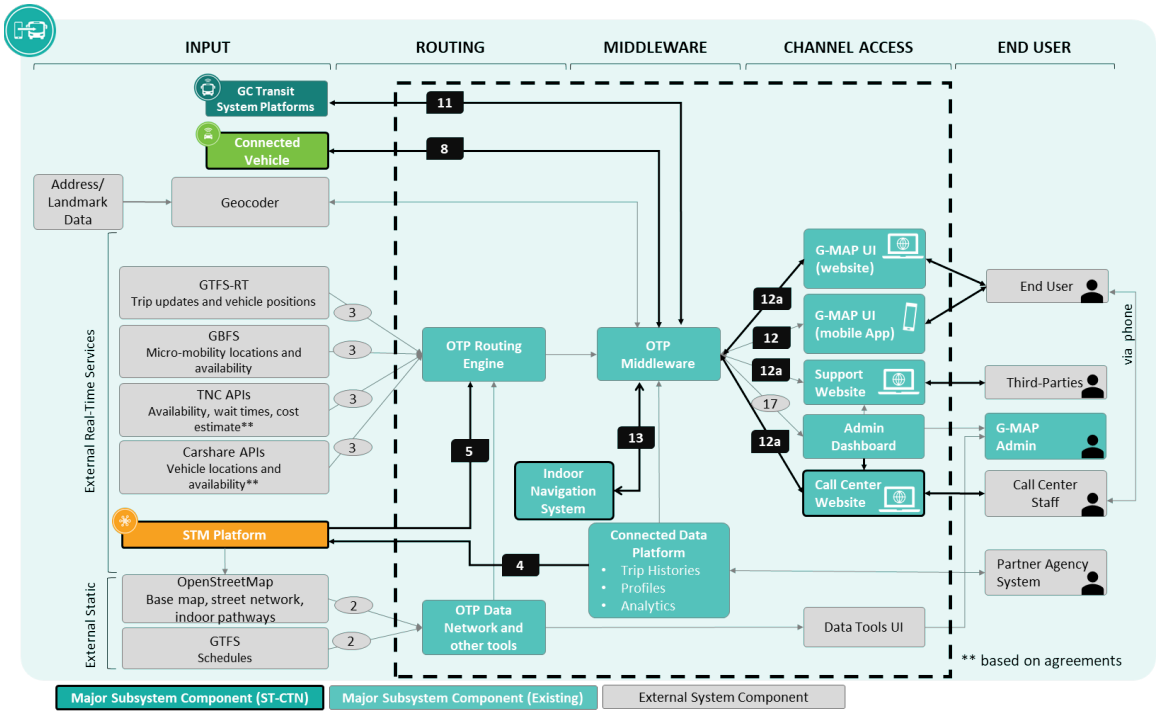

Figure 18. Proposed G-MAP Subsystem Extension (Source: ARC)

Channel Access (responsive web application, native mobile app, and call center) – New features that augment the current functionality for the ST-CTN include the following:

- Additional user preference settings such as through path dimension, features, and condition of shared use paths (sidewalk and intersections), indoor navigation needs (elevators/escalators), assistive device types (wheelchair type) and support aides (service dog, caregiver), sensory delivery of event triggers and notifications (for hands-off operation), third-party user support (e.g., dial caregiver or guardian), and turn by turn direction support will be added to the existing profile description and routing engine.
- Specific notifications to additional recipient(s) (e.g., arrived at destination).
- Synchronization with user device(s).
- Presentation of mobile app notifications to users based on their preferences (e.g., voice, text, haptic).
- Trigger 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.

It is expected that additional features may be added based on the Agile processes during Phase 2 of the ST-CTN project.

Middleware – New features that augment the current functionality for the ST-CTN include the following:

- Interface with a call center to handle calls from phones.
- Interface with the STM Platform and STM Network Impedance API for real-time condition information on user trip itineraries.

Routing – New features that augment the current functionality for the ST-CTN include the following:

- Incorporate OSM graph for sidewalks and roadways using updates from STM network (update frequencies to be defined in Phase 2). This new feature will incorporate the information from the STM Network Impedance API and use that network for routing in the OTP routing module.

Data and Administration Tools – The data and administration tools provide data management and curation services for specific data such as GTFS, 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.

Interfaces. Current and new interfaces will be deployed in the G-MAP subsystem. New interfaces will include:

- Real-time Data Input
    - STM Network Impedance API
- Output APIs and Services
    - Performance data output to the STM Performance Measurement Dashboard
    - Data exchange between the mobile app (Mobile Unit) and other existing CV / signal control applications

Description of these interfaces are included in **Section 5.2.4** System Interfaces and Interoperability and **Section 5.2.5** External System Interfaces.

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.

Modes. The modes of operation will not change from the current system and are further described in **Section 5.5** (Modes of Operations for Proposed System).

5.2.2 Space Time Memory Platform 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.

Description. The STM Platform Subsystem will be deployed with the current functionality and the extended functionality as described in its roadmap (see **Section 3.2.2** System Schedule). Developed as a research platform, the platform will be hardened to be deployed as a production system 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 production model will be updated to increase the origin-destination shortest path query response speed and will be integrated with new real-time data streams. **Figure 19** provides the proposed STM Platform subsystem context diagram with added functionalities and connectivity presented in bold. Existing data exchanges are displayed with a grey line, a grey oval shape, and normal, black text. New data exchanges are displayed with a thick black line, a black rectangular shape, and bolded, white text.

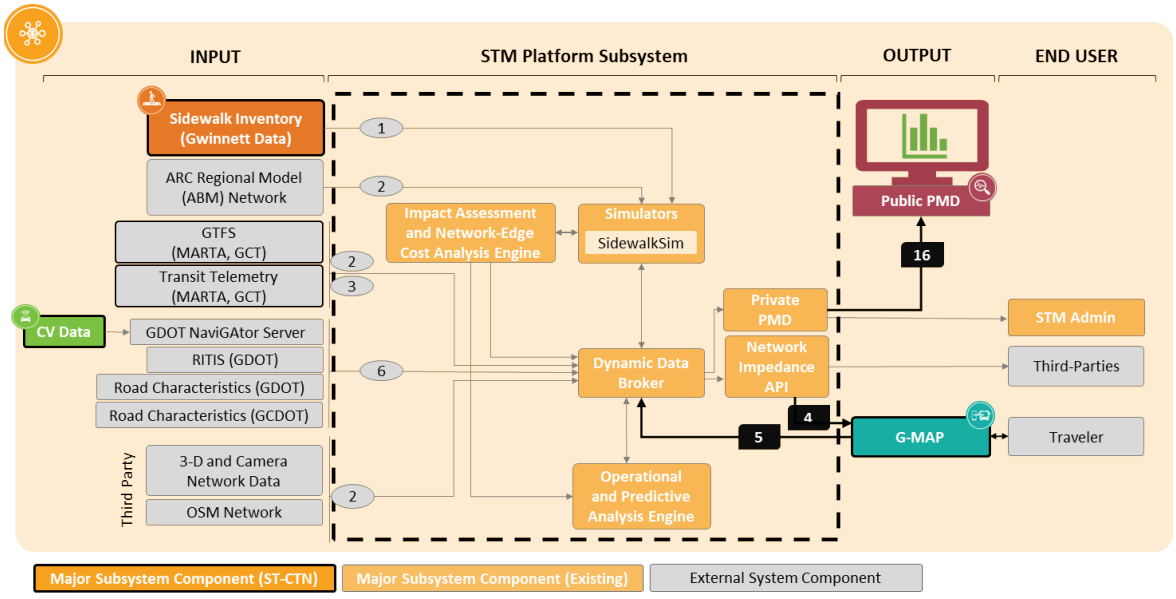

Figure 19. Proposed STM Subsystem Extension (Source: ARC)

The overall architecture and functionality of the system will not change, rather, additional input, such as completing an inventory of the sidewalk network within the project area, and output data flows will be added or updated, and some component functionality will be upgraded. The upgrades are described for functions, interfaces, support environment, and modes.

Functions. Upgraded and expanded functions are described below.

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
- Augmented dynamic sidewalk data feeds from G-MAP mobile app crowdsourced reporting
- 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)

Simulators – After creating an inventory of the infrastructure in the study area, the SidewalkSim simulator processes will be upgraded to 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 current G-MAP app, the OSM network will be regularly updated to reflect changes in static network elements identified via SidewalkSim inventory and inspection tools outlined in **Section 3.2.3** (Sidewalk Sentry, Sidewalk Scout, Sidewalk MV, etc.) and as machine-learning processes identify network refinements that can increase route efficiency.

- Sidewalk network changes will be updated using construction permit final inspection reports generated by Gwinnett County, regular Sidewalk MV and Sidewalk Sentry inspections, and agency field inspections and crowdsourced reporting via the Sidewalk Scout app.
- Sidewalk infrastructure conditions will be associated with sidewalk links, ramps, curb cuts, and other elements that are explicitly tracked. These elements will be updated regularly via regular Sidewalk MV and Sidewalk Sentry inspection, and via agency field inspection and crowdsourced reporting from the Sidewalk Scout app.

Impact Assessment and Network-Edge Cost Analysis Engine – The Network-Edge Cost Analysis Engine will undergo the most critical upgrade because these algorithms calculate the customized impedance value for traveling on a segment of the trip.

Impact Assessment and Network-Edge Cost Computing Engine – The Network-Edge Cost Computing Engine will undergo the most critical upgrade because these algorithms 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 and temporary protrusions will be crowd sourced.

The algorithms will be upgraded to assign impedance values to different features based on an enumerated set of preferences that are consistent with the G-MAP user created profiles (see **Section 5.2.1** Channel function). 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.

Operational and Prediction Analysis Engine – As noted in the existing STM platform, Operational and Prediction Analysis Engine serves as the machine learning function of the STM. This module will consume feedback from traveler's execution of their trip plans and will update the Cost Analysis Engine edge costs based on changes made by users of the tools. The processes are already implemented in the platform, the extension will be to interpret planned versus actual travel of various user classes.

Performance Monitoring Dashboard – The performance monitoring dashboard will serve as the performance monitoring engine for the project both 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.

Commute Advisor Mobile App – The Commute Advisor Mobile app which is deployed in the current research platform will not be used for the ST-CTN project. Instead, the G-MAP Multimodal Trip Planner Subsystem will consume the maps through two methods. These are described in the Interfaces section.

Interfaces. The STM Platform will add or upgrade two interfaces, represented by Data Exchange ID 4 and 5 in **Figure 17**.

OSM updates (new) – The STM will transform the continuously updated simulations (transit and traffic models) to an OSM network model that can be ingested into the G-MAP OTP 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 (new) – 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. The API will be developed during the Agile development phase in collaboration with STM and G-MAP platform developers.

Operating Environment. Given the production needs of the STM platform, the infrastructure will be hardened to ensure subsystem reliability, scalability and availability. The system requires a dedicated server environment in a cloud-based infrastructure. This will ensure scalability and redundancy to meet reliability and expansion needs.

Modes. The STM platform will include the current modes of operation with additional modes to ensure operations in the broader system. The ST-CTN modes of operation are describe in **Section 5.5**.

5.2.3 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.

Description. 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. Additional RSUs may need to be purchased to accommodate the full ST-CTN project area or if transit routes are changed. Devices that are currently deployed have been transitioned to comply with FCC Report & Order and are operating on a single channel (Channel 180). Existing services are operating sufficiently on a single channel. Additional testing will need to occur in Phase 2 to determine if operating on a reduced set of channels will have an impact on new services. As described in the current system, the center components consist of components located at the GDOT TMC and Gwinnett County TCC – Navigator TMC, MaxTime/View 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. The equipment and operations of the subsystems will not be changed in the ST-CTN project. Specifically, the equipment will consist of OBUs installed on GCT vehicles to support TSP and communications channels between the traveler mobile unit and the signal system to support pedestrian safety applications. To achieve the goals of this project, that is, more effectively integrating the mobile units (MUs) (pedestrian and other vulnerable road users) into the CV environment, this project will deploy a direct connection between MUs (represented by the G-MAP subsystem) and the CV Vehicle Subsystem through the Secure Mobile Unit (MU) Gateway as depicted in **Figure 20.**

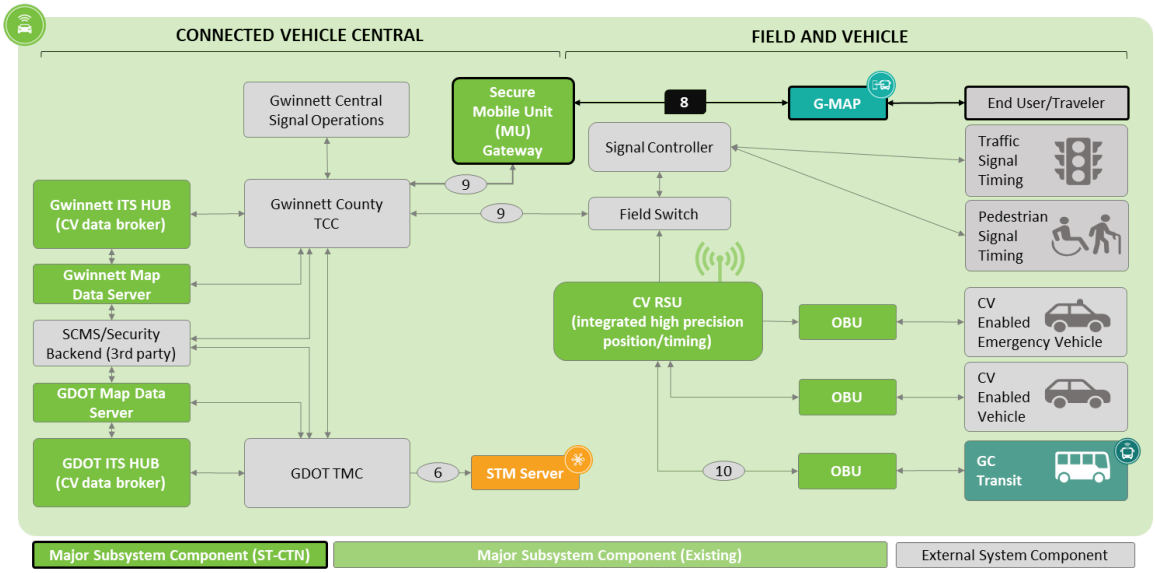

Figure 20. Proposed CV Subsystem Extension (Source: ARC)

Functions. The functions will be driven by the applications that are deployed by the CV Smart Corridor project (as detailed in **Table 5**). *Secure Mobile Unit (MU) Gateway* – The MU Gateway will serve as a secure means of exchanging information between a mobile unit (or proxy such as the G-MAP subsystem) and the CV environment. The MU Gateway serves to provide authenticated access, validate messages, transform and direct the messages to the appropriate destination. In addition, it serves to respond to messages as appropriate. In summary, the Secure MU Gateway acts as a gatekeeper of non-RSU or non-OBU derived messages into the CV subsystem.

Each application will include additional logic to ensure conformant message exchange protocols are deployed. An initial set of applications are proposed, the highest priorities include TSP and PSM broadcast. These applications along with the medium and low priority applications are described further in **Table 24** (located in **Section 6**).

Interfaces. Interfaces used to exchange information between the CV components (RSU, OBU and MU) will be based on SAE J2945 series messages. Additional message sets may be adapted from other standards including NTCIP.

The interfaces will occur between the following CV components:

- SMUG and OBU on Ride Gwinnett bus (for TSP)
- RSU and OBU on vehicles (for pedestrian safety applications)

The pathways between the MU and field components (RSU) and transit bus (OBU) may be channeled through various subcomponents of the G-MAP and CV subsystems.

All communications between the CV subsystem and other subsystems will only be accepted and trusted if the appropriate security headers have been applied through a trusted security credentialing system.

Operating Environment. The CV subsystem support environment consists of communications network infrastructure, OBUs, MUs, and TMC/TCC/ITS Hub as described below.

Communications Network – The CV subsystem will be supported by the existing communications infrastructure which consists of fiber optic cable and wireless devices.

OBU – The OBU is supported by the router and onboard equipment (AVL and processor) already deployed in the transit vehicles, in addition to the wireless communications radios that connect the bus systems back to the transit CAD.

MU – The mobile units may be supported by several communications technologies including Bluetooth, WiFi and cellular, and navigational sensors such as GPS and accelerometers which support location positioning.

TMC/TCC – The TMC/TCC will support the proposed CV subsystem as is consistent with the existing CV infrastructure. The ST-CTN system will not impact day-to-day TMC operations but will offer the ability to provide TMC/TCC staff more data through the STM platform to leverage for performance monitoring within the transportation network within the ST-CTN deployment area.

ITS Hub – The ITS Hub will support the proposed CV subsystem as is consistent with the existing CV infrastructure.

Modes. The modes of operation will not change from the current system and are further described in **Section 5.5**.

5.2.4 System Interfaces and Interoperability

All system interfaces to be exchanged between subsystems in the ST-CTN and external sources are identified by numbered links in **Table 14** and **Figure 17.** These system interfaces are

described more comprehensively below in **Table 15**. Several of these interfaces are already developed and implemented. During the design phase, they may be updated to accommodate additional functionality.

Table 15. ST-CTN System Interfaces and Interoperability

Interface	Description
Data Exchange 1	**Sidewalk inventory data, including accessibility features to the STM Platform simulators**
Subsystems Involved	From Sidewalk Inventory Collection Tools external to the system (see Table 16 for source details) to STM simulators
Exchange Description	No major change. Sidewalk and pedestrian path asset characteristics within the ST-CTN deployment area which include accessibility features like sidewalk roughness, slope, curbs, obstructions, etc.
Data Exchange 2	**Static and dynamic data from various existing sources to the STM Platform dynamic data broker**
Subsystems Involved	From various existing data sources external to the system (see Table 16 for source details) to STM
Exchange Description	No major change. May be expanded to accept additional data sources as available outside the scope of the ST-CTN project.
Data Exchange 3	**Static and dynamic data from various existing sources to the G-MAP multimodal trip planner and access tools**
Subsystems Involved	From various existing data sources external to the system (see Table 16 for source details) to G-MAP
Exchange Description	No major change. May be expanded to accept additional data sources as available outside the scope of the ST-CTN project.
Data Exchange 4	**G-MAP Mobile App logs / trip feedback**
Subsystems Involved	From G-MAP to STM
Exchange Description	New data exchange. G-MAP Mobile app log files which include all the trips, trip preferences and travel results will be forwarded to the STM dynamic data broker for analysis and aggregation into performance measures.
Data Exchange 5	**STM Network Impedance API**
Subsystems Involved	Between STM and G-MAP
Exchange Description	New data exchange. 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. The API will be developed during the Agile development phase in collaboration with STM and G-MAP platform developers.

Interface	Description
Data Exchange 6	**CV and Traffic Operations Messages: NaviGAtor ITS, road characteristics, traffic data**
Subsystems Involved	From GC ITS Hub and NaviGAtor to STM
Exchange Description	No major change. The information provided to the STM dynamic data broker from the GC ITS Hub will include traffic operations messages from the NaviGAtor ITS, road characteristics, and second-by-second traffic data acquired from all the upstream data sources fused by the TMC and CV platforms.
Data Exchange 7	**OTP APIs and G-MAP APIs**
Subsystems Involved	Between G-MAP middleware and UI, internal to the G-MAP subsystem
Description	No major change. May be configured differently or add additional user preferences and options.
Data Exchange 8	**Mobile Accessible Pedestrian Signal System (PED-SIG)**
Subsystems Involved	Between MU (G-MAP) and CV Subsystem through the Secure MU Gateway
Description	New data exchange. Trigger to actuate request to pedestrian signal controller.
Data Exchange 9	**CV Messages**
Subsystems Involved	Between RSU and TMC/ITS CV back center system, internal to the CV subsystem
Description	No change to existing message sets.
Data Exchange 10	**TSP and other CV application messages**
Subsystems Involved	Between RSU and OBU on transit bus
Description	No major change. Messages that request priority service for transit vehicles.
Data Exchange 11	**Ride Request messages**
Subsystems Involved	From G-MAP mobile app to bus operator display in the external GCT subsystem
Description	New data exchange. Information on traveler boarding bus to alert operator about their need for additional time boarding and alighting.

Interface	Description
Data Exchange 12	**G-MAP Mobile App APIS and Traveler exchange – profile, trip plan, settings, notifications, feedback, etc.**
Subsystems Involved	To and from G-MAP mobile app to end user, external to the system
Description	Upgraded data exchange. Information exchange from end user to G-MAP regarding trip planning requests, profile, preferences, and feedback. Enhancements include expanded accessibility profile and trip planning settings, notification options, feedback options, and UI. Information exchange from G-MAP to end user regarding turn by turn directions, rerouting, accessible routes, transit status and request, etc. Enhancements include expanded interface notification preferences on mobile app (voice, text, haptic), application type, trusted companion notifications, transit operator notifications, etc.
Data Exchange 13	**Dynamic information from building facilities (including beacons to the G-MAP mobile app) and INS vendor cloud SDK**
Subsystems Involved	From Building Systems (facilities) to G-MAP
Description	New data feed. Provides near real time information on conditions and status of pathways including elevator/escalator operations.
Data Exchange 14	**CV data**
Subsystems Involved	Between enabled connected vehicles external to the system (see Table 17 for destination details) and RSUs within the CV subsystem
Description	No change to existing message sets. These messages will conform to SAE J2945 message sets Part 9 for Vulnerable Road Users including the Personal Safety Message (PSM).
Data Exchange 15	**Project data for USDOT-managed Public System**
Subsystems Involved	Public PMD and public data access
Description	Summary performance metrics in a tabular and visual representation. The public can download the data in a comma separated format.
Data Exchange 16	**Public facing data and visualizations for reporting on system operations and performance**
Subsystems Involved	Private PMD (STM) to Public PMD
Description	Anonymized summary performance metrics from the private to public PMD.

5.2.5 External System Interfaces

The system interfaces to be exchanged between external sources and ST-CTN subsystems are identified in each of the detailed subsystem context diagrams in **Section 5.2.1** to **Section 5.2.3**.

The types of data flows are identified by categorized by inputs and outputs, and further detailed by static and real-time data sets. Different subsystems require various data sources. The specifics are listed in the description of each subsystem. The data exchange ID associated with the input or output is included for each interface (associated with **Figure 17**). The organization that will provide the data and destination of each interface is provided as well. **Table 16** summarizes the external system interfaces that input to specific ST-CTN subsystems.

Table 16. External System Interfaces – Inputs

EX-ID	Input Data	Static / RT	Description	Organization	Destination (subsystem)
2, 13	Facility Assets	Static	The location of wayfinding signs and announcements in facilities including transit hubs and stations.	GCDOT	STM
2	Facility Conveyance Status	RT	The status of current obstructions and vertical conveyances status (e.g., operating, out of order, under maintenance).	GCDOT	STM
2, 3	GTFS	Static	General Transit Feed Specification data including accessibility attributes for Gwinnett County Transit and MARTA.	GCT MARTA	G-MAP, STM
2, 3	GTFS-RT	RT	GTFS-RT data including for GCT and MARTA. The telemetry data will be used for STM and the comparison between the static and real-time GTFS data will be used to generate on-time performance measures particularly when signal priority was granted.	GCT MARTA	G-MAP, STM

EX-ID	Input Data	Static / RT	Description	Organization	Destination (subsystem)
1, 3, 13	Indoor Pathways	Static	The description of indoor pathways including the location and description of vertical conveyances and planned or current obstructions.	GCDOT	STM, G-MAP
2, 3	OpenStreetMap	Static	Open Street Map network needed to support G-MAP OTP engine and STM simulator component.	OSM ATL	G-MAP, STM
1	Sidewalk Inventory	Static	Sidewalk collected by sidewalk inventory tools.	GA Tech sidewalk data collection	STM
1	Sidewalk data Updates	RT	Using the sidewalk inventory tools that provide crowdsourced updates on obstacles and changes to the pathways, this information will be used to update the sidewalk asset inventory.	GA Tech sidewalk data collection	STM
2	Traffic Assets	Static	The location of assets located for managing intersections particularly crosswalk characteristics and asset features that cater to pedestrians (e.g., ped crossing signals).	GCDOT, GA Tech Sidewalk Data Collection	STM
2	VRU Categories	Static	List of categories and their related edge impedance values. The enumerated list will correspond to the list of disabilities and assistive devices offered in the G-MAP preference menu.	ATL ARC GA Tech	STM

Table 17 identifies the output interfaces that are offered by subsystem.

Table 17. External System Interfaces – Outputs

EX-ID	Output Data	Static / RT	Description	Source (subsystem)	Destination
10, 15	CV Messages, Alerts and Warnings	RT	Based on GC CV applications (including pedestrian awareness)	Connected Vehicle	Connected Vehicles GCT
12	Travel Notifications and Alerts	Static and RT	Trip planning and turn by turn travel notifications based on their preferences	G-MAP	End User
15, 16	Performance Data	RT	Performance measurement data collected and aggregated by the ST-CTN system. The details will be described in the Performance Measurement and Evaluation Plan.	STM	Public PMD

5.3 Stakeholders and Actors of the Proposed System

The following sections describe the stakeholders, other involved personnel, and actors in the proposed system.

5.3.1 Stakeholder Roles

Table 18 provides the ST-CTN stakeholders, along with their roles, in the proposed system:

Table 18. Stakeholders and Roles in the ST-CTN System

User Group	Roles
End User Classification	
Person with Disability	**Role:** Traveler (End user of the system).
Older Adult	**Role:** Traveler (End user of the system).
Person with Limited English Proficiency	**Role:** Traveler (End user of the system).
Person considered to have Low Income	**Role:** Traveler (End user of the system).

User Group	Roles
Infrastructure Owner Operator Classification	
Gwinnett County DOT - Transit	**Role:** Owner / operator / maintainer of the Gwinnett County Transit system including bus fleet, stop, station, signage and service information.
Gwinnett County DOT - Traffic and Operations	**Role:** Owner / operator / maintainer of the Gwinnett County traffic operations, including Gwinnett County TCC, traffic signal and CV infrastructure and applications. Owner / operator of the Gwinnett County communications network including communications to traffic signals and ATMS devices and maintaining server infrastructure within the Gwinnett County TCC.
Gwinnett County Department of Transportation	**Role:** Owner / operator / maintainer of sidewalks and ramps in Gwinnett County
The Atlanta-Region Transit Link Authority (The ATL)	**Role:** Owner / operator of the ATL RIDES application.
Georgia Department of Transportation (GDOT)	**Role:** Owner / operator / maintainer of the GDOT Traffic Management Center (TMC), statewide ATMS (NaviGAtor), and CV infrastructure and responsible for funding development and oversight.
Gwinnett County Information Technology	**Role:** Owner / operator of the Gwinnett County network security components within the county.
Atlanta Regional Commission (ARC)	**Role:** Owner/operator of ST-CTN application extension and Metropolitan Planning Organization (MPO) for the Atlanta Region responsible for funding development and oversight.

ST-CTN stakeholder roles and responsibilities by subsystem are provided in **Section 5.3.3**.

5.3.2 Other Involved Personnel

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

- **USDOT.** Sponsoring agency.
- **SILCGA.** Outreach coordinator and major system testing sponsor.
- **disABIILITY Link.** Provides outreach and system testing.
- **CPACS.** Provides outreach and system testing. Provides demand-responsive service for Gwinnett County travelers.
- **Georgia Department of Education (DOEd).** Provides outreach and system testing.

- **Georgia Department of Behavioral Health and Developmental Disabilities (DBHDD).** Provides outreach and system testing.
- **GA Tech Tools for Life.** Provides outreach and system testing.
- **Third Party Application Developers.** Developers interested in using open data created by the proposed system.

5.3.3 Roles and Responsibilities

Stakeholder roles and responsibilities by subsystems are described in **Table 19**, **Table 20**, and **Table 21** below. The tables present subsystem roles, the primary stakeholder, and their primary responsibilities. Responsibilities are inclusive of tasks needed to ensure the proper operations of this proposed system.

Roles and responsibilities for the G-MAP subsystem are provided in **Table 19**.

Table 19. Roles and Responsibilities for the G-MAP Subsystem

Role	Stakeholder	Responsibilities
Call Center Operators	GCT	• Provide en route guidance for end users. • Aid traveler / account holder with profile setup. • Aid traveler / account holder with accessibility settings in application. • Address customer service requests and recommendations.
Data Custodians	GCT ATL	• Maintain accurate transit route data through generation and verification of GTFS data. (GCT) • Continually improve the quality of the data generated by the system. (ATL)
Maintenance	ATL ARC Arcadis	• Perform preventative maintenance on the proposed subsystem. • Perform corrective maintenance on the proposed subsystem. • Provide technical support for end users. • Upgrade and test software including infrastructure software, UIs, and web systems. • Maintain external input format of data that are consumed by the proposed system. • Update web system and interface based on currently accepted standards. • Update mobile application based on currently accepted standards.

Role	Stakeholder	Responsibilities
Outreach	ATL	• Inform partner agencies of application roll out. • Inform partner agencies of application updates that will impact end user operations.
Subsystem Operators	ATL ARC Arcadis	• Operate parallel applications of ATL RIDES (ATL) and ST-CTN expansion, G-MAP (ARC). • Continuously monitor operations, communications network, and interface flows. • Monitor security system for potential intrusions. • Protect the PII of end users. • Preserve data streams for verification and backup purposes in accordance to the PII policies.
Subsystem Owners	ATL ARC	• Financial responsibilities for maintaining the current ATL RIDES system (ATL) and ST-CTN expansion, G-MAP (ARC) with updated roles and responsibilities.
Trainers	ATL SILCGA disABILITY Link CPACS Georgia DOEd Georgia DBHDD Georgia Tech Tools for Life	• Train traveler / trusted person with who are accessing and using the application. • Train call center dispatch and operators on the application features and functions to provide assistance to end users.
Travelers	End User including but not limited to: Person with Disability Older Adult Limited English Proficiency Low Income	• Setup mobile application including installation of mobile application on personal cell phone. • Create profile and input personal accessibility settings. • Update application as required. • Use trip planner for pre-trip and en-route travel.

Roles and responsibilities for the STM subsystem are provided in **Table 20**.

Table 20. Roles and Responsibilities for the STM Subsystem

Role	Stakeholder	Responsibilities
Data Collectors	GA Tech GCDOT	• Collect and catalog sidewalk data within the project study area. • Respond to requests for data collection based on end user feedback if a path is deemed not accessible but programed as such. • Complete and upload construction permit final inspection reports to network when sidewalk improvements are completed.
Data Custodians	GA Tech ATL / ARC	• Generate simulations of road and sidewalk networks. • Maintain database of accessible paths. • Continually improve the quality of the data generated by the system.
Maintenance	GA Tech	• Perform preventative maintenance on the proposed subsystem. • Perform corrective maintenance on the proposed subsystem. • Upgrade and test software including infrastructure software, UIs, and web systems. • Maintain external inputs to proposed system. • Complete performance monitoring goals and objectives as defined for the subsystem in the Performance Measurement and Evaluation Plan.
Subsystem Operators	GA Tech	• Continuously monitor operations, communications network, and interface flows. • Monitor security system for potential intrusions. • Maintain and operate the SidewalkSim simulator to ensure current data is included in route mapping. • Maintain Network-Edge Cost Computing Engine to ensure that current data is being accounted for in the algorithm. • Update system parameters and algorithms based on feedback from G-MAP and end users.
Subsystem Owners	GA Tech ARC	• Financial responsibilities for maintaining the proposed system.

Role	Stakeholder	Responsibilities
Trainers	GA Tech	• Train system operators and maintainers to ensure that established connections and data streams are maintained.

Roles and responsibilities for the CV subsystem are provided in **Table 21**.

Table 21. Roles and Responsibilities for the CV Subsystem

Role	Stakeholder	Responsibilities
Data Custodians	GDOT GCDOT	• Collect and store data in ITS Hub. • Ensure PII security of collected data and remove PII for third party access. • Continually improve the quality of the data generated by the system.
Maintenance	GDOT GCDOT	• Maintain infrastructure equipment. • Complete performance monitoring goals and objectives as defined for the subsystem in the Performance Measurement Plan.
Subsystem Operations	GDOT GCDOT	• Operate and monitor CV equipment (RSU) • Ensure interfaces and communication networks operate properly and connect with current traffic control systems. • Collect operations data for performance measurement review.
Subsystem Owners	GCDOT	• Financial responsibilities for maintaining the proposed system

5.3.4 Interactions Among System Stakeholders

Many interactions between stakeholders remain unchanged as described in **Section 3**. A greater degree of coordination will need to occur among ARC, GCDOT, GCT, and the ATL. The status of accessibly infrastructure is of critical importance to the travelers benefiting from this system. Prompt programming of construction activities resulting in temporary closures, verification of and maintenance actions on inaccessible paths, and programming of equipment outages on transit vehicles will be a high priority during the life cycle of the application. Additionally, temporary or permanent transit route changes will need to be communicated between all parties early to address any deficiencies in the network. Finally, interaction between travelers and IOOs will

increase significantly as there will be crowdsourced data collection of inaccessible paths or infrastructure that may require follow up conversations and engagement.

5.4 Support Environment

The support environment described in **Section 3.4** will remain mostly unchanged. GDOT and GCDOT ATMS systems will provide real-time information on signal operations within the project limits, allowing for and informing stakeholders of any TSP or remote pedestrian activations. The system will be supported by the fiber and 4G communications network deployed by GCDOT and GDOT. ITS infrastructure that supports CV and connected infrastructure operations will be deployed through the CVTMP related applications and will be maintained by GCDOT.

Communication uptime is of critical importance to the overall functionality of the proposed system. The failure of a single subsystem through a communication loss will degrade the functionality of the entire system. The GCDOT ATMS system will monitor and report on the communication status of signals, ITS equipment, and other field devices. The communication status of OBUs, including AVL equipment and TSP responders, along with the GTFS feed will be managed by GCT.

The initial deployment of ST-CTN will require the support of the Sidewalk Inventory Collection Tools described in **Section 3.2.3**. Upon completion of the deployment phase of ST-CTN, sidewalk and pedestrian pathways infrastructure characteristics will be maintained through GCDOT updates and crowdsourced data.

The status of sidewalk improvements, temporary sidewalk closures due to construction or other activities, and temporary signal closures will be managed by Gwinnett County. This will include pushing updates to the proposed system so routing decisions can be completed in real-time. Additionally, when sidewalk improvements are completed, GCDOT will be responsible for publishing construction permit final inspection reports to the network to be ingested by SidewalkSim.

5.5 Modes of Operations for Proposed System

This section describes the modes of operation for the proposed system.

Normal Operation: During normal operations, the full system, as described in **Section 5.2**, is functional and available to front facing and backend stakeholders. All objects in the environment are functioning normally and are being monitored by specified personnel.

Degraded Modes: In degraded mode, some or all of the subsystems are not functioning as intended. As the proposed system is a “system of systems,” several degraded modes are explained below.

- If the GCDOT and/or GDOT communications network experience a loss of communications, the ST-CTN system will function with limited functionality depending on where the communications loss occurs. Degraded functionality could include the lack of STM real-time routing updates, and TSP.

- If the STM Simulator experiences a loss of functionality, impedance values will not be provided to the G-MAP subsystem. The G-MAP subsystem, including the G-MAP Mobile App will be able to function in a degraded mode by providing routing information to the end user, but will not be able to provide accurate impedance values.
- If communication between the Sidewalk Inventory and the STM Platform is interrupted, accurate, real-time, impedance values for travel will not be provided to the G-MAP subsystem. The G-MAP subsystem, including the G-MAP Mobile App will be able to function in a degraded mode by providing routing information and historical impedance values for travel to the end user.
- If the Dynamic Data Broker experiences a loss of functionality, impedance values for travel and CV functionality will not be available for the G-MAP subsystem. The G-MAP subsystem, including the G-MAP Mobile App will be able to function in a degraded mode by providing routing information to the end user, but will not be able to provide accurate impedance values for travel. Additionally, connection to the CV subsystem will be severed if the Dynamic Data Broker experiences a loss of functionality. GCT will still be able to issue TSP commands, but pedestrian safety messages or pedestrian signal requests will not be available.
- If the Traffic Management or ITS Hub experience a loss of functionality, CV functionality will not be available to the G-MAP subsystem or the GCT subsystem. The G-MAP subsystem, including the G-MAP Mobile App will be able to function in a degraded mode by providing routing information and impedance values for travel to the end user, but pedestrian safety messages, pedestrian signal requests, and TSP will not function. When communication loss to the CV subsystem is detected, the STM subsystem will be able to add a penalty to the impedance value for travel.
- If the connected intersection portion of the CV subsystem experiences a loss of functionality, through device failure or communication loss, CV functionality will not be available for all or part of the G-MAP subsystem or GCT subsystem. Communication or device malfunction can impact the performance of isolated parts of the CV subsystem or can be widespread throughout the entire project area. Regardless of the scale, the G-MAP subsystem, including the G-MAP Mobile App will be able to function in a degraded mode by providing routing information and impedance value for travel to the end user, but pedestrian safety messages, pedestrian signal requests, and TSP will not function for all or part of the network. When communication loss to the CV subsystem is detected, the STM subsystem will be able to add a penalty to the impedance value for travel.
- If GCT OBUs experience a loss in functionality, through device malfunction or communication loss, TSP functionality and travel requests for service will be interrupted. The G-MAP subsystem, including the G-MAP Mobile App will be able to function in a degraded mode by providing routing information, impedance value for travel, pedestrian safety messages, and pedestrian signal requests, but the full functionality of TSP and travel requests for service will be interrupted. The scale of the outage (i.e. a single OBU vs multiple OBU malfunctions) will determine the level of degradation the system experiences.
- If the GCT System Platforms experiences a loss in functionality, travel requests for service will be interrupted. TSP functionality operates independent of the subsystems ability to connect with the G-MAP subsystem, meaning TSP will still be available for buses running behind schedule. The G-MAP subsystem, including the G-MAP Mobile

App will be able to function in a degraded mode by providing all services outside of travel requests for service.

- If the Building Access Wayfinding Assets experience a loss in functionality, possibly through malfunction of communication loss, indoor wayfinding functionality will be interrupted. The G-MAP subsystem including the G-MAP Mobile App will be able to function in a degraded mode by providing all services outside of indoor navigation.

Failure Mode: In failure mode, the ST-CTN application is not available to the end user in an operational or degraded mode. There are several scenarios that could cause the system to operate in failure mode, these include:

- If the G-MAP Mobile App experiences a loss of functionality, end users will not have functional access to the ST-CTN application. Trip feedback will not be provided to the STM Platform during this time, but all other system functions may remain operational.
- If the G-MAP Multimodal Trip Planner and Access Tools experiences a loss in functionality, the ST-CTN application will not function. Subsystems that push information to G-MAP Multimodal Trip Planner and Access Tools may still be able to communicate and provide data without any loss.

5.6 Operational Policies and Constraints

It is anticipated that the ST-CTN project will need to work within the partner agency operational policies and constraints. Specifically, the funding mechanisms, resources, and network communications will be critical aspects to understand and define such that long-term deployment, management, operations, and maintenance may be put in place to support the ST-CTN system.

5.6.1 Funding and Resources

All agencies involved in ST-CTN have separate funding sources, each of which comes with different requirements and constraints. ARC, as the project lead primarily has access to federal funding. While there are several different federal funding sources that could apply to various types of transportation projects, ARC has the sole authority to program funding from the following FHWA programs: (1) Surface Transportation Block Grant Program (STBGP) – Urbanized Area Apportionment, (2) Congestion Mitigation and Air Quality Program (CMAQ), and (3) Transportation Alternatives Program (TAP), which is a sub-program within STBGP [FAST]. The total funding availability from these three programs is approximately $120 million (based on FAST Act authorization levels). STBGP and CMAQ are best suited for ITS programs and projects, though both have a 20% match requirement for local funding.

In addition to the FHWA programs, there are three FTA, formula-based funding programs that are annually apportioned to Atlanta Urbanized Area (totaling $140 million per year, based on the current FAST Act funding levels): Section 5307/5340 - Urbanized Area Formula Program; Section 5337 - State of Good Repair Grants Program; and Section 5339 - Bus and Bus Facilities Program. ARC has a direct annual suballocation of 5307 (approximately $175,000 per year), which can be used for any ITS-related activity. Gwinnett County is also entitled to an annual suballocation for all three FTA programs (about $7 million per year).

ARC's transportation planning program is summarized annually in the Unified Planning Work Program (UPWP), which documents proposed expenditures of metropolitan planning funds (a.k.a. "PL" and "5303" funds) that are apportioned to FHWA and FTA. ARC receives approximately $9 million per year in planning funds, which are eligible for planning support, concept development, and most activity associated with systems engineering.

GDOT is able to use federal funding, but also has state funds available, which have fewer restrictions and does not require a local match. As part of the CV1K program, GDOT has also locked in pricing for connected vehicle RSUs, ensuring there are no price jumps in case future purchases of that equipment are necessary. Gwinnett County has access to local funds including their Special Purpose Local Option Sales Tax (SPLOST).

It is not anticipated that any agency will be required to make staffing changes for this project. Additionally, GDOT Operations has a full staff with expertise in connected vehicle infrastructure and applications who will be able to support the project. Likewise, ARC has a staffed transportation technologist position that requires experience with software and data integration, which will be supporting the project.

5.6.2 Information Technology and Communications

Each agency involved in ST-CTN likewise has their own IT and communications policies. GDOT's network security policies are the strictest and forbid any devices directly connected to their signals from also connecting to the cloud. This constraint has been addressed in this ConOps through the use of a Secure MU Gateway in the connected vehicle diagram as seen in **Section 5.2.3**, Connected Vehicle Subsystem. It is anticipated that ATL RIDES will continue to be hosted via Amazon Web Services with 24/7 hours of operation.

6. Operational Scenarios

The following operational scenarios (also referred to as use cases) provide a description of the proposed system operational flow. The purpose of these operational scenarios is to provide a step by step description of how the proposed system should operate. Two use cases are described in this section: *Use Case 1: Traveler's Complete Trip with ST-CTN* depicts interactions between the end user (referred to as the traveler) and the ST-CTN system, and *Use Case 2: Connected Vehicle* depicts interactions between subsystems (also referred to as system actors). The scenarios cover major capabilities and user classes but are not exhaustive of every detail of the system.

The actions within each use case verify the specific user needs (end user, IOO and system needs) as listed in **Section 4**. The following use case scenarios have been developed to demonstrate how the system will operate and how the end users and system actors interact with the system. Travelers will use the ST-CTN system to plan and navigate their complete trip using the G-MAP subsystem (with the augmented functionality described in **Section 5.2.1**). The end user needs, along with the IOO needs drive the system needs; together, the end user, IOO, and system needs form the consolidated needs list in **Section 4.2.2**, **Section 4.2.3**, and **Section 4.2.4**.

6.1 Use Case Structure

The ST-CTN project is focused on integration and enhancements to multiple existing subsystems to provide a complete trip solution which will support underserved communities. As such, the traveler is the primary focus of the system. Use Case 1 describes the traveler's experience with the proposed system and the actions that will be required by the system to support that experience. Use Case 1 considers the traveler's complete trip and is comprehensive in nature, thus, operational flows of the ST-CTN subsystems are identified throughout Use Case 1. This approach provides context to how the various ST-CTN subsystems relate to each other and work together to support the complete system. Use Case 1 is broken into several sections:

- **Description.** High level description of the complete trip and the steps (segments and transitions) taken by a traveler illustrated in **Figure 21.**
- **Purpose.** The goal of the use case.
- **Constraints.** The constraints and limitations for which travelers will face.
- **Actors.** The people and systems that interact in the use case.
- **Preconditions.** The actions that are needed or assumed prior to the start of the use case.
- **Needs.** A reference to how the needs drive the actions described in the operational flow.
- **Operational Flows.** A set of actions, categorized by each step in the complete trip description. These actions are driven by end user needs, and drive the system needs.

These are shown in the columns of **Table 23** that describe the action and the corresponding end user, IOO, and system needs listed in the appropriate column.

Use Case 2 is focused on the CV subsystem and the interfaces that are necessary to support the CV applications. Use Case 2 may be considered a family of applications wherein the field equipment (RSU), vehicles – particularly Ride Gwinnett buses (OBU), and travelers (MU) interact with system in the following ways: (1) the traveler and connected intersection pedestrian infrastructure, (2) traveler and adjacent CVs, and (3) the traveler and connected transit vehicle. Each of these interactions are described by one or more CV applications within the operational flow. The interaction with a traveler may be a passive detection of the person as a *vulnerable road user*, or as an active participant in the connected infrastructure using a MU. The Use Case includes the following sections:

- **Description.** Because the CV subsystem is composed of applications already considered for deployment by the Gwinnett County Smart Corridor project, the application descriptions, detailed in **Table 24**, are extracted from the CVTMP (2019). The illustration presents information flows among the actors included in the set of applications.
- **Constraints.** The constraints and limitations of the CV equipment including integration of the MU with the CV subsystem.
- **Actors.** The travelers, systems, and equipment that interact in the use case.
- **Preconditions.** The actions that are needed or assumed prior to the start of the use case.
- **Needs.** Specific IOO and System needs associated with all the CV applications.
- **Operational Flows.** The operational flows for each application are listed in **Table 26**. An entry for each application includes the general purpose and any preconditions related to the application.

6.2 Use Case 1: Traveler's Complete Trip with ST-CTN

The traveler will use the G-MAP subsystem to interact with the ST-CTN system. This Use Case describes the complete trip experience for the primary actor, the traveler.

Description. Use Case 1 describes how a traveler will plan and navigate their complete trip with the ST-CTN system. The use case identifies the major actions by trip segment, as shown in **Figure 21**. The trip segments include the trip planning through completion using the extended multimodal complete trip ATL RIDES platform, rebranded as G-MAP subsystem. The traveler will interact with the system through one or more of the G-MAP UI channels – mobile app, web site, or call center/IVR. The technology method for accessing the system is seamless and synchronized so that the method of access provides similar functionality. It should be noted that the technology solutions will be identified in a later phase of the project. In this asynchronous operational flow, the traveler uses the G-MAP subsystem functionality to plan, execute travel, and complete a trip. The user is able to do so by personalizing, selecting, and activating information on directions, conditions, and status along their trip. The traveler will leverage their device to communicate with CV infrastructure to experience a safer trip. The six steps of the complete trip are shown in **Figure 21** and the steps are listed below.

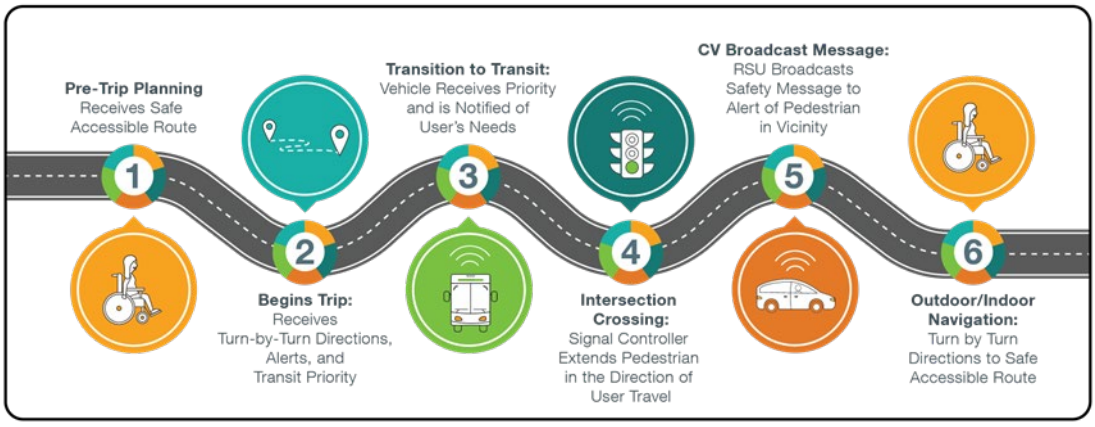

Figure 21. End User's Complete Trip with ST-CTN (Source: ARC)

Step 1 **Pre-Trip Planning.** The traveler plans and receives a safe accessible route.

Step 2 **Begins Trip.** The traveler receives turn by turn directions, alerts, and transit priority.

Step 3 **Transition to Transit.** The traveler transitioned to transit. The transit vehicle receives priority and is notified of users' needs.

Step 4 **Intersection Crossing.** The traveler interacts with the signal controller which extends pedestrian phase in the direction of user travel.

Step 5 **CV Broadcast Message.** RSUs broadcast safety message to alert of pedestrian/bicyclist in vicinity.

Step 6 **Outdoor/Indoor Navigation.** Turn by turn directions are provided to the traveler to enable a safe accessible route.

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.

Purpose. The purpose of this use case is to illustrate how a traveler will interact with the ST-CTN system through the G-MAP app to navigate their complete trip; integrating wayfinding across multiple trip segments and receiving directions, conditions, and status on the links between legs based on their preferences and abilities.

Constraints. A significant constraint for all underserved populations is the need for the solution to be integrated across each trip segment in a seamless manner. There are also constraints that are specific to underserved populations. For example, individuals with visual loss may need information provided audibly or may need additional assistance navigating. Individuals with loss of mobility, may need accessible routes based on their preferences and abilities.

Additional constraints related to the G-MAP multimodal complete trip subsystem include the following:

- The ability to integrate and notify travelers of real-time information is dependent on external data collection methods.
- The addition of multiple preferences will limit the number of travel options available to users. Note: During the Agile development phase, stakeholders will contribute to the types of preferences incorporated into the application to verify that the system is not overly constrained such that a traveler cannot receive a trip plan.
- Off-line usage of trip plan will be limited to download of an existing trip plan and map. Many of the navigation and provision of notifications depend on the mobile app user opting-in to tracking services.
- Interaction between the G-MAP mobile app and the Ride Gwinnett bus will depend on communication upgrades and augmentation of bus onboard systems. These are still in development as discussed in **Section 3**.

Actors. The following actors will participate in this use case:

- End User (Traveler and Trusted Companion / service animal)
- G-MAP UI devices (Web, Mobile App, Call Center connection)
- Ride Gwinnett Vehicles
- Connected Intersection
- Facility Navigation Assets

Preconditions. It is assumed that the traveler has access to the G-MAP UI such as the web application or mobile app. Full system functionality also requires that the traveler creates a secure profile and defines their personal preferences and abilities. In addition, connected vehicle equipment (OBU and RSU) are required for a traveler to communicate with connected intersections and Ride Gwinnett transit vehicles. Finally, the call center must be staffed with knowledgeable agents.

Needs. The needs associated with this use case consist of all the end user needs as identified in **Section 4**. End user needs are associated with actions in the Operational Flow Table (see **Table 23**), column entitled “End User ID.” The end user needs (see **Section 4.2.2**) were elicited from end users to describe their needs for a complete trip scenario. This process enabled validation of end user needs against the use case actions to ensure completeness.

Most actions in **Table 23** reference needs that are consistent with their trip segments as denoted by the naming conventions used in the need identifier. For example, needs associated with *Transition to Transit (TT)* are assigned to actions in *Step 3 Transition to Fixed Route Transit*. Some needs from other steps, primarily Begin Trip (BT), are associated with pre-trip preference selection (Step 1). For example, BT-EU-2.2.5 – which describes what and how notifications are received while traveling is associated with Step 1 Action 1.1.6 *Traveler selects Opt-in preferences (tracking, off-line navigation, notifications to 3rd parties, link to other accounts, support types).* The Begin Trip (BT) needs drive actions that require the traveler to select their trip preferences prior to beginning their trip. Hence, the actions are derived from the needs solicited from other segments.

In addition, the end user needs were elicited to identify what the users need from the system. The system needs, subsystem interactions, and their operational flow are driven by what the traveler needs from the system. As such the system needs were derived from the user interaction (scenarios) with the G-MAP UIs. These system needs are associated with the end user needs and each action in **Table 23**.

Information Needs. References for the Information Exchange IDs are shown in **Figure 22**. It is assumed that the current network conditions (static and real-time) for transit, road (intersection), sidewalk, and indoor pathways are current and ingested by the G-MAP (Exchange ID 3). Facility pathways, destinations, and current conveyance status are ingested by the G-MAP (Exchange ID 13). Simulation network models that contain impedance values personalized for end user preferences will be provided by the STM to the G-MAP for trip planning and for regeneration while en-route (Exchange ID 5). The updated networks incorporate crowdsourced information on network conditions (Exchange ID 12 to Exchange ID 4).

Data exchanged between the end users (travelers and caregivers) and the G-MAP trip planner occurs using a thin client exchange (Exchange ID 7), and then are distributed through two communication channels (Exchange ID 12 and 12a). Exchange ID 12 has a full set of static and real time exchanges that occur during all of use case 1 actions. Exchange ID 12a is a subset of the same interfaces that support trip planning and a few notifications. Crowdsourced data input by end users in the actions in Step 7 – Reporting and History, are collected and sent by the G-MAP UIs and directed to the STM using Exchange ID 4. Anonymized end user data is sent from the STM Platform to the Public PMD to be displayed by all relevant stakeholders using Exchange ID 16.

Information exchanged between the Traveler and Connected Vehicle and Intersection are described in Use Case 2.

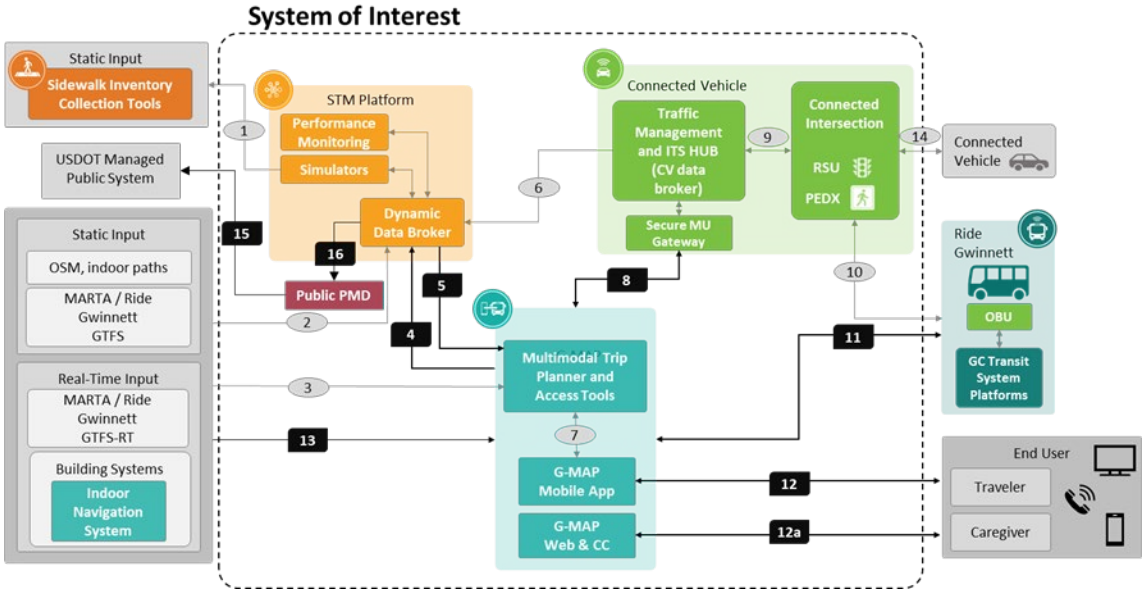

Figure 22. Use Case #1 Information Flow in the ST-CTN System (Source: ARC)

Table 22. Critical ST-CTN Connection Descriptions

Data Exchange ID	Description
1	Sidewalk inventory data, including accessibility features to the STM Platform simulators
2	Static and dynamic data from various existing sources to the STM Platform dynamic data broker
3	Static and dynamic data from various existing sources to the G-MAP multimodal trip planner and access tools
4	G-MAP Mobile App logs and trip feedback
5	STM Network Impedance API
6	CV and Traffic Operations Messages: NaviGAtor ITS, road characteristics, traffic data
7	OTP APIs and G-MAP APIs
8	Mobile Accessible Pedestrian Signal System (PED-SIG)
9	CV messages
10	TSP and other CV application messages
11	Ride Request messages
12, 12a	G-MAP Mobile App APIs and Traveler exchange – profile, trip plan, settings, notifications, feedback, etc. Note: Data Exchange ID 12a includes similar flows with restrictions on viewing and changing certain data.
13	Dynamic information from building facilities (including beacons to the G-MAP mobile app) and INS vendor cloud SDK
14	CV data
15	Project data for USDOT-managed Public System

Data Exchange ID	Description
16	Public facing data and visualizations for reporting on system operations and performance

Operational Flow. The operational flow between the traveler interactions with the ST-CTN system, manifested by their interaction with the G-MAP UIs, are listed in **Table 23**. The first column provides the step ID that corresponds to the six-step complete trip shown in **Figure 21**. The second column lists the corresponding step name followed by the action category and specific actions. The column entitled End User Need ID associates the End User Need ID and IOO Need ID (referenced in **Section 4.2.2** and **Section 4.2.3**) to the action and provides a method to verify that the system will address all of the end user needs. Finally, the System Need ID column encapsulates the End User Needs into a consolidated System Need as referenced in **Section 4.2.4**.

Table 23. Use Case 1: End User's Complete Trip with ST-CTN Operational Flow

Action ID	Use Case Action	End User/ IOO Need ID	SN ID
Step 1	**Pre-Trip Planning** *Traveler registers, completes preferred trip preferences including what information and when it should be delivered, and when ready to set up trip, generates trip plan. These processes are conducted by the traveler* via their phone *(call center agent), web browser or mobile app* (**Exchange ID #12, 12a, and 7**).		
PT-UC1-1.1	Preferences. Traveler completes their Trip Preferences. The preferences contribute to generate the network impedances. The networks (transit, road, and sidewalk) are used to optimize the personalized alternative itineraries, and to identify obstacles to travel when traveler is en-route. Preferences include the following:		
1.1.1	Traveler selects preferences by ability (i.e., types of assistive devices, language, etc.).	PT-EU-1.1.6 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 PT-EU-1.2.6 PT-EU-1.2.9	PT-SY-1.3
1.1.2	Traveler selects preferences for route options (i.e., max distance, modes etc.).	PT-EU-1.1.1 PT-EU-1.1.2 PT-EU-1.1.3 PT-EU-1.1.4	PT-SY-1.3
1.1.3	Traveler selects preferences for mobility service/mode, shortest route, fewest transfers, cheapest fare, etc. Note: these settings exist already in the ATL RIDES application.	PT-EU-1.1.1 PT-EU-1.1.2 PT-EU-1.1.3	PT-SY-1.3

Action ID	Use Case Action	End User/ IOO Need ID	SN ID
1.1.4	Traveler selects user interface notification preference on mobile app (voice, text, haptic), SMS, or other.	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-2.2.5	BT-SY-2.4
1.1.5	Traveler selects preferences for trip support service: • Accompanied by service animal or caregiver • Link to call for support and help (caregiver, call center) • Notifications using alternative communications channels (SMS, telephone)	BT-EU-2.1.1 BT-EU-2.1.2 BT-EU-2.1.3	PT-SY-1.5 PT-SY-1.2
1.1.6	Traveler opts-in to specific services: • Link their G-MAP account with other mobility services (link to other accounts, support types) • Opt-in to tracking (or prefer off-line navigation features only) • Opt-in to notify third parties (e.g., caregiver, guardian) about their navigation status	BT-EU-2.2.5	PT-SY-1.1
1.1.7	Traveler selects options for automated services: • Reroute when trip plan has obstruction • Request for PED-X (CV) • Communication with indoor navigation aids • Couple with assistive device • Communicate with transit operator about needs • Notifications for request for stop or request for service	BT-EU-2.2.5	BT-SY-2.6
1.1.8	Traveler assigns customized preferences for specified trip types.	PT-EU-1.1.7	PT-SY-1.5

Action ID	Use Case Action	End User/ IOO Need ID	SN ID
PT-UC1-1.2	Notification Types. Traveler completes their preferences for the types of notification they require. The selections are used by G-MAP to push notifications to their preference UI channel (including telephone, mobile app, or caregiver).		
1.2.1	Traveler selects type of turn by turn directions desired. Alternative visual, audio, or haptic feedback.	BT-EU-2.2.1 BT-EU-2.2.2	BT-SY-2.2 BT-SY-2.6
1.2.2	Traveler selects notification on their orientation when transitioning to new trip segment (e.g., alighting vehicle, exit/enter facility).	BT-EU-2.2.2 BT-EU-2.2.3 BT-EU-2.2.4	BT-SY-2.6
1.2.3	Traveler selects notification on ETA for transit.	BT-EU-2.2.4	BT-SY-2.6
1.2.4	Traveler selects notification on transit schedule delay.	BT-EU-2.2.3	BT-SY-2.6
1.2.5	Traveler selects notification on disruption in trip plan (transit, walking, elevator/escalator, obstacle in pathway, work zone).	PT-EU-1.1.2 BT-EU-2.2.2 BT-EU-2.2.3	BT-SY-2.6
1.2.6	Traveler selects notification with detour or re-routing instructions (if deviated from trip plan or encounter disruption).	PT-EU-1.1.2 BT-EU-2.2.2 BT-EU-2.2.3	BT-SY-2.6
1.2.7	Traveler selects status notification sent to third party such as guardian / caregiver.	BT-EU-2.1.2 BT-EU-2.1.3	BT-SY-2.5
PT-UC1-1.3	Trip Plan. Traveler generates trip plan.		
1.3.1	Traveler starts setting trip plan by setting their origin / destination and timing.	PT-EU-1.2.1 PT-EU-1.2.2	PT-SY-1.4
1.3.2	Traveler reviews and if desired, updates their preferences and notifications for this trip (including notifications and other preferences).	PT-EU-1.2.1 PT-EU-1.2.2	PT-SY-1.4

Action ID	Use Case Action	End User/ IOO Need ID	SN ID
1.3.3	Traveler reviews and if desired, updates navigation alerts for trip.	BT-EU-2.2.1 BT-EU-2.2.2 BT-EU-2.2.5	BT-SY-2.4
1.3.4	Traveler generates trip (and if not satisfied, return to Action 1.3.1 to repeat).	PT-EU-1.2.1 PT-EU-1.2.2	PT-SY-1.4 BY-SY-2.1.3
1.3.5	Traveler plays trip plan using preferred user interface channels (e.g., for user practice).	PT-EU-1.2.8	PT-SY-1.6
1.3.6	Traveler plans indoor route to their destination (if data is available for facility).	PT-EU-1.1.3 PT-EU-1.1.4	NV-SY-6.1 NV-SY-6.2
1.3.7	Travelers can opt-in or opt-out of tracking. Note: When the app monitors their trip; this request will not work when off-line functionality is requested.	PT-EU-1.1.8 BT-EU-2.1.2 BT-EU-2.2.5 BT-EU-2.2.6	PT-SY-1.1 PT-SY-1.2
Step 2 (BT)	**Begin Trip** *Traveler begins their trip using their mobile app to navigate based on their selected trip plan. These processes are conducted by the traveler* via *mobile app* (**Exchange ID #12 and 7**). *Selected notifications may be supported through SMS or telephone message.*		
BT-UC1-2.1	Begin Trip. Traveler begins their trip using the G-MAP Mobile app; when tracking is on, the app will track the traveler's location (geofence), and appropriate navigation alerts and notifications will be triggered. During the trip, the G-MAP platform will continuously monitor the traveler's location and trigger alerts, identify obstacles and re-route based on traveler's preferences.		
2.1.1	Traveler opens their trip plan in their mobile app (or sync with assistive device – e.g., cane, cochlear implant, wearable).	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-2.3

Action ID	Use Case Action	End User/ IOO Need ID	SN ID
2.1.2	Alternatively, Traveler initiates trip plan using phone call to activate notification requests on pre-planned route.	BT-EU-2.2	PT-SY-1.2
2.1.3	Traveler journeys to first trip segment (station, stop) receiving selected navigation alerts and notifications.	PT-EU-1.1.1 PT-EU-1.1.2 PT-EU-1.1.3 PT-EU-1.1.4	BT-SY-2.6
Step 3 (TT)	**Transition to Fixed Route Transit** *Traveler journeys to transit, boards, travels on and alights transit vehicle. These actions occur between the G-MAP and Transit Vehicle. The path may flow from the Transit Operations to G-MAP back office (to the traveler) or directly between the Transit Vehicle and Traveler (**Exchange #11**). The CV applications flow through the CV platform and follow the flows designated by appropriate Use Case 2 descriptions. Most flows follow the path to / from the G-MAP and Secure MU Gateway (**Exchange ID #8**).*		
TT-UC1-3.1	Boarding. Traveler boards transit vehicle.		
3.1.1	As traveler waits at transit stop, they request transit service. If they opt-in to communicate with the transit operator, the transit operator will be informed if they need additional time boarding or alighting based on their abilities (see Use Case 2: Transit Pedestrian Indication Application).	TT-EU-3.1.1 TT-EU-3.1.3 TT-EU-3.1.5 CV-EU-5.1.1 CV-EU-5.1.2	TT-SY-3.1
3.1.2	Travelers will be sent notification of incoming bus to a station or stop when the notification is selected.	BT-EU-2.2.4	BT-SY-2.6
3.1.3	Travelers will be sent notification of location and estimated time of arrival of transit vehicle when the notification is selected.	BT-EU-2.2.4	BT-SY-2.6

Action ID	Use Case Action	End User/ IOO Need ID	SN ID
3.1.4	As traveler boards vehicle, the app will inform driver of traveler's need for additional time to board or alight when traveler opts-in.	BT-EU-2.1.3 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	BT-SY-2.6
TT-UC1-3.2	Traveling in Vehicle. Traveler riding in the transit vehicle.		
3.2.1	Traveler requests next stop using the hands-free function on the mobile app which triggers the vehicle's next stop indicator. The stop request is based on their trip selection.	TT-EU-3.1.7 CV-EU-5.1.1 CV-EU-5.1.2	FUTURE
3.2.2	Travelers receives next stop information (using their mobile app to connect directly to their assistive device such as a hearing aid).	BT-EU-2.1.4 BT-EU-2.2.4	FUTURE
Step 4 (IC)	**Intersection Crossing** *Traveler, when approaching and crossing an intersection interacts with the connected intersection to request pedestrian crossing signal and to safely cross the crosswalk.*		
IC-UC1-4.1	Crosswalk. Traveler requests pedestrian crossing and traverses crosswalk.		
4.1.1	Traveler receives alert about sidewalk path they are currently on or along their path that has an obstacle. Upon receipt, the traveler may request support through their assistive services (call center) or request a reroute using their trip planner. These alternatives may be automatically generated if their preferences included Action 1.1.7.	PT-EU-1.1.2 BT-EU-2.2.3	BT-SY-2.6
4.1.2	As traveler approaches a crosswalk, they transmit a request via the G-MAP app for the pedestrian crossing. This request is triggered by their G-MAP trip plan which incorporate the crossing street, signal phasing cycle and preference for hands-off and automated notification of the pedestrian signal request.	IC-EU-4.1.1 IC-EU-4.1.2 IC-EU-4.1.3	TT-SY-3.1

Action ID	Use Case Action	End User/ IOO Need ID	SN ID
4.1.3	If automatically requested a pedestrian crossing actuation, they will receive a confirmation that the request was received by signal system.	IC-IOO-4.1	TT-SY-3.2
4.1.4	As pedestrian enters the intersection, the CV Subsystem sends alert to nearby connected equipped vehicles that traveler is in the intersection (see Use Case 2: Pedestrian in Signalized Crosswalk Warning (Transit) and PED-SIG Applications).	CV-EU-5.2.2	CV-SY-5.1.1
4.1.5	While tracking traveler, the G-MAP app sends message to CV subsystem that traveler is in or completed crossing intersection and the alert ceases.	CV-EU-5.2.2	CV-SY-5.1.2
Step 5 (CV)	**Connected Vehicle Broadcast Message** *The data flow path begins from the CV Platform to the GDOT ATMS (external system) which is then ingested by the G-MAP* (**Exchange ID 6**) *and STM Platforms* (**Exchange ID 8**).		
CV-UC1-5.1	Traveling. Traveler navigates near connected intersection (see Use Case 2).		
Step 6 (NV)	**Outdoor / Indoor Navigation** *Traveler navigates trip through outdoor and indoor paths. The data exchange occurs between the traveler and their access method (web, mobile app, call center alert) and G-MAP (***Exchange 12***) for outdoor navigation. For indoor navigation, the main flow is between the G-MAP and the building facility (***Exchange 13***).*		
NV-UC1-6.1	Orienteering to trip segment. Traveler orients their navigation when they transition between segments or modes.		

Action ID	Use Case Action	End User/ IOO Need ID	SN ID
6.1.1	As traveler begins next trip segment, they receive a notification that they are traveling in the correct (or incorrect) direction. The traveler specifies how they want to receive the notification (e.g., text message, haptic sensor) and when they receive the information (going in the correct or incorrect direction).	BT-EU-2.2.2	BT-SY-2.6
6.1.2	Traveler is directed to the most accessible path to their bus stop or pick up location (or alternatively from their alighting or drop off location). Note: The system provides the traveler with navigation alerts to the most accessible path to their next trip segment. This might be the bus pickup location or accessible entrance to a facility.	PT-EU-1.1.1 PT-EU-1.1.2 PT-EU-1.1.3 PT-EU-1.1.4	BT-SY-2.6
NV-UC1-6.2	Transition Outdoor/ Indoor Navigation. Traveler transitions between outdoor and indoor locations.		
6.2.1	Traveler receives alert about facility accessibility or disruptions to access (elevator/escalator outages).	BT-EU-2.2.3 NV-EU-6.1.1 NV-EU-6.1.2 NV-EU-6.1.3	BT-SY-2.6
6.2.2	Traveler receives turn by turn directions (based on their preferences) about how best to access indoor facility (accessible entrance/exit).	BT-EU-2.2.3 NV-EU-6.1.1 NV-EU-6.1.2 NV-EU-6.1.3	BT-SY-2.6
NV-UC1-6.3	Indoor Navigation (including at Transit Hub / Station). Traveler travels to indoor facilities and connects to wayfinding assets for facility information.		
6.3.1	Traveler receives notification that app has synced with indoor navigation assets.	NV-EU-6.1.2 NV-EU-6.1.3	NV-SY-6.2
6.3.2	Traveler receives wayfinding information from indoor wayfinding assets via their preferred UI (e.g., "You are here" notification).	NV-EU-6.1.2 NV-EU-6.1.3	NV-SY-6.1

Action ID	Use Case Action	End User/ IOO Need ID	SN ID
6.3.3	Traveler receives directions to elevator (or alternative elevator bank if out of service).	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	NV-SY-6.1
Step 7	**Reporting and History** *Travelers may report problems about their journeys, obstacles to travel and review trip histories. The data exchange is between the G-MAP application and traveler (***Exchange ID #12***). The stored data is ingested by the STM evaluation module (***Exchange #4***). The stored data is then anonymized and sent to the public PMD to be viewed and downloaded by interested parties (***Exchange ID #15 and #16***).*		
RP-UC1-7.1	Reporting and Performance Monitoring. Traveler reports a problem or obstacle to traveler (crowd-sourced information) or reviews their trip feedback history.		
7.1.1	Traveler reports problem about challenges during travel (obstacles and issues) including transit or shared use paths. • Traveler pulls down report form that includes fields to describe issue such as: type of problem (trip plan, infrastructure, transit, etc), the location, location feature type, problem details, and more. • Submits form to G-MAP • Receives confirmation of receipt of problem report. Note: G-MAP uses this crowd sourced reporting for traveler alerts and notifications and sends information to STM Subsystem to be integrated into the routing networks.	RP-EU-7.1.1 RP-EU-7.1.2 RP-EU-7.1.3 RP-EU-7.1.4	RP-SY-7.2

Action ID	Use Case Action	End User/ IOO Need ID	SN ID
7.1.2	Traveler or traveler's trusted person reviews their trip histories for verification and safety purposes.	RP-EU-7.1.1 RP-EU-7.1.2 RP-EU-7.1.3 RP-EU-7.1.4	RP-SY-7.1 RP-SY-7.3
RP-UC1-7.2	Performance Reporting. Traveler, as well as USDOT and interested public parties, view publicly available system performance data.		
7.2.1	Traveler, as well as USDOT and interested public parties, views and downloads public PMD system performance data.	RP-EU-7.1	RP-SY-7.3

6.3 Use Case 2: Connected Vehicle

The ST-CTN proposed system leverages the Gwinnett County and GDOT CV Program to connect the end user to the surrounding transportation infrastructure and broadcast safety messages to enabled CVs. Use Case 2 describes how the CV subsystem will operate to provide functionality and support for system actions.

Description. CV applications will be implemented as part of the Gwinnett County and GDOT CV Program (see **Section 3.2.4**). The ST-CTN system will connect the traveler with the connected intersections and connected platform based on several applications currently being deployed in the aforementioned program. The traveler will receive alerts and trigger safety messages and requests through the G-MAP platform (i.e., mobile app). Since the CV field and center systems are fully networked, the path by which the transmission occurs will be determined during the design phase. The Gwinnett County CVTMP identified several applications that will incorporate communication notifications directly to the traveler through their MU (G-MAP mobile app). In all these applications, the interaction between the traveler and intersection, or traveler and bus will conform to the security policies and message exchanges of CV equipment. The applications and associated priority (column 3) that will be implemented are listed in **Table 24**.

Table 24. CV Application Descriptions

CV Application	Description	Priority
Mobile Accessible Pedestrian Signal System (PED-SIG)	An application that allows for an automated call via the Secure MU Gateway from the smart phone of [any authorized] pedestrian [using the MU – G-MAP app] to the traffic signal to safely navigate the crosswalk.	High
Pedestrian in Signalized Crosswalk Warning (Transit)	An application that warns transit bus operators when pedestrians within the crosswalk of a signalized intersection are in the intended path of the bus. Since the warning is broadcast, any vehicle with onboard equipment may receive the alert.	High
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 an infrastructure device, if they require assistance onboarding or alighting the bus, and at which stop they will alight.	Medium

CV Application	Description	Priority
Transit Signal Priority	An application that provides signal priority to transit vehicles at intersections and along arterial corridors. The TSP application uses V2I communications to allow a transit vehicle to request a priority at one or a series of intersections. The application includes feedback to the transit driver indicating whether the signal priority was granted or not. This application can contribute to improved operating performance of the transit vehicles by reducing the time spent stopped at a signal during the red indication.	High

The exchange of information between the traveler (represented by G-MAP mobile app) and the field or vehicles represented by the RSU and OBU equipment are shown in **Figure 23**. More specific information relevant to Use Case 2 is provided herein, however data exchanges are represented consistent with the ST-CTN context diagram shown in **Figure 17** and described in **Table 25**.

The public portal is implemented through the GDOT ATMS. To interface with the CV applications that require security credentials, the G-MAP platform will work with the GDOT/Gwinnett Smart Corridor project to implement the most practical solution including registering and receiving valid certificates from the SCMS.

Use Case 2 is organized as a traditional use case, highlighting the system interactions (**Figure 23**), application descriptions adapted from the GDOT/Gwinnett stakeholder needs (**Table 24**), constraints, actors, preconditions, related system needs, main flows (**Table 26**), and information needs.

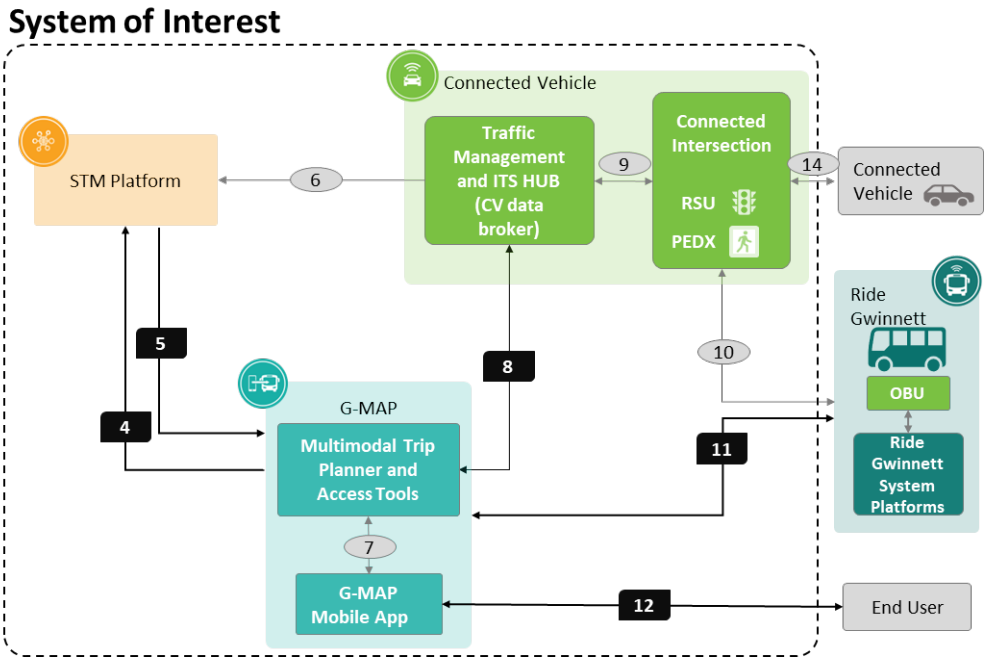

Figure 23. Use Case 2 Connected Vehicle Applications Information Flow in the ST-CTN System (Source: ARC)

Table 25 provides the descriptions of the associated data exchanges shown in **Figure 23**. These connections are consistent with the ST-CTN system context diagram but provide more specific information related to Use Case 2 where appropriate.

Table 25. Critical ST-CTN Use Case 2 CV Connection Descriptions

Data Exchange ID	Description
1	Not relevant for UC2
2	Not relevant for UC2
3	Not relevant for UC2
4	G-MAP mobile app logs and trip feedback
5	STM network impedance API
6	CV operations messages: NaviGAtor ITS, road characteristics, traffic data
7	OTP APIs and G-MAP APIs
8	Mobile Accessible Pedestrian Signal Request [PED-SIG]
9	CV Messages
10	TSP and other CV application messages
11	Ride Request messages
12	G-MAP mobile app APIs and traveler exchange – profile, trip plan, settings, notifications, feedback, etc.
13	Not relevant to UC2
14	CV broadcast messages including PSM.
15	Not relevant for UC2
16	Not relevant for UC2

Constraints. All the use cases with the MU as a key actor are constrained by the smartphone capabilities. These include the following:

- Smartphone battery life. The location accuracy and communications drain the power from the smartphone to the extent that the mobile unit power may not be available throughout the complete trip.
- Location accuracy. The location quality generated by the smartphone may not be sufficient for precisely locating and tracking the pedestrian in and around an intersection particularly in an urban canyon, multipath including tree canopy, and indoor navigation.
- Latency of the MU in transmitting its PSM in person to infrastructure (P2I) or person to a transit vehicle (P2V), receiving safety critical messages from the infrastructure (I2P) or other vehicles (V2P).

In addition, if the MU, or by extension, the G-MAP platform is sending a request to a CV component (RSU or central system), then it must follow security guidelines and acquire authorization. The use case diagram, shown in **Figure 23**, includes a conceptual processor to verify proper credentialing of the requesting actor.

Note: There are several initiatives that are exploring mitigation of these constraints, in addition, solutions may be implemented that reduce the impact of the constraints.

Actors. The main actors in the CV applications include the following:

- MU – represented by the G-MAP Platform (may be the mobile app or a trigger issued by the G-MAP back office).
- RSU – Represented by the connected intersection or through the connection to the CV Data Broker.
- Ride Gwinnett Bus OBU – represented by the Ride Gwinnett bus in revenue service.
- STM Platform – represents a supporting service to allocate the impedance value of the safety alert to the traveler through the STM Network Impedance API.

Precondition. The following preconditions are required by the system to enable CV subsystem functionality.

- The account holder will opt-in to a notification from the G-MAP prior to the G-MAP triggering a request from the CV and sending a notification on its behalf.
- Prior to a request from the CV, all connected devices will be enrolled in the SCMS and have valid security certificates or equivalent (as described in the Secure MU Gateway in **Section 5.2.3)**. Authorized MU devices will be validated through the G-MAP and CV subsystems.
- RSU is broadcasting a compliant SAE J2735 Pedestrian Safety Message (PSM).

Related Needs.

- End User Needs. The CV applications and associated actions express the end user needs identified within the trip segment steps 3 (transition to transit), 4 (intersection crossing), and 5 (connected vehicle) and as described in **Section 4.2.2**.

  - TT-EU-3.1
  - IC-EU-4.1
  - CV-EU-5.1
- IOO Needs. The CV applications and associated actions express the IOO needs by GDOT and Gwinnett County and as described in **Section 4.2.3**.
  - PT-OO-1.1
  - TT-OO-3.1
  - TT-OO-3.2
  - TT-OO-3.3
  - IC-OO-4.1
  - IC-OO-4.2
  - CV-OO-5.1
  - CV-OO-5.2
  - FT-OO-8.1
  - FT-OO-8.2
- System Needs. The CV applications and associated actions express the following system needs and as described in **Section 4.2.4**.
  - TT-SY-3.1
  - TT-SY-3.2
  - IC-SY-4.1
  - IC-SY-4.2
  - CV-SY-5.1
  - CV-SY-5.1.1
  - CV-SY-5.1.2
  - RP-SY-7.3
  - FT-SY-8.1.2

Operational Flow. The CV use case operational flows are described in **Table 26** for each CV application.

Table 26. Use Case 2: Connected Vehicle Application Operational Flows

CV Application	Scenarios – Main Flow
Transit Signal Priority	The TSP will use a typical flow of operations traditionally applied to the priority request generator (PRG)- priority request server (PRS). Preconditions include: • The logic for generating a priority request is loaded into the PRG. It depends on whether a traveler is waiting for a transit vehicle. The PRG is generated by G-MAP. • The logic for granting priority request is loaded in the PRS. Priority request is granted for any delay when the "enhanced TSP" message is received from the PRG. The actions will flow occurs using Exchange ID 10 as follows: Main Flow 1. The use case begins when the PRG determines a priority request is desired. 2. The PRG generates a TSP signal request message (SRM) to the PRS. The TSP request message contains the identifier of the vehicle that desires priority, the identifier of the route for the vehicle, a request identifier, the priority strategy requested, route, trip, pickup and dropoff stop, and whether the passenger requires additional time to board/alight the transit vehicle. 3. The PRG generates a TSP request message and transmits it to the PRS. 4. The Controller function is out of scope of the system, but it behaves as expected, granting TSP to the vehicle. 5. The PRG keeps TSP on throughout the corridor from the time it receives the message until the passenger alights from the transit vehicle. Then the PRG resets the request to its default state.

CV Application	Scenarios – Main Flow
Mobile Accessible Pedestrian Signal System (PED-SIG)	The PED-SIG scenario enables a traveler using a MU to request pedestrian signal actuation and exchange a message transaction set encapsulated by Flow 8. G-MAP triggers a PED-X actuation request when a traveler is detected near an intersection on their trip plan. G-MAP sends a secure message (Exchange ID 8) to the SMUG (proxy server) that requests signal actuation for a specific signal and approach (direction of travel). The SMUG will format a formal request to the signal controller (signal ID) using the NTCIP 1201/1202 Management Information Base (MIB) to request pedestrian signal actuation. The PED signal would then initiate a request (which would activate the ped request on the ped-sig) and activate the RSU (Exchange ID 9) to broadcast a PSM to connected vehicles (Exchange ID 14). Preconditions • G-MAP queries and loads intersections and approaches for each trip plan into its server. • G-MAP has the security credentials to query the SMUG • The SMUG has the security credentials to send messages to the GCDOT signal controllers The actions will flow (using Exchange ID 8) as follows: Main Flow 1. When a traveler schedules a trip plan with an intersection crossing, the G-MAP checks if the intersection is supported by the SMUG. 2. If so, G-MAP determines if the traveler will need extra time to cross the intersection based on their VRU category. 3. G-MAP will then prepare a notification template to alert the SMUG that a traveler requires actuation of a pedestrian signal request in the direction of travel (based on their trip plan). 4. When the traveler is within a geofence area around the intersection, G-MAP will send the event to the SMUG to request PED-X. 5. When the actuation request is received by the signal, it does the following: a. Communicates with the RSU that a pedestrian is present. b. Changes the state of the Ped signal to request activated (depending on the ped-head series, this might be indicated by a countdown and / or lighted button) 6. The RSU will then broadcast a PSM message. 7. When the Ped-X signal is activated, the audible, haptic and visual cues will alert the traveler to cross the street.

CV Application	Scenarios – Main Flow
Pedestrian in Signalized Crosswalk Warning (Transit)	In this scenario the RSU broadcasts a message that are received by OBUs on transit vehicles to notify transit bus operators when pedestrians are within the crosswalk of a signalized intersection that is in the intended path of the bus. The actions will flow as follows: 1. When the pedestrian crossing signal is on, a pedestrian in crosswalk warning is broadcast (Exchange ID 10 and 14) to all vehicles (OBUs) in the vicinity including transit buses. 2. The second-by-second traffic information near the pedestrian crossing and the MU locations (collected by G-MAP) will be processed by the STM Performance Measure Dashboard through the Exchange ID 6.
Ride Request	The Ride Request scenario allows a transit passenger to send a stop request to an approaching transit vehicle. The actions will flow as follows: 1. When a traveler plans a trip with a transit leg, G-MAP will initiate a Ride Request template for the route, trip, pickup and dropoff location. This message is the same as the message that was sent to the Enhanced TSP. The message will include a flag that indicates that the rider requires extra time to board or alight the transit vehicle. 2. When the traveler is detected within a certain area near the bus stop, G-MAP will request that a transit vehicle stop at a specific stop (Exchange ID 6 or Flow 9). 3. The Transit vehicle will receive a message (via Exchange ID 11) on their mobile data terminal with the information on the traveler and pickup/stop location.

Information Needs. The flows and information needs will conform to messages described in the family of SAE J2945 series, as well as the ongoing ITE Connected Intersections systems engineering as appropriate.

Security protocols and transactions follow the IEEE 1609.2-2016 Standard for Wireless Access in Vehicular Environments (WAVE) – Security Services for Applications and Management Messages.

7. Summary of Impacts

This section describes the operational impacts of the new ST-CTN system on the users and other agencies and organizations involved with the system. It also explains how any transition periods will impact system stakeholders and users moving from the current set of independent systems to the new ST-CTN system. This information is intended to be used for stakeholders to plan for these impacts during the development of and transition to the new system.

7.1 Operational Impacts

The ST-CTN proposed system will have a direct impact on the operational nature of GCT, GCDOT, GDOT, G-MAP, and travelers using the G-MAP application from the underserved community. The following sections describe potential impacts for each user group within the ST-CTN system.

7.1.1 Gwinnett County Transit Operational Impacts

The operational changes for the GCT user group include:

- Changes to the onboard equipment on transit vehicles and practices that support the maintenance of the onboard equipment. The existing onboard operator communications equipment will be used to provide the driver feedback about a boarding passenger if they require additional boarding/alighting time or need assistance from the driver to operate mobility assistive devices.
- Changes to the ways that GCT transit vehicles receive stop requests which will allow passengers to request a stop through the application. This will not impact existing bus stop locations or routing.
- Additional information including whether a traveler has specific needs to board/alight the vehicle will be sent to bus drivers. Reviewing the information while operating a vehicle may be against Standard Operating Procedures.
- Changes to stop facilities management and maintenance practices that support the need for accessible bus stops and shelters, and accessible pathways to bus stops and shelters. Ride Gwinnett will need to monitor the condition and accessibility of bus stop assets, prepare for and complete repairs, disseminate accessibility information to the proposed system, and accept user submitted inventory updates.
- Changes to operations may be made based on aggregated data received from the ST-CTN expansion. GCT may decide to prioritize future transit expansion or projects based on the type of users interacting with the system and their mobility needs.
- Changes to the method that TSP is activated, potentially resulting in situations where a bus arrives prior to its scheduled time. TSP will be activated automatically based on programmed trip plans and traveler preferences, resulting in more frequent activations of

TSP then before deployment of the ST-CTN. This increased frequency could alter the bus travel patterns, causing them to have to wait at a stop until a scheduled departure time is met.

7.1.2 GCDOT Operational Impacts

The operational changes for the GCDOT user group include:

- Changes to asset management and field maintenance practices that support the need for accessible sidewalks and shared-use paths. GCDOT will have access to more ways to monitor the condition and accessibility of shared use right of way assets through crowdsourced data. This data can be used to prioritize repairs. Staff resources will be required to maintain accessibility information in a way that will enable it to feed back into the proposed system.
- Potential change to deploy a Secure MU Gateway in the traffic signal cabinets or central system which would allow connected vehicle and connected infrastructure inputs and outputs to communicate with mobile devices.
- Changes to connected vehicle and connected infrastructure inputs and outputs to allow for TSP and pedestrian safety applications as described in the proposed system.

7.1.3 GDOT Operational Impacts

The operational changes for the GDOT user group include:

- Changes to connected vehicle and connected infrastructure inputs and outputs to allow for communication needs through Secure MU Gateway of the proposed system.
- Changes to connected vehicle and connected infrastructure inputs and outputs to allow for TSP and more active role of MU (pedestrians using smartphones) as described in the proposed system.

7.1.4 G-MAP Operational Impacts

The G-MAP user group will consist of both ATL and ARC. Operational changes include:

- Changes to UI to allow users from the underserved community access the application including from a phone, computer, or with assistive technologies.
- Changes to the system that allows for greater scalability without losing connections with end users.
- Changes to application to allow for hands-free, turn by turn directions.
- Long-term technical support assistance will be needed for the web and mobile versions of the ST-CTN application. These will include addressing bugs in the system or software disruptions. Technical support personnel will have additional tasks added to their responsibilities with the new application and workflow processes may have to be adjusted.

- An agreement between Georgia Tech and ARC will be made for maintenance and operational support for STM for the duration of the project.

7.1.5 Transit Users Operational Impacts

The operational changes for the Transit Users user group include:

- Addition of a new tool a transit rider can use to plan their trip and access transit schedule information.
- Additional information needed from users to determine the most accessible route according to their needs.
- Additional application to connect to user's existing wearable technologies such as a smart cane.
- Operational risk in relying on application's location accuracy for users who those who require precise location details including people with visual disabilities.

7.2 Organizational Impacts

The ST-CTN proposed system will have a direct impact on the organizational nature of GCT, GCDOT, GDOT, ATL, and ARC. Impacts are broken out per user group below.

7.2.1 Gwinnett County Transit Organizational Impacts

The organizational impact for the GCT user group include:

- Changes to policies and operating procedures regarding how vehicle operators receive information from riders to include automatic ST-CTN messages.
- Training for GCT operators and administrators is expected to be included in the development phase to give them a better understanding of the application and the impacts to their position.
- Long-term impacts include updating training materials for drivers and will not require additional staffing or budget.

7.2.2 GCDOT Organizational Impacts

The organizational impact for the GCDOT user group include:

- Technology infrastructure maintenance responsibilities will be minimal for the ST-CTN system and fall under current maintenance practices. Long-term impacts of maintenance are already budgeted and planned for in existing CV plans.
- Enhanced sidewalk facility data will enable GCDOT to more efficiently maintain assets but could create more work to incorporate data into current system.
- GCDOT staff and support consultants need to develop capabilities to understand and operate CV systems.

7.2.3 GDOT Organizational Impacts

The organizational impact for the GDOT user group include:

- ITS staff and support consultants need to develop capabilities to understand and operate CV systems.
- Long-term impacts are minimal as GDOT already has these work tasks covered by their current staff and work plans.

7.2.4 ARC Organizational Impacts

The organizational impact for the ARC user group include:

- ARC will facilitate a group of all the project partners to collaborate to manage the system integration during the 8 years of development and operations.
- Long-term maintenance of the G-MAP app. ARC will be responsible for the maintenance of the additional functionality provided by the ST-CTN system, including the maintenance of, and functionality provided by, the STM Platform and Sidewalk Inventory Connection Tools subsystems. This task will be managed by the existing position of Transportation Technologist. If necessary, ARC may need to hire a consultant to help maintain the app. This will be budgeted in the annual UPWP.
- Expansion of the ST-CTN system. Expanding the system will require coordination among the local jurisdictions, as well as software developers. This task will be led by the regional planning team at ARC and the regional TSMO planner will work with the transportation technologist to decide how and where to expand the system. If necessary, ARC may need to hire a consultant to help update and adjust the app for multiple jurisdictions. This will be budgeted in the annual UPWP.
- Long-term call center support services will be needed for the ST-CTN application. The call center will need to be staffed by operators who are well versed in the application including the setup process in order to properly assist end users. Additionally, operators who speak multiple languages or are familiar with the Text Telephone (TTY) system in order to properly assist all end users. The call center may need to expand as the ST-CTN application is deployed outside of the project area. An agreement between ARC and ATL will need to be made to designate ownership of Call Center operations.

7.2.5 SILCGA Organizational Impacts

The organizational impact for the SILCGA user group include:

- Long-term training and promotion of the user app. While ARC will be promoting the expansion of the system regionally, SILCGA will work with their partners including DisAbility Link and GA Tech's Tools 4 Life Program to continue to engage and train potential users. This task is currently in line with their mission and work program so no staff or budget changes will need to be made.

7.3 Impacts During Development

The development phase for the proposed system involves system design, testing, and verification. During this phase IOO and system developer stakeholder engagement will continue to support the development of the application. End user stakeholder engagement will continue in the form of reviews and demonstrations of the application. It is expected that the proposed system will operate in parallel to the existing system, with a portion of the underserved community being given access to the proposed system for testing purposes.

The STM platform has one upgrade listed that will take place during the development phase of the ST-CTN application, which is the development of a tool and processes used to perform network reconciliation for the ABM and OSM networks. The STM platform uses the ABM as its base network for roadway links and will need to add bicycle pathways from OSM. The Sidewalk Inventory Collection tools will also be going through continuous improvements prior to and during the development phase. Should any of these upgrades not take place prior to the development phase, the real-time routing and impedance value analysis functionality of the ST-CTN application will be diminished. The schedules for these deployments is discussed in more detail in **Section 3.2.2** and **Section 3.2.3**.

The development phase will overlap several infrastructure improvement projects that are planned within the project limits including the Gwinnett County CVTMP and the CV1K project which will deploy CV infrastructure to signals and transit vehicles. If these project timelines are delayed or the deployment area is altered, there will be impacts to the development of the ST-CTN application with sub-systems that relate to CVs. The schedule for these deployments is discussed in detail in **Section 3.2.4**. These other improvement projects may include resurfacing, widening, or other projects that may cause temporary transit rerouting or communication interruptions.

Ride Gwinnett is planning on implementing route adjustments during the development phase of the project. These route adjustments will need to be considered while completing system development and coordination will be needed to ensure that the new routes are active in the application once they are active for GCT. Additionally, GCT has several system development milestones occurring during the deployment phase including router upgrades, TSP implementation and ATL RIDES integration. The schedule for these upgrades is discussed in **Section 3.2.5**. Any impact to these schedules could delay deployment of the entirety of, or specific portions of the ST-CTN project. In addition, service changes that impact route operations may be implemented, such as micro or flex routing. These require additional services including hailing functionality.

The ST-CTN application will run in parallel with the ATL RIDES application. There are not expected to be any impacts to either application during the system testing processes.

8. Analysis of the Proposed Systems

This section will focus on the expected benefits of the proposed system from a quantitative and qualitative perspective. The analysis approach will be summarized, and the expected benefits, limitations, disadvantages, and trade-offs considered will be provided. The Performance Measurement Plan (Task 5) will expand on the information provided below and offer a more detailed description of the quantitative and qualitative assessments.

8.1 Analysis of the Proposed System

The analysis of the proposed system will include the benefits, limitations, and disadvantages of the proposed system as described in **Section 5**. In general, it is the goal of the proposed system to increase reliability of access to the transit system, increase the safety of transit users throughout their trip, and increase mobility of the underserved community.

8.1.1 Expected Benefits

The expected benefits of the proposed system are included below. Expected benefits are categorized by trip segment, as discussed in **Section 4.2**. The expected benefits are tied to the user needs discussed in **Section 4.2.1.** Each need was assigned a priority of Essential (E), Desirable (D), or Optional (O). The priority of the needs tied to the benefit are included in **Table 27**.

Table 27. Proposed System Expected Benefits

Trip Segment	Proposed Improvement	Expected Benefit	Benefited Stakeholder	Priority
Pre-Trip Planning	Provide travelers with real-time, secure, and reliable traveler information regarding their planned trip.	-Increased Reliability -Increased Mobility	Traveler GCDOT Gwinnett County Transit	E
Pre-Trip Planning	Provide travelers with trip personalization tools that allow them to program and complete trips that match their ability levels.	-Increased Safety -Increased Reliability -Increased Mobility	Traveler	E

Trip Segment	Proposed Improvement	Expected Benefit	Benefited Stakeholder	Priority
Pre-Trip Planning	Provide travelers with the option to set trip preferences to group travel, which will base the trip routing choices on the ability level of a group of travelers as opposed to a single traveler.	-Increased Safety -Increased Reliability -Increased Mobility	Traveler	D
Pre-Trip Planning	Provide travelers with the ability to set notification preferences, such as haptic feedback, voice, text, or image alerts.	-Increased Safety -Increased Reliability -Increased Mobility	Traveler	E
Pre-Trip Planning	Provide travelers with the ability to preview trips prior to departure to ensure that the traveler understands the extent of their trip.	-Increased Safety -Increased Reliability -Increased Mobility	Traveler	E
Begin Trip	Providing a call center line through the application will allow travelers who get disoriented or need assistance to complete their trip.	-Increased Safety -Increased Reliability -Increased Mobility	Traveler	E
Begin Trip	Provide travelers with alerts that they have departed the designated route, or that they are getting on the wrong transit vehicle.	-Increased Safety -Increased Reliability -Increased Mobility	Traveler	E

Trip Segment	Proposed Improvement	Expected Benefit	Benefited Stakeholder	Priority
Transition to Transit	Provide some high-level information to transit vehicle operators which will ensure that all travelers have enough time to board or alight a transit vehicle, are provided the assistance they require when operating mobility assistance devices or need additional time to pay the fare.	-Increased Safety -Increased Reliability -Increased Mobility	Traveler Gwinnett County Transit	E
Transition to Transit	Provide travelers with the ability to remotely request service to alight a vehicle, the application will ensure that all travelers are able to reach their destination.	-Increased Safety -Increased Reliability -Increased Mobility	Traveler Gwinnett County Transit	D
Intersection Crossing	By allowing the travelers to request pedestrian service, extend crossing times, and by providing the traveler with information about the crossing.	-Increased Safety -Increased Reliability -Increased Mobility	Traveler Gwinnett County DOT	D
Connected Vehicles	Connected vehicle applications will allow travelers to remotely request service from transit vehicles, request a pedestrian signal, or notify vehicles of their presence.	-Increased Safety -Increased Reliability -Increased Mobility	Traveler Gwinnett County Transit	D
Connected Vehicles	Travelers will be alerted about, as well as alert, passing CVs, making both parties aware of the other.	-Increased Safety	Traveler	D

Trip Segment	Proposed Improvement	Expected Benefit	Benefited Stakeholder	Priority
Connected Vehicles	Implementing TSP will improve transit schedule reliability and on time performance.	-Increased Reliability -Increased Mobility	Traveler Gwinnett County Transit	E
Indoor Navigation	Travelers will be provided with information on indoor navigation at select locations including accessible access points and service outages.	-Increased Reliability -Increased Mobility	Traveler	D
Reporting	Travelers will have the ability to report on infrastructure, including elevators, escalators, or sidewalks that are not accessible.	-Increased Safety -Increased Reliability -Increased Mobility	Traveler Gwinnett County DOT	D

Key performance measures and targets are difficult to establish in transportation studies, specifically when focusing on the perception of safety and mobility from the end users' point of view. The goals of the proposed system include:

- Increased Trip Reliability – Providing travelers in the underserved community with the ability to program and complete a trip reliably, from origin to destination, and all the transitions between trip segments, based on their abilities is the ultimate goal of the project. This can be measured in several ways, including:
    - Qualitative: Solicit feedback from the travelers on their ability to program and complete trips while using the ST-CTN application.
    - Quantitative: Collect and analyze non identifiable data about trip completion percentage through the application.
    - Quantitative: Collect and analyze data about network and application uptime and number of users.
    - Quantitative: Collect and analyze data about transit service on-time performance and speed.
    - Quantitative: Collect and analyze non identifiable data about remote service calls for transit or pedestrian services.

- Increased Trip Safety – Providing travelers in the underserved community with the ability to program and complete a trip safely, from origin to destination, based on their abilities is the major goal of the project. This can be measured in several ways, including:
    - Qualitative: Solicit feedback from the travelers on their perception of safety while using the ST-CTN application.
    - Quantitative: Collect and analyze non identifiable data about the number and type of CV broadcasts to determine if near-miss situations are occurring.
    - Quantitative: Collect and analyze non identifiable data on pedestrian extension requests.
    - Quantitative: Track crashes in the project area to note any decrease in occurrences.
- Increased Mobility and Accessibility – Providing travelers in the underserved community increased mobility and accessibility is a major goal of the project. This can be measured in several ways, including:
    - Qualitative: Solicit feedback from travelers on their mobility options and the accessibility of transportation choices with access to the ST-CTN application.
    - Quantitative: Collect and analyze non identifiable data about existing travel patterns through the deployment of a control version of the application during the development and testing phase. Compare this data to travel patterns after the full system is deployed.
    - Quantitative: Collect and analyze key performance data produced by third parties including employment data, travel time data, and quality of life data before and after the deployment of the application.

These performance measures will be expanded on during the development of the Performance Measurement Plan (Task 5).

8.1.2 Limitations and Disadvantages

The following limitations and disadvantages of the proposed system are acknowledged below. The ST-CTN project team will determine if there are ways to measure the impact during the development of the Performance Measurement Plan (Task 5).

- Outreach – Recruiting and keeping volunteer users engaged throughout the development process presents a challenge to the deployment of the proposed system. As users relocate, change travel patterns due to job changes, or become disengaged, the accuracy of the data produced will be impacted. The engagement rate of the application will be measured during the development phases to ensure that a reliable data set is maintained.
- Technology Access – Access to the mobile application will require the use of a smart phone with a data plan. The application will be available through a web browser, but

enhanced features, such as CV applications or real-time route guidance will not be available. The method of access will be monitored throughout the development phase.

- Location Data – Mobile devices and CV have limitations to the accuracy of data they are able to broadcast. The ability to accurately determine orientation or low latency direction of travel presents a challenge for both end users and CVs. The application will have to predict end user movement based on planned trip routing when activating pedestrian service requests. Similarly, CV broadcasts will have to be based on near term direction of travel information and may not always accurately portray the true nature of a vehicle. Qualitative data can be collected during the development and deployment stage to understand the impact of inaccurate location data, such as questionnaires issued post trip.
- Service Mode – The ST-CTN application focuses on transit-based trips. Third-party integration of ride hailing/booking service or flex/micro transit services can be integrated at a future time but will not be available during the development phase. This could impact the way users interact with the app during the development phase, causing a reduction of reliable data. Qualitative data can be collected to understand this impact through user surveys.
- Information Overload – The ST-CTN application will be simple to use but highly customizable. Some users may experience information overload when customizing the application preferences and their abilities into the application. Outreach services and reset functions can be included to minimize these challenges. Qualitative data can be collected to understand the ease of which the user can customize the application.
- Customization Lock Out – The ST-CTN application is highly customizable with many preferences impacting route generation. It is possible that a specific preference or set of preferences could be selected which would return a trip plan that far exceeds an ideal trip travel time or does not return a trip plan at all. This could be avoided by generating several trip plans for each trip with indicators of the different characteristics of each plan, allowing the user to select the route that best suits their needs at the time. Quantitative data can be collected to understand what preferences are linked to trips with higher travel times and how often trips with characteristics that do not match the traveler's selected preferences.
- Limited Indoor Environments – The initial deployment of the application will only feature two indoor navigable environments, the Gwinnett Justice and Administration Center (GJAC) and OneStop Norcross. This limitation could cause some confusion when travelers are attempting to navigate other indoor environments with the application. These features are expected to expand as the application is developed further and additional data sources are incorporated. Qualitative data can be collected in the form of trip surveys to understand how often users are accessing indoor spaces as a part of their trip.
- Limited Geographic Area – The ST-CTN application will be developed and deployed in the project area identified in **Section 5**. This limitation will impact the traveler's ability to make a complete trip if they are starting or ending their trip outside of the project limits. The base ATL RIDES application will be able support the traveler's transit and routing needs outside of the project area, but the generated routes will not account for all their preferences. Quantitative data can be collected to understand how many trips are starting or ending outside of the project area. This data can be used to support further expansion of the ST-CTN application.

8.2 Alternatives and Trade-Offs Considered

The proposed concept, as described in **Section 5**, meets the goals of the ST-CTN project by providing an application that allows users to complete trips, from origin to destination, safely, while accounting for their preferences and abilities. There were needs discussed during the stakeholder engagement that fell outside of the scope of the project or did not contribute to the goal of the projects. Changes considered but not included in the proposed concept are discussed in **Section 4.3** and expanded on below.

Expansion of Transit Service – Alternative that include the expansion of transit service, through the addition of new routes, extended operating hours, or purchasing of OBUs for microtransit vehicles are outside of the scope of this project and not considered as a part of this ConOps. The proposed system will be using the existing infrastructure that is deployed or will be deployed through upcoming infrastructure projects. Likewise, the transit system that is currently operational or that will be operational during the deployment phase, is a fixed route system, and altering the service area or schedule would have detrimental impacts on the system.

Construction of Additional Infrastructure – Alternatives that include adding street lighting, modifying building features including entry points and signage, modifying intersections, or expanding transit stops are outside of the scope of this project and not considered as a part of this ConOps. The proposed system and project are not capable of building new infrastructure within the project limits.

Additional Training for Transit Operators – Alternatives that include additional training for transit vehicle operators including training on how to recognize and respond to traveler specific mobility challenges or training on how to better operate mobility assistive devices on the bus are outside of the scope of this project and not considered as a part of this ConOps. Information will be provided to the drivers on passengers who need additional time to board or alight the bus. The proposed system and project are not capable of providing training to transit vehicle operators.

On-Demand Application Customization – Alternatives that include application customization to match the traveler's ability, such as map customization, or application simplification (i.e., the removal of options from menus) are not considered as a part of this ConOps. The effort required to provide additional customization to base map features, or the simplification of the application are not aligned with the goals of the proposed system. Support through outreach programs and call centers is included in the proposed system to assist users with understanding how to use the application.

The ST-CTN team and system developers considered trade-offs between Agile and Waterfall software development methodologies. Ultimately, the system developers were able to choose their preference for software development that is included in the proposed system. Many of the subsystems are fully developed with modifications being applied to operate in or interface with the proposed system and it would have been disruptive to the individual development cycles to require the developers to shift to a new methodology. Agile development will also be able to keep pace with the feedback that is received during the development phase.

Mobile App Limitations. Issues such as latency, positional accuracy, battery life limit the ability for the mobile app to actively participate in the connected vehicle environment as an active participant. Research and demonstration projects are currently underway that may mitigate the

impacts of the limits. For example, the NavCog project is addressing improved locational accuracy, additional Bluetooth and Wi-Fi sensors using triangulation are improving locational precision, mobile handsets are extending the life of batteries, including additional capabilities that improve location accuracy and ranging such as machine vision and ultrawide band sensors. In addition, there are also potential solutions using the batteries on electric wheelchairs to support travel execution for people using wheelchairs.

Appendix A. Acronyms

ABM - Activity-based Model

ACS – American Community Survey

ADA – Americans with Disability Act

API – Application Programming Interface

ARC – Atlanta Regional Commission

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

BSM – Basic Safety Message

CAD – Computer-Aided Dispatch

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

GOSystems – GO Systems and Solutions

GPS – Geographic Positioning System

GRTA – Georgia Regional Transit Authority

GTFS – General Transit Feed Specification

I2P – infrastructure to person

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

KHA – Kimley-Horn and Associates, Inc.

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

OBU – Onboard Unit

OSM – Open Street Map

OSS – Open Source Software

OST – Office of the Secretary

OTP – Open Trip Planner

P2I – Person to Infrastructure

P2V – Person to Vehicle

PED-SIG – Mobile Accessible Pedestrian Signal System

PII – Personally Identifiable Information

PRG – Priority Request Generator

PRS – Priority Request Service

PSM – Personal Safety Message

RITIS – Regional Integrated Transportation Information System

RSU – Roadside Unit

RTP – Regional Transportation Plan

SCMS – Security Credential Management System

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

TAP – Transportation Alternatives Program

TBD – To Be Determined

TCC – Traffic Control Center

TIP – Transportation Improvement Program

TMC – Traffic Management Center

TNC – Transportation Network Company

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

Appendix B. Glossary

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 – 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 works over the cellular network to provide vehicle-to-vehicle, vehicle-to-infrastructure, and vehicle-to-pedestrian communication. It is similar to DSRC but uses the cellular network instead of a short-range spectrum [CVTMP].

Cellular V2X – Cellular V2X (C-V2X) is a 3GPP standard 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 associating 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].

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 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]

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

Personal Safety Message (PSM) – A data broadcast by a vulnerable road user (such as pedestrians) to announce their presence to approaching vehicles. [CAV]

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]

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 prioritizes buses and granting their right of way based on schedule adherence or passenger loads. [CAV]

U.S. Department of Transportation
ITS Joint Program Office-HOIT
1200 New Jersey Avenue, SE
Washington, DC 20590

Toll-Free “Help Line” 866-367-7487
www.its.dot.gov

FHWA-JPO-21-857



U.S. Department of Transportation