Phase 1 Performance Measurement and Evaluation Support Plan

Atlanta Regional Commission ITS4US Deployment Project

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COMPLETE TRIP

ITS4US

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16. Abstract

The Atlanta Regional Commission Complete Trip - 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, aging adults, and those with limited English proficiency.

This document serves as the Performance Measurement and Evaluation Support Plan (PMESP) for the deployment project. The PMESP identifies performance measures based on goals, objectives and project use case scenarios. The performance measures are explained along with confounding factor and mitigation strategies. Plans are developed for evaluating these performance measures in terms of targets to determine the overall success of the project.

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1. Introduction

The Performance Measurement Evaluation and Support Plan (PMESP) identifies and defines the performance measures that will be used to measure and analyze the success of the Safe Trips in a Connected Transportation Network (ST-CTN) project. In addition to defining performance measures, the document also captures the plans for collecting data and reporting on performance. The PMESP is a companion document to the program and project-level systems engineering documents, including the Concept of Operations (ConOps), System Requirements Specification (SyRS), Data Management Plan (DMP), Safety Management Plan (SMP), and the Human Use Approval (HUA) Summary.

The ST-CTN project seeks to provide accessible transportation and route safety information in an effective and equitable manner to underserved communities such as aging adults, users with physical or cognitive disabilities, and users with limited English proficiency (LEP).

1.1 Intended Audience

The ST-CTN project is being led by the Atlanta Regional Commission (ARC) 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:

- **ARC.** Project management, concept development, and concept collaboration lead
- **Gwinnett County Department of Transportation (GCDOT).** System development and local agency deployment lead
- **Gwinnett County Transit (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 Department of Transportation (GDOT).** CV integration lead
- **Georgia Institute of Technology (GA Tech).** Technical innovation lead
- **GO Systems and Solutions (GOSystems).** System development lead
- **IBI Group.** ATL RIDES system and mobility application development lead
- **Kimley-Horn and Associates, Inc. (KHA).** Concept development and production management leads

The intended audience of this PMESP 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. The document provides goals, objectives, and performance measures that stakeholders will use

to plan for, monitor, and report on the performance of the ST-CTN system. These stakeholders include GCDOT personnel involved with transportation systems management and operations and connected vehicle (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 Atlanta-Region Rider Information and Data Evaluation System (ATL RIDES) system. Additionally, U.S. Department of Transportation (USDOT) personnel, the USDOT independent evaluation (IE) team, and future deployment teams will find this document useful for developing assessment documents and understanding the context of the ST-CTN system.

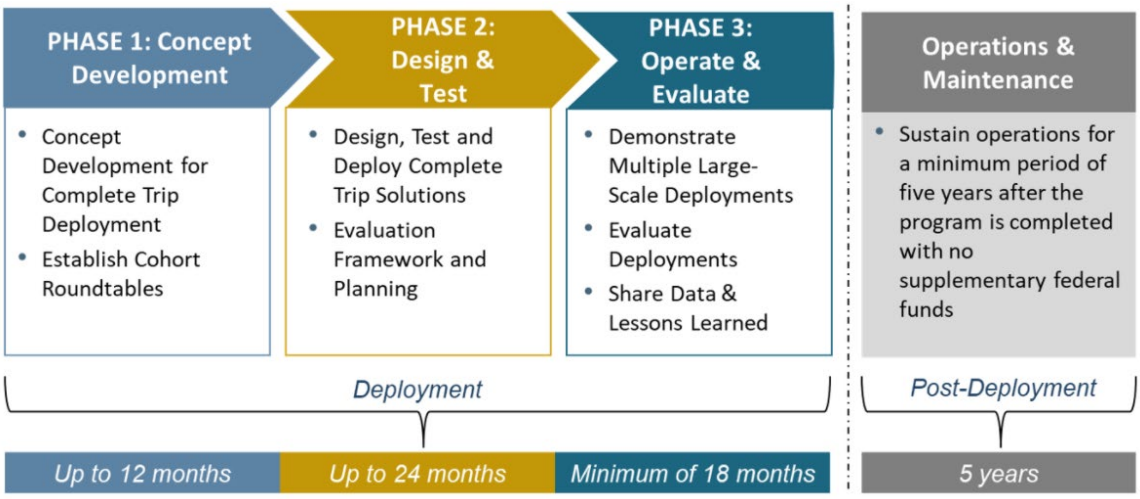
1.2 Project Background

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 physical or cognitive 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 1**, 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.



Source: USDOT, 2020

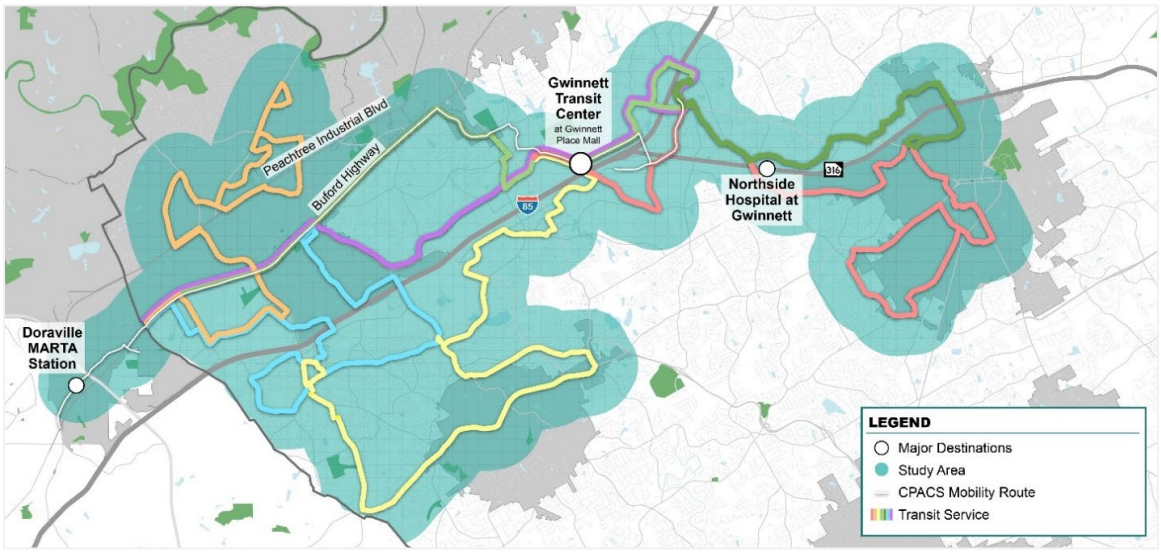
Figure 1. Phases of the Complete Trip – ITS4US Deployment Program

The 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 all users with the ability to dynamically plan and navigate trips based on their personal needs and preferences. Consistent with the ITS4US Program goals, the ST-CTN project is specifically focused on supporting the following underserved communities:

- **People with Physical Disabilities.** People with physical disabilities are limited in independent, purposeful physical movement of the body or of one or more extremities, and substantially limits one or more major life activities.
- **People with Cognitive Disabilities.** People with cognitive disabilities have a condition that makes it more difficult to interact or participate in the environment around them. Cognitive disabilities may affect a person's thinking, remembering, learning, communicating, mental health, sensory processing, or social interactions.
- **Aging Adults.** Aging adults may have trouble performing specific tasks within a set time (e.g., crossing a road or boarding a transit vehicle), standing for an extended period of time, or be more sensitive to the elements (e.g., waiting for transit in excessive heat). Aging adults are people (typically 60 years of age or older) who have physical or cognitive limitations that impact 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 culture 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. Which was chosen partially due to its representative nature. It 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 CV planning work recently completed. A map of the project area can be found in **Figure 2**.

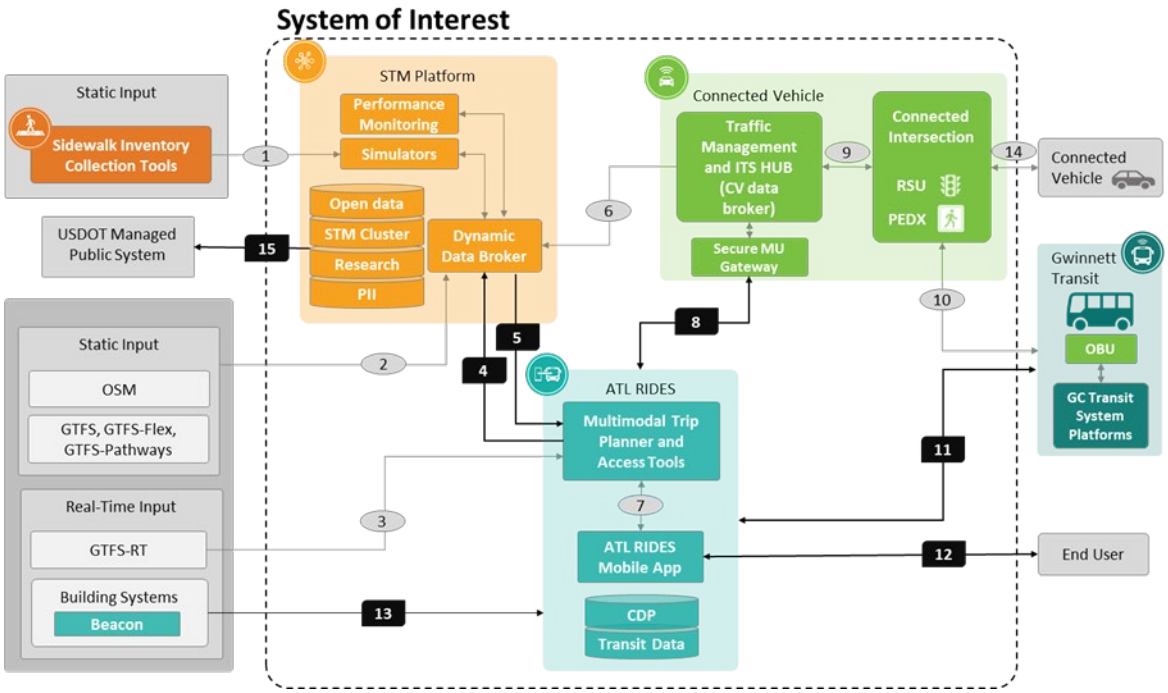


Source: ARC, 2020

Figure 2. ST-CTN Deployment Site Map

1.3 System Overview

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 3** 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; space time memory (STM) Platform is peach; CV is green; ATL RIDES is turquoise; and GCT is teal. The STM Platform, ATL RIDES, and CV subsystems will each require expanded capability and added connectivity to support the proposed ST-CTN system. The Sidewalk Inventory Collection Tools and GCT existing independent systems will serve to support the proposed ST-CTN system. Data exchanges between subsystems are denoted by a gray or black line. A gray line indicates an existing and unchanged data exchange between subsystems. A black line indicates a new or upgraded data exchange between subsystems.



Source: ARC, 2021

Figure 3. ST-CTN Network Data Exchange Flow Diagram and Data Storage Systems

Critical ST-CTN data exchanges are identified by number in the context diagram above and described in **Table 1**. 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. In addition, dataset storage systems and their access levels (personally identifiable information (PII) confidential, operational, open or research) embedded in the ATL RIDES and STM subsystems are described in **Table 2.** These dataset storage systems as well as the datasets stored in each system are detailed in the Task 3 DMP.

Table 1. 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 ATL RIDES multimodal trip planner and access tools
4	Mobile App logs and trip feedback
5	STM Network Impedance application programming interface (API)

Data Exchange ID	Description
6	CV and Traffic Operations Messages: signal phasing and timing (SPaT), Map Data (MAP), CV automatic terminal information service (ATIS) broadcast data, NaviGAtor ITS, road characteristics, traffic data
7	Open Trip Planner (OTP) APIs and ATL RIDES APIs
8	Mobile Accessible Pedestrian Signal System (PED-SIG) / pedestrian safety message (PSM)
9	CV messages
10	Transit signal priority (TSP) and other CV application messages
11	CV application transactions for transit applications including transit stop request (TSR)
12	ATL RIDES and traveler exchange – profile, trip plan, settings, notifications, feedback, etc.
13	Static and dynamic information from building facilities to the ATL RIDES
14	CV broadcast messages
15	Project data for USDOT-managed public system

Table 2 provides a summary of dataset storage systems, shown as cylinders in the figure above.

Table 2. ST-CTN Network Dataset Storage Systems

Subsystem	Dataset Storage System Name	Access Level
ATL RIDES	ATL RIDES Connected Data Platform (CDP) Module	PII Confidential
External	External (not stored in project data stores including ITS Data Hub in CV subsystem)	Operational
STM	Open Data Server (Open data)	Open
STM	PII Server (PII)	PII Confidential
STM	Research Server (Research)	Research
STM	STM Server Cluster (STM Cluster)	Open and Research
ATL RIDES	TRANSIT-data-tools (Transit Data)	Open

1.4 Scope

The PMESP document defines the performance measures that will be used to evaluate the deployment of the ST-CTN project. Goals and objectives were derived from user group needs and use cases described in the ConOps. Performance measures—associated performance metrics, evaluation processes, and improvement targets—provide the framework with which the goals and objectives of the ST-CTN project will be assessed. The document also documents confounding factors and discusses strategies to mitigate and/or avoid their impact. Finally, the PMESP describes the data collection and performance measure evaluation efforts that build upon and add to content described in the DMP.

The PMESP is developed based on the Phase 1 concept for the ST-CTN project. There will be further development of the established performance measures during Phases 2 and 3 of the ST-CTN project. Therefore, it is expected that the PMESP document will serve as a living document and will be updated throughout the length of the project (i.e., during Phases 2 and 3 of the project).

1.4.1 Document Overview

The ST-CTN PMESP is based on the PMESP template provided by the USDOT for the ITS4US-Complete Trip program. The remainder of this document consists of the following sections and content:

- **Section 2** (Goals and Objectives) describes the goals and objectives for the ST-CTN project derived from user group needs and use cases documented in ConOps.
- **Section 3** (Performance Measurements and Targets) identifies performance measures and improvement targets associated with the goals and objectives developed in **Section 2**.
- **Section 4** (Confounding Factors and Mitigation Approaches) discusses confounding factors for the identified performance measures as well as mitigation factors to reduce the impact or avoid the impacts of the confounding factors.
- **Section 5** (System Deployment Impact Analysis Design) identifies areas within the project limits that will have the most impact on achieving target performance measure goals.
- **Section 6** (Support to Independent Evaluation Effort) summarizes the support and timing expectations for the IE effort.
- **Section 7** (Data Collection Plan) discusses the data collection and evaluation plans for performance measure data needed to evaluate the ST-CTN project.
- **Section 8** (Performance Reporting) provides information on the methods used to share performance measure information during the deployment of the ST-CTN project.

- **Section 9** (Performance Measurement and Evaluation Support Schedule) organizes the schedule and timeline of milestones, data collection, analysis periods, test and analysis dates and the frequency of updates for the ST-CTN project.

- **Section 10** (References) identifies external documents referenced throughout the PMESP document.

1.4.2 Related Tasks

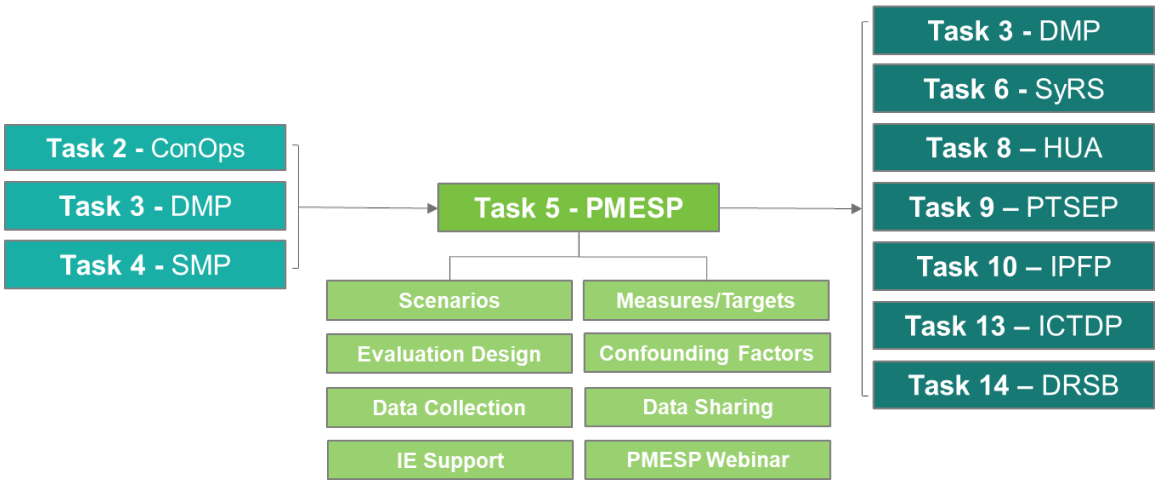
The ST-CTN system is evaluated through performance measurements and their associated metrics, and targets. **Table 3** provides a summary of the performance measurement related interactions within the planned deployment and key task areas that provide supporting information or will be guided by the PMESP.

Table 3. PMESP Related Project Tasks

Related Task	Summary
Task 2 – Concept of Operations (ConOps)	The ConOps is an input for the PMESP. The user group needs and use cases were leveraged to refine the initial project goals and objectives developed within the ConOps. In addition, ConOps use cases drove the development of performance measures for this document.
Task 3 – Data Management Plan (DMP)	The DMP is an input and output for the PMESP. Data collection streams and methods are identified in both the DMP and PMESP. The DMP informs the initial data streams that support the PMESP. The PMESP develops those streams and identifies new streams needed and thus informs future versions of the DMP.
Task 4 – Safety Management Plan (SMP)	The SMP is an input for the PMESP. Safety needs and scenarios identified in the SMP are used to determine the performance measures needed to ensure safety of users and of the system.
Task 6 – Deployment System Requirements (SyRS)	The SyRS includes the requirements for systems and subsystems that will be deployed as a part of the ST-CTN project. The data collection and evaluation needs defined in the PMESP will drive performance measure related system requirements.
Task 8 – Human Use Approval (HUA)	The PMESP will utilize anonymized trace data to evaluate the success of the ST-CTN project. HUA will use PMESP as an input and will need to review the use of this data to ensure that PII is protected.
Task 9 – Participant Training and Stakeholder Education Plan (PTSEP)	The PTSEP identifies participant roles, activities, responsibilities, and training requirements. The PTSEP will be consistent with the plans discussed in the PMESP for performance measurement evaluation.

Related Task	Summary
Task 10 – Institutional, Partnership, and Financial Plan (IPFP)	The IPFP provides definitive documentation on institutional and financial agreements necessary for the successful deployment. The IPFP will use the PMESP as an input for data collection and performance measure evaluation agreements.
Task 13 – Integrated Complete Trip Deployment Plan (ICTDP)	Content from the PMESP will be used to inform challenges that need to be addressed through the deployment plan. The PMESP will identify data streams and performance measure evaluation methods that then inform the deployment approach of specific subsystems.
Task 14 – Deployment Readiness Summary Briefing (DRSB)	Information from the PMESP will be used to demonstrate the project's readiness for deployment in order to begin the Design/Build/Test Phase.

Figure 4 illustrates the key elements and interactions between the PMESP and related project tasks.



Source: ARC, 2021

Figure 4. PMESP Related Tasks

1.5 Performance Measurement and Evaluation Support Plan Purpose

The PMESP will be used to document the performance measures and strategies that will be employed to demonstrate the effectiveness of the ST-CTN project during the deployment phase. User needs generated from stakeholder engagement through the ConOps process were used to build use case scenarios. These use case scenarios were then used to derive the performance

measurements. Thus, it is important that the performance measurements can be tied to the challenges identified by end users so that the project team can assess to what extent the ST-CTN project addressed those challenges. Assess performance is done leveraging numerous systems and strategies used to measure deployment performance and success. Performance measurements are used to describe data collection and analysis plans for reporting.

2. Goals and Objectives

The vison of the ST-CTN system is to leverage existing advanced transportation technology solutions to support safe, reliable, accessible, complete trips for all, particularly for undeserved communities, including people with disabilities, aging adults, people with LEP, and low-income travelers. To demonstrate the effectiveness of the ST-CTN project, well defined goals and objectives need to be established to evaluate the success of the project against key performance measures and targets.

2.1 Deployment Goals and Objectives

Goals and associated objectives for the ST-CTN project were defined based on the user needs identified during the development of the ConOps. These user needs include end user needs, infrastructure owner/operator (IOO) needs, and system needs. The goals and objectives clearly establish the intent of the project such that project performance may be measured and evaluated. The success of the project will be determined based on the ability of the deployment to achieve the stated goals and objectives. Project goals and associated objectives are presented in **Table 4**.

Table 4. ST-CTN Goals and Objectives

Goal / Objective ID	Goal and Objectives
Goal 1	**Enhance the traveler's multimodal complete trip experience with the ST-CTN system functions and features, particularly for underserved communities.**
Objective 1.1	Enhance traveler's multimodal complete trip experience with safe and accessible ST-CTN system functions and features.
Objective 1.2	Enhance enroute traveler support to increase traveler confidence and independence.
Objective 1.3	Enhance the ability for travelers to seamlessly transfer between modes throughout their complete trip – while considering changes in routes due to unplanned events.
Goal 2	**Enhance safety for ST-CTN system users, particularly for underserved communities.**
Objective 2.1	Reduce transportation-related incidents and injuries along pedestrian routes within the study area.
Objective 2.2	Reduce transportation-related incidents and near-misses at signalized intersections within the study area.
Objective 2.3	Increase driver awareness of pedestrians crossing a signalized intersection.

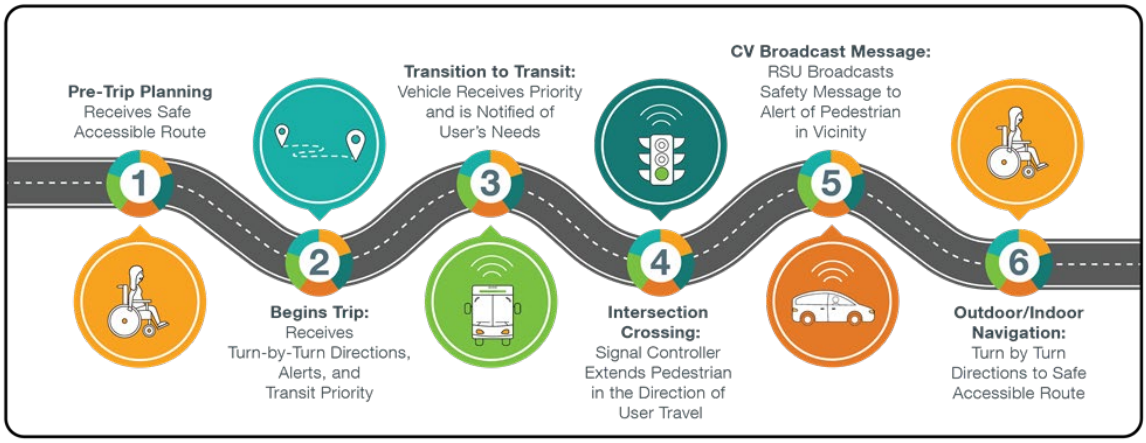
Goal / Objective ID	Goal and Objectives
Objective 2.4	Increase pedestrian awareness of connected and emergency vehicles near intersections.
Goal 3	**Improve reliability for system users, particularly for underserved communities.**
Objective 3.1	Enhance and maintain transit reliability by implementing enhanced TSP configurations for ST-CTN system users.
Objective 3.2	Reduce traveler transit wait times at bus stops.
Objective 3.3	Increase transportation system reliability by providing timely traveler information and routing for system users.
Goal 4	**Improve mobility and accessibility for system users, particularly for underserved communities.**
Objective 4.1	Leverage optimized transit schedules along key corridors to remove additional schedule slack and improve transit travel times as part of on-going TSP operations.
Objective 4.2	Increase traveler knowledge of accessible routes within the study area based on their individual needs and preferences.
Objective 4.3	Increase accessibility by implementing automated actuation of walk phase requests at signalized intersections within the study area.
Objective 4.4	Increase mobility and accessibility by implementing TSRs through travelers' mobile device or automated TSR based on a traveler's planned route within the application.
Objective 4.5	Increase accessibility in locations where travelers identify existing barriers with infrastructure enhancements.

2.2 Use Cases/Scenarios

Two uses cases were developed as a part of the ST-CTN ConOps to describe the operational flow of the proposed system. This section provides a summary of both use cases as well as the relationship between the goals and objectives and the uses cases.

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

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 from the trip planning through completion. In this asynchronous operational flow, the traveler can personalize, select, and activate information on directions, conditions, and status along their trip. The traveler will also be able to leverage their device to communicate with CV infrastructure to experience a safer trip. The six steps of the complete trip are shown in **Figure 5** and the steps are listed below.



Source: ARC, 2020

Figure 5. End User's Complete Trip with ST-CTN

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.

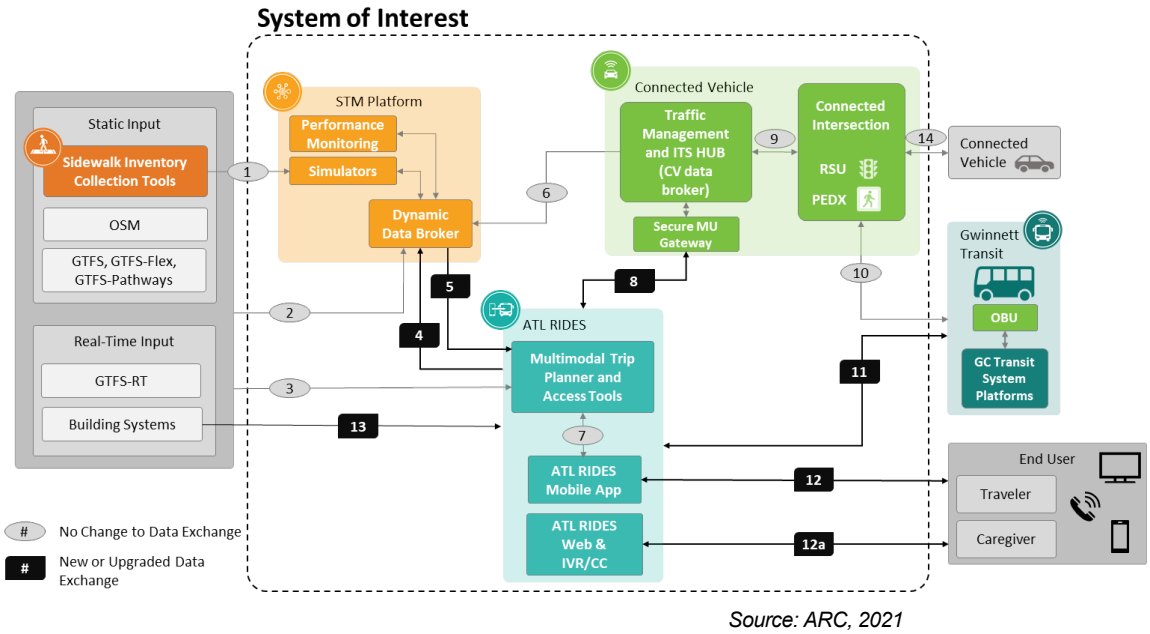
Step 4 **Intersection Crossing.** The traveler interacts with the signal controller which extends pedestrian phase in the direction of user travel.

Step 5 **CV Broadcast Message.** Roadside units (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.

This use case was formed around the system's end user needs, which can be found in detail in the Phase 1 ConOps. The end user needs 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. 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. All end user needs identified for this study are associated with this use case.

Figure 6 contains the information flows for Use Case 1. A detailed breakdown of the information flows can be found in Section 6 of the Phase 1 ConOps.

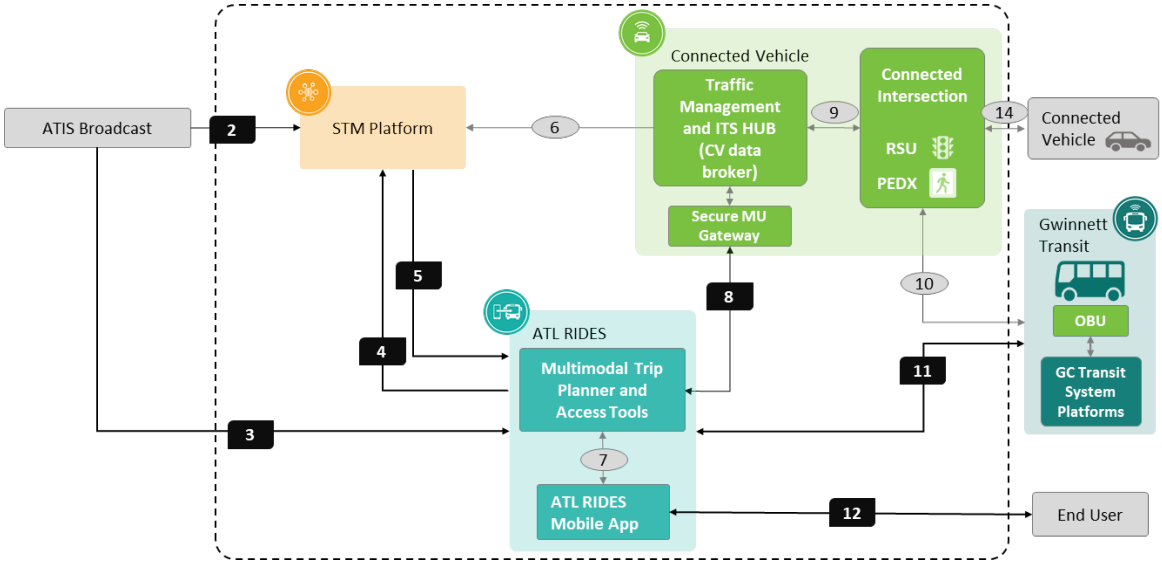


Source: ARC, 2021

Figure 6. Use Case #1 Information Flow in the ST-CTN System

2.2.2 Use Case 2: Connected Vehicle

The ST-CTN proposed system leverages the area's current 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. CV applications being implemented include ATIS, PED-SIG, Pedestrian in Signalized Crosswalk Warning, and TSP. **Figure 7** illustrates the information flow between the traveler (represented by ATL RIDES mobile app) and the field or vehicles represented by the RSU and onboard unit (OBU) equipment. **Table 5** provides the descriptions of the associated data exchanges shown in **Figure 7**. A detailed breakdown of the user and system needs associated with Use Case 2 as well as the operational flows and be found in the Phase 1 ConOps.



Source: ARC, 2021

Figure 7. Use Case 2 CV Applications Information Flow

Table 5 provides CV connection descriptions for each data exchange ID illustrated in the figure above.

Table 5. Critical ST-CTN Use Case 2 CV Connection Descriptions

Data EX ID	Description
1	Not relevant for Use Case 2
2	ATIS broadcast Including warnings of EV preemption and railroad crossing to STM
3	ATIS broadcast Including warnings of EV preemption and railroad crossing to ATL RIDES
4	Mobile app logs and trip feedback
5	STM network impedance API
6	CV operations messages: SPaT, NaviGAtor ITS, road characteristics, traffic data
7	OTP APIs and ATL RIDES APIs
8	[PED-SIG] / PSM
9	CV messages
10	TSP and other CV application messages using existing CV standards such as SAE J2735 and J2945/x
11	CV application transactions including TSR
12	ATL RIDES and end user exchange – profile, trip plan, notifications, feedback, etc.
13	Not relevant for Use Case 2
14	CV broadcast messages

2.3 Use Case and Goals Relationship

There are direct relationships between the use cases and goals. Use Case 1 focuses primarily on the user experience, accessibility, safety, and convenience. A user centric approach was taken to develop the ST-CTN system, therefore Use Case 1 supports 13 of the 15 identified objectives.

Use Case 2 focuses on the data exchanges between the end user, CVs, and infrastructure to enhance safety and mobility. The communications and connected technology have been included in this project to make the user's trip safer and more convenient. Use Case 2 supports 7 of the 15 identified objectives.

Due to the expansive nature of both use cases, 5 of the 15 objectives align with both use cases. The relationships that exist between the use cases and the goals and objectives listed in **Section 2.1** are illustrated in **Table 6** below.

Table 6. Use Case and Goals Relationship

Goal / Objective ID	Goal and Objectives	Use Case Relationship
Goal 1	**Enhance the traveler's multimodal complete trip experience with the ST-CTN system functions and features, particularly for underserved communities.**	
Objective 1.1	Enhance traveler's multimodal complete trip experience with safe and accessible ST-CTN system functions and features.	• Use Case 1 ○ Step 1
Objective 1.2	Enhance enroute traveler support to increase traveler confidence and independence.	• Use Case 1 ○ Step 2
Objective 1.3	Enhance the ability for travelers to seamlessly transfer between modes throughout their complete trip – while considering changes in routes due to unplanned events.	• Use Case 1 ○ Step 3
Goal 2	**Enhance safety for ST-CTN system users, particularly for underserved communities.**	

Objective 2.1	Reduce transportation-related incidents and injuries along pedestrian routes within the study area.	• Use Case 1
		  ○ Step 4
		  ○ Step 5

Objective 2.2	Reduce transportation-related incidents and near-misses at signalized intersections within the study area.	• Use Case 1
		  ○ Step 4
		  ○ Step 5
		• Use Case 2

Objective 2.3	Increase driver awareness of pedestrians crossing a signalized intersection.	• Use Case 2

Goal / Objective ID	Goal and Objectives	Use Case Relationship
Objective 2.4	Increase pedestrian awareness of connected and emergency vehicles near intersections.	• Use Case 2
Goal 3	**Improve reliability for system users, particularly for underserved communities.**	
Objective 3.1	Enhance and maintain transit reliability by implementing enhanced TSP configurations for ST-CTN system users.	• Use Case 1 ○ Step 3 • Use Case 2
Objective 3.2	Reduce traveler transit wait times at bus stops.	• Use Case 1 ○ Step 3 • Use Case 2
Objective 3.3	Increase transportation system reliability by providing timely traveler information and routing for system users.	• Use Case 1 ○ Step 2
Goal 4	**Improve mobility and accessibility for system users, particularly for underserved communities.**	
Objective 4.1	Leverage optimized transit schedules along key corridors to remove additional schedule slack and improve transit travel times as part of on-going TSP operations.	• Use Case 1 ○ Step 3

Objective 4.2	Increase traveler knowledge of accessible routes within the study area based on their individual needs and preferences.	• Use Case 1
		  ○ Step 1
		  ○ Step 2

Objective 4.3	Increase accessibility by implementing automated actuation of walk phase requests at signalized intersections within the study area.	• Use Case 1 ○ Step 4 • Use Case 2
Objective 4.4	Increase mobility and accessibility by implementing TSRs through travelers' mobile device or automated TSR based on a traveler's planned route within the application.	• Use Case 1 ○ Step 3
Objective 4.5	Increase accessibility in locations where travelers identify existing barriers with infrastructure enhancements.	• Use Case 1 ○ Step 6

3. Performance Measurements and Targets

The ST-CTN system seeks to improve the traveler's experience, safety, travel reliability, and the mobility and accessibility of all system users with particular focus on undeserved communities, including people with disabilities, aging adults, people with LEP, and travelers with low-income. These goals are discussed in additional detail in **Section 2.1** of this document and align with the expected benefits discussed in **Section 8.1.1** of the ST-CTN ConOps.

The expected benefits of the ST-CTN system are increased safety, increased reliability, and increased mobility and accessibility. These benefits combined will improve the traveler's experience, allowing them to plan and make complete trips within the project network.

The development of ST-CTN project goals and objectives drove the development of the use cases and the complete trip concept. Expected benefits for the proposed system are organized by the complete trip segments as discussed in **Section 2.2.1**. **Table 6** presented the goals, objectives, and associated use case and trip segment. **Table 7** presents a summary of ST-CTN improvements and expected benefits by use case and trip segment, providing traceability to project goals and objectives and supporting the development of performance measures presented in **Table 8**.

Table 7. ST-CTN System Expected Benefits

Use Case	Trip Segment	ST-CTN Improvement	Expected Benefit
UC 1: Complete Trip	Step 1: Pre-Trip Planning	Provide travelers with real-time, secure, and reliable traveler information regarding their planned trip.	• Enhanced Experience • Increased Safety • Increased Reliability • Increased Mobility • Increased Accessibility
UC 1: Complete Trip	Step 1: Pre-Trip Planning	Provide travelers with trip personalization tools that allow them to program and complete trips that match their ability levels.	• Enhanced Experience • Increased Safety • Increased Reliability • Increased Mobility • Increased Accessibility

Use Case	Trip Segment	ST-CTN Improvement	Expected Benefit
UC 1: Complete Trip	Step 1: 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 off of a group of travelers as opposed to a single traveler.	• Enhanced Experience • Increased Safety • Increased Reliability • Increased Mobility • Increased Accessibility
UC 1: Complete Trip	Step 1: Pre-Trip Planning	Provide travelers with the ability to set notification preferences, such as haptic feedback, voice, text, or image alerts.	• Enhanced Experience • Increased Safety • Increased Reliability • Increased Mobility • Increased Accessibility
UC 1: Complete Trip	Step 1: 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.	• Enhanced Experience • Increased Safety • Increased Accessibility
UC 1: Complete Trip	Step 1: Pre-Trip Planning	Provide a call center line through the system will allow travelers who get disoriented or need assistance to complete their trip.	• Enhanced Experience • Increased Safety • Increased Reliability • Increased Accessibility
UC 1: Complete Trip	Step 2: Begin Trip	Provide travelers with alerts that they have departed the designated route, or that they are getting on the wrong transit vehicle.	• Enhanced Experience • Increased Safety • Increased Reliability • Increased Mobility • Increased Accessibility
UC 1: Complete Trip	Step 2: Begin Trip	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.	• Enhanced Experience • Increased Safety • Increased Reliability • Increased Mobility • Increased Accessibility
UC 2: Connected Vehicle	Step 3: Transition to Transit	Provide travelers with the ability to remotely request service to alight a vehicle, the system will ensure that all travelers are able to reach their destination.	• Enhanced Experience • Increased Safety • Increased Reliability • Increased Mobility • Increased Accessibility

Use Case	Trip Segment	ST-CTN Improvement	Expected Benefit
UC 2: Connected Vehicle	Step 4: Intersection Crossing	Allow the travelers to request pedestrian service, extend crossing times, and by providing the traveler with information about the crossing.	• Enhanced Experience • Increased Safety • Increased Reliability • Increased Mobility • Increased Accessibility
UC 2: Connected Vehicle	Step 5: Connected Vehicles	Allow travelers to remotely request service for transit vehicles, without having to stand for long periods of time, flag down a vehicle, or rush to make an internal connection.	• Enhanced Experience • Increased Safety • Increased Reliability • Increased Mobility • Increased Accessibility
UC 2: Connected Vehicle	Step 5: Connected Vehicles	Enables travelers to be alerted about oncoming vehicles, as well as alert passing CVs about pedestrians, making both parties aware of the other.	• Enhanced Experience • Increased Safety
UC 2: Connected Vehicle	Step 5: Connected Vehicles	Improve transit schedule reliability and on time performance by leveraging TSP.	• Enhanced Experience • Increased Reliability • Increased Mobility
UC 2: Connected Vehicle	Step 6: Indoor Navigation	Provide travelers with information on indoor navigation at select locations including accessible access points and service outages.	• Enhanced Experience • Increased Reliability • Increased Accessibility
UC 1: Complete Trip	Step 6: Indoor Navigation	Provide the ability for travelers to report on infrastructure, including elevators, escalators, or sidewalks that are not accessible.	• Enhanced Experience • Increased Safety • Increased Reliability • Increased Accessibility

3.1 Identification of Potential Performance Measures and Targets

The ST-CTN project team worked together with project stakeholders to develop user needs for the ST-CTN system. The goals and objectives were developed to address the identified user needs and the use cases were created to illustrate and guide the development of the project concept. The successful delivery of the ST-CTN project concept will be evaluated based on performance measures and targets described within this section. Performance measures, metrics, and associated targets were developed through an iterative process in which a core team of researchers and engineers created and vetted measures, metrics, and targets with the ST-CTN technical team. Targets were difficult to define at this stage because of a lack of understanding of the potential range of deployment data. It is expected that targets, although preliminarily defined in this section, will be refined during Phase 2 after a better understanding of

baseline data can be assessed. During Phase 2, specific features (e.g., profile) will be designed, developed, and implemented prior to full deployment of the ST-CTN system to support baseline data needs.

An established relationship between the user needs, goals and objectives, use cases, and performance measures has been developed. This format provides traceability between the performance measures and project goals and objectives, allowing the project to be evaluated both internally and externally for success.

Performance measures are organized by use case, complete trip (use case 1) and connected vehicle (use case 2). Complete trip and CV performance measures are associated with the use cases described in **Section 2.2** and are used to evaluate the success of the ST-CTN system from the perspective of the end user (traveler) and focus on the user experience, safety, mobility, and accessibility. Greater impacts to the community, population, and system may be realized over time and pilot expansion, however, initial deployment and evaluation is anticipated to be primarily focused on the individual end user.

The performance measures for the ST-CTN system are included in **Table 8** and are expanded upon in the sections that follow. Each subsection describes a performance measure and associated metrics used to evaluate the measure. The measure and metrics are referenced to specific project goals and objectives and initial targets are defined for discussion. Each performance measure and associated metrics have been given a unique identifier with the following nomenclature:

AB-CD-E. F, where:

- AB = Performance measurement category
    - CT = Complete Trip (Use Case 1)
    - CV = Connected Vehicle (Use Case 2)
- CD = Measure or metric
    - PM = Performance Measure
    - ME = Metric
- E = Performance Measure ID
- F = Metric ID

Table 8. ST-CTN Performance Measures

Performance Measure ID	Performance Measure Name	Goal
CT-PM-1	Enhance Traveler Experience	Goal 1 – Enhance Traveler Experience
CT-PM-2	Improve Accessibility	Goal 1 – Enhance Traveler Experience Goal 4 – Improve Mobility and Accessibility
CT-PM-3	Enhance Complete Trip Pedestrian Safety	Goal 2 – Enhance Safety

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

3.1.1 Complete Trip Performance Measure 1: Enhance Traveler Experience (CT-PM-1)

This performance measure will assess the user's complete trip travel experience while using the ST-CTN system. The measure will be used to evaluate the system's achievement of Goal 1 (Objectives 1.1 – 1.3) which is to improve the traveler's experience throughout their complete trip. Travel experience surveys, unique user log-ins, anonymized user data, and GCT complaint logs will be used to understand the impact of the ST-CTN system on the travelers' complete trip travel experience. Performance measure CT-PM-1 will demonstrate the successful (or unsuccessful) delivery of Use Case 1, steps 1 through 3 as described in **Section 2.2.1**.

Table 9 provides a summary of evaluation questions that will be assessed within CT-PM-1. Associated metrics, targets, and objectives are identified.

Table 9. CT-PM-1 Metrics

Metric ID	Evaluation Question	Metric	Target	Objective / Use Case
CT-ME-1.1	Did the ST-CTN system enhance the travelers' complete trip travel experience?	Distribution of Likert score survey response of travelers' complete trip travel experience rating over time.	The distribution of Likert scale response score shows an increase in positive responses (3, 4, 5) of 5% over the first eighteen months of ST-CTN system deployment for each end user classification listed below: • Person with physical disability, • Person with cognitive disability, • Aging adult, • Person with limited English proficiency, and • Person considered to have low income.	O-1.1 / UC-1 (Step 1)
CT-ME-1.2	Did the useability (i.e. was the system easy to use, easy to configure, intuitive, etc.) of the ST-CTN system enhance the travelers' complete trip travel experience?	Distribution of Likert score survey response of travelers' rating of how the useability of the ST-CTN system enhanced their complete trip travel experience.	The distribution of Likert scale response score shows an increase in positive responses (3, 4, 5) of 5% over the first eighteen months of ST-CTN system deployment for each end user classification as defined in CT-ME-1.1.	O-1.1 / UC-1 (Step 1)

Metric ID	Evaluation Question	Metric	Target	Objective / Use Case
CT-ME-1.3	Did the ST-CTN system features and functions (i.e. alert and notification method, accessible route selection, remote stop request, automated ped actuation, etc.) enhance the travelers' complete trip travel experience?	Distribution of Likert score survey response of travelers' rating of how the ST-CTN system features and functions enhanced their complete trip travel experience.	The distribution of Likert scale response score shows an increase in positive responses (3, 4, 5) of 5% over the first eighteen months of ST-CTN system deployment for each end user classification as defined in CT-ME-1.1.	O-1.1 / UC-1 (Step 1)
CT-ME-1.4	Did access to the travelers' caregiver through the ST-CTN system enhance the travelers' complete trip travel experience?	Distribution of Likert score survey response, from those requiring caregiver support, of travelers' rating of how the ability to access support from their caregiver through the ST-CTN system during travel enhanced their complete trip travel experience.	The distribution of Likert scale response score shows an increase in positive responses (3, 4, 5) of 3% over the first eighteen months of ST-CTN system deployment for each end user classification as defined in CT-ME-1.1.	O-1.1 / UC-1 (Step 1)
CT-ME-1.5	Did access to call center support through the ST-CTN system enhance the travelers' ability to complete their trip independently?	Distribution of Likert score survey response of travelers' rating of how access to the call center through the ST-CTN system enhanced their complete trip travel experience.	The distribution of Likert scale response score shows an increase in positive responses (3, 4, 5) of 5% over the first eighteen months of ST-CTN system deployment for each end user classification as defined in CT-ME-1.1. A not applicable (N/A) option will be available for users who did not use the call center.	O-1.1 / UC-1 (Step 1)
CT-ME-1.6	Did access to call center support through the ST-CTN system allow the travelers to better understand the application and complete future trips without having to utilize the call center.	The average monthly number of call center support calls per user through the ST-CTN system.	The average daily number of calls through the ST-CTN system decrease by 5% per user who utilize the feature over the initial year of ST-CTN deployment.	O-1.1 / UC-1 (Step 1)

Metric ID	Evaluation Question	Metric	Target	Objective / Use Case
CT-ME-1.7	Did the ST-CTN system improve the travelers' complete trip travel time by trip segment (e.g., wait time, arrival time, travel time, total journey time)?	ST-CTN system user average complete trip travel time by trip segment.	The average ST-CTN system users' complete trip travel time decreases by 5% over time for similar trips.	O-1.1 / UC-1 (Step 1) O-1.2 / UC-1 (Step 2) O-1.3 UC-1 (Step 3)
CT-ME-1.8	Did travelers feel greater confidence and independence during their complete trip, including transitions, with the ST-CTN system or did they deviate from the ST-CTN system complete trip recommended routes?	Variance between recommended ST-CTN system complete trip recommended routes and actual ST-CTN system travel routes that were taken.	Variance between recommended ST-CTN system complete trip recommended routes and actual ST-CTN system travel routes taken decreases by 5% over time.	O-1.2 / UC-1 (Step 2) O-1.3 / UC-1 (Step 3)
CT-ME-1.9	Did traveler's access to new destinations increase with use of the ST-CTN system?	Number and variety of destination types accessed by ST-CTN system users. The destination types will be defined based on data reviewed in Phase 2 of the ST-CTN project.	Number and variety of destination types accessed by ST-CTN system users increases by 2% annually per user.	O-1.2 / UC-1 (Step 2) O-1.3 / UC-1 (Step 3)
CT-ME-1.10	Did the accessible routes recommended by the ST-CTN system enhance the travelers' complete trip travel experience?	Number of complaints filed to GCT per month pertaining to lack of accessible routes to transit stops.	Number of complaints filed to GCT pertaining to lack of accessible routes to transit stops is reduced by 5% during the first 18 months. Complaint backlogs will be reviewed to create a complaint tracking methodology in Phase 2.	O-1.1 / UC-1 (Step 1) O-1.3 / UC-1 (Step 3)
CT-ME-1.11	Did the number of unique travelers using the ST-CTN system increase over time?	Number of unique ST-CTN system users per day.	Number of unique ST-CTN system users increased by 5% during the first 18 months.	O-1.1 / UC-1 (Step 1) O-1.2 / UC-1 (Step 2) O-1.3 UC-1 (Step 3)

Metric ID	Evaluation Question	Metric	Target	Objective / Use Case
CT-ME-1.12	Did travelers use the ST-CTN system with increased frequency over time?	Number of trips planned and completed by unique ST-CTN system users per day.	Number of trips planned and completed per day by unique ST-CTN system users increased by 5% during the first 18 months.	O-1.1 / UC-1 (Step 1) O-1.2 / UC-1 (Step 2) O-1.3 UC-1 (Step 3)

3.1.2 Complete Trip Performance Measure 2: Improve Accessibility (CT-PM-2)

This performance measure will evaluate the impact that the ST-CTN system has on the traveler's independence and ability to access employment and other types of trips with use of the ST-CTN system. Trip types such as employment, education, shopping, leisure activities, and other essential trips will be considered.

The measure will evaluate the system's achievement of Goal 1 (Objective 1.1), to improve the traveler's experience throughout their complete trip, which is associated with Use Case 1, Step 1 as described in Section 2.2.1. In addition, this measure will evaluate the system's achievement of Goal 4 (Objective 4.2 – 4.5), to improve the traveler's accessibility, which is associated with Use Case 1 (Steps 1-6) and Use Case 2. Travel experience surveys will be used to understand the impact of the ST-CTN system on the travelers' accessibility. Performance measure CT-PM-2 will support the demonstration of the successful (or unsuccessful) delivery of Use Case 1, steps 1 through 6 and Use Case 2 as described in **Section 2.2**.

Table 10. CT-PM-2 Metrics

Metric ID	Evaluation Question	Metric	Target	Objective / Use Case
CT-ME-2.1	Did the ST-CTN system enhance the travelers' ability to access destinations (i.e., employment, education, social activities, healthcare, shopping, etc.)?	Distribution of Likert score survey response of travelers' ability to access destinations rating.	The distribution of Likert scale response score shows an increase in positive responses (3, 4, 5) of 5% over the first eighteen months of ST-CTN system deployment for each end user classification as defined in CT-ME-1.1.	O-4.2 / UC-1 (Step 1, 2) O-4.3 / UC-1 (Step 4, 5) and UC-2 O-4.4 / UC-1 (Step 3) O-4.5 / UC-1 (Step 6)
CT-ME-2.2	Did the ST-CTN system enhance the travelers' quality of life? Quality of life, in the context of this project, may include the following: • Additional time within their schedule, • Reduced time and stress to plan travel, • Increased awareness and confidence to travel independently, and • Ability to schedule more reliably.	Distribution of Likert score survey response of travelers' quality of life rating.	The distribution of Likert scale response score shows an increase in positive responses (3, 4, 5) of 5% over the first eighteen months of ST-CTN system deployment for each end user classification as defined in CT-ME-1.1.	O-1.1 / UC-1 (Step 1) O-4.2 / UC-1 (Step 1, 2) O-4.3 / UC-1 (Step 4, 5) and UC-2 O-4.4 / UC-1 (Step 3) O-4.5 / UC-1 (Step 6)
CT-ME-2.3	Did travelers access a variety of trip purposes with use of the ST-CTN system? Trip purposes may include: employment, education, social, healthcare, and shopping.	Monthly average number of trip purposes reported by survey response. The trip purpose types will be defined based on data reviewed in Phase 2 of the ST-CTN project.	Annual 10% increase in monthly average number of trips not related to employment or commuting, reported by survey response over time.	O-4.2 / UC-1 (Step 1, 2) O-4.3 / UC-1 (Step 4, 5) and UC-2 O-4.4 / UC-1 (Step 3) O-4.5 / UC-1 (Step 6)

3.1.3 Complete Trip Performance Measure 3: Enhance Complete Trip Pedestrian Safety (CT-PM-3)

This performance measure will evaluate the impact of the ST-CTN system to enhanced pedestrian safety and driver awareness. Analysis of pedestrian incident data and pedestrian routing within the project area will be done to evaluate the system. Pedestrian incident data tends to be extremely sparse and unreliable. The ST-CTN project team intends to collect this data throughout the life of the project, however, statistically significant analysis is not expected to be possible during the timeframe of this project and there is not a specific metric related to reported pedestrian incidents.

This performance measure evaluates Goal 2 (Objectives 2.1 – 2.4), to improve safety and increase awareness for ST-CTN system users, which is associated with Use Case 1 (Steps 4 and 5) and Use Case 2. Travel surveys and crash data will be analyzed within the study area. Performance measure CT-PM-3 will support the demonstration of the successful (or unsuccessful) delivery of Use Case 1, steps 4 and 5 and Use Case 2 as described in **Section 2.2**.

Table 11. CT-PM-3 Metrics

Metric ID	Evaluation Question	Metric	Target	Objective / Use Case
CT-ME-3.1	Did the ST-CTN system enhance the travelers' perception of safety within the project study area?	Distribution of Likert score survey response of travelers' perception of safety while using the ST-CTN system.	The distribution of Likert scale response score shows an increase in positive responses (3, 4, 5) of 2% over the first eighteen months of ST-CTN system deployment for each end user classification as defined in CT-ME-1.1.	O-2.1 / UC-1 (Step 4, 5) O-2.3 / UC-2 O-2.4 / UC-2
CT-ME-3.2	Did travelers deviate from the ST-CTN system complete trip recommended routes while crossing signalized intersections (i. e. are travelers receiving the benefits of the ST-CTN intersection crossing features)?	Variance between recommended ST-CTN system complete trip recommended routes and actual ST-CTN system travel routes taken at signalized intersection crossings.	Variance between recommended ST-CTN system complete trip recommended routes and ST-CTN system travel routes decreases over time at signalized intersection crossings.	O-2.2 / UC-1 (Step 4, 5) and UC-2 O-2.3 / UC-2 O-2.4 / UC-2

Metric ID	Evaluation Question	Metric	Target	Objective / Use Case
CT-ME-3.3	Why did travelers deviate from the ST-CTN system complete trip recommended routes while crossing signalized intersections (i. e. are travelers receiving the benefits of the ST-CTN intersection crossing features) and why?	Survey response to understand the variance between recommended ST-CTN system complete trip recommended routes and actual ST-CTN system travel routes taken at signalized intersection crossings. If the traveler indicates that they deviate from the recommended route, they will be asked why.	Variance between recommended ST-CTN system complete trip recommended routes and ST-CTN system travel routes decreases over time at signalized intersection crossings.	O-2.2 / UC-1 (Step 4, 5) and UC-2 O-2.3 / UC-2 O-2.4 / UC-2
CT-ME-3.4	Did the ST-CTN system enhance the travelers' ability to avoid pedestrian related incidents within the project study area?	Average number of pedestrian-related near-miss incidents reported by survey response, described as “the vehicle had to abruptly brake or swerve to avoid striking the traveler or the traveler had to take sudden evasive action to avoid being struck.”	Decrease of 0.5% in average number near-miss pedestrian related incidents reported by survey response over time.	O-2.1 / UC-1 (Step 4, 5) O-2.2 / UC-1 (Step 4, 5) O-2.3 / UC-2 O-2.4 / UC-2

3.1.4 Complete Trip Performance Measure 4: Enhance Fixed-Route Transit (CT-PM-4)

This performance measure will evaluate the impact of the ST-CTN system to transit ridership by analyzing fixed-route transit ridership and paratransit ridership. The purpose of this measurement is to collect and analyze data about fixed-route transit ridership to determine if there is a mode shift from paratransit or other modes due to the ST-CTN system. A mode shift from paratransit to fixed-route service with the use of the ST-CTN system could demonstrate a traveler’s improved experience and increased safety, reliability, mobility, and/or accessibility.

This performance measure evaluates Goal 3 (Objectives 3.1 – 3.4) associated with Use Case 1 (Steps 2 and 3) and Use Case 2 and Goal 4 (Objectives 4.1 – 4.5) associated with Use Case 1 (Steps 1-6) and Use Case 2, to improve the traveler’s experience throughout their complete trip and improve safety, reliability, mobility, and accessibility for ST-CTN system users. GCT ridership data will be analyzed within the study area. Performance measure CT-PM-4 will support the demonstration of the successful (or unsuccessful) delivery of Use Case 1, steps 1 through 6 and Use Case 2 as described in **Section 2.2**.

Table 12. CT-PM-4 Metrics

Metric ID	Evaluation Question	Metric	Target	Objective / Use Case
CT-ME-4.1	Did the ST-CTN system impact fixed-route transit ridership?	Average number of fixed-route riders within the ST-CTN project area.	Increase in average number of fixed-route riders in the ST-CTN project area by 2% over the first eighteen months of ST-CTN system deployment.	O-3.1 / UC-1 (Step 3) and UC-2 O-3.2 UC-1 (Step 3) and UC-2 O-3.3 / UC-1 (Step 2)
CT-ME-4.2	Did the ST-CTN system impact fixed-route transit ridership by end user classification?	Average number of ST-CTN system users who choose fixed-route transit riders based on direction from system.	Average number of fixed-route transit rides taken per ST-CTN system user per month increased by an average of 1% over the first eighteen months of ST-CTN system deployment for each end user classification.	O-3.1 / UC-1 (Step 3) and UC-2 O-3.2 UC-1 (Step 3) and UC-2 O-3.3 / UC-1 (Step 2)
CT-ME-4.3	Did the ST-CTN system impact paratransit ridership?	Average number paratransit trips for ST-CTN users.	Increase percent of non-paratransit trips per month for ST-CTN users by 1%.	O-3.1 / UC-1 (Step 3) and UC-2 O-3.2 UC-1 (Step 3) and UC-2 O-3.3 / UC-1 (Step 2)
CT-ME-4.4	Did the ST-CTN system enhance fixed-route transit service?	Survey response of travelers' perception of fixed-route transit service while using the ST-CTN system (i.e., was service enhanced).	Travelers indicate a perception of enhanced fixed-route transit service, particularly to safety, reliability, mobility, and/or accessibility while using the ST-CTN system.	O-3.1 / UC-1 (Step 3) and UC-2 O-3.2 UC-1 (Step 3) and UC-2 O-3.3 / UC-1 (Step 2) O-4.1 / UC-1 (Step 3) O-4.4 / UC-1 (Step 3)
CT-ME-4.5	Did the ST-CTN system cause a mode shift for paratransit travelers to fixed-route transit?	Survey response of ST-CTN travelers' who indicate they have shifted to fixed-route transit service.	Travelers indicate that their shift to fixed-route transit service is due to the ST-CTN system.	O-3.1 / UC-1 (Step 3) and UC-2 O-3.2 UC-1 (Step 3) and UC-2 O-3.3 / UC-1 (Step 2) O-4.1 / UC-1 (Step 3) O-4.4 / UC-1 (Step 3)

3.1.5 Connected Vehicle Performance Measure 1: Enhance Safety and Awareness with Connected Vehicle (CV-PM-1)

This performance measure will evaluate the impact of the ST-CTN system to pedestrian safety and vehicular awareness. Analysis of pedestrian signalized intersection crossing times, CV PSM messages, and CV real-time speed data will support the evaluation.

This performance measure evaluates Goal 2 (Objectives 2.1 – 2.4) associated with Use Case 1 (Steps 4 and 5) and Use Case 2, to improve safety and awareness for ST-CTN system users. Performance measure CV-PM-1 will support the demonstration of the successful (or unsuccessful) delivery of Use Case 1, steps 4 and 5, and Use Case 2 as described in **Section 2.2**.

Table 13. CV-PM-1 Metrics

Metric ID	Evaluation Question	Metric	Target	Objective
CV-ME-1.1	Did the ST-CTN system enhance the travelers' perception of safety while crossing signalized intersections within the project study area?	Distribution of Likert score survey response of travelers' (end user of the ST-CTN system) rating of their perception of enhanced safety while using pedestrian crossing extensions through the ST-CTN system.	The distribution of Likert scale response score shows an increase in positive responses (3, 4, 5) of 5% over the first eighteen months of ST-CTN system deployment for each end user classification as defined in CT-ME-1.1.	O-2.1 / UC-1 (Step 4, 5) O-2.2 / UC-1 (Step 4, 5) and UC-2
CV-ME-1.2	Did the ST-CTN system allow for a greater number of completed pedestrian crossings (i.e., pedestrian crossed the intersection within the walk time and walk time extension) at signalized intersections within the ST-CTN project area?	Number of successful (i.e., pedestrian crossed the intersection within the walk time and walk time extension) pedestrian crossings at signalized intersections within the ST-CTN project area.	Increase average number of successful pedestrian intersection crossings with the ST-CTN system at signalized intersections by 2% over the first eighteen months of ST-CTN system deployment.	O-2.1 / UC-1 (Step 4, 5) O-2.2 / UC-1 (Step 4, 5) and UC-2

Metric ID	Evaluation Question	Metric	Target	Objective
CV-ME-1.3	Did the ST-CTN system improve (reduce) enabled connected vehicle speeds during PSM broadcast messages?	Delta of enabled connected vehicle calculated average speed prior to a PSM broadcast and the 95th percentile speed recorded during a PSM broadcast.	Speed will be reduced during a PSM broadcast vs the average speed prior to message broadcast. This target will be considered during Phase 2 when enabled connected vehicle data can become available and sufficient to be assessed.	O-2.3 / UC-2 O-2.4 / UC-2

3.1.6 Connected Vehicle Performance Measure 2: Improve Transit Reliability (CV-PM-2)

This performance measure will assess transit data to determine the impact of ST-CTN on transit reliability. The purpose of this measure is to assess changes in transit service performance over time.

This performance measure evaluates Goals 3 (Objectives 3.1 – 3.4) and 4 (Objective 4.1), to improve reliability, mobility, and accessibility for ST-CTN system users. Performance measure CV-PM-2 will support the demonstration of the successful (or unsuccessful) delivery of Use Case 2.

Table 14. CV-PM-2 Metrics

Metric ID	Evaluation Question	Metric	Target	Objective
CV-ME-2.1	Did the ST-CTN system improve transit schedule adherence within the project area?	Average transit schedule adherence within the project area, measured by GCT as 0 minutes before / 5 minutes after scheduled time for on-time performance (OTP).	The average transit OTP increases by 1% compared to the OTP prior to TSP deployment, within the project area over time.	O-3.1 O-3.2 O-3.3

Metric ID	Evaluation Question	Metric	Target	Objective
CV-ME-2.2	Did the ST-CTN system improve transit schedule reliability within the project area?	Standard deviation of average OTP distribution by route.	The average distribution of OTP with TSP is narrowed by +/-5%.	O-3.1 O-3.2 O-3.3
CV-ME-2.3	Did the ST-CTN system TSP enhancements improve transit traveler wait times within the project area?	Average transit traveler wait times within the project area.	The average transit traveler wait times decrease by 2% when ST-CTN system TSP enhancements are activated within the project area over time.	O-3.2
CV-ME-2.4	Did the ST-CTN system improve transit traveler missed connections?	Average number of transit traveler missed connections within GCT fixed-transit service (i.e., missed transit to transit connection). 'Missed connection' will be defined explicitly within the design and development of the baseline ATL RIDES and connection protection applications during Phase 2.	The number of transit traveler missed connections decrease by 5% within the project area during the first eighteen months of ST-CTN system deployment.	O-3.1

3.2 Relationship between Performance Measures and Subsystems/Technologies/Components

The performance measures described above will provide a method to evaluate the ST-CTN system. As described in **Section 1.3**, the ST-CTN system is composed of several existing systems that will be integrated and enhanced through this project. The ST-CTN subsystems include ATL RIDES, STM Platform, and CV. Each of the subsystems rely on enabling technologies, interfaces, and supporting components to function and integrate. Examples of subsystem enabling technologies that have been identified include:

- ATL RIDES – ATL RIDES user interface (UI), TSR, traveler needs and preferences profiles, traveler feedback surveys
- STM Platform – Network impedance API, STM simulator, impact assessment and network edge-cost analysis engine, operational and prediction analysis engine trip compliance analysis, dynamic broker
- CV – Secure Mobile Unit Gateway (SMUG), PED-SIG, Pedestrian transit indication

More information specific to the technology and interfaces of the enabling technologies are provided within the Enabling Technology Readiness Assessment (ETRA) document. **Table 15** provides a summary of the relationship between ST-CTN performance measures and subsystems. These relationships will in some cases include the transfer of data between subsystems to support performance measures.

Table 15. ST-CTN Performance Measures and Subsystem Relationships

Performance Measure ID	Performance Measure Name	ATL RIDES	STM	CV
CT-PM-1	Enhance Traveler Experience	●	●	●
CT-PM-2	Improve Accessibility	●	●	●
CT-PM-3	Enhance Complete Trip Pedestrian Safety	●	●	●
CT-PM-4	Enhance Fixed-Route Transit			●
CV-PM-1	Enhance Connected Vehicle Safety and Awareness	●		●
CV-PM-2	Enhance Transit Signal Priority			●

3.3 Potential Constraints

The successful evaluation of ST-CTN performance measures will be dependent upon obtaining, processing, and analyzing necessary data. The metrics and associated data are critical to the performance measurement and evaluation of the ST-CTN system. Potential data constraints have been identified through the development of the PMESP and are provided herein.

Quality

The quality of data used to assess and analyze the ST-CTN performance measures has the potential to impact the evaluation outcome and confidence in not only the evaluation, but the ST-CTN system. The process for ensuring the quality of data collected, processed, and analyzed is described in **Section 7.5**.

Availability

Potential constraints pertaining to data availability were considered during the process of determining the feasibility and reasonableness of ST-CTN performance measures. Those measures that were reliant on data that was not available were eliminated from the PMESP. However, should supporting data be determined unavailable, the associated metric and performance measure will be constrained. For example, pedestrian related incidents that occur during the timeframe of the evaluation may be minimal in which case, understanding the safety impact of the ST-CTN system will be challenging.

Furthermore, several ST-CTN performance measures rely on traveler feedback survey responses. Survey participation is considered a potential constraint for those measures. Potential mitigation strategies for this particular constraint include, incentivizing survey participation, limiting survey questions, and varying survey requests by user.

Duration

The anticipated duration of the ST-CTN system evaluation is a potential constraint. Specifically, those performance measures and associated metrics that rely on before-and-after analysis will be constrained by the expedited schedule of the ST-CTN system deployment. In some cases, such as pedestrian safety data, the ST-CTN project team determined that the analysis methodology may need to be modified to accommodate a limited timeframe of data. However, it is envisioned that performance measure monitoring and evaluation will continue beyond the initial deployment phases of the project and although the expedited schedule will be a constraint initially, analysis will be more robust as the deployment becomes more established over time.

Potential constraints are considered further in **Section 5** and the experimental design approach has been developed to consider the potential constraints. The ST-CTN project team has performed an initial analysis to determine the feasibility of evaluating the identified performance measures as described. Those measures relying on data that was determined not to be feasible to reasonably obtain were eliminated from the PMESP.

4. Confounding Factors and Mitigation Approaches

This section serves to outline the confounding factors that are outside of the team's control that may adversely impact the team's ability to assess the ST-CTN performance measures or can influence the results of the performance measures. This section also details strategies that will be implemented to mitigate the potential impacts of those confounding factors.

Confounding factors are any changes that may arise during the deployment that may influence both the dependent variable (i.e., the performance measures) as well as other independent variables that are hypothesized to lead to the change in the performance measures. Analyses might indicate that an independent variable has an apparent effect on a dependent variable of interest, when in fact a change in an external factor may have influenced both the change in the dependent and the independent variables. For example, historical analyses may indicate that an electric vehicle purchase incentive influenced the sales rate of electric vehicles, but it is also possible that a large increase in gasoline prices triggered both the implementation of the incentive and also independently influenced the purchase of the electric vehicles (i.e., these potential explanatory variables are not independent). If confounding factors are not accounted for during experimental design and data analysis, analytical results may understate or overstate the relevance of treatment effects upon treated units. In extreme cases, confounding factors can lead to spurious correlations between explanatory and dependent variables, with the variables having no direct causal connection (and analytical results may wrongly infer that they do). Some confounding factors are likely to have a large influence on performance measures, while others may have a minor or fleeting influence. Some confounding factors have a high probability of occurring during a specific study period, while others have very little chance of occurring. Finally, some confounding factors are easy to identify and control in statistical analyses, and others are much more difficult to identify and control.

Measurement of the effectiveness of any investment in the transportation sector needs to consider the confounding factors affecting the results; transportation studies are not performed in a vacuum. As an example, the ongoing COVID-19 pandemic is clearly having a major impact on travel behavior and the transportation system. The pandemic has disrupted the economy, employment, family life, and travel behavior in a myriad of ways that continue to change over time. This rare event is particularly difficult to address in the assessment of travel behavior because the pandemic has led to major changes in both travel behavior and the operation of the transportation system. Further complicating any analysis of transit activity is the fact that social distancing goals led to major changes in transit service including the curtailment of many routes so that others could be doubled-up with increased service frequency to reduce vehicle occupancy.

4.1 Confounding Factors, Potential Impact, Risk and Mitigation

The primary factors identified in this project as potential disrupters include many areas in which the pandemic has already caused very complicated disruptions. Changes in the economy, population and demographics, travel behavior, and weather have been identified as having the potential to impact the measurement of the ST-CTN system performance. While all of these confounding factors are outside of the study's control, there are strategies that can be employed to minimize their effect.

4.1.1 Confounding Factor #1: Changes in Regional Economy

Transportation trends and employment are tightly tied to economic trends. Many of the most common trips made include commuting for work, leisure, and shopping trips and are dependent on economic factors. While economic conditions are always changing, ST-CTN will be evaluated during an especially unstable economic period due to the continuing impacts of the COVID-19 pandemic. Closures of businesses and job losses have caused many people to take fewer trips and led to wholesale changes in transit service offerings. The segments of the population this study is most interested in also make up some of the hardest hit communities in terms of economic losses. It is also possible that the economy may surge back only to drop off again during the study period, which would cause large fluctuations in the travel data collected in this study. However, having knowledge of the situation ahead of time will enable the team to plan around this hurdle. The team will track monthly economic indicators, including regional employment, tax revenues, sales of gasoline, and sales of other goods and services. In previous studies (i.e., the 2009 economic downturn) reductions in morning peak freeway traffic volumes were highly correlated with employment. However, during the pandemic, remote working arrangements have increased significantly. To the extent that ongoing commuter survey data can be employed to assess changes in remote work arrangements, the team will do so. Transit routes and schedules are also explicitly controlled in the analyses, to ensure that analyses control for transportation system changes as well as economic changes over time. Hence, economic indicators as well as traffic volumes will be tracked as surrogates for economic impacts.

The potential influence of regional economics on performance measures is high. The probability of major changes in regional economics during the study period is moderate. The ability to identify and control for changes regional economics is moderate.

4.1.2 Confounding Factor #2: Changes in Regional Population and Demographics

Population changes in the study area could disrupt the continuity of the data collected for the performance measures outlined above. Larger population shifts can occur during economic instability, particularly for vulnerable populations that we will be most interested in studying. For example, low-income households may be priced out of their neighborhoods as the housing prices in the region continue to rise. Economic disruptions could lead to a significant percentage of vulnerable road users moving in with family for support, or to locations closer to services or new employment. Additionally, changes in land use and local business development may attract different subsections of the population to relocate. These types of population shifts may make it

more difficult to see results in the ST-CTN system, particularly if there is a low sample size. Plus, the potential influence of regional population and demographics over the 18-month study period is predominantly dependent upon whether pandemic conditions continue. To mitigate for potential changes in the vulnerable road user (VRU) population presence in the study area and demographic conditions, the team will work with stakeholder community to undertake an ongoing census of the study area VRU population. Most performance measures are prescribed on a per-user basis to try to ensure that wholesale changes in activity control for changes in the population presence. The team will also track changes in the demographic conditions of the participants over time through quarterly follow-up surveys to ask whether base demographic changes have occurred.

The potential influence of regional population and demographics on performance measures is moderate. The probability of major changes in population and demographics during the study period is low. The ability to identify and control for changes in population and demographics is low.

4.1.3 Confounding Factor #3: Changes in Regional Travel Behavior

The COVID-19 pandemic has significantly changed travel behaviors in the Atlanta region. Telecommuting and business closures greatly reduced vehicle miles traveled (VMT) across the region and drastically reduced transit ridership. As the economy begins to reopen, travel patterns have begun to balance out, but with COVID-19 variants, there may still be future closures and/or another state of emergency announced during the period of study. Not only will this disrupt travel patterns regionally, but COVID-19 policies may also cause disparities spatially and demographically. For example, policies that impact whether businesses can remain open are typically localized at the city level, which could obscure data across jurisdictions. Additionally, the impacts of the virus are disproportionately distributed across populations with older adults and people with autoimmune disorders being the most vulnerable. Because the ST-CTN system is being developed to support underserved populations that have been found to be most vulnerable to COVID-19, it may be more difficult to get their travel data, as they would be the most likely groups to severely limit their trips due to health concerns.

Additionally, the Atlanta region is undertaking a massive construction program, the Major Mobility Investment Program, with different sections of interstates and highways going under construction near the project area during the study. The periods of construction with certainly impact the level of congestion on the major arterials in the area but will likely not remain consistent for the entirety of the study timeframe, which could cause inconsistencies in the data.

The potential influence of changes in regional travel behavior on performance measures is high. With the on-going COVID-19 pandemic and imminent construction schedule, the probability of major changes in regional travel behavior during the study period is high. The ability to identify and control for changes in regional travel behavior is moderate.

4.1.4 Confounding Factor #4: Disruptions in Travel Behavior due to Weather

Unpredictable weather events can cause major disruptions to Atlanta's transportation system. With respect to the assessment of performance measures, weather can directly affect user travel behavior, the performance of the transportation system, and user response to the performance of the system. Heat and humidity are seasonal, and both have a significant impact on travel behavior and system performance. Rain events can be severe but are not typically seasonal in Atlanta (an average of 50+ inches throughout the year). Hurricane remnants passing through Atlanta can lead to large numbers of downed trees that disrupt the transportation system. Seasonal snow and ice events have the most severe impacts on Atlanta transportation systems. Severe winter weather events may be rare, but can cause much of the region to shut down due to the lack of infrastructure necessary to handle ice and snow. While the ST-CTN system will aim to mitigate some of the negatives impacts of weather for users, such as alerts for high heat indices and TSP for vulnerable populations, it is likely that certain weather conditions may force large populations to change their travel patterns temporarily.

The team will be tracking NOAA temperature, humidity, and precipitation data by geographic subarea by hour for the duration of the project. Hence, statistical analyses of performance measures will be able to account for these external weather condition data. Criteria for excluding extreme weather event data from all performance measure assessments (exclusion of data-days by geographic subarea) will be developed in Phase 2. In assessing changes in performance measure, the team will incorporate potential weather effects into analysis of variance assessments to ensure that the noted changes are driven by the system, rather than in some combination with weather conditions.

The potential influence of regional travel behavior due to weather on performance measures is low. The probability of major changes in regional travel behavior due to weather during the study period is low. The ability to identify and control for changes regional travel behavior due to weather is high.

4.2 Additional Mitigation Approaches

As described in the previous section, the team will monitor changes in regional and sub-regional economic conditions, population and demographics, COVID-19 policies, and weather conditions throughout the duration of the study. Additional data will be monitored during the study, including weather, demographic data of the study area and study participants, traffic conditions, special events, major construction, maintenance activities, new businesses, and transit conditions. This information will be used to ensure that the impacts of the ST-CTN system can be isolated and are statistically significant outside of the surrounding conditions. The specific statistical methods will be refined in Phase 2, but will include significance testing of the study's performance measure trends against the confounding factors data as described in this section, i.e. weather events, construction, etc. This analysis will be used to identify and remove outliers from the study dataset. The research team will monitor the following conditions and datasets to ensure that data are available for exploratory analyses:

- Number of pedestrian pathways and related infrastructure elements (sidewalks, ramps, curb cuts, etc.)
- Number of ADA-required pathway infrastructure elements that are missing

- Number and percentage of pathway elements with design and condition defects (width, slope, cross-slope, and other ADA-required design specifications, by type) per mile
- Daily transit vehicle miles of travel per vehicle
- Average transit vehicle speed per route per vehicle
- Daily passenger miles of travel per vehicle
- Transit vehicle speeds per origin-destination pair
- Revenue miles and deadhead miles per route per time period
- Revenue hours and deadhead hours per route per time period.
- ABM/STM simulated travel time (trip speeds) by mixed transit mode vs. automobile
- Hours of operation by route
- Frequency of service per route
- Number of stops per route
- Changes in transit routes over time
- Number of potential passengers by transit stop - 10-minute, 20-minute, and 30-minute access time by ADA mobility mode
- Regional Commuter Survey
- NextGen National Household Travel Survey

5. System Deployment Impact Analysis Design

The assessment and analysis of system deployment impacts must be designed such that there is confidence in the design and execution approach. This is accomplished by focusing on those use cases where high impacts to performance are expected and can reasonably be measured considering the confounding factors and mitigation strategies as described in **Section 4**. The following subsections describe performance analysis strategies and the experimental design that will be implemented to measure and analyze the performance of the ST-CTN system.

5.1 Strategies for Focused Performance Analysis

There are many facets to the analysis of complex systems like ST-CTN. This section describes what methods will be used to analyze the system, including survey methods and time-based assessments. It will also provide some details on the data collection methods, which are covered in more depth in **Section 7**.

Survey Methods

Survey research is typically used to collect stated preference data, to assess differences in activities and opinions of sub-populations, and to assess changes in these activities or preferences over time. Survey research is often used to gauge differences in system use and the factors affecting decision making between the users and non-users of specific systems (e.g., transit users vs. non-transit users). In the ST-CTN implementation, the team will be undertaking traditional commuter and customer service surveys that are designed to assess changes in regional activity over time and to assess differences in local user and non-user travel performance over time, as well as real-time, app-based trip-level surveys to gauge customer satisfaction with the system over time.

To evaluate the performance of the ST-CTN system, the team will conduct surveys of users that live, work, or frequently travel within the deployment area. There will be two types of surveys: short form and long form. Short form surveys will be given at the end of some of the trips made using the system. These sporadic surveys will only consist of a few questions about that trip specifically including trip purpose, etc. Long form surveys will be given to all participants before they engage with the ST-CTN system, after they have used the system for several months, and at the end of Phase 3. Performance metrics using short form survey questions will analyze responses made using the unintegrated ATL RIDES in comparison to the same questions asked during full ST-CTN deployment. Similarly, the long form surveys will be analyzed to capture trends as users become more familiar with the system. In addition to standard questions related to home/work locations, primary travel patterns, and customer household demographic information, system implementation questions will include questions related to frequency of use, reasons for using the system, satisfaction with specific system elements, and willingness to recommend the system to others. Customer satisfaction is generally assessed using multi-attribute measures of

performance where respondents evaluate various performance measures on multi-point Likert scales. Surveys will include multiple open-ended questions to solicit customer comments.

The most innovative survey elements associated with this project come in the form of trip feedback reports that contain traditional survey questions. There are very few examples of real-time interactive surveys in the transportation sector. In this project, the ATL RIDES app allows the team to query travelers about very specific aspects of individual trips. For example, the user can be asked to provide the purpose of the trip for a subset of interactions. Trip feedback reports also allow the team to track customer satisfaction with the routes provided by the system. Moreover, by noting deviations from the route and asking users for specific reasons for the deviation, the team will be able to calibrate impedance algorithms used in shortest path prediction for each ADA mobility group. That is, when persons using a wheelchair divert around a specific crosswalk and their trip report feedback identifies the lack of a push button as being a reason for the diversion, algorithms can be modified to increase relevant crossing penalties and provide preferable routes when the model is updated.

Time Based Assessments

Time based studies typically focus on identifying whether a specific set of modified system conditions or policies have led to a system response in some set of dependent variables.

Changes in network design and accessibility can lead to significant changes in travel behavior. Behavioral responses are complex, depending upon such factors as trip purpose, trip cost, user demographics, viable travel alternatives, etc. For example, a change in cost may affect low-income household travel much more than high-income household travel. Hence, assessing causality in before-and-after studies can be complex. Furthermore, the influence of exogenous variables on behavior must also be controlled in these analyses. For example, the impact of a regional change in fuel price or parking pricing may have as significant an impact on travel behavior as an increase in congestion over time. It is critical that before-and-after studies integrate and control for all of the most important factors likely to influence changes in travel behavior. Such studies also need to include control regions, locations where the treatments of interest have not been implemented, but exogenous variables also will have changed. In this project, the entire metro area is assessed via annual household surveys and annual commuter surveys. By assessing the statistical significance of regional trends compared to this study's performance measure, the ST-CTN project team will ensure that it was actually the treatment that led to the change in observed system response.

Data Collection

Survey design in before-and-after research is critical to ensure that enough data or data of the proper types are collected. Similarly, field data collection must also ensure that the proper variables at proper spatial and temporal resolution are collected. The ST-CTN project team has extensive experience in the design of surveys and field experiments and team members have published many papers associated with most of the performance metrics that will be used in this project. These plans will also specifically address the methods that will be used to ensure data integrity and applicability. The project sponsor and external peer-reviewers will review these plans as they are developed in Phase 2. The goal will be to ensure that the data streams employed adequately control for exogenous variables and collect sufficient spatial and temporal data resolution to assess statistical significance of changes in systems operations (linking the

response signal to project variables and ensuring that the response was not likely caused by other factors).

Baseline data establishes the conditions before a change in operations or policy is implemented. For the ST-CTN deployment, before-and-after studies will focus on changes in mobility and accessibility prior to the implementation of the system (baseline), after the system has begun to achieve market penetration (nine months after the system is implemented), and after the system has achieved some level of maturity (18 months after the system is implemented). This study will use the ATL RIDES application before it has been integrated into the ST-CTN system to gather all baseline data. The ATL RIDES application will be slightly enhanced to ensure it can collect all necessary baseline data to include specific features (e.g., profile preferences, survey questions) during Phase 2 and will be released approximately halfway through Phase 2 to support baseline data needs. At the start of Phase 3 baseline data collection will cease, the fully integrated system will be deployed, and test data collection will begin.

5.2 Experimental Design

Section 3 described the measures that will be used to evaluate the performance of Use Case 1 – Complete Trip and Use Case 2 – Connected Vehicle. The following sections describe how the ST-CTN system will impact the complete trip of travelers and underserved communities such as aging adults, users with physical or cognitive disabilities, and users with LEP.

The intended experimental design is described for each use case and associated performance measures in the following sections.

5.2.1 Use Case 1 – Complete Trip

The ST-CTN project is intended to provide accessible transportation and route safety information in an effective and equitable manner to support complete trips for underserved communities such as aging adults, users with physical or cognitive disabilities, and users with LEP. Use Case 1 – Complete Trip is focused on the travelers' experience throughout their complete trip including transitions between trip segments. Measuring the performance of the ST-CTN system to support this use case will require a comprehensive assessment of the traveler's complete trip experience using ST-CTN.

The approach to analysis, participants, and baseline conditions are summarized below:

Analysis Approach

The analysis approach to measure the performance of the ST-CTN system delivery of Use Case 1 – Complete Trip will rely on the following experimental design strategies:

- Survey – Use Case 1 is focused on the traveler experience throughout their complete trip. Short form surveys will be used to solicit feedback from the user about their experience completing their trip with the support of the ST-CTN system. These surveys will be in the form of application feedback requests, i.e., the user will be asked to respond to specific survey questions immediately following individual trips as described in Section 3 performance measures (tables 9 – 12). Additionally, long form surveys will be given 3 times during the study to get more thorough information about how the users

travel. A sampling approach will be developed in Phase 2 to establish questions, frequency of queries across trips, and whether targeted questions will be triggered based upon observed activities. In addition, feedback will be solicited during the training and testing phases of deployment to understand the performance of system features and functions from a user and trainer perspective which will be able to provide an understanding of the performance of Use Case 1.

- Time Based Assessments
    - Before-and-After Study – The ST-CTN system, as described in Use Case 1, is expected to improve a traveler's complete trip travel experience. Before-and-after studies will be performed to measure the impact and performance of the system to enhance and improve the complete trip travel experience.
    - Time Series Study – The ST-CTN system and system users are expected to gain improved trip experience, safety, reliability, mobility, and accessibility over time. Time series studies will be used to measure and analyze the use of and performance of the ST-CTN system for the duration of Phase 3.

More specific information pertaining to the analysis approaches for each performance measure are provided in the tables below. Additional granularity of information that will be used to assess the set of metrics associated with each performance measure for Use Case 1 are provided in the **Appendix C**.

Participants

The performance measurement and evaluation of Use Case 1 will rely on the support and participation of system users to assess the function, ease of use, accuracy, and reliability of the system through their complete trip. Participants will support evaluation either through directed survey responses or anonymized user data. ST-CTN system participants include not only direct application users, but also can include the caregivers of users or ST-CTN system trainers who will complete the survey as a 'traveler' based on the shared experience of ST-CTN function and feature use. Understanding the importance of survey participation, participants will be provided incentives to encourage their support. Participant support will be outlined and discussed further during development of Task 8 HUA Summary.

Baseline conditions

Before-and-after studies will be conducted to measure the performance of Use Case 1 and will require that baseline conditions be established. Baseline data collection for Use Case 1 will include the use of surveys, anonymized trace data, GCT Call Center complaint logs, historical pedestrian crash data, and transit mode and ridership data. The measures, metrics, and associated data which require baseline data collection are presented in **Section 7** in more detail.

Table 16 provides a summary of metrics, experimental design approach, data needs, tools, hypothesis, targets, and risks associated with the ST-CTN System Use, CT-PM-1 performance measure.

Table 16. Use Case 1 – Complete Trip: Enhance Traveler Experience (CT-PM-1)

	Use Case 1 – Complete Trip: Enhance Traveler Experience (CT-PM-1)
Description	Measure of the travelers' ability to program and complete trips using the ST-CTN application. Performance of ST-CTN route and system accessibility; system functions and features; and traveler complete trip experience will be measured.
Metrics	The following metrics will be analyzed to measure the performance of CT-PM-1: • Distribution of Likert score survey response of travelers' perception of safety while using the ST-CTN system. • Distribution of Likert score survey response of travelers' rating of how the useability of the ST-CTN system enhanced their complete trip travel experience. • Distribution of Likert score survey response of travelers' rating of how the ST-CTN system features and functions enhanced their complete trip travel experience. • Distribution of Likert score survey response, from those requiring caregiver support, of travelers' rating of how the ability to access support from their caregiver through the ST-CTN system during travel enhanced their complete trip travel experience. • Distribution of Likert score survey response of travelers' rating of how access to the call center through the ST-CTN system enhanced their complete trip travel experience. • The average monthly number of call center support calls per user through the ST-CTN system. • ST-CTN system user average complete trip travel time by trip segment. • Variance between recommended ST-CTN system complete trip recommended routes and actual ST-CTN system travel routes that were taken. • Number and variety of destination types accessed by ST-CTN system users. • Number of complaints filed to GCT per month pertaining to lack of accessible routes to transit stops. • Number of unique ST-CTN system users per day. • Number of trips planned and completed by unique ST-CTN system users per day.
Experimental Design	The experimental design to measure the performance of CT-PM-1 will include a multi-strategy approach to collect and analyze data relevant for each metric. User feedback surveys, before-and-after studies, and time series studies will be used to quantitively and qualitatively measure the performance.

	Use Case 1 – Complete Trip: Enhance Traveler Experience (CT-PM-1)
Data Needs	Data needs include trip feedback reports, mobile app logs, traverse data, and GCT complaint logs. See **Section 7** for more detailed CT-PM-1 data needs.
Modeling/Tools	The ATL RIDES application will be leveraged as a tool to solicit traveler feedback on use of the ST-CTN system. The STM subsystem will collect and provide access to anonymized trace data. In addition, the GCT currently registers complaint information through their existing system; this system will be leveraged to observe complaint trends over time.
Hypothesis	It is expected that the complete trip travel experience will be improved with use of the ST-CTN system.
Targets	Travelers indicate improved travel experience with use of the ST-CTN system. Specific targets include: • The distribution of Likert scale response score shows an increase in positive responses (3, 4, 5) of 5% over the first eighteen months of ST-CTN system deployment for each end user classification. • The distribution of Likert scale response score shows an increase in positive responses (3, 4, 5) of 5% over the first eighteen months of ST-CTN system deployment for each end user classification. • The average daily number of calls through the ST-CTN system decrease by 5% per user who utilize the feature over the initial year of ST-CTN deployment. • The average ST-CTN system users' complete trip travel time decreases by 5% over time for similar trips. • Variance between recommended ST-CTN system complete trip recommended routes and actual ST-CTN system travel routes taken decreases by 5% over time. • Number and variety of destination types accessed by ST-CTN system users increases by 2% annually per user. • Number of complaints filed to GCT pertaining to lack of accessible routes to transit stops is reduced by 5% during the first 18 months. • Number of unique ST-CTN system users increased by 5% during the first 18 months. • Number of trips planned and completed per day by unique ST-CTN system users increased by 5% during the first 18 months.
Risks	The CT-PM-1 performance measure is highly dependent upon ST-CTN user trip feedback participation. Should travelers opt not to participate in these short feedback requests, limited data will be available for analysis.

Table 17 provides a summary of metrics, experimental design approach, data needs, tools, hypothesis, targets, and risks associated with the ST-CTN Accessibility Impact, CT-PM-2 performance measure.

Table 17. Use Case 1 – Complete Trip: Improve Accessibility (CT-PM-2)

	Use Case 1 – Complete Trip: Improve Accessibility (CT-PM-2)
Description	Measure of the travelers' ability to access employment and other types of trips with use of the ST-CTN system and measure of how this increased access and use of the system may impact the traveler's quality of life. Quality of life, in the context of this project, may include the following: • Additional time within their schedule, • Reduced time and stress to plan travel, • Increased awareness and confidence to travel independently, and • Ability to schedule more reliably.
Metrics	The following metrics will be analyzed to measure the performance of CT-PM-2: • Distribution of Likert score survey response of travelers' ability to access destinations rating. • Distribution of Likert score survey response of travelers' quality of life rating. • Monthly average number of trip purposes reported by survey response.
Experimental Design	The experimental design to measure the performance of CT-PM-2 will include a multi-strategy approach to collect and analyze data relevant for each metric. User feedback surveys and time series studies will be used to quantitively and qualitatively measure the performance.
Data Needs	Data needs include trip feedback reports. See **Section 7** for more detailed CT-PM-2 data needs.
Modeling/Tools	The ATL RIDES application will be leveraged as a tool to solicit traveler feedback on use of the ST-CTN system.
Hypothesis	It is expected that access to many destinations including employment will be increased and therefore, quality of life will be improved with the use of the ST-CTN system.
Targets	Travelers indicate improved access to many destinations including employment with use of the ST-CTN system. Specific targets include: • The distribution of Likert scale response score shows an increase in positive responses (3, 4, 5) of 5% over the first eighteen months of ST-CTN system deployment for each end user classification. • Annual 10% increase in monthly average number of trips not related to employment or commuting, reported by survey response over time.
Risks	The CT-PM-2 performance measure is dependent upon ST-CTN user trip feedback participation. Should travelers opt not to participate in these short feedback requests, limited data will be available for analysis.

Table 18 provides a summary of metrics, experimental design approach, data needs, tools, hypothesis, targets, and risks associated with the Complete Trip Safety, CT-PM-3 performance measure.

Table 18. Use Case 1 – Complete Trip: Enhance Complete Trip Pedestrian Safety (CT-PM-3)

	Use Case 1 – Complete Trip: Enhance Complete Trip Pedestrian Safety (CT-PM-3)
Description	Measure of the ST-CTN system impact to pedestrian safety. Analysis of ST-CTN system user perception and pedestrian routing will be done in order to evaluate the system.
Metrics	The following metrics will be analyzed to measure the performance of CT-PM-3: • Distribution of Likert score survey response of travelers' perception of safety while using the ST-CTN system. • Variance between recommended ST-CTN system complete trip recommended routes and actual ST-CTN system travel routes taken at signalized intersection crossings. • Survey response to understand the variance between recommended ST-CTN system complete trip recommended routes and actual ST-CTN system travel routes taken at signalized intersection crossings. If the traveler indicates that they deviate from the recommended route, they will be asked why. • Average number of pedestrian-related near-miss incidents reported by survey response, described as “the vehicle had to abruptly brake or swerve to avoid striking the traveler or the traveler had to take sudden evasive action to avoid being struck.”
Experimental Design	The experimental design to measure the performance of CT-PM-3 will include a multi-strategy approach to collect and analyze data relevant for each metric. User feedback surveys, trace data, and time series studies will be used to quantitively and qualitatively measure the performance.
Data Needs	Data needs include trip feedback reports and traverse data. See **Section 7** for more detailed CT-PM-3 data needs.
Modeling/Tools	The ATL RIDES application will be leveraged as a tool to solicit traveler feedback on use of the ST-CTN system. The STM subsystem will also collect and provide access to anonymized trace data.
Hypothesis	It is expected that pedestrian safety will improve with use of the ST-CTN system.

	Use Case 1 – Complete Trip: Enhance Complete Trip Pedestrian Safety (CT-PM-3)
Targets	Travelers indicate improved perception of safety with use of the ST-CTN system. Specific targets include: • The distribution of Likert scale response score shows an increase in positive responses (3, 4, 5) of 2% over the first eighteen months of ST-CTN system deployment for each end user classification. • Variance between recommended ST-CTN system complete trip recommended routes and ST-CTN system travel routes decreases over time at signalized intersection crossings. • Decrease of 0.5% in average number near-miss pedestrian related incidents reported by survey response over time.
Risks	The CT-PM-3 performance measure is highly dependent upon ST-CTN user trip feedback participation. Should travelers opt not to participate in these short feedback requests, limited data will be available for analysis.

Table 19 provides a summary of metrics, experimental design approach, data needs, tools, hypothesis, targets, and risks associated with the Transit Mode Shift, CT-PM-4 performance measure.

Table 19. Use Case 1 – Complete Trip: Increase Fixed-Route Transit Ridership (CT-PM-4)

	Use Case 1 – Complete Trip: Improve Fixed-Route Transit Ridership (CT-PM-4)
Description	Measure changes in fixed route ridership due to the ST-CTN system. Analysis of fixed-route transit ridership ridership will be used for evaluation.
Metrics	The following metrics will be analyzed to measure the performance of CT-PM-4: • Average number of ST-CTN system users who choose fixed-route transit based on direction from system. • Average number paratransit trips for ST-CTN users. • Survey response of travelers' perception of fixed-route transit service while using the ST-CTN system (i.e., was service enhanced). • Survey response of ST-CTN travelers' who indicate they have shifted to fixed-route transit service.
Experimental Design	The experimental design to measure the performance of CT-PM-4 will include a multi-strategy approach to collect and analyze data relevant for each metric. User feedback surveys, and fixed-route transit ridership will be used to quantitatively and qualitatively measure the performance.

	Use Case 1 – Complete Trip: Improve Fixed-Route Transit Ridership (CT-PM-4)
Data Needs	Data needs include user feedback surveys, fixed-route transit ridership, fixed-route transit ridership by accessibility need, and General Transit Feed Specification (GTFS) Realtime GCT. See **Section 7** for more detailed CT-PM-4 data needs.
Modeling/Tools	The STM subsystem and the ATL subsystem will be integrated with the GCT Real-time GTFS feeds that will include data from on board automated passenger counters.
Hypothesis	It is expected that travelers, particularly those from underserved populations, will increase their fixed-route transit trips with the ST-CTN system.
Targets	An increase in fixed-route transit use with the ST-CTN system. Specific targets include: • Increase in average number of fixed-route riders in the ST-CTN project area by 2% over the first eighteen months of ST-CTN system deployment. • Average number of fixed-route transit rides taken per ST-CTN system user per month increased by an average of 1% over the first eighteen months of ST-CTN system deployment for each end user classification. • Increase percent of non-paratransit trips per month for ST-CTN users by 1%. • Travelers indicate a perception of enhanced fixed-route transit service, particularly to safety, reliability, mobility, and/or accessibility while using the ST-CTN system. • Travelers indicate that their shift to fixed-route transit service is due to the ST-CTN system.
Risks	The CT-PM-4 performance measure is looking at GCT ridership broadly, which may increase the likelihood of introducing more confounding factors. More details on confounding factors and mitigation strategies can be found in **Section 4.**

5.2.2 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 – Connected Vehicle is focused on how the CV subsystem will operate to provide functionality and support for system actions.

Measuring the performance of the ST-CTN system to support this use case will require focused metrics on the CV applications as were described in **Section 2.2.2**.

The approach to analysis, participants, and baseline conditions are summarized below:

Analysis Approach

The analysis approach to measure the performance of the ST-CTN system delivery of Use Case 2 – Connected Vehicle will rely on the following experimental design strategies:

- Survey – Surveys will be used to solicit feedback from the user about their experience that is not feasible to be understood with current detection methods. These surveys will be in the form of short form application feedback requests, i.e., the user will be asked to respond to a survey immediately following their trip. For example, users will be asked if they felt that the extended walk time provided them with safer conditions while crossing at a signalized intersection.

- Time Based Assessments

    - Before-and-After Study – The ST-CTN system, as described in Use Case 2, is expected to improve a traveler's safety, reliability, mobility, and accessibly. Before-and-after studies will be performed to measure the impact and performance of the system to achieve these goals. Examples of these studies include considering transit on-time performance before and after ST-CTN system deployment to determine if the enhanced CV subsystem has impacted the performance of TSP and transit reliability.

    - Time Series Study – The ST-CTN system and system users are expected to gain safety, reliability, mobility, and accessibility over time. Time series studies will be used to measure and analyze the performance of the ST-CTN system.

More specific information pertaining to the analysis approaches for each performance measure are provided in the tables below. Additional granularity of information that will be used to assess the set of metrics associated with each performance measure for Use Case 2 are provided in **Appendix C**.

Participants

The performance measurement and evaluation of Use Case 2 will rely on the support and participation of system users either through directed survey responses or anonymized user data. Participants will need to utilize the ST-CTN system CV applications such as, TSP, TSRs, and automated pedestrian actuation. To do so, participants or users, will need to opt-in to these features in their profile settings. Participant support will be outlined and discussed further during development of Task 8 HUA Summary.

Baseline conditions

Before-and-after studies will be conducted to measure the performance of Use Case 2 and will require that baseline conditions be established. Baseline data collection for Use Case 2 will include the use of anonymized trace data, GCT GTFS data, and GDOT/GCDOT CV data. The measures, metrics, and associated data which require baseline data collection are presented in **Section 7** in more detail. **Table 20** provides a summary of metrics, experimental design

approach, data needs, tools, hypothesis, targets, and risks associated with the ST-CTN System Use, CV-PM-1 performance measure.

Table 20. Use Case 2 – Connected Vehicle: Enhance Safety and Awareness with Connected Vehicle (CV-PM-1)

	Use Case 2 – Connected Vehicle: Enhance Safety and Awareness with Connected Vehicle (CV-PM-1)
Description	Measure of pedestrian safety and enabled connected vehicle awareness for pedestrians using the ST-CTN system at signalized intersections. Analysis of travelers' perception of safety, number of completed crossings within walk time, and enabled connected vehicle speeds during PSM broadcast messages will be used for evaluation.
Metrics	The following metrics will be analyzed to measure the performance of CV-PM-1: • Distribution of Likert score survey response of travelers' (end user of the ST-CTN system) rating of their perception of enhanced safety while using pedestrian crossing extensions through the ST-CTN system. • Number of successful (i.e., pedestrian crossed the intersection within the walk time and walk time extension) pedestrian crossings at signalized intersections within the ST-CTN project area. • Enabled connected vehicle travel speed prior to and during a PSM broadcast.
Experimental Design	The experimental design to measure the performance of CV-PM-1 will include a multi-strategy approach to collect and analyze data relevant for each metric. Before-and-after studies and time series studies will be used to quantitively and qualitatively measure the performance.
Data Needs	Data needs include Ped-X, PSM, NaviGAtor data, and Trip Feedback Reports. See **Section 7** for more detailed CV-PM-1 data needs.
Modeling/Tools	The ATL and GCDOT systems will collect pedestrian crossing time data within the project study area. In addition, GDOT and GCDOT data brokers will collect data for vehicle speeds during CV broadcasts.
Hypothesis	It is expected that the ST-CTN system will enhance pedestrian safety along complete trip routes and at signalized intersections.

	Use Case 2 – Connected Vehicle: Enhance Safety and Awareness with Connected Vehicle (CV-PM-1)
Targets	Targets for this performance measure include: • The distribution of Likert scale response score shows an increase in positive responses (3, 4, 5) of 5% over the first eighteen months of ST-CTN system deployment for each end user classification as defined in CT-ME-1.1. • Increase average number of successful pedestrian intersection crossings with the ST-CTN system at signalized intersections by 2% over the first eighteen months of ST-CTN system deployment. • The 95th percentile speed will be reduced during a PSM broadcast vs the average speed prior to message broadcast. This target will be considered during Phase 2 when enabled connected vehicle data can become available and sufficient to be assessed.
Risks	Part of the CV-PM-1 performance measure is dependent on adoption of vehicles enabled to receive PSMs. However, it is unknown when a significant portion of the fleet will be enabled with this technology. Connected vehicle adoption will be collected as part of the study's confounding factors mitigation strategy.

Table 21 provides a summary of metrics, experimental design approach, data needs, tools, hypothesis, targets, and risks associated with the ST-CTN System Use, CV-PM-3 performance measure.

Table 21. Use Case 2 – Connected Vehicle: Improve Transit Reliability (CV-PM-2)

	Use Case 2 – Connected Vehicle: Improve Transit Reliability (CV-PM-2)
Description	Measure of transit reliability through transit data to determine the impact of the ST-CTN system.
Metrics	The following metrics will be analyzed to measure the performance of CV-PM-2: • Average transit schedule adherence within the project area, measured as the GCT on-time performance (OTP). • Standard deviation of average OTP distribution by route. • Average transit traveler wait times within the project area. • Average number of transit traveler missed connections within GCT fixed-transit service (i.e., missed transit to transit connection).
Experimental Design	The experimental design to measure the performance of CV-PM-2 will include a multi-strategy approach to collect and analyze data relevant for each metric. Before-and-after studies will be used to quantitively and qualitatively measure the performance.

	Use Case 2 – Connected Vehicle: Improve Transit Reliability (CV-PM-2)
Data Needs	Data needs include GTFS GCT and trip feedback reports. See **Section 7** for more detailed CV-PM-2 data needs.
Modeling/Tools	The ATL RIDES application will be leveraged as a tool to obtain trip feedback reports on use of the ST-CTN system. In addition, the GCT data broker will be used to obtain GTFS data.
Hypothesis	It is expected that transit reliability will improve through the ST-CTN system.
Targets	Travelers and quantitative data indicate improved transit reliability.
Risks	The CV-PM-2 performance measure is dependent upon ST-CTN user trip feedback participation, as well as transit operating in mixed traffic. Confounded factors impacting transit service are covered in more depth in Section 4.

6. Support to Independent Evaluation Effort

A significant level of support will be needed between the Independent Evaluator (IE) and the ST-CTN team. Over the course of Phase I, II and III of the program, the ST-CTN team will provide access to all drafts and final reports to the independent evaluator for review and possible comment. Furthermore, the BAA states *"performance against baseline measurements and targets are anticipated to be routinely and publicly reported throughout Phase 3. Summaries/dashboards of performance to date covering key measures are anticipated to be required features in all Phase 3 deployment sites."* The ST-CTN team is prepared to provide any additional information (such as data sources or availability of baseline data) or clarification. In addition to providing access to deliverables and performance measurements, the ST-CTN team will assist the IE in conducting two sets of interviews, one during pre-deployment and one during post deployment.

This section will outline details regarding methods for data sharing, private data access, and key stakeholders needed for an efficient evaluation effort and will be updated as IE's plans are developed.

Standard Data Sharing

All performance measures that are summarized and placed into the various project dashboards will be directly accessible to the IE via an online interface. All open-source data that are processed to populate dashboards will be made available to the research team in accordance with the DMP, which outlines the data flows from project servers to FHWA servers. The methods for generating each performance metric that appears in a dashboard will be clearly documented and posted to the dashboards so that the IE team can replicate any dashboard values using their own systems.

Private Data Access

Proprietary data and protected data that are used in all project metrics cannot be transmitted to, or reside upon, third-party servers. If the IE team elects to license the same proprietary data sets (e.g., household level economic data from the same third-party marketing firm), the project team will coordinate with them to ensure that the same exact data sets are used on the project and FHWA servers. The ST-CTN team will provide the IE team with access to protected data which will only be made available by those physically present in the Secure Data Lab at GA Tech, in accordance with approved Institutional Review Board (IRB) human subject agreements. Datasets with Access Levels of "PII Certification" in Table 7 of the Phase 1 DMP are subject to this restriction.

The team will develop IRB protocols for each data flow so that individual protocols can be updated and modified as needed. Each primary protocol will identify that data access will be provided to the IE team through an amendment to the IRB protocol. After each protocol is

approved by the IRB, the team will coordinate with the IE team to prepare amendments to each protocol, as needed per data flow, to facilitate access to protected data for pre-identified members of the IE team. Each amendment will outline the specific purpose of data access, identify the individual(s) who will have access, will define how the data will be treated, and will ensure that only data summaries that do not contain PII leave the Georgia Tech Secure Data Center. This is the standard approach employed in prior federal research projects (e.g., Commute Atlanta) to provide access to electronic travel diary data and second-by-second instrumented vehicle data.

The project team will also provide the IE team with metadata and dummy data, so that the IE team can create any scripts that may need to be run for their evaluation purposes in advance of any visit to the Secure Data Center. Support of the IE task is of the highest priority to the project team, who will ensure that data analysts are available to provide access to data and to support any data processing required by the evaluators. As each data set begins populating the system, evaluator access will be provided. The timing for data availability and evaluator access is provided in Table 10 of the Phase 1 DMP.

Access to protected data by third-party users (such as or researchers who desire to use PII data in research) may also be granted through the implementation of an NDA and approval of an IRB human subjects protocol amendment developed specifically for the data access purpose and need. This method was implemented in the Commute Atlanta study to allow external researchers to travel to the Georgia Tech secure data lab to use instrumented vehicle data for development of new energy, emissions, and travel behavior models. The project team will ensure that staff resources are available for such purposes.

Key Stakeholders

The project team will engage directly and continuously with the project sponsor and independent evaluators to address any questions or clarifications associated with data and data flows, as well as the data collection methods (e.g., surveys). In addition to the two sets of interviews conducted by the IE, the project team will host quarterly online meetings with the IE team to address methods documentation, data uncertainty, data analysis recommendations, potential updates to metrics, and data access schedules. The ST-CTN team will coordinate with the IE team in February 2022 at the beginning of Phase 2 for pre-deployment interviews and in Phase 3 in February 2024 for post deployment interviews. Additionally, the ST-CTN team will assist the IE in conducting a survey in Phase 3 to all project stakeholders. An initial list of key stakeholders that the independent evaluators may want to interview is below in **Table 22.**

Table 22. Key Stakeholders

No.	Name	Organization	Participant Role	Phase 2	Phase 3	Survey
1	Angshuman Guin	Georgia Institute of Technology	Deployment Partner	**X**	**X**	
2	Randall Guensler	Georgia Institute of Technology	Deployment Partner	**X**	**X**	
3	Daniel Walls	The ATL	Deployment Partner	**X**	**X**	
4	Jonathan Campbell	The ATL - IBI	Deployment Manager	**X**	**X**	

No.	Name	Organization	Participant Role	Phase 2	Phase 3	Survey
5	Tom Sever	Gwinnett County Department of Transportation	Deployment Manager	X		X
6	Ken Keena	Gwinnett County Department of Transportation	Deployment Partner	X	X	
7	Alex Hofelich	Gwinnett County Department of Transportation	Deployment Partner	X	X	
8	Loammi Aviles	Gwinnett County Department of Transportation	Deployment Manager	X	X	
9	Alan Davis	Georgia Department of Transportation	Deployment Manager	X	X	
10	Maria Roell	Atlanta Regional Commission	Deployment Manager	X	X	
11	Kofi Wakhisi	Atlanta Regional Commission	Deployment Manager	X	X	
12	Polly Okunieff	Go Systems and Solutions	Deployment Manager	X	X	
13	Natalie Smusz-Mengelkoch	Kimley-Horn and Associates	Deployment Manager	X		X
14	Jordan Hall	Statewide Independent Living Council	Project Stakeholder			X
15	Greg Morris	FHWA- GA Division	Government Entity			X
16	John Crocker	FTA- GA Division	Government Entity			X

7. Data Collection Plan

Section 7.1 summarizes data resources that need to be collected to support each performance measure and associated metric. The table in this section is organized by dataset. The Data ID from Phase 1 DMP is included for each dataset for convenient referencing, as that document provides relevant details on how these data sets are being collected, processed, stored, and shared. Additional details are provided in **Section 7.1** to describe which datasets will be required for each performance metric. The subsequent sections then identify which of the datasets presented in **Section 7.1** are:

- Used in establishing baseline values for before-and-after assessments (**Section 7.2**)
- Generated during the deployment, directly by the deployment system (**Section 7.3.1**)
- Generated during the deployment, external to the deployment system (**Section 7.3.2**)
- Generated during the deployment, via survey or interaction methods (**Section 7.3.3**)

Section 7.4 contains generalized cost discussions for the data sets used in these metrics. Quality assurance/quality control features are described in general terms in **Section 7.5** and **Section 7.6** provides an overview of the data sharing framework previously provided in the Phase 1 DMP.

7.1 Data Needed

Many datasets will be used to measure the performance of the ST-CTN system. Important information, including information regarding the privacy storage and maintenance of these datasets can be found in the Phase 1 DMP. **Table 23** below contains the major datasets that will be used in the study's evaluation. It is organized by Dataset Name and includes the lead agency in collecting the dataset, how frequently it will be updated and for which metrics it will be used. It also includes the DMP ID which can be used to cross reference the dataset with more detailed information found in Table 5 in the Phase 1 DMP and in **Appendix D** of this plan.

Table 23. Data Needed

Dataset Name	DMP Data ID	Collection Lead (Data Owner)	Update Frequency	Metric ID
Trip Feedback Reports	53	ATL	As Needed	CT-ME-1.1 CT-ME-1.2 CT-ME-1.3 CT-ME-1.4 CT-ME-1.5 CT-ME-1.9 CT-ME-2.1 CT-ME-2.2 CT-ME-2.3 CT-ME-3.1 CT-ME-3.3 CT-ME-3.4 CT-ME-4.3 CT-ME-4.4 CT-ME-4.5 CV-ME-1.1
Traverse Data	52	GA Tech	Continuous	CT-ME-1.7 CT-ME-1.8 CT-ME-1.9 CT-ME-3.2 CT-ME-4.2 CT-ME-4.3 CV-ME-1.2
Mobile App Logs	51	ATL	As Needed	CT-ME-1.11 CT-ME-1.12
GTFS-Realtime GCT	36	GCT	Continuous	CV-ME-2.1 CV-ME-2.2 CV-ME-2.3
GCT Complaint Log	65	GCT	As Needed	CT-ME-1.6 CT-ME-1.10
Fixed-Route Transit Ridership	64	GCT	As Needed	CT-ME-4.1
Connection Protection	67	GCT	As Needed	CV-ME-2.4
Paratransit Ridership	66	GCT	As Needed	CT-ME-4.3
SPaT	41	Gwinnett DOT	Continuous	CV-ME-1.2
PSM	40	Gwinnett DOT	Continuous	CV-ME-1.3
NaviGAtor	15	GDOT	Continuous	CV-ME-1.3
Subscription Roadway Operating Condition	18	Ga Tech	Continuous	CV-ME-1.3
Ped-X	44	Gwinnett DOT	Continuous	CV-ME-1.1

7.2 Baseline Data Collection

The team will rely heavily on time series and before-and-after methods to evaluate the ST-CTN system. A strong set of baseline data is required to adequately evaluate the impact of the system. Most of the datasets gathered will need to be obtained as baseline data when initiating the study. Baseline data will be collected to establish the conditions in the project area prior to the implementation of the system, as well as be used to evaluate changes in response to system implementation.

Table 24 below outlines which datasets will be used to set an initial baseline.

Table 24. Baseline Datasets by Performance Metric

Dataset Name	DMP Data ID	Collection Lead (Data Owner)	Update Frequency	Metric ID
Trip Feedback Reports	53	ATL	As Needed	CT-ME-1.1 CT-ME-1.2 CT-ME-1.3 CT-ME-1.4 CT-ME-1.5 CT-ME-1.9 CT-ME-2.1 CT-ME-2.2
Traverse Data	52	GA Tech	Continuous	CT-ME-1.7 CT-ME-1.8 CT-ME-1.9 CT-ME-3.2 CT-ME-4.2 CT-ME-4.3 CV-ME-1.2
Mobile App Logs	51	ATL	As Needed	CT-ME-1.11 CT-ME-1.12
GTFS-Realtime GCT	36	GCT	Continuous	CV-ME-2.1 CV-ME-2.2 CV-ME-2.3
GCT Complaint Log	65	GCT	As Needed	CT-ME-1.6 CT-ME-1.10
Fixed-Route Transit Ridership	64	GCT	As Needed	CT-ME-4.1
Connection Protection	67	GCT	As Needed	CV-ME-2.4
Paratransit Ridership	66	GCT	As Needed	CT-ME-4.3
SPaT	41	Gwinnett DOT	Continuous	CV-ME-1.2
PSM	40	Gwinnett DOT	Continuous	CV-ME-1.3
NaviGAtor	15	GDOT	Continuous	CV-ME-1.3
Subscription Roadway Operating Condition	18	Ga Tech	Continuous	CV-ME-1.3
Ped-X	44	Gwinnett DOT	Continuous	CV-ME-1.1

The primary method for obtaining most of the baseline data needed for this study will be through the ATL RIDES application initial deployment. The development of ATL RIDES is currently

underway and is scheduled to be released in 2022. All participants recruited for this study will be trained on and asked to use ATL RIDES for several months ahead of the ST-CTN system deployment. The ATL RIDES application will be slightly enhanced to ensure it can collect all necessary baseline data to include specific features (e.g., profile preferences, survey questions) during Phase 2 and will be released approximately halfway through Phase 2 to support baseline data needs. This will be approximately six months after ATL RIDES released and it is expected that the system will have stabilized prior to ST-CTN baseline collection. At the start of Phase 3 baseline data collection will cease, the fully integrated system will be deployed, and test data collection will begin. Participants will be recruited through existing stakeholder organizations. This study will be able to use the initial deployment to collect traverse data, trip feedback reports, and mobile app logs from study participants before the ST-CTN system goes live. Additional datasets, such as safety data and ridership data will be available for collection before, throughout, and after the study.

7.3 Deployment Data Collection

A substantial amount of data will need to be collected, stored, and analyzed during the study. More detailed information on data storage is available in the Phase 1 DMP. This section will provide a summary of the datasets to be collected during the study, both through the ST-CTN system itself, and datasets that originate outside of the system. Additionally, it includes more specifics on how survey data will be obtained an applied.

7.3.1 Data Collected Through Deployment System

The ST-CTN system will produce several new datasets, as well as provide a platform for storing traditional datasets. As a travel information app, much of the data collected will be through the mobile app logs and location tracking. However, many datasets will also be integrated into the system including static real-time GTFS feeds. Additionally, the CV integration into the system will allow for collection of signal and communications data at the intersection. Data back up and storage policies are covered more in depth in the Phase 1 DMP. Georgia Tech will be the lead partner for data collection, storage, and analysis. **Table 25** outlines the primary datasets that will be obtained through the ST-CTN system.

Table 25. Data Captured Through ST-CTN

Dataset Name	DMP Data ID	Collection Lead (Data Owner)	Update Frequency	Metric ID
Trip Feedback Reports	53	ATL	As Needed	CT-ME-1.1 CT-ME-1.2 CT-ME-1.3 CT-ME-1.4 CT-ME-1.5 CT-ME-1.9 CT-ME-2.1 CT-ME-2.2 CT-ME-2.3 CT-ME-3.1 CT-ME-3.3 CT-ME-3.4 CT-ME-4.3 CT-ME-4.4 CT-ME-4.5 CV-ME-1.1
Traverse Data	52	GA Tech	Continuous	CT-ME-1.7 CT-ME-1.8 CT-ME-1.9 CT-ME-3.2 CT-ME-4.2 CT-ME-4.3 CV-ME-1.2
Mobile App Logs	51	ATL	As Needed	CT-ME-1.11 CT-ME-1.12
GTFS-Realtime GCT	36	GCT	Continuous	CV-ME-2.1 CV-ME-2.2 CV-ME-2.3
PSM	40	Gwinnett DOT	Continuous	CV-ME-1.3
Ped-X	44	Gwinnett DOT	Continuous	CV-ME-1.1

7.3.2 Data Collected Outside Deployment System

Most of the performance metrics used to evaluate the ST-CTN system will come from the system itself. However, there are a few datasets that will need to be obtained separately from the system to get a better understanding of its impacts. All of the datasets that will be obtained from outside the system and the metrics that will use them are outlined below in **Table 26.** The ST-CTN project team is currently well situated to obtaining all of the datasets needed, as of the agencies currently collecting these data are ST-CTN partners. Georgia Tech will lead the analysis of these datasets, as well as ensuring that they are spatially and temporally linked with the system data.

Table 26. Data Collected Outside of the ST-CTN System

Dataset Name	DMP Data ID	Collection Lead (Data Owner)	Update Frequency	Metric ID
GCT Complaint Log	65	GCT	As Needed	CT-ME-1.6 CT-ME-1.10
Fixed-Route Transit Ridership	64	GCT	As Needed	CT-ME-4.1
Connection Protection	67	GCT	As Needed	CV-ME-2.4
Paratransit Ridership	66	GCT	As Needed	CT-ME-4.3
SPaT	41	Gwinnett DOT	Continuous	CV-ME-1.2
PSM	40	Gwinnett DOT	Continuous	CV-ME-1.3
NaviGAtor	15	GDOT	Continuous	CV-ME-1.3
Subscription Roadway Operating Condition	18	Ga Tech	Continuous	CV-ME-1.3
Ped-X	44	Gwinnett DOT	Continuous	CV-ME-1.1

7.3.3 Data Collected Through Survey/Interview

As a user focused system, many of the goals and objectives will only be adequately evaluated by hearing directly from users and their caregivers. The majority of this information will be collected through surveys that will be available through the ATL RIDES application. Information regarding user's perceived safety, trip convenience, and overall level of confidence traveling will be key metrics obtained from these surveys given at least during pre-deployment and at the study's conclusion, with the option to add more if needed. Additional surveys of one or two questions will also randomly occur at the end of a trip to gauge level of satisfaction with their trip and their trip purpose. Additionally, surveys will be conducted with the study participants after their training to gain information of overall UI design and training materials and procedures. Participants will also be asked what level of participation with the study they would like to have in the future, the highest of which will be interviewed for the team to gain a greater understanding of the system from a user perspective. It is envisioned that participants will be recruited through training events conducted with advocacy organizations throughout the study area.

A list of the official performance metrics that will be evaluated based on survey results is outlined below in **Table 27**.

Table 27: Metrics Reliant on Survey Data

ID	Metric
CT-ME-1.1	Distribution of Likert score survey response of travelers' complete trip travel experience rating over time
CT-ME-1.2	Distribution of Likert score survey response of travelers' rating of how the useability of the ST-CTN system enhanced their complete trip travel experience.

ID	Metric
CT-ME-1.3	Distribution of Likert score survey response of travelers' rating of how the ST-CTN system features and functions enhanced their complete trip travel experience.
CT-ME-1.4	Distribution of Likert score survey response, from those requiring caregiver support, of travelers' rating of how the ability to access support from their caregiver through the ST-CTN system during travel enhanced their complete trip travel experience.
CT-ME-1.5	Distribution of Likert score survey response of travelers' rating of how access to the call center through the ST-CTN system enhanced their complete trip travel experience.
CT-ME-1.9	Number and variety of destination types accessed by ST-CTN system users.
CT-ME-2.1	Distribution of Likert score survey response of travelers' ability to access destinations rating.
CT-ME-2.2	Distribution of Likert score survey response of travelers' quality of life rating.
CT-ME-2.3	Monthly average number of trip purposes reported by survey response. .
CT-ME-3.1	Distribution Likert score survey response of travelers' perception of safety while using the ST-CTN system.
CT-ME-3.3	Survey response to understand the variance between recommended ST-CTN system complete trip recommended routes and actual ST-CTN system travel routes taken at signalized intersection crossings. If the traveler indicates that they deviate from the recommended route, they will be asked why.
CT-ME-3.4	Average number of pedestrian-related near-miss incidents reported by survey response, described as “the vehicle had to abruptly brake or swerve to avoid striking the traveler or the traveler had to take sudden evasive action to avoid being struck. ”
CT-ME-4.3	Average number of non-paratransit trips for ST-CTN users.
CT-ME-4.4	Survey response of travelers' perception of fixed-route transit service while using the ST-CTN system (i.e., was service enhanced).
CT-ME-4.5	Survey response of ST-CTN travelers' who indicate they have shifted to fixed-route transit service.
CV-ME-1.1	Distribution of Likert score survey response of travelers' (end user of the ST-CTN system) rating of their perception of enhanced safety while using pedestrian crossing extensions through the ST-CTN system.

7.4 Cost Data

The team will also be reporting on the costs associated with this project to help any future deployers better plan for implementation financially. Of course, every region is different, but hopefully ARC's experience with ST-CTN will help others interested in deploying a similar system do so more efficiently and effectively.

Cost Data Reporting

The costs associated with implementing this system will be categorized into two groups: Initial Deployment and Lifecycle Costs. Initial Deployment costs will include the upfront costs of the deployment including the unit costs of any hardware or software needed. Life Cycle Costs will include the average operations and maintenance costs necessary as the system continues. Most of the Initial Deployment costs will be finalized by the end of Phase 2 for reporting, but the Life Cycle Costs will need to be reported on an annual basis as it will likely change as the system matures.

Performance Measurement Costs

Future deployments may or may not want to participate in the performance measurement methods we will have completed, but the act of purchasing and collected data for that effort can be a significant part of deploying this type of system. The costs associated with that data are included in this section.

The costs associated with the assessment of individual performance measures are dependent upon whether the performance metric is derived from data generated directly by project systems, requires the use of open-source data external to the project systems, or requires the use of proprietary data sources that are external to the system (which requires a license agreement for project use).

Data Collected Through Deployment System

The costs of assessing performance measures that employ data internal to the project systems involve capital costs (three-year lifespan server systems, desktop computers, communications hardware, software, etc.), labor costs (server setup and management, initial programming costs to support data flows and develop client dashboards), ongoing data management costs, and ongoing data analysis costs, various materials and supplies, and overhead costs associated with server locations and work space. All costs for internal data streams are embedded in the Phase 2 and 3 estimated costs.

The costs of assessing performance measures that employ open-source data external to the project systems include minor marginal capital costs (three-year lifespan data storage systems) and labor (ongoing data management and analysis). All costs for open-source external data streams are embedded in the Phase 2 and 3 estimated costs. Costs will be appropriated to individual performance metrics during the development of the ICTDP.

Data Collected Outside Deployment System

The costs of assessing performance measures that employ proprietary data external to the project systems include minor capital costs (three-year lifespan data storage systems) and labor

costs (establishing the data flows and ongoing data management/analysis). Performance measures that employ proprietary data collected outside of the deployment system also impose costs associated with data licensing for the project performance period. Examples of these metrics proposed for this project may include the use of household demographic data, employer-level economic data, and on-road performance data streams from third-party providers. Costs will be appropriated to individual metrics during the development of the ICTDP.

Data Collected Through Survey

The costs of assessing performance measures that employ traveler feedback surveys include labor costs for developing the survey questions and ongoing data management/analysis. It is also anticipated that incentives will be needed to encourage user survey participation. This may come in the form of small participation payments, contest entry with prizes, etc. In addition, continued monitoring, processing, and analysis will need to be provided to assess the survey response. This will primarily be completed with use of the ATL RIDES subsystem. Costs develop the surveys, monitor, evaluate, and report performance will be considered during the development of the ICTDP.

Data Processing and Reporting

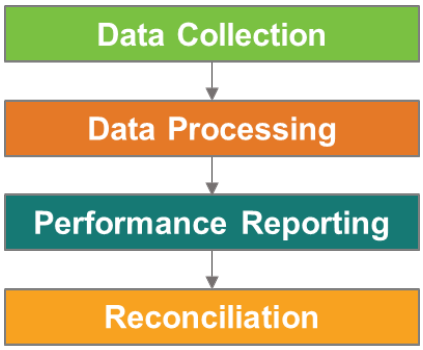
The initial ST-CTN system implementation, including data processing and reporting, will be performed on dedicated servers. However, it is envisioned that development of cloud-based approaches will be implemented during Phase 3 which is expected to reduce project cost and support project scalability. Cost to accommodate this transfer with respect to performance measurement and associated lifecycle costs will be considered during the development of the ICTDP.

7.5 Data Quality Check Approach

Confirming the quality of the data used to measure the performance of the ST-CTN system is of critical importance. Confidence in that data not only ensures confidence in the ST-CTN performance; it also provides an opportunity to seek ways to increase performance. The ST-CTN Project Management Lead (PML) is responsible for overall direction to the ST-CTN project team, including monitoring consistency and ensuring quality of data and associated reporting and deliverables. The PML will confirm that data quality processes are being followed as intended. The PML will rely on the ST-CTN project team, data owners, and data stewards to implement the data quality process.

The DMP presents data owners and data stewards for each data set expected to be utilized for this project (see **Appendix D** for comprehensive list). The data owner is the person or organization with the authority, ability, and responsibility to access, create, modify, store, use, share, and protect the data. Data stewards, at the direction of the data owner, are the persons or organization that is delegated the privileges and responsibilities to manage, control, and maintain the quality of a data asset throughout the data lifecycle.

The data quality process will be implemented to ensure the data quality throughout the life of the ST-CTN project and is illustrated below in **Figure 8**. The data quality process will be implemented consistent with the performance reporting cycle discussed in **Section 8**.



Source: ARC, 2021

Figure 8. Data Quality Management Process

The data quality process will be conducted in four steps:

- **Step 1 – Data Collection.** The data owner (data collection lead) will collect the data and verify that the data exists and will perform an initial continuity check. This will be done based on the frequency with which the data is collected – weekly for continuously collected data; each collection for as needed collected data; and monthly for monthly collected data.

- **Step 2 – Data Processing.** The data steward will receive or retrieve the data and perform a standard continuity check, filter out-of-range values and smooth, and compare with other datasets to identify and resolve any spatial/temporal deviations. Performance measurement data processing will be conducted consistent with the performance reporting cycle.

- **Step 3 – Performance Reporting.** The performance reporting lead will be responsible for developing the metrics and reporting the performance of the ST-CTN system. The performance reporting lead will review the processed data and verify that associated data sets are reasonable and relatively consistent with previous reporting cycles.

- **Step 4 – Reconciliation.** The performance reporting lead will work with the data owners and/or data stewards to reconcile any inconsistencies, outliers, or missing data. Data collection and processing errors will be reviewed and resolved such that data quality is regained as soon as possible.

The ST-CTN project team is committed to data quality and performance measurement evaluation and reporting that encourages confidence.

7.6 Data Sharing Framework

The performance measures data sharing framework for this project will ensure transparency with respect to the data and methods employed to generate performance metrics. As described in **Section 6**, the team will implement systems to share the methods and data required to support the Broad Agency Announcement (BAA)-required independent evaluation of the project, using the data and data management systems described in the Phase 1 DMP. The majority of the

performance metrics defined in this performance measures plan are being published directly to the project dashboard in near real-time or at regular intervals, depending on the performance measure update frequency requirements and input data update frequency. As such, these performance metrics and their archives will be directly accessible to the contracting officer representation (COR) and the IE team. A comprehensive schedule of data availability is available in **Section 9.** The team will manage the transmission of underlying data flows to the COR (data used to generate the performance metrics) in accordance with the Phase 1 DMP.

As outlined in Section 4.2 of the Phase 1 DMP, this project includes a large number of datasets used in a wide variety of applications. Open-source data used to generate performance measures described in this report will be made directly available to the COR and the IE team via direct server-to-server push connections into the USDOT-managed – Public System in Phase 2 (in accordance with all relevant security protocols). Proprietary data and protected data used in all project metrics cannot be transmitted to, or reside upon, third-party servers. In the event that the IE team elects to license the same proprietary data sets (e.g., household level economic data from the same third-party marketing firm), the project team will coordinate with the independent evaluator team to ensure that the same exact data sets are used on the project servers and COR servers.

The team will publish all methods and Python code required to generate performance metrics via GitHub. The project team will also work with the COR to ensure that all of the working and research data sets described in the Phase 1 DMP that are generated by published project code are replicated properly on the COR servers. As described in **Section 6**, the team will also provide the IE team with access to protected data in the Secure Data Lab at the GA Tech, in accordance with approved IRB human subject agreements contained in the HUA Summary, so that the IE team can confirm how any metric that employs PII is generated and can independently replicate these performance metrics.

8. Performance Reporting

ST-CTN performance reporting will be a combination of semi-static reports and dynamic monitoring dashboards. Semi-static reports include the outcomes of field data collection efforts periodic surveys and before-after studies. Dashboards for dynamic systems monitoring provide a window into those performance measures and metrics that are summarized over specific time increments and those that are reported in near real-time. Dashboard systems and algorithms automatically ingest data from the various subsystems, automatically summarize data and calculate metrics, and present these metrics in a standard format and/or an interactive format allowing dashboard users to select different metrics or variables within a presentation window. The performance monitoring system will generate the metrics in near real-time or at regular intervals, depending on the performance measure update frequency requirements and input data update frequency. For some metrics dashboard output frequency may also depend upon data variability. In some cases, longer averaging times may need to be employed when a performance metric that depends on a sparse data-stream or a noisy data stream to ensure that sufficient data are employed in each calculation interval for robust computations. In Phase 2 the project team will develop semi-static reports and dynamic data dashboards as applicable for each performance metric shown below in **Table 28.**

Table 28. Reporting Frequency by Metric

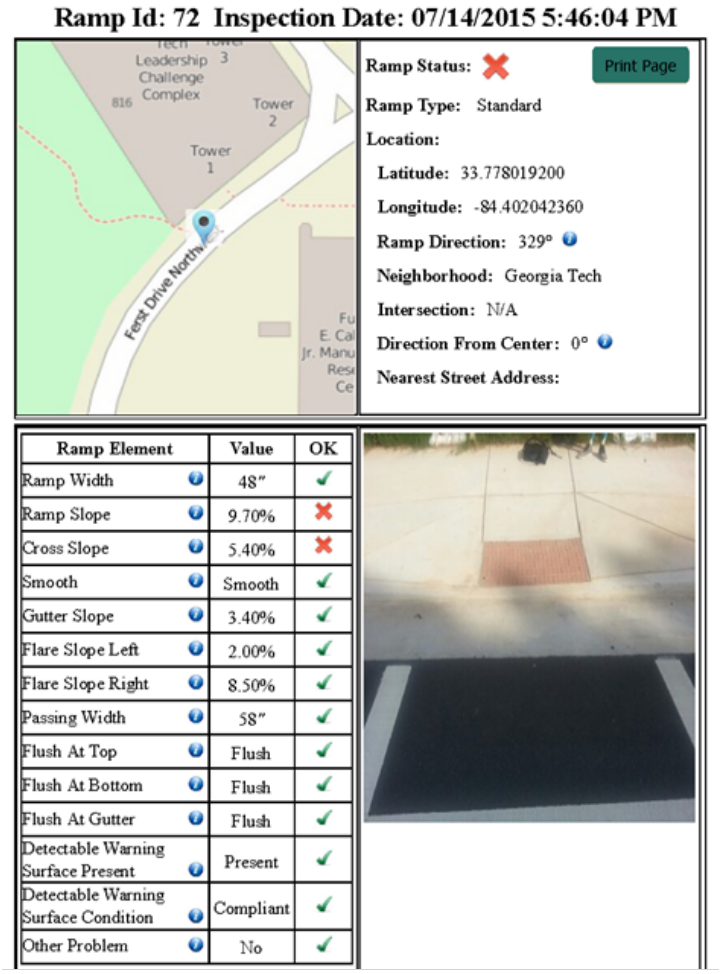
ID	Measure / Metric	Reporting Frequency
CT-PM-1	**Enhance Traveler Experience**	
CT-ME-1.1	Distribution of Likert score survey response of travelers' complete trip travel experience rating over time.	Semi-Static
CT-ME-1.2	Distribution of Likert score survey response of travelers' rating of how the useability of the ST-CTN system enhanced their complete trip travel experience.	Semi-Static
CT-ME-1.3	Distribution of Likert score survey response of travelers' rating of how the ST-CTN system features and functions enhanced their complete trip travel experience.	Semi-Static

ID	Measure / Metric	Reporting Frequency
CT-ME-1.4	Distribution of Likert score survey response, from those requiring caregiver support, of travelers' rating of how the ability to access support from their caregiver through the ST-CTN system during travel enhanced their complete trip travel experience.	Semi-Static
CT-ME-1.5	Distribution of Likert score survey response of travelers' rating of how access to the call center through the ST-CTN system enhanced their complete trip travel experience.	Semi-Static
CT-ME-1.6	The average monthly number of call center support calls per user through the ST-CTN system.	Semi-Static
CT-ME-1.7	ST-CTN system user average complete trip travel time by trip segment.	Dynamic
CT-ME-1.8	Variance between recommended ST-CTN system complete trip recommended routes and actual ST-CTN system travel routes that were taken.	Dynamic
CT-ME-1.9	Number and variety of destination types accessed by ST-CTN system users.	Dynamic
CT-ME-1.10	Number of complaints filed to GCT per month pertaining to lack of accessible routes to transit stops.	Semi-Static
CT-ME-1.11	Number of unique ST-CTN system users per day.	Semi-Static
CT-ME-1.12	Number of trips planned and completed by unique ST-CTN system users per day.	Semi-Static
CT-PM-2	**Improve Accessibility**	
CT-ME-2.1	Distribution of Likert score survey response of travelers' ability to access destinations rating.	Semi-Static
CT-ME-2.2	Distribution of Likert score survey response of travelers' quality of life rating.	Semi-Static
CT-ME-2.3	Monthly average number of trip purposes reported by survey response.	Semi-Static

ID	Measure / Metric	Reporting Frequency
CT-PM-3	**Enhance Complete Trip Pedestrian Safety**	
CT-ME-3.1	Distribution of Likert score survey response of travelers' perception of safety while using the ST-CTN system.	Semi-Static
CT-ME-3.2	Variance between recommended ST-CTN system complete trip recommended routes and actual ST-CTN system travel routes taken at signalized intersection crossings.	Semi-Static
CT-ME-3.3	Survey response to understand the variance between recommended ST-CTN system complete trip recommended routes and actual ST-CTN system travel routes taken at signalized intersection crossings. If the traveler indicates that they deviate from the recommended route, they will be asked why.	Dynamic
CT-ME-3.4	Average number of pedestrian-related near-miss incidents reported by survey response, described as “the vehicle had to abruptly brake or swerve to avoid striking the traveler or the traveler had to take sudden evasive action to avoid being struck.”	Semi-Static
CT-PM-4	**Enhance Fixed-Route Transit**	
CT-ME-4.1	Average number of fixed-route riders within the ST-CTN project area.	Dynamic
CT-ME-4.2	Average number of ST-CTN system users who choose fixed-route transit based on direction from system.	Dynamic
CT-ME-4.3	Average number paratransit trips for ST-CTN users.	Dynamic
CT-ME-4.4	Survey response of travelers' perception of fixed-route transit service while using the ST-CTN system (i.e., was service enhanced).	Semi-Static
CT-ME-4.5	Survey response of ST-CTN travelers' who indicate they have shifted to fixed-route transit service.	Semi-Static

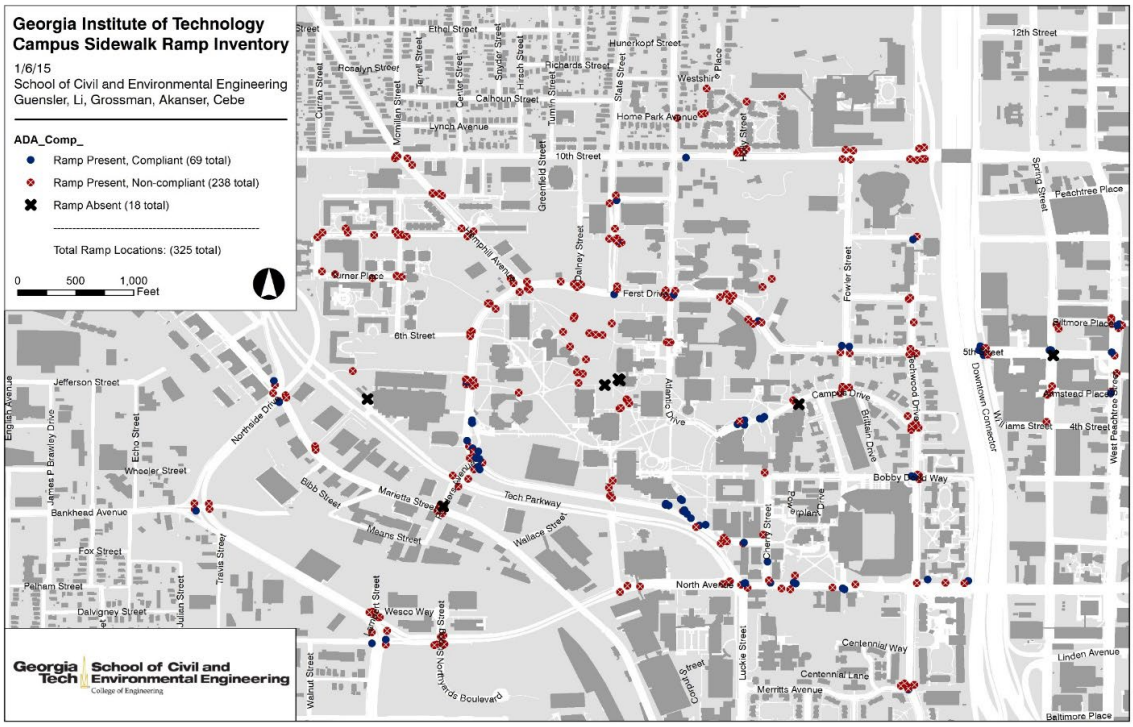
ID	Measure / Metric	Reporting Frequency
CV-PM-1	**Enhance Safety and Awareness with Connected Vehicle**	
CV-ME-1.1	Distribution of Likert score survey response of travelers' (end user of the ST-CTN system) rating of their perception of enhanced safety while using pedestrian crossing extensions through the ST-CTN system.	Semi-Static
CV-ME-1.2	Number of successful (i.e., pedestrian crossed the intersection within the walk time and walk time extension) pedestrian crossings at signalized intersections within the ST-CTN project area.	Dynamic
CV-ME-1.3	Enabled connected vehicle travel speed prior to and during a PSM broadcast.	Dynamic
CV-PM-2	**Improve Transit Reliability**	
CV-ME-2.1	Average transit schedule adherence within the project area, measured as the GCT on-time performance (OTP).	Dynamic
CV-ME-2.2	Standard deviation of average OTP distribution by route.	Dynamic
CV-ME-2.3	Average transit traveler wait times within the project area.	Dynamic
CV-ME-2.4	Average number of transit traveler missed connections within GCT fixed-transit service (i.e., missed transit to transit connection).	Semi-Static

Figure 9 and **Figure 10** show examples of semi-static field inspection reports implemented by project team members in the past for individual curb ramp inspections and for an interactive report summarizing network problems. Users click on reported defects to see the underlying defect reports. Both of these reports are semis-static in that they are only updated when changes to the field conditions occur and new data are integrated into the system. Typically, this would occur when sidewalk infrastructure repairs are performed, and repair reports trigger a change in sidewalk infrastructure status.



Source: GA Tech, 2021

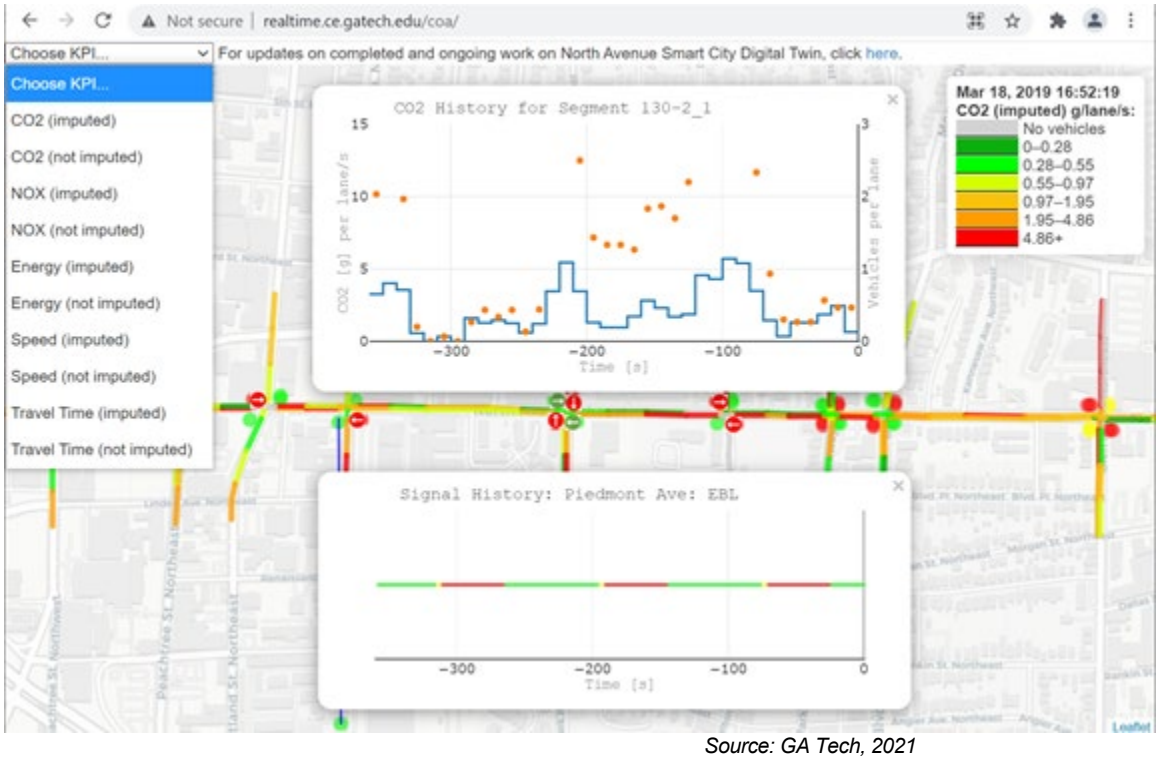
Figure 9. Example of a Semi-Static Dashboard for Individual Ramp Field Inspection Results



Source: GA Tech, 2021

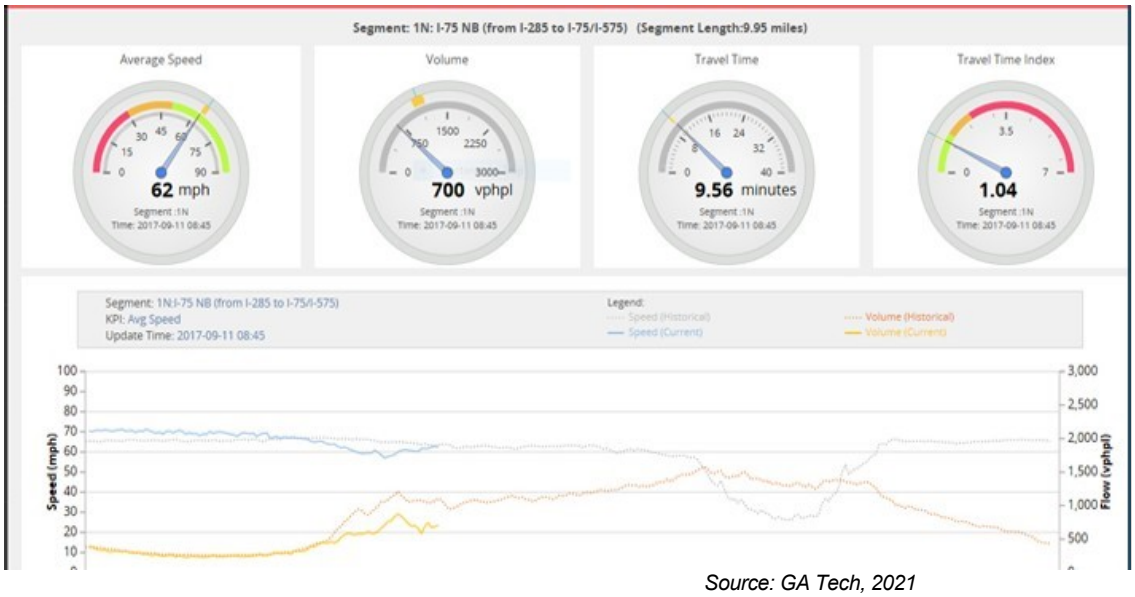
Figure 10. Example of a Semi-Static Dashboard for a Sidewalk Network Field Inspection Result Summary

Figure 11 provides an example of a dynamic data dashboard developed by project team members for near-real-time emissions performance metrics for the North Avenue Smart Corridor in Atlanta. **Figure 12** provides an example of a dynamic data dashboard for traffic flow on one of Atlanta's freeway sections showing real-time vehicle speeds, travel times, fundamental speed-flow relationships. Both **Figure 11** and **Figure 12** are composite dashboards, in that they each report more than one metric using near-real-time observed traffic conditions reported from machine vision sensors and calculated energy use and emissions from embedded MOVES-Matrix algorithms that are integrated into the dashboard graphics code. The dashboard graphics for these examples are always in motion, changing as data are updated in real-time.



Source: GA Tech, 2021

Figure 11. Example of a Near-Real-Time Performance Dashboard for Vehicle Operations Energy and Emissions on the North Avenue Corridor



Source: GA Tech, 2021

Figure 12. Example of a Near-Real-Time Performance Dashboard for Traffic Operations on a Freeway Section in Atlanta, GA

9. Performance Measurement and Evaluation Support Schedule

The PMESP schedule includes major milestones, data collection and analysis periods, test and analysis periods, and frequency of PMESP updates. Performance measurement and reporting is dependent on the receipt, processing, and analysis of data to support the calculation of metrics. Provision of access to data is dependent upon server construction, data exchange programming, interface and dashboard programming completion, and active data availability.

The Phase 1 DMP provides a schedule (by Phase and Quarter) of anticipated data availability which accounts for the time associated with server construction and data exchange programming in Phase 2. The ST-CTN project team will finalize each metric and interface/dashboard programming in the quarter following the availability of the last data set to come online required for the metric. For example, if a metric requires one data stream that becomes available in Phase 2, October 2022 and another data set that becomes available in Phase 2, November 2022, the metric dashboard and data flows will be available for performance measurement in Phase 2, December 2022.

The Phase 1 DMP schedule was leveraged to develop the following PMESP schedule in **Table 29**.

Table 29. PMESP Schedule

ID	Event Title	Description	Date
1	Draft Phase 1 PMESP is delivered to USDOT	• Draft Phase 1 PMESP with basic information known at the time of writing.	August 2021 (Phase 1)
2	Final Phase 1 PMESP	• Phase 1 PMESP is updated with USDOT comments addressed.	October 2021 (Phase 1)
3	Enterprise Data Governance (EDG) Data Committees	• Establish EDG data committees to establish governance data for integrated datasets. • The EDG data committees will include USDOT and IE representatives as observers.	March 2022 (Phase 2)

ID	Event Title	Description	Date
4	Performance Measure Requirements	• Refine datasets needed to generate performance measurement (and methods for collecting data)	April/May 2022 (Phase 2)
5	Initial data samples provided to USDOT	• Initial data samples are created, validated, and submitted to USDOT for review.	May/June 2022 (Phase 2)
6	Initial meeting with USDOT data team to review performance measures and data	• Meeting to review with USDOT and walkthrough the measures and PMESP.	August 2022 (Phase 2)
7	Baseline data collection starts	• Initial collection of data on current conditions starts. • Baseline data collection starts as described in Section 7.2.	August 2022 (dependent on weather) (Phase 2)
8	PMESP Update	• PMESP updated based on changes that have occurred during design and collection.	Starting after Minimum Viable Project (MVP) of integrated system deployment and annually (September 2023; annually) (Phases 2/3)
9	Baseline data provided to USDOT	• Baseline datasets and metadata files are made available for the USDOT and the IE to access.	Starting at MVP of integrated system deployment (Phases 2/3)
10	Performance measure targets refined and set	• Baseline data is analyzed, and targets are refined.	Starting one month after MVP of integrated system deployment (Phases 2/3)
11	Month of testing of deployment begins	• Initial upload of “after datasets” are collected and stored on project research data storage systems through testing.	Starting at MVP of integrated system deployment (Phases 2/3)

ID	Event Title	Description	Date
12	Data accessed by USDOT	• Daily updates of *after case data* are available to USDOT and IE to access.	TBD (Phase 2/3)
13	Performance metric analysis methods delivered to USDOT	• All scripts and methods are provided to USDOT and IE for replicability of analysis	TBD (Phase 2/3)
14	Draft Final Performance Measurement Evaluation Report submitted (test report will include a section on data fidelity)	• Draft Final Performance Measurement Evaluation Report submitted to USDOT.	TBD (Phase 3)
15	Final Performance Measurement Evaluation Report submitted	• Draft Final Performance Measurement Evaluation Report submitted to USDOT.	TBD (Phase 3)

10. References

The following table lists the documents that were used to support the development of the ST-CTN PMESP document. References to these documents are identified with the acronym provided in brackets.

Table 30. References

ID	Referenced Documents
[CVTMP]	AECOM. "Gwinnett County Connected Vehicle Technology Master Plan (CVTMP). " Duluth: Gwinnett County Department of Transportation. (2019).
[ARCRTP]	Atlanta Regional Commission. “The Atlanta Region’s Plan: Regional Transportation Plan” Atlanta: Atlanta Regional Commission. (2021).
[ConOps]	Atlanta Regional Commission. Deliverable Task 2.3 Concept of Operations. Atlanta: U. S. Department of Transportation. (2021).
[DMP]	Atlanta Regional Commission. Deliverable Task 3 Data Management Plan. Atlanta. : U. S. Department of Transportation. (2021).
[SMP]	Atlanta Regional Commission. Deliverable Task 4 Safety Management Plan. 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).
[ATIS]	Federal Aviation Administration. Section 9: Automatic Terminal Information Service Procedures. Washington D. C.: U. S. Department of Transportation. (2021).
[CV1K]	Georgia Department of Transportation. "The Regional Connected Vehicle Program Scope of Work. " Atlanta: Georgia Department of Transportation. (2019).
[GCDOT]	Gwinnett County Department of Transportation. Transportation. Duluth: Gwinnett County Board of Commissioners. (2021).
[GBFS]	GitHub. General Bikeshare Feed Specification. Washington D. C. : GTFS. (2019).
[GTFS-RT]	GTFS Realtime. GTFS Realtime Reference v2. Washington D. C. : GTFS Realtime. (2019)

ID	Referenced Documents
[GTFSP]	GTFS. General Transit Feed Specification Pathway. Washington D. C. : GTFS. (2019).
[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).
[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. Gwinnett County Destination 2040 - Gwinnett's Comprehensive Transportation Plan - Executive Summary. Atlanta: Gwinnett County. (2017).
[GCTP-2]	Kimley-Horn, Bleakly Advisory Group, Pond, Sycamore, VHB, & Debra Semans. Gwinnett County Destination 2040 - Gwinnett's Comprehensive Transportation Plan - Existing Conditions. Atlanta: Gwinnett County. (2017).
[GCTP-3]	Kimley-Horn, Bleakly Advisory Group, Pond, Sycamore, VHB, & Debra Semans. Gwinnett County Destination 2040 - Gwinnett's Comprehensive Transportation Plan - Needs Assessment. Atlanta: Gwinnett County. (2017).
[GCTP-4]	Kimley-Horn, Bleakly Advisory Group, Pond, Sycamore, VHB, & Debra Semans. Gwinnett County Destination 2040 - Gwinnett's Comprehensive Transportation Plan - Recommendations Report. Atlanta: Gwinnett County. (2017).
[API]	IBM Cloud Education. Application Programming Interface (API). Armonk: IBM. (2020).
[LS]	McLeod, Saul. Likert Scale. Grandville: Simply Psychology. (2019).
[OSM]	OpenStreetMap Foundation. Open Street Map. Washington D. C. : UCL, ByteMark. (2021).

ID	Referenced Documents
[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).
[OSEP]	Ryen, Ed. Overview of the System Engineering Process. Bismarck: North Dakota Department of Transportation. (2008).
[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.
[IMISOW]	The ATL. Integrated Mobility Innovation Statement of Work - Atlanta-Region Rider Information and Data Evaluation System. Atlanta: Federal Transit Administration. (2020).
[MPM]	TransitCenter, Applied Predictive Technologies, Texas A&M Transportation Institute. Mobility Performance Metrics (MPM) for Integrated Mobility and Beyond. Washington D. C. : Federal Transit Administration. (2020). `
[FAST]	U. S. Department of Transportation Federal Highway Administration. Fixing America's Surface Transportation Act. (2015).
[BAA]	U. S. Department of Transportation, Federal Highway Administration. ITS4US Broad Agency Announcement. Washington D. C. : U. S. Department of Transportation. (2020).
[TB]	Shaheen, Susan; Bell, Corwin; Cohen, Adam; Yelchuru, Balaji Travel Behavior – Shared Mobility and Transportation Equity. Washington D. C. : U. S. Department of Transportation. (2017).
[ACS]	United States Census Bureau. American Community Survey. Washington D. C. : U. S. Department of Commerce. (2017).
[ADA]	United States Department of Justice, Civil Rights Division. Americans with Disabilities Act of 1990. Washington D. C. : United States Government. (2009).

Appendix A. Acronyms

ADA – Americans with Disabilities Act

API – application programming interface

ARC – Atlanta Regional Commission

ARPA-E – Advanced Research Projects Agency – Energy

ATIS – automatic terminal information service

ATL – Atlanta-Region Transit Link Authority

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

ATTRI – Accessible Transportation Technologies Research Initiative

BAA – broad agency announcement

CDP – connected data platform

ConOps – Concept of Operations

COR – contracting officer representative

CV – connected vehicle

DMP – Data Management Plan

ETRA – Enabling Technology Readiness Assessment

EV – emergency vehicle

FHWA – Federal Highway Administration

FTA – Federal Transit Administration

GA Tech – Georgia Institute of Technology

GCDOT – Gwinnett County Department of Transportation

GCT – Gwinnett County Transit

GDOT – Georgia Department of Transportation

GEARS – Georgia Electronic Accident Reporting System

GOSystems – GO Systems and Solutions

GTFS – General Transit Feed Specification

HUA – Human Use Approval

IE – Independent Evaluation

IOO – infrastructure owner/operator

IRB – Institutional Review Board

ITS – Intelligent Transportation Systems

JPO – Joint Program Office

KHA – Kimley-Horn and Associates, Inc.

LEP – limited English proficiency

MAP – Map Data

NDA – non-disclosure agreement

OBU – onboard unit

OST – Office of the Secretary

OTP – Open Trip Planner

PED-SIG – Mobile Accessible Pedestrian Signal System

PII – personally identifiable information

PMESP – Performance Measurement Evaluation and Support Plan

PML – project management lead

PSM – pedestrian safety message

QA – quality assurance

QC – quality control

RSU – roadside unit

SILCGA – Statewide Independent Living Council of Georgia

SMP – Safety Management Plan

SMUG – Secure Mobile Unit Gateway

SpaT – signal phasing and timing

SRTA – State Road and Tollway Authority

ST-CTN – Safe Trips in a Connected Transportation Network

STM – space time memory

SyRS – Deployment System Requirements

TRANSNET – traveler response architecture using novel signaling for network efficiency in transportation

TSP – transit signal priority

TSR – transit stop request

UI – user interface

USDOT – U. S. Department of Transportation

VMT – vehicle miles traveled

VRU – vulnerable road user

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]

Automatic Terminal Information Service (ATIS) – service that provides continuous broadcasting of recorded information in order to improve controller effectiveness and relieve frequency congestion. [ATIS]

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]

Fixed-Route Transit – a system of transporting individuals on which a vehicle operates on a prescribed route based on a fixed schedule. Vehicle options include van, bus, train, but excludes aircraft. [GCDOT]

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].

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].

Likert Scale – a five or seven point scale used to allow travelers to express their degree of agreement or disagreement with a particular statement. The scale typically ranges from “Strongly disagree” to “strongly agree”. [LS]

Mobile Accessible Pedestrian Signal System (PED-SIG) - A mobile application system that exchanges information between roadside or intersection sensors and mobile devices carried by a pedestrian. The system is used to inform pedestrians with disabilities when to begin traversing a crosswalk and how to remain within the crosswalk. [CAV]

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

Onboard Unit (OBU) – An ITS related hardware that performs the 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]

Paratransit – a shared-ride program that provides origin-to-destination transportation services to persons with disabilities complementary to the fixed-route transit options. [GCDOT]

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

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

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

Roadside Unit (RSU) -- A transportation field device that performs the data exchange between OBUs, MUs, and other infrastructure elements. [CI]

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

Signal Status Message – Broadcast sent out by an RSU to announce a preemption request. [CAV]

Transit Signal Priority (TSP) – It is a feature of signal operations that allow for transit agencies to manage service by prioritizing buses and granting their right of way based on schedule adherence or passenger loads. [CAV]

Traverse Data – Customer traverse data through the system (in space and time at highest practical resolution) for use in performance assessment (response times, wait times, travel times, etc.) and that can be compared to recommended routes for use in refining impedance calculations and route recommendations.

Appendix C. Performance Measures and Metrics

The following table provides an exhaustive list of performance measures and associated metrics, with evaluation and data information.

Table 31. ST-CTN Performance Measures and Metrics

ID	Performance Measure/Metric	Evaluation Question	Data ID	Dataset Name	Data Owner/ Collection Lead	Reporting Lead
CT-PM-1	**Enhance Traveler Experience**					
CT-ME-1.1	Distribution of Likert score survey response of travelers' complete trip travel experience rating over time.	Did the ST-CTN system enhance the travelers' complete trip travel experience?	53	Trip Feedback Reports	ATL	ATL
CT-ME-1.2	Distribution of Likert score survey response of travelers' rating of how the useability of the ST-CTN system enhanced their complete trip travel experience.	Did the useability (i.e. was the system easy to use, easy to configure, intuitive, etc.) of the ST-CTN system enhance the travelers' complete trip travel experience?	53	Trip Feedback Reports	ATL	ATL
CT-ME-1.3	Distribution of Likert score survey response of travelers' rating of how the ST-CTN system features and functions enhanced their complete trip travel experience.	Did the ST-CTN system features and functions (i.e. alert and notification method, accessible route selection, remote stop request, automated ped actuation, etc.) enhance the travelers' complete trip travel experience?	53	Trip Feedback Reports	ATL	ATL

ID	Performance Measure/Metric	Evaluation Question	Data ID	Dataset Name	Data Owner/ Collection Lead	Reporting Lead
CT-ME-1.4	Distribution of Likert score survey response, from those requiring caregiver support, of travelers' rating of how the ability to access support from their caregiver through the ST-CTN system during travel enhanced their complete trip travel experience.	Did access to the travelers' caregiver through the ST-CTN system enhance the travelers' complete trip travel experience?	53	Trip Feedback Reports	ATL	ATL
CT-ME-1.5	Distribution of Likert score survey response of travelers' rating of how access to the call center through the ST-CTN system enhanced their complete trip travel experience.	Did access to call center support through the ST-CTN system enhance the travelers' ability to complete their trip independently?	51	Mobile App Logs	ATL	ATL
CT-ME-1.6	The average monthly number of call center support calls per user through the ST-CTN system.	Did access to call center support through the ST-CTN system allow the travelers to better understand the application and complete future trips without having to utilize the call center.	65	GCT Complaint Log	GCT	GA Tech
CT-ME-1.7	ST-CTN system user average complete trip travel time by trip segment.	Did the ST-CTN system improve the travelers' complete trip travel time by trip segment (e.g., wait time, arrival time, travel time, total journey time)?	52	Traverse Data	GA Tech	GA Tech

ID	Performance Measure/Metric	Evaluation Question	Data ID	Dataset Name	Data Owner/ Collection Lead	Reporting Lead
CT-ME-1.8	Variance between recommended ST-CTN system complete trip recommended routes and actual ST-CTN system travel routes that were taken.	Did travelers feel greater confidence and independence during their complete trip, including transitions, with the ST-CTN system or did they deviate from the ST-CTN system complete trip recommended routes?	52	Traverse Data	GA Tech	GA Tech
CT-ME-1.9	Number and variety of destination types accessed by ST-CTN system users. The destination types will be defined based on data reviewed in Phase 2 of the ST-CTN project.	Did traveler's access to new destinations increase with use of the ST-CTN system?	A. 52 B. 53	A. Traverse Data B. Trip Feedback Reports	A. GA Tech B. ATL	A. GA Tech B. ATL
CT-ME-1.10	Number of complaints filed to GCT per month pertaining to lack of accessible routes to transit stops.	Did the accessible routes recommended by the ST-CTN system enhance the travelers' complete trip travel experience?	A. 65 B. 53	A. GCT Complaint Log B. Trip Feedback Reports	A. GCT B. ATL	A. GA Tech B. ATL
CT-ME-1.11	Number of unique ST-CTN system users per day.	Did the number of unique travelers using the ST-CTN system increase over time?	51	Mobile App Logs	ATL	GA Tech
CT-ME-1.12	Number of trips planned and completed by unique ST-CTN system users per day.	Did travelers use the ST-CTN system with increased frequency over time?	51	Mobile App Logs	ATL	GA Tech
CT-PM-2	**Improve Accessibility**					
CT-ME-2.1	Distribution of Likert score survey response of travelers' ability to access destinations rating.	Did the ST-CTN system enhance the travelers' ability to access destinations (i.e., employment, education, social activities, healthcare, shopping, etc.)?	53	Trip Feedback Reports	ATL	GA Tech

ID	Performance Measure/Metric	Evaluation Question	Data ID	Dataset Name	Data Owner/ Collection Lead	Reporting Lead
CT-ME-2.2	Distribution of Likert score survey response of travelers' quality of life rating.	Did the ST-CTN system enhance the travelers' quality of life? Quality of life, in the context of this project, may include the following: • Additional time within their schedule, • Reduced time and stress to plan travel, • Increased awareness and confidence to travel independently, and • Ability to schedule more reliably.	53	Trip Feedback Reports	ATL	GA Tech
CT-ME-2.3	Monthly average number of trip purposes reported by survey response. The trip purpose types will be defined based on data reviewed in Phase 2 of the ST-CTN project.	Did travelers access a variety of trip purposes with use of the ST-CTN system? Trip purposes may include: employment, education, social, healthcare, and shopping.	53	Trip Feedback Reports	ATL	GA Tech
CT-PM-3	**Enhance Complete Trip Pedestrian Safety**					
CT-ME-3.1	Distribution of Likert score survey response of travelers' perception of safety while using the ST-CTN system.	Did the ST-CTN system enhance the travelers' perception of safety within the project study area?	A. 62 B. 63	A. Pedestrian Crash Data B. Pedestrian Incident Police Reports	GDOT	GA Tech

ID	Performance Measure/Metric	Evaluation Question	Data ID	Dataset Name	Data Owner/ Collection Lead	Reporting Lead
CT-ME-3.2	Variance between recommended ST-CTN system complete trip recommended routes and actual ST-CTN system travel routes taken at signalized intersection crossings.	Did travelers deviate from the ST-CTN system complete trip recommended routes while crossing signalized intersections (i. e. are travelers receiving the benefits of the ST-CTN intersection crossing features)?	53	Trip Feedback Reports	ATL	GA Tech
CT-ME-3.3	Survey response to understand the variance between recommended ST-CTN system complete trip recommended routes and actual ST-CTN system travel routes taken at signalized intersection crossings. If the traveler indicates that they deviate from the recommended route, they will be asked why.	Why did travelers deviate from the ST-CTN system complete trip recommended routes while crossing signalized intersections (i. e. are travelers receiving the benefits of the ST-CTN intersection crossing features) and why?	52	Traverse Data	GA Tech	GA Tech
CT-ME-3.4	Average number of pedestrian-related near-miss incidents reported by survey response, described as “the vehicle had to abruptly brake or swerve to avoid striking the traveler or the traveler had to take sudden evasive action to avoid being struck.”	Did the ST-CTN system enhance the travelers' ability to avoid pedestrian related incidents within the project study area?	53	Trip Feedback Reports	ATL	GA Tech
CT-PM-4	**Enhance Fixed-Route Transit**					
CT-ME-4.1	Average number of fixed-route riders within the ST-CTN project area.	Did the ST-CTN system impact fixed-route transit ridership?	64	Fixed-Route Transit Ridership and Para-Transit Ridership	GCT	GA Tech

ID	Performance Measure/Metric	Evaluation Question	Data ID	Dataset Name	Data Owner/ Collection Lead	Reporting Lead
CT-ME-4.2	Average number of ST-CTN system users who choose fixed-route transit riders based on direction from system.	Did the ST-CTN system impact fixed-route transit ridership by end user classification?	36	GTFS Realtime GCT	GCT	GA Tech
CT-ME-4.3	Average number paratransit riders within the ST-CTN project area.	Did the ST-CTN system impact paratransit ridership?	A. 52 B. 53 C. 66	A. Traverse Data B. Trip Feedback Reports C. Paratransit Ridership	A. ATL RIDES B. ATL RIDES C. GCT	GA Tech
CT-ME-4.4	Survey response of travelers' perception of fixed-route transit service while using the ST-CTN system (i.e., was service enhanced).	Did the ST-CTN system enhance fixed-route transit service?	53	Trip Feedback Reports	ATL RIDES	GA Tech
CT-ME-4.5	Survey response of ST-CTN travelers' who indicate they have shifted to fixed-route transit service.	Did the ST-CTN system cause a mode shift for paratransit travelers to fixed-route transit?	53	Trip Feedback Reports	ATL RIDES	GA Tech
CV-PM-1	**Enhance Safety and Awareness with Connected Vehicle**					
CV-ME-1.1	Distribution of Likert score survey response of travelers' (end user of the ST-CTN system) rating of their perception of enhanced safety while using pedestrian crossing extensions through the ST-CTN system.	Did the ST-CTN system enhance the travelers' perception of safety while crossing signalized intersections within the project study area?	A. 44 B. 53	A. Ped-X B. Trip Feedback Report	A. GCDOT B. ATL RIDES	GA Tech

ID	Performance Measure/Metric	Evaluation Question	Data ID	Dataset Name	Data Owner/ Collection Lead	Reporting Lead
CV-ME-1.2	Number of successful (i.e., pedestrian crossed the intersection within the walk time and walk time extension) pedestrian crossings at signalized intersections within the ST-CTN project area.	Did the ST-CTN system allow for a greater number of completed pedestrian crossings (i.e., pedestrian crossed the intersection within the walk time and walk time extension) at signalized intersections within the ST-CTN project area?	A. 52 B. 41	A. Traverse Data B. SPaT	GDOT/GCDOT	GA Tech
CV-ME-1.3	Delta of enabled connected vehicle calculated average speed prior to a PSM broadcast and the 95th percentile speed recorded during a PSM broadcast.	Did the ST-CTN system improve (reduce) enabled connected vehicle speeds during PSM broadcast messages?	A. 40 B. 15 C. 18	A. PSM B. NaviGAtor Data C. Subscription Roadway Operating Condition Data	GDOT/GCDOT	GA Tech
CV-PM-2	**Improve Transit Reliability**					
CV-ME-2.1	Average transit schedule adherence within the project area, measured by GCT as 0 minutes before / 5 minutes after scheduled time for on-time performance (OTP).	Did the ST-CTN system improve transit schedule adherence within the project area?	36	GTFS-Realtime GCT	GCT	GA Tech
CV-ME-2.2	Standard deviation of average OTP distribution by route.	Did the ST-CTN system improve transit schedule reliability within the project area?	36	GTFS-Realtime GCT	GCT	GA Tech
CV-ME-2.3	Average transit traveler wait times within the project area.	Did the ST-CTN system TSP enhancements improve transit traveler wait times within the project area?	36	GTFS-Realtime GCT	GCT	GA Tech

ID	Performance Measure/Metric	Evaluation Question	Data ID	Dataset Name	Data Owner/ Collection Lead	Reporting Lead
CV-ME-2.4	Average number of transit traveler missed connections within GCT fixed-transit service (i.e., missed transit to transit connection). 'Missed connection' will be defined explicitly within the design and development of the baseline ATL RIDES and connection protection applications during Phase 2.	Did the ST-CTN system improve transit traveler missed connections?	36	GTFS-Realtime GCT	GCT	GA Tech

Appendix D. Data Management Plan – Table 5

Table 32. Data Management Plan – Table 5

#	EX ID	Dataset Type	Dataset Name	Dataset Description	Dataset Subset Description	Collection Method
1	2	Land Use	Parcel-level Land Use Data	Polygon data for sidewalk network development, land use classification, geographic research, etc. used to develop simulation network models in STM.	Data subsets are employed in: 1. Demographic analysis, coupled with licensed demographic data 2. Sidewalk asset allocation to parcel boundaries	External Input
2	2	Land Use	Building Address and Landmark Data	Address directory with addresses in the geographic region (referenced to parcel-level land use data) for use in navigation and pathfinding apps. Full data set is used in research and geographic performance metrics related to land use.	Data subsets are employed in: 1. Wayfinding routines 2. Interior pathway referencing	External Input

#	EX ID	Dataset Type	Dataset Name	Dataset Description	Dataset Subset Description	Collection Method
3	2	Network	Whole Road Network	Comprehensive roadway network for Metro Atlanta, including all facility type roadway links and intersection nodes. The network is mapped to, and reconciled with, all other network data sources (serving as the master network). Full data set serves as underlying disaggregate link-node structure for all roadway networks in the region. Includes nodes needed for future Activity Based Model (ABM) and simulation model application (e.g., large parking lots that input/absorb demand). Basis for link-to-link mapping between multi-provider roadway networks. Working data sets are generated for pathway and impedance analyses. Link-and-nodes collapsed to improve algorithm processing time. Research analysis subsets created for case studies.	Data subsets are employed in: 1. STM Network structures 2. Connections between sidewalk, transit, and road networks 3. Updating the Open Street Map (OSM) network 4. Connecting data across travel demand and simulation models	Derived

#	EX ID	Dataset Type	Dataset Name	Dataset Description	Dataset Subset Description	Collection Method
4	2	Network	ABM Network	Road network employed by the ARC regional activity-based travel demand model (condensed link and node structure from the whole road network). ABM outputs are used to provide STM data for conditions that have not been observed (e.g., freeway closure) and for research purposes (e.g., comparing predicted vs observed traffic). ABM networks are generated for each ARC modeling scenario (e.g., RTP vs. TIPA1) and calendar year for scenario analysis (e.g., 2030 model network containing roads that will be in place in 2030). Standardized naming convention ABM2020-TIPA1-2030 (150k-link network).	Data subsets are employed in: 1. STM Network structures 2. Connections between sidewalk, transit, and road networks 3. Connecting data across travel demand and simulation models	External Input
5	5	Network	STM Network	Road and pathway network employed by the STM for impedance calculations and shortest path analyses. Includes all ABM links and as many links from the whole road network as deemed necessary to support mode and pathway analyses. Network is employed with full data set (Historic STM contains link-by-link over time for research and machine learning), working data set for current conditions (previous two hours), and forecast conditions from machine learning projections (future one hour).	Data subsets are employed in: 1. Connections between sidewalk, transit, and road networks 2. Updating the OSM network 3. Connecting data across travel demand and simulation models	Derived

#	EX ID	Dataset Type	Dataset Name	Dataset Description	Dataset Subset Description	Collection Method
6	2	Network	NaviGAtor Network	Road network employed by NaviGAtor for reporting on-road operating condition data. Will be referenced to the whole road network to enrich basic simulation network in STM. The road network provides underlying network basis for Georgia Department of Transportation (GDOT) on-road working data sets for lane-by-lane and corridor speed, volume, and vehicle class splits.	Data subsets are employed in: 1. Spatial referencing between the STM and other networks 2. Establishing data flow connections between connected infrastructure elements, the STM, and other databases	External Input
7	2	Network	SRTA Managed Lane Network	Road network employed by State Road and Tollway Authority (SRTA) of Georgia for reporting on-road operating condition data. Will be referenced to the whole road network to enrich basic simulation network in STM. The network will provide underlying network basis for SRTA on-road working data sets for lane-by-lane and corridor speed, volume, and vehicle class splits.	Data subsets are employed in: 1. Referencing data collection locations with the STM and other networks	External Input

#	EX ID	Dataset Type	Dataset Name	Dataset Description	Dataset Subset Description	Collection Method
8	2, 3	Network	OpenStreetMap Network	OpenStreetMap network needed to support ATL RIDES OTP engine and STM simulator component. OSM serves as the basis for all routing processes in ATL RIDES app. The extract OSM network will be updated to reflect the whole road, STM, and sidewalk networks to ensure data compatibility. APIs will provide update linkages and transfer of path impedance costs from the STM to the OSM format for full compatibility with the routing app. Note: the updated OSM data will not be published during operations; rather the project team will work with OSM consortium to update permanent changes to the network when necessary.	Data subsets are employed in: 1. ATL Rides Wayfinding 2. Connectivity between STM and OSM reference network 3. Processes designed to update OSM spatial accuracy	External Input and Derived during operations
9	2	Network	Licensed Networks (HERE/Navteq, etc.)	Licensed subscription road network data from HERE/Navteq and/or other system performance data providers. Data flows for subscription speed and volume data will be mapped to all other roadway networks via the whole road network. These networks serve as the basis for the import of licensed operating condition data sets are used in machine learning predictions, performance metrics, and research. Working data for lane-by-lane and corridor speed, volume, and vehicle class splits.	Data subsets are employed in: 1. Spatial referencing to improve ABM an OSM network data 2. Spatial referencing for licensed STM speed and volume data into machine learning	External Input

#	EX ID	Dataset Type	Dataset Name	Dataset Description	Dataset Subset Description	Collection Method
10	1	Network	Sidewalk Network	Link and node structure for all sidewalks and potential sidewalks developed from parcel-level land use and roadway link data. Full network includes sidewalks that do not yet exist (coded as width=0 and high link impedance).	Data subsets are employed in: 1. Referencing between STM and OSM wayfinding network 2. Impedance calculations 3. Shortest path planning analyses	Derived
11	1, 13	Network	Indoor Pathways	The description of indoor pathways including the location and description of vertical conveyances and planned or current obstructions. Includes connectivity to the sidewalk network. Data will be formatted in OSM structure for use in ATL RIDES app wayfinding.	Data subsets are employed in: 1. Referencing between STM and OSM wayfinding network 2. Impedance calculations 3. Shortest path planning analyses (with impedance)	External Input
12	2, 3	Network	GTFS Transit Network	General Transit Feed Specification (GTFS) standard structures for routes serving the study area. Coupled with GTFS stops, schedule and other GTFS files for use in the ATL RIDES app and to develop the TransitSim shortest path research tool.	Data subsets are employed in: 1. ATL Rides wayfinding 2. TransitSim network connectivity for mode transfers	Derived
13	5	Network	TransitSim Network	Link and node structure for transit pathways used in server-based shortest path planning analyses.	Data subsets are employed in: 1. Impedance cost calculations for wayfinding	Derived
14	5	Network	BikewaySim Network	Link and node structure for bicycle-accessible facilities (includes roadway links as well as dedicated and shared use paths).	Data subsets are employed in: 1. Impedance cost calculations for wayfinding	Derived

#	EX ID	Dataset Type	Dataset Name	Dataset Description	Dataset Subset Description	Collection Method
15	2, 3	Network Operating Conditions	NaviGAtor Data	Roadway facility volume and speed data mapped to whole road network and STM links. GDOT roadway operating condition data sets are integrated into the STM for machine learning predictions, performance metrics, and research. Working data for lane-by-lane and corridor speed, volume, and vehicle class splits.	Data subsets are employed in: 1. STM speed and volume data for machine learning	External Input
16	2, 3	Network Operating Conditions	SRTA Data	SRTA machine vision and loop count data provide traffic volumes and speeds for managed lane facilities.	Data subsets are employed in: 1. STM speed and volume data for machine learning	External Input
17	2	Network Operating Conditions	SRTA Tolling Data	Spatial and temporal toll rates by toll segment (which impact route selection and travel times). These data are used in network performance predictions for future time steps in machine learning.	Data subsets are employed in: 1. Machine learning for impact of variable tolls on mode choices and route decisions	External Input
18	2	Network Operating Conditions	Subscription Roadway Operating Condition Data	Subscription roadway facility volume and speed data procured from commercial data provider(s) and mapped to an aggregated whole road network and STM network. The team will evaluate and select data providers in Phase 2. A DMP element will be prepared for the data from each provider. Licensed operating condition data sets are imported into the STM and used in machine learning predictions, performance metrics, and research. Working data for lane-by-lane and corridor sped, volume, and vehicle class splits.	Data subsets are employed in: 1. STM estimation of real-time route impedance factors 2. Machine learning processes 3. Benchmark performance assessment	External Input

#	EX ID	Dataset Type	Dataset Name	Dataset Description	Dataset Subset Description	Collection Method
19	2	Network Operating Conditions	Historic Roadway Operating Condition Data	Historic roadway facility volume and speed data procured from commercial data providers and mapped to an aggregated whole road network and STM network. The team will evaluate and select data providers in Phase 2. A DMP element will be prepared for the data from each provider. Licensed historic operating condition data sets by vendor are imported into the STM and used in machine learning predictions, performance metrics, and research.	Data subsets are employed in: 1. STM speed and volume data for machine learning	External Input
20	2	Network Operating Conditions	Modeled Future Operating Conditions	Model-predicted (regional ABM and simulation) future roadway facility on-road spatial and temporal operating conditions (e.g., volume and speed data) mapped to STM links for conditions that may not have been encountered in observational data for use in machine learning analyses. Each modeling run generates subsets of data employed in the STM.	Data subsets are employed in: 1. STM speed and volume data from model predictions for machine learning	Derived
21	2	Network Operating Conditions	Waze Alerts	Alerts about traffic, incidents, and work zones from Waze via the Connected Citizens Program.	Data subsets are employed in: 1. STM speed, volume, and alert triggers for machine learning	External Input
22	14	Network Operating Conditions	GDOT TMC Incident Data	GDOT TMC incident real-time reports (NaviGAtor data set).	Data subsets are employed in: 1. STM speed, volume, and incident severity triggers for machine learning	External Input
23	14	Network Operating Conditions	GDOT TMC Special Event Data	GDOT TMC pre-planned and real-time special event reporting (NaviGAtor data set).	Data subsets are employed in: 1. STM speed, volume, and incident severity triggers for machine learning	External Input

#	EX ID	Dataset Type	Dataset Name	Dataset Description	Dataset Subset Description	Collection Method
24	14	Network Operating Conditions	GDOT TMC Work-Zone Data	GDOT TMC work-zone planned and real-time reporting (NaviGAtor data set).	Data subsets are employed in: 1. STM speed, volume, and incident severity triggers for machine learning	External Input
25	5	Network Operating Conditions	Network Impedance API	New data exchange to communicate changes in network impedance values for complete paths to the ATL RIDES app using OSM/OTP data structures. The API will be developed during the agile development cycles in collaboration with STM and ATL RIDES platform developers.	Data subsets are employed in: 1. Machine learning 2. Performance measurement	Derived
26	1	Assets	Roadway Design and Condition Data	Roadway characteristics typically carried with planning models and operating characteristic tracking (number of lanes, lane width, speed limit, design capacity, etc.). STM carries all available design elements from each vendor data source for use in machine learning analyses.	Data subsets are employed in: 1. Machine learning 2. Performance measurement	Derived
27	1	Assets	Roadway Intersection Design and Condition Data	Intersection design and operations data for vehicle operations (intersection lane design, bay length, lane-by-lane signal technology and configuration, sensors, timing plans, etc.).	Data subsets are employed in: 1. Machine learning 2. Performance measurement	Derived
28	1	Assets	Pedestrian Pathway Asset Design and Condition Data	Sidewalk ramps, curb cuts, crossings, pedestrian signals, and signage. Referenced to sidewalk network links and used in impedance calculations.	Data subsets are employed in 1. Pedestrian impedance calculations 2. Wayfinding via shortest path	Derived

#	EX ID	Dataset Type	Dataset Name	Dataset Description	Dataset Subset Description	Collection Method
29	1	Assets	Pedestrian Intersection Asset Design and Condition Data	Sidewalk ramps, curb cuts, crossings, pedestrian signals, and signage at signalized intersections. Referenced to sidewalk crossing network links and used in impedance calculations. Subsets are generated by asset type for performance reporting and scenario analysis for accessibility improvement scenarios (ramps, curb cuts, crossings, etc.).	Data subsets are employed in: 1. Pedestrian impedance calculations 2. Wayfinding via shortest path	Derived
30	13	Assets	Building Pathway Asset Design and Condition Data	Building interior pathway assets such as door access, thresholds, ramps, push-button activations, signage, etc. Referenced to sidewalk approach links and interior pathway links and used in impedance calculations.	Data subsets are employed in: 1. Pedestrian impedance calculations 2. Wayfinding via shortest path	Derived
31	13	Assets	Building Wayfinding Asset Design and Condition Data	The location of wayfinding signs and announcements in facilities including transit hubs and stations. Includes status of current obstructions and vertical conveyances status (e.g., operating, out of order, under maintenance). Used in impedance calculations and shortest path generation.	Data subsets are employed in: 1. Pedestrian impedance calculations 2. Wayfinding via shortest path	Derived
32	2, 3	Transit, Assets	Transit Stop Asset Design and Condition Data	Bus stop shelters, landing pads, benches, approaches, door access points, ramps, signage, etc. Referenced to sidewalk network links and used in impedance calculations. Not currently a GTFS or OSM features but can be used in server-side impedance calculations.	Data subsets are employed in: 1. Pedestrian impedance calculations 2. Wayfinding via shortest path	External Input

#	EX ID	Dataset Type	Dataset Name	Dataset Description	Dataset Subset Description	Collection Method
33	2, 3	Transit	Transit Vehicle Asset Design and Condition Data	Information about the accessibility of specific transit vehicles (lift presence/configuration/design, lift operational status, etc.) for which real-time AVL data are employed. Not currently a GTFS or OSM features but can be used in server-side impedance calculations.	Data subsets are employed in: 1. Pedestrian impedance calculations 2. Wayfinding via shortest path	External Input
34	2, 3	Transit	GTFS (GCT)	General Transit Feed Specification data files including accessibility attributes for Gwinnett County Transit.	Data subsets are employed in: 1. Wayfinding for ATL Rides 2. Development of the TransitSim network for multi-modal impedance calculations	External Input
35	2, 3	Transit	GTFS (MARTA)	General Transit Feed Specification data files including accessibility attributes for MARTA.	Data subsets are employed in: 1. Wayfinding for ATL Rides 2. Development of the TransitSim network for multi-modal impedance calculations	External Input
36	2, 3	Transit	GTFS Realtime (GCT)	GTFS-RT API for GCT. Data on where transit vehicles are located in real-time, event data, and data on when transit vehicles will arrive and depart from a stop.	Data subsets are employed in: 1. Wayfinding for ATL Rides 2. Development of the TransitSim network for multi-modal impedance calculations	External Input
37	2, 3	Transit	GTFS Real-time (MARTA)	GTFS-RT API for MARTA transit service. Data on where transit vehicles are located in real-time, event data, and data on when transit vehicles will arrive and depart from a stop.	Data subsets are employed in: 1. Wayfinding for ATL Rides 2. Development of the TransitSim network for multi-modal impedance calculations	External Input

#	EX ID	Dataset Type	Dataset Name	Dataset Description	Dataset Subset Description	Collection Method
38	3	Transit	GTFS-Flex	General Transit Feed Specification Flex data files for Gwinnett paratransit services. This is typically a combination of GTFS and GTFS Flex.	Data subsets are employed in: 1. Wayfinding for ATL Rides 2. Development of the TransitSim network for multi-modal impedance calculations	External Input
39	15	CV	BSM	The basic safety message (BSM) is used in a variety of applications to exchange safety data regarding vehicle state and location. The BSM data will be used in this application to enhance the network operations state information in the STM.	Data subsets are employed in: 1. STM traffic operations state updates 2. Machine learning 3. Mobility performance measure computations	External Input
40	8, 15	CV	PSM	Personal safety message (PSM) is used to broadcast safety data regarding the kinematic state of various types of VRUs, such as pedestrians, cyclists, or road workers. Archived PSM messages will be used in the STM for performance monitoring. This includes messages sent from the CV subsystem warnings about emergency vehicles preemptions at specific intersections and railroad crossing gate closing.	Data subsets are employed in: 1. Safety Performance measure computations 2. Machine learning	External Input

#	EX ID	Dataset Type	Dataset Name	Dataset Description	Dataset Subset Description	Collection Method
41	8, 15	CV	SPaT	Signal phase and timing (SPaT) is a message type which describes the current state of a signal system and its phases and relates this to the specific lanes (and therefore to movements and approaches) in the intersection. It is used along with the MapData message (MAP) to describe an intersection and its current and future control states. The SPaT data will be used in this application to enhance the network operations state information in the STM.	Data subsets are employed in: 1. STM traffic operations state updates 2. Machine learning 3. Mobility performance measure computations 4. Pedestrian impedance calculations	External Input
42	8,15	CV	MAP	The MAP message is used to convey many types of geographic road information. At the current time, its primary use is to convey one or more intersection lane geometry maps within a single message. The map message content includes such items as complex intersection descriptions, road segment descriptions, high speed curve outlines (used in curve safety messages), and segments of roadway (used in some safety applications). A given single MAP message may convey descriptions of one or more geographic areas or intersections. The contents of this message involve defining the details of indexing systems that are in turn used by other messages to relate additional information (for example, the signal phase and timing via the SPaT message) to events at specific geographic locations on the roadway.	Data subsets are employed in: 1. STM traffic operations state updates 2. Machine learning 3. Mobility performance measure computations	External Input

#	EX ID	Dataset Type	Dataset Name	Dataset Description	Dataset Subset Description	Collection Method
43	11	CV	Signal Status Message Exchange	The signal status message (SSM) and signal request message (SRM) are messages exchanged between the OBUs and an RSU at a signalized intersection. The SSM is issued by the RSU while the SRM is sent by the OBU (or mobile unit). The SSM is used to relate the current status of the signal and the collection of pending or active preemption or priority requests acknowledged by the controller. It is also used to send information about preemption or priority requests which were denied. This in turn allows a dialog acknowledgment mechanism between any requester and the signal controller. The data contained in this message allows other users to determine their "ranking" for any request they have made as well as to see the currently active events. When there have been no recently received requests for service messages, this message may not be sent. While the outcome of all pending requests to a signal can be found in the signal status message, the current active event (if any) will be reflected in the SPaT message contents.	Data subsets are employed in: 1. STM traffic operations state updates 2. Machine learning 3. Mobility performance measure computations 4. Pedestrian impedance calculations	External Input
44	8	CV	Ped-X	A series of messages associated with pedestrian signal control including change interval, clearance time, phase, and walk interval. Archived Ped-X messages will be used in the STM for performance monitoring.	Data subsets are employed in: 1. STM traffic operations state updates 2. Machine learning 3. Mobility performance measure computations 4. Pedestrian impedance calculations	Collect/ Forward

#	EX ID	Dataset Type	Dataset Name	Dataset Description	Dataset Subset Description	Collection Method
45	12	Mobility Service API	Trip options	Trip options calculated from OTP Routing Engine. Calculated itinerary results when inputting an origin and destination in the OTP engine based on the personalized OSM network.	Data subsets are employed in: 1. Benchmark performance assessment 2. Trip destination and purpose research 3. Route adherence research to improve impedance factors	Collect/ Forward
46	2	VRU Modes	VRU categories	List of categories and their default edge impedance values. The enumerated list will correspond to the list of disabilities and assistive devices offered in the ATL RIDES preference menu.	Data subsets are employed in: 1. Benchmark performance assessment by VRU category 2. Trip destination and purpose research by VRU category 3. Route adherence research to improve impedance factors by VRU category	Derived
47	2	Weather	Weather data	Open weather information from NOAA, including precipitation and temperature data as well as severe weather alerts for use in impedance calculations and routing decisions. Precipitation subset, temperature subset, severe weather alert subset	Data subsets are employed in: 1. Impedance calculations 2. Machine learning related to mode and route choice	External Input
48	2	Demographics	Customer Demographic Data	User demographic data (standard transportation planning categories) for use in research analyses.	Data subsets are employed in: 1. Benchmark performance assessment 2. Socioeconomic impact assessment research	External Input
49	2	Demographics	Household Level Licensed Demographic Data	Licensed household-level demographic data for use in research analyses licensed from marketing firms.	Data subsets are employed in: 1. Benchmark performance assessment 2. Socioeconomic impact assessment research	External Input

#	EX ID	Dataset Type	Dataset Name	Dataset Description	Dataset Subset Description	Collection Method
50	2	Demographics	Household Level Vehicle Registration Data	Licensed household-level vehicle ownership data (not available from licensed demographic providers) for use in research analyses.	Data subsets are employed in: 1. Benchmark performance assessment 2. Socioeconomic impact assessment research	External Input
51	4	System-Customer Performance	Mobile App Logs	ATL Mobile app log files which include all the trips, trip preferences and travel results as well as user's app usage logs will be forwarded to the STM dynamic data broker for analysis and aggregation into performance measures.	Data subsets are employed in: 1. Benchmark performance assessment 2. Socioeconomic impact assessment research	Collect/ Forward
52	4	System-Customer Performance	Traverse Data	Customer traverse data through the system (in space and time at highest practical resolution) for use in performance assessment (response times, wait times, travel times, etc.) and that can be compared to recommended routes for use in refining impedance calculations and route recommendations.	Data subsets are employed in: 1. Benchmark performance assessment 2. Socioeconomic impact assessment research	Collect/ Forward
53	4	System-Customer Performance	Trip Feedback Reports	ATL RIDES trip reports and feedback from app users including survey data from app users.	Data subsets are employed in: 1. Benchmark performance assessment 2. Socioeconomic impact assessment research	Collect/ Forward
54	Flows from 12 to 4	Crowdsource	Trip Crowdsource Reports	Crowdsourced updates on asset design and condition data for use in verified updating of the asset data sets. Extracted subsets from ATL RIDES Trip Feedback reports include information on impacts to sidewalks, intersections, bus stops, ramps, curb cuts, signage, etc.	Data subsets are employed in: 1. Proposed updates to network feature attributes (to be reviewed and approved) 2. Network impedance calculations 3. Alert messaging by data type	Collect/ Forward

#	EX ID	Dataset Type	Dataset Name	Dataset Description	Dataset Subset Description	Collection Method
55	3	Mobility Service API	Geocode. earth API	Address information that is used to generate locations in the ATL RIDES trip planner. The API is used to convert addresses/landmarks into spherical coordinates and back for trip planning purposes.	Data subsets are employed in: 1. ATL RIDES navigation routines 2. Trip destination and trip purpose research	External Input
56	2	Demographics	Business Level Licensed Facility Data	Business demographic data (standard transportation planning categories) for use in research analyses.	Data subsets are employed in: 1. Simulating changes in network accessibility by mobility mode 2. Socioeconomic impact assessment research	External Input
57	2	Energy/Emissions	MOVES-Matrix Energy Consumption and Emission Rates	Energy and emission rate matrix from the US Environmental Protection Agency's MOVES model. The matrix contains rates per vehicle source type, on-road operating condition, environmental conditions, calendar year, etc., for the metro area.	Data subsets are employed in energy and emissions analyses employed as performance metrics.	External Input
58	-	System-Customer Performance	ST-CTN Performance Measures Data	Ongoing random sample data collection conducted through the ATL RIDES app will gather customer opinion data on system performance. Standardized questions on a Likert scale and open comment fields will be used to collect data.	Likert scale values will be collected to gauge changes in individual satisfaction with specific system features and outcomes.	Derived

#	EX ID	Dataset Type	Dataset Name	Dataset Description	Dataset Subset Description	Collection Method
59	-	STM Performance Logs	STM Communication Logs	The STM will continuously track inbound and outbound communications with time-stamps for use in assessing latency.	Logged time stamps will be used to continuously track and quantify latency along each communications leg.	Derived
60	-	STM Performance Logs	STM Impedance Calculation Logs	The STM will continuously track the time at which impedance calculations begin and are completed to assess computational speed.	Logged time stamps will be used to continuously track and quantify algorithm speeds.	Derived
61	-	CV Performance Logs	Secure MU Gateway event logs	The CV will collect and store the transactions received and transmitted to the ATL RIDES through the SMUG.	Separated by CV application.	Derived
62	-	Incident Data	Pedestrian Crash Data	GDOT retains a database (queriable) of all individual crash reports (i.e., data from all form-fillable crash report fields). These reports can be screened to eliminate PII; however, the data cannot be released without review to ensure that the officers left no data in the sketch or comments fields that could be used to identify individuals.	The crash database can be employed to assess changes in the numbers and types of crash events in the deployment zone over time. The team anticipates that there will be insufficient numbers of events to infer impacts on causality, so a case control analysis of pedestrian events will also be conducted using crash data coupled with police reports. Furthermore, many pedestrian and bicycle incidents are not reported into the database.	External Input

#	EX ID	Dataset Type	Dataset Name	Dataset Description	Dataset Subset Description	Collection Method
63	-	Incident Data	Pedestrian Incidents Police Reports	Individual police reports for each crash are retained by GDOT (sent by police agencies to the GDOT clearinghouse). The police reports contain the original information used by officers to populate the crash database fields for each event. The police reports contain officer descriptions of the incidents, drawings, and other details.	Police descriptions and drawings are used in case-control analysis of individual crash events to assess potential causal factors.	External Input
64		Transit	Ridership: Fixed Route	Transit vehicle ingress and egress counts collected by automated passenger count (APC) equipment.	Pedestrian count data will be used to assess changes in vehicle occupancy and passenger throughput for transit metrics.	External Input
65		Transit	GCT Complaint Log	GCT maintains an electronic incident log that contains the records of individual passenger complaints that reach the call center.	Subset of complaints associated with transit service, routes, stop locations, navigation, and other factors employed in user-related performance metrics.	External Input
66		Transit	Ridership: Paratransit	Transit vehicle ingress and egress counts collected by automated passenger count (APC) equipment.	Pedestrian count data will be used to assess changes in vehicle occupancy and passenger throughput, logs of users including whether or not they are a study participant.	External Input
67		Transit	Connection Protection	Logs from connection protection software.	Subset of logs including number of connections maintained, dwell times required, number of missed connections	External Input

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