

System Design Document (SDD)

Buffalo, NY ITS4US Deployment Project

www.its.dot.gov/index.htm

Draft Final—June 5, 2024

Final – June 21, 2024

As-Built – October 8, 2024

As-Built version 2– September 25, 2025

FHWA-JPO-23-999



U.S. Department of Transportation

Produced by NFTA
U.S. Department of Transportation
Intelligent Transportation Systems Joint Program Office
Federal Highway Administration
Office of the Assistant Secretary for Research and Technology
Federal Transit Administration

Notice

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

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

Technical Report Documentation Page

1. Report No. FHWA-JPO-23-999	2. Government Accession No.	3. Recipient's Catalog No.	
4. Title and Subtitle System Design Document (SDD) Buffalo, NY ITS4US Deployment Project		5. Report Date September 25, 2025	
		6. Performing Organization Code	
7. Author(s) Polly Okunieff (ICF), Lina Abounassif (ICF), Nayel Urena Serulle (ICF), Robert Jones (NFTA), Kelly Dixon (GBNRTC), Jamie Hamann-Burney (BNMC), Darlene Magold (Etch), Adel Sadek (UB), Darren Weibler (Neaera), Kyeongsu Kim (RSG), Maggie Kochman (RSG), Mark Bradley (RSG contractor)		8. Performing Organization Report No.	
9. Performing Organization Name and Address NFTA, 181 Ellicott Street, Buffalo, NY 14203 BNMC, 640 Ellicott Street, Buffalo, NY 14203 ICF International, 9300 Lee Highway, Fairfax, VA 22031 ETCH, 4696 Smothers Road, Westerville, OH 43081		10. Work Unit No. (TRAIS)	
		11. Contract or Grant No. 693JJ32250011	
12. Sponsoring Agency Name and Address U.S. Department of Transportation ITS Joint Program Office 1200 New Jersey Avenue, SE Washington, DC 20590		13. Type of Report and Period Covered Final, As-Built Report version 2	
		14. Sponsoring Agency Code HOIT-1	
15. Supplementary Notes Elina Zlotchenko (USDOT ITS-JPO) is the Award Officer Representative (AOR) and Sarah Tarpgaard (USDOT) is the Award Officer (AO)			
16. Abstract The Buffalo NY ITS4US Deployment Project seeks to improve mobility to, from and within the Buffalo Niagara Medical Campus by deploying new and advanced technologies with a focus on addressing existing mobility and accessibility challenges. The technologies to be deployed are self-driving shuttles, a trip planning app that is customized for accessible travel, intersections that use tactile and mobile technologies to enable travelers with disabilities to navigate intersections, outdoor and indoor paths and destinations. The deployment geography includes the 120-acre Medical Campus and surrounding neighborhoods with a focus on three nearby neighborhoods (Allentown, Fruit Belt and Masten Park) with underserved populations (low income, vision impaired, deaf or hard of hearing, wheeled mobility device users and older adults). This document, the System Design Document (SDD), details the design of all sub-systems and system components of the Buffalo, NY ITS4US Deployment project, as well as provides complete traceability from requirements to system design.			
17. Keywords ITS4US; deployment; ITS; Intelligent Transportation Systems; installation; system design		18. Distribution Statement	
19. Security Classif. (of this report) Unclassified	20. Security Classif. (of this page) Unclassified	21. No. of Pages 232	22. Price N/A

Revision History

Name	Date	Version	Summary of Changes	Approver
Buffalo, NY ITS4US SDD	14 March 2023	0.1	Initial Draft (working)	Kelly Dixon
Buffalo, NY ITS4US SDD	22 April 2024	0.2	Draft	Kelly Dixon
Buffalo, NY ITS4US SDD	5 June 2024	1.0	Draft Final	Kelly Dixon
Buffalo, NY ITS4US SDD	21 June 2024	1.1	Fixed typos	Kelly Dixon
Buffalo, NY ITS4US SDD	30 August 2024	1.2	Added GPS Signal Warning	Kelly Dixon
Buffalo, NY ITS4US SDD	8 October 2024	1.3	Edited GPS Warning	Kelly Dixon
Buffalo, NY ITS4US SDD	25 September 2025	1.4	With enhancements to improve safety and user experience	Robert Jones

Table of Contents

1	Introduction.....	1
1.1	Intended Audience.....	1
1.2	Project Background	1
1.3	Project Scope.....	3
1.4	Purpose of the Design Document.....	4
1.5	Branded Naming Conventions	4
2	System Description.....	5
2.1	Physical System Overview	5
2.2	List of Subsystems and Components	7
2.2.1	Complete Trip Platform Subsystem	7
2.2.2	Community Shuttle Subsystem.....	11
2.2.3	Smart Infrastructure Subsystem.....	14
2.2.4	Performance Measurement Dashboard Subsystem.....	17
3	System Design Approach	19
3.1	Turnkey Systems and Components	19
3.2	Agile Development Process	19
3.3	Tracking Software Design Elements to Requirements	24
4	Turnkey Systems and Components.....	27
4.1	Self-Driving Shuttle – Community Shuttle Subsystem	28
4.1.1	Hardware.....	28
4.1.2	Software	29
4.1.3	Interface with the Infrastructure	32
4.1.4	Vehicle Models	32
4.1.5	Accessibility Features.....	33
4.1.6	Operator HMI	34
4.1.7	The Shuttle Operations Center (SOC).....	34
4.1.8	Passenger Information System.....	35
4.1.9	Data Logging and Storing.....	35
4.1.10	SDS Requirements Traceability	35
4.2	Human Driven Shuttle	41
4.2.1	HDS Vehicles.....	41
4.2.2	On-Demand RSD	42
4.2.3	NFTA Operations and Dispatch Center.....	47
4.2.4	HDS Requirements Traceability.....	47

4.3 Indoor Navigation System	48
4.3.1 Hardware Components	49
4.3.2 SaaS Computing Platform.....	50
4.3.3 Interface Components	53
4.3.4 Asset and Map Update Tools.....	56
4.3.5 INS Requirements Traceability	60
4.4 Pedestrian Signal / Intersection Crossing	61
4.4.1 Hardware.....	61
4.4.2 Signal Communications and Traffic Operations Platform	62
4.4.3 Beacon Enhancement at Intersections	65
4.4.4 PED-X Requirements Traceability	66
4.5 Transportation Information Hub	67
4.5.1 Kiosk Hardware	67
4.5.2 Engage IoT Software.....	69
4.5.3 TIH Requirements Traceability.....	71
4.6 Sidewalk Collection.....	73
4.6.1 Sidewalk Collection Overview	73
4.6.2 Attributes Collected.....	74
4.6.3 Encoding Sidewalk Data to OSM.....	75
5 Complete Trip Platform Subsystem.....	77
5.1 CTP Design and Agile Backlog.....	77
5.2 Platform.....	77
5.2.1 Core Functionality	78
5.2.2 Data Layer: Base Platform / System.....	79
5.2.3 Data Layer: Internal APIs	80
5.2.4 Data Layer – Trip History and Unique Trip Identifier	82
5.2.5 Data Layer: Booking Interfaces.....	83
5.3 User Management.....	85
5.3.1 Data Management: Account Removal and PII	86
5.3.2 User Management Process Flows.....	88
5.3.3 User Management: Registration Process.....	94
5.3.4 User Management Account Setting Processes.....	96
5.4 Trip Planning.....	113
5.4.1 Trip Planning Process Flow.....	113
5.4.2 Base Trip Planning User Stories	115
5.4.3 Req-CTP-011: Buffalo and NFTA Service Coverage.....	115
5.4.4 Req-CTP-015: Allow travelers to plan and update their trip preferences when they plan their trip	116
5.4.5 Req-CTP-009: Pre-populate Trip Mode Preferences.....	117
5.4.6 Req-CTP-010: Pre-populate Trip Location (Origin).....	118
5.4.7 Integration with Transit Options User Stories	118
5.4.8 PAL Integration	120

5.4.9	Contradictory Preferences User Story	122
5.4.10	Explore Mode.....	122
5.4.11	Notification and Navigation Messages.....	125
5.5	Trip Management	137
5.5.1	Indoor / Outdoor Navigation	138
5.5.2	Coordinator View	145
5.5.3	Pedestrian Crossing Actuation Request (PED-X)	152
5.5.4	Help and Feedback Functions	156
5.5.5	TIH Functions.....	158
5.5.6	Trip History.....	162
5.6	Enhanced Accessibility Features	162
5.6.1	Natural Language Assistant	170
5.7	User Interface (UI)	172
5.7.1	Navigation Features	172
5.7.2	Icons.....	173
5.7.3	User Interface and Platforms.....	175
5.7.4	Differences among Android App, iOS Mobile App and Web	175
5.8	Security and Privacy Design Summary	176
5.9	Operational Performance and Reliability	177
5.10	CTP Requirements Traceability	178
6	Performance Measurement Dashboard	183
6.1	Overview	183
6.2	Detailed Design	184
6.2.1	Survey Processing.....	184
6.2.2	Data Ingestion.....	196
6.2.3	Processing	202
6.2.4	Performance Measurement Dashboard (Visualization and Distribution)	203
6.3	PMD Requirements Traceability	207
7	References	209
8	Requirements Traceability Matrix	211
	Appendix A. Acronyms	213

List of Tables

Table 1.	Demographics of Targeted Neighborhoods	2
Table 2.	Information Flows in System of Interest.....	6
Table 3.	Priority of Backlog Items	21
Table 4.	Agile Development Schedule for CTP and PMD	22
Table 5.	Type of System or Component	27
Table 6.	SDS Sensor Hardware Components	28

Table 7. SDS Requirements Traceability to Design (Mandatory).....	36
Table 8. SDS Requirements Traceability to Design (Desired).....	39
Table 9. HDS Dispatcher Functions.....	46
Table 10. HDS Requirements Traceability to SDD Section.....	48
Table 11. SDK Functions by Functional Group.....	55
Table 12. INS Requirements Traceability to SDD Section.....	60
Table 13. PED-X Requirements Traceability to SDD Section.....	67
Table 14. Functions -- Engage IoT Server.....	69
Table 15. Functions -- Engage Client (CTP).....	71
Table 16. TIH Requirements Traceability to SDD Section.....	71
Table 17. OSM Tags Used for Sidewalk Feature Set.....	75
Table 18. Core Functionality User Stories.....	78
Table 19. Base Platform Layer User Stories.....	80
Table 20. Base Platform Layer User Stories.....	81
Table 21. Trip History and Unique Trip Identifier.....	83
Table 22. Reservation API User Stories.....	84
Table 23. Account Removal and PII User Stories.....	87
Table 24. Registration Process Web UI Flow.....	94
Table 25. CTP Registration User Stories.....	95
Table 26. Selections for Account Settings.....	97
Table 27. Account User Name and Password User Stories.....	101
Table 28. Favorite Places User Stories.....	104
Table 29. Preferred Modes Places User Stories.....	109
Table 30. Accessible Notification User Stories.....	112
Table 31. Trip Planning Process Flow with Screen Shots.....	114
Table 32. Service Coverage User Stories.....	115
Table 33. Trip Planning Preference Updates User Stories.....	116
Table 34. Pre-populate Mode Preferences User Stories.....	117
Table 35. Pre-populate Trip Location User Stories.....	118
Table 36. Integration with Transit Options User Stories.....	119
Table 37. Contradictory Preference User Story.....	122
Table 38. Explore Mode User Stories.....	123
Table 39. Navigation Event Personas.....	128
Table 40. Traveler Message Events.....	129
Table 41. Enhanced Mobility Traveler Message Events.....	130
Table 42. Coordinator (3 rd Party or companion) Message Events.....	132
Table 43. Indoor / Outdoor User Stories.....	138
Table 44. Rider / Coordinator Request Functional Flow Description.....	147
Table 45. Coordinator View User Stories.....	151
Table 46. PED-X Integration User Story Descriptions.....	153
Table 47. Help and Feedback User Stories.....	158
Table 48. Kiosk Configuration Functions User Story Descriptions.....	159
Table 49. TIH User Story Descriptions.....	160

Table 50. Enhanced Accessibility Features associated with System Requirements.....	163
Table 51. Selected Enhanced Accessibility Feature Capabilities and Limitations.....	165
Table 52. Enhanced Accessibility Feature User Stories	166
Table 53. Internationalization User Stories	169
Table 54. Natural Language Assistant User Story Descriptions.....	171
Table 55. Buttons and Link graphics.....	172
Table 56. CTP Application Iconography.....	173
Table 57. Buffalo All Access User Interfaces and Platforms.....	175
Table 58. User Management Security and Privacy User Story Trace to Requirements.....	176
Table 59. CTP Requirements Traceability to SDD Section	178
Table 60. Survey Data Collection Process	185
Table 61. Performance Metrics collected from Surveys	190
Table 62. Performance Metrics related to CTP User Experience and Trip Data	196
Table 63. Performance Metrics related to NFTA PAL Data.....	200
Table 64. Performance Metrics Related to SDS and HDS Trip and Operation Data	200
Table 65. Performance Metrics to rate overall System.....	201
Table 66. PMD Requirements Traceability to SDD Section	207
Table 67. List of Acronyms.....	213

List of Figures

Figure 1. Buffalo Niagara Medical Campus relative to the neighborhoods of focus: Allentown, the Fruit Belt, and Masten Park	2
Figure 2. Components the Buffalo, NY ITS4US System	3
Figure 3. Buffalo Deployment Project Context Diagram.....	5
Figure 4. Complete Trip Platform Subsystem.....	8
Figure 5. Proposed Service Area for the Community Shuttle.....	12
Figure 6. Community Shuttle SDS System	13
Figure 7. Community Shuttle HDS System	14
Figure 8. Smart Infrastructure Complete Trip Examples	15
Figure 9. Indoor Navigation Module	16
Figure 10. Pedestrian Signal Request (PED-X) Module	16
Figure 11. Performance Measurement Dashboard Subsystem	18
Figure 12. PBI Workflow and Agile Sprint Cycle	20
Figure 13. System Components Development Schedule	21
Figure 14. Screenshot of Requirements Traceability Matrix	25
Figure 15. ADASTEC's flowride.ai Autonomous Driving Stack	30
Figure 16. NFTA On-Demand Vehicle with Tablet	42
Figure 17. Reservation-Scheduling-Dispatch Architecture and Interfaces.....	43
Figure 18. CXApp Content Management Home Page	53
Figure 19. Map Manager Tool with Path and Location Information.....	57
Figure 20. Map Editor Tool viewing Structural Map Layers	58
Figure 21. Map Styler Tool Viewing Saved Map Style Page	59

Figure 22. Geofence Manager Viewing Public Areas in the Facility.....	60
Figure 23. Miovision Intersection Hardware	61
Figure 24. Example UI of Miovision Implementation at Summer and Best Streets	63
Figure 25. Telemetry Data (Signal View) from Ellicott and High Streets	64
Figure 26. Telemetry Data (Timing Diagram) from Ellicott and High Streets.....	65
Figure 27: Measuring Pole Dimensions for Ellicott and High Northwest Corner <i>source: NFTA / BNMC</i>	66
Figure 28: View of the beacon housing on each of the intersection poles <i>source: NFTA/BNMC</i> ..	66
Figure 29. Transportation Information Hub -- RedyRef Empire 3.0.....	68
Figure 30. Kiosk Software Architecture	69
Figure 31. Engage Lockdown browser – General Settings.....	70
Figure 32. Engage -- Lockdown browser – Session Mode	71
Figure 33. Map of the Sidewalk Data Collection Area at BNMC	73
Figure 34. User Management Functional Flow -- high level <i>Source: NFTA</i>	86
Figure 35. Buffalo All Access App Splash Screen <i>Source: NFTA</i>	86
Figure 36. Global User Management Flow Diagram Legend for Figures 25-27	88
Figure 37. Login Process Flow	90
Figure 38. Logout Process Functional Flow	91
Figure 39. Account Troubleshooting Functional Flow.....	92
Figure 40. Forget Password? Flow Process (from login page).....	93
Figure 41. Profile and Settings Web Page	96
Figure 42. Account Setting - User Name and Contact Information Web UI	99
Figure 43. Account Setting: Delete Account Web UI	100
Figure 44. User Settings -- Password Web UI.....	100
Figure 45. Search to Select From / To Locations	105
Figure 46. Save or Cancel Request to Add Address	105
Figure 47. Favorite Locations and Favorite Trips	107
Figure 48. Account Settings -- Trip Preferences Web UI.....	108
Figure 49. Account Settings – Notification Preference Type Web UI	110
Figure 50. Account Setting Accessibility Web UI.....	111
Figure 51. Account Setting Accessibility Web UI (with Spanish Language Set)	111
Figure 52. Access to PAL Reservations	121
Figure 53. Explore Mode on Home Page (user story #1).....	125
Figure 54. Summon On-demand (HDS) Shuttle (user story #2)	126
Figure 55. Summon Shuttle Not in Service (user story #2).....	126
Figure 56. NFTA Fixed Route (user story #3).....	127
Figure 57. Traveler Notifications and Wayfinding Messages	128
Figure 58. Example of Coordinator Notifications.....	135
Figure 59: GPS Signal Warning	137
Figure 60. Toggle between Outdoor and Indoor User Interface	142
Figure 61. Rider and Coordinator Request Functional Flow	146
Figure 62. Pending Request to Add Coordinator.....	147
Figure 63. Email Message Requesting Coordinator.....	147

Figure 64. Screen Prompting Coordinator to Login or Register for an Account.....	148
Figure 65. Coordinator Invitation Request.....	148
Figure 66. Coordinator Account Setting Screen.....	149
Figure 67. Coordinator View of List of Dependents.....	149
Figure 68. Coordinator View of Traveler Trips.....	150
Figure 69. Map View with Option to Request Crosswalk Signal	154
Figure 70. Navigation View with Option to Request Crosswalk Signal	155
Figure 71. Help Selection and Support	156
Figure 72. Feedback Form and Categories List (web view).....	157
Figure 73. Screenshot of Splash Page for TIH and Guest Mode.....	162
Figure 74. Enhanced Accessibility Settings in Web UI.....	169
Figure 75. Natural Language Assistant	171
Figure 76. Performance Measure Dashboard Subsystem	183
Figure 77. Screenshot of Baseline Survey Admin Page	186
Figure 78. Web User Interface of Baseline Survey – example question.....	187
Figure 79. Web User Interface of Baseline Survey – completion message	187
Figure 80. Mobile User Interface of Baseline Survey (via Chrome and Safari from iPhone).....	188
Figure 81. Screenshot of Survey Monkey Admin Page.....	188
Figure 82. Survey Data Access Flow	193
Figure 83. Survey Data Processing Flow	193
Figure 84. Examples of PM Visualization for Survey Data.....	195
Figure 85. CTP Data Access/Processing Flow.....	199
Figure 86. Screenshot of R Studio	202
Figure 87. Performance Metrics Data Sources and Data Processing Flow.....	203
Figure 88. Example of PM Table	204
Figure 89. Example of Main Performance Measurement Type Dropdown Menu	204
Figure 90. Example of Customization Dropdown Menu.....	205
Figure 91. Shiny Dashboard Examples.....	206
Figure 92. Screenshot of Shinyapps.io Admin Page.....	207

1 Introduction

The System Design Document (SDD) is a detailed design of all sub-systems and system components of the Buffalo, NY ITS4US System. This document follows the guidance provided in the IEEE Standard 1016-2009 (IEEE Recommended Practice for Software Design Descriptions). The SDD is complemented by the Interface Control Document (ICD) (FHWA-JPO-22-981) [1], which details the information flows and associated interface specifications, network and communications protocols and information standards used by the interface when available.

The SDD defines the complete traceability from requirements to system design and describes the process by which traceability will be maintained throughout the life of the project. This traceability is provided through references to other documentation, such as the System Requirements Specification (SyRS) (FHWA-JPO-21-883) [2] and ICD. Every requirement trace to at least one design element, but in some cases traces to many design elements.

1.1 Intended Audience

This document is intended to provide guidance to agencies looking to deploy a system similar to the Buffalo, NY ITS4US System. Potential audiences include system designers working in collaboration with peer public agencies, the United States Department of Transportation (USDOT) and private agencies (e.g., medical and academic campuses). As the guiding design document, the project team will also reference this document during the development process.

1.2 Project Background

Buffalo is moving toward a sustainable future for all, incorporating actions in the community, government, and private entities in the area. Providing access to the City's underserved populations to jobs and healthcare is the primary motivation for all the regional partners involved in this deployment. A lack of public transportation that adequately addresses "first/last mile" challenges is a major problem for community mobility, especially for people with disabilities. This often leads to compromised healthcare (e.g., rescheduled or missed appointments, delayed care) and/or dependence on paratransit service, which is much costlier for transit agencies and can be burdensome for riders. The Complete Trip Deployment concept proposed here directly addresses these concerns by:

1. **Focusing on providing transit access to healthcare and jobs** to underserved residents or persons and allowing them to share in the economic development in downtown Buffalo.
2. **Putting technology to work in support of accessible transportation**, bringing leading edge researchers in accessible transportation, transit, and connected automation to solve a transportation need.

3. **By developing a scalable model** for considering accessibility and universal design in transportation technology projects.

The deployment location is targeted around the downtown Buffalo area with a focus on travel to and from the Buffalo Niagara Medical Campus (BNMC). The deployment includes the 120-acre Medical Campus and surrounding neighborhoods with a focus on three nearby neighborhoods (Fruit Belt, Masten Park, and Allentown) with underserved populations—see **Figure 1**.

More than 16,000 people work or study at the BNMC and more than 1.5 million visit each year for health care and other services, generating significant transportation demand for the area, its visitors, and its employees. The demographics of the surrounding neighborhoods (see **Table 1**) are emblematic of a broader socioeconomic and racial divide in Buffalo along Main Street, which this deployment seeks to bridge. In Allentown (west of Main Street), the percentage of traditionally underserved populations is significantly less than other neighborhoods east of Main Street, namely Fruit Belt and Masten Park. **Table 1** indicates percentages for Allentown that are far below average of the Metropolitan Statistical Area (MSA) in many categories, and percentages for Fruit Belt and Masten Park that are above average for the MSA.



Figure 1. Buffalo Niagara Medical Campus relative to the neighborhoods of focus: Allentown, the Fruit Belt, and Masten Park

Source: Buffalo, NY ITS4US

While the Allentown neighborhood is not characterized by underserved populations, it contains a high concentration of transit service and commercial activity, including health care offices. Allentown hosts several significant bus lines (including the #20-Elmwood, the #25-Delaware, the #11-Colvin, and the #8-Main) that connect the BNMC and Downtown Buffalo with neighborhoods to the north, carrying over 10,500 riders on an average weekday.

Table 1. Demographics of Targeted Neighborhoods

Geography (American Census Survey (ACS) 2018 tracts)	Percent 0- vehicle households	Percent population 65+	Percent poverty	Percent Black	Percent Hispanic / Latino	Percent limited English ability	Percent income <\$25k	Percent with a disability (18 to 65 years old)	Percent veteran	Percent commute by transit	Total households	Total population
Fruit Belt	47.0%	21.9%	28.0%	77.0%	8.9%	4.2%	39.5%	20.0%	6.7%	16.1%	976	2,435
Allentown	18.4%	6.2%	28.8%	7.2%	6.6%	0.0%	17.4%	8.0%	7.8%	4.8%	1978	3,143
Masten Park	35.0%	18.5%	34.7%	89.7%	3.1%	2.9%	38.9%	15.2%	6.6%	11.7%	1496	3,208
Buffalo MSA	36.6%	12.0%	31.1%	36.6%	11.6%	4.8%	30.7%	9.7%	5.7%	11.5%	11,0701	255,423

U.S. Department of Transportation
Office of the Assistant Secretary for Research and Technology
Intelligent Transportation System Joint Program Office

BNMC sits adjacent to the Fruit Belt neighborhood, which has a poverty rate of 28%, and 47% zero-car households. Several community and social services are found within the neighborhood, which is relatively close to the wider array of services and jobs offered in downtown Buffalo. Several bus lines serve the area, although headways are relatively infrequent, ranging between half hour and one hour. Access to dispersed jobs in the suburbs via public transportation tends to be difficult. Although accessible to the Fruit Belt residents, the Niagara Frontier Transportation Authority (NFTA) Metro Rail station is 0.25 – 0.75 miles away, a distance that becomes amplified during the winter and for travelers with physical difficulties. While BNMC continues to improve pedestrian accessibility, sidewalk quality and intersection crossings are still a challenge for wheelchair users and users with audible or visual impairments. The Fruit Belt struggles with aging infrastructure and infrastructure management issues, issues that have been consistently noted in community forums over the years.

This project seeks to improve transportation access for this population and utilize an innovative approach to find the most effective approaches for supporting trip-making. BNMC's user population makes it an ideal location to test accessibility designs for safety and usability. The Complete Trip Deployment in Buffalo focuses on two primary trip purposes: employee-related travel and patient/visitor travel to the campus from the three neighborhoods.

1.3 Project Scope

The project seeks to deploy an integrated suite of technologies chosen to address identified needs of users and gaps within the systems and services provided. These technologies include a Complete Trip Platform (CTP), Community Shuttle (CS), Smart Infrastructure and Performance Measure Dashboard (PMD)—see **Figure 2**. A more detailed explanation of the system is provided in **Section 2**.

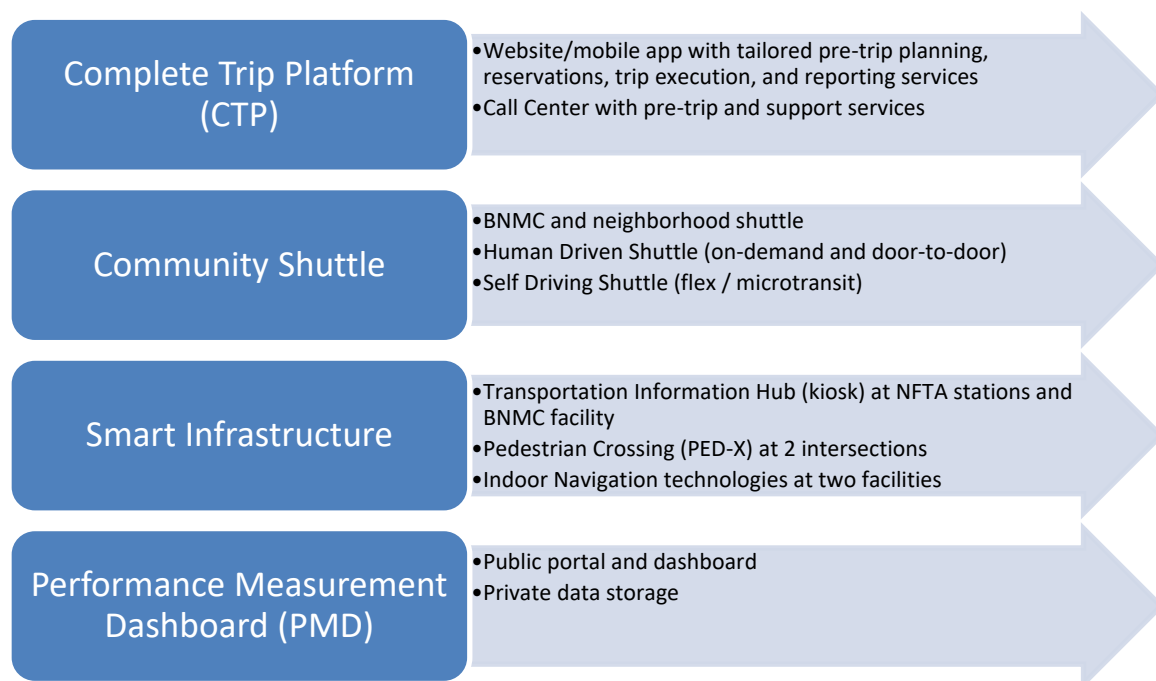


Figure 2. Components of the Buffalo, NY ITS4US System

Source: Buffalo, NY ITS4US

U.S. Department of Transportation
Office of the Assistant Secretary for Research and Technology
Intelligent Transportation System Joint Program Office

1.4 Purpose of the Design Document

The SDD details the design of the sub-systems and system components developed during the deployment of the Buffalo, NY ITS4US Deployment project. In addition, the SDD provides traceability from requirements to system elements including developed (and detailed in this document), acquired and existing functionality, data, operational and other specifications documented in the SyRS.

The Buffalo, NY ITS4US system was designed to address all needs identified in the Concept of Operations (ConOps) (FHWA-JPO-21-860) [3], satisfy all the requirements listed in the SyRS, and follow the architecture detailed in the System Architecture Design (SAD) (FHWA-JPO-22-981) [4].

1.5 Branded Naming Conventions

This document uses the technical names for subsystems and systems. Equivalent public-facing brand names are as follows:

- Niagara Frontier Transportation Authority (NFTA) ITS4US or Buffalo NY ITS4US project will be branded as the Buffalo All Access project
- Complete Trip Platform (CTP) will be branded as the Buffalo All Access App
- Human-Driven Shuttle (HDS) will be branded as the Buffalo All Access On-demand Community Shuttle Service (or On-demand service)
- Self-Driving Shuttle (SDS) will be branded as Buffalo All Access Automated Community Shuttle

2 System Description

The following subsections provide a high-level overview of the full scope of the system. This information is consistent with the SAD.

2.1 Physical System Overview

This section provides a high-level description of the four subsystems of the Buffalo, NY ITS4US system. The following system of interest (SOI) diagrams are updated versions of the Context Diagrams described in the ConOps and SyRS.

The high-level context diagram which includes the four subsystems (Smart Infrastructure, CTP, CS, and PMD) are shown in **Figure 3**.

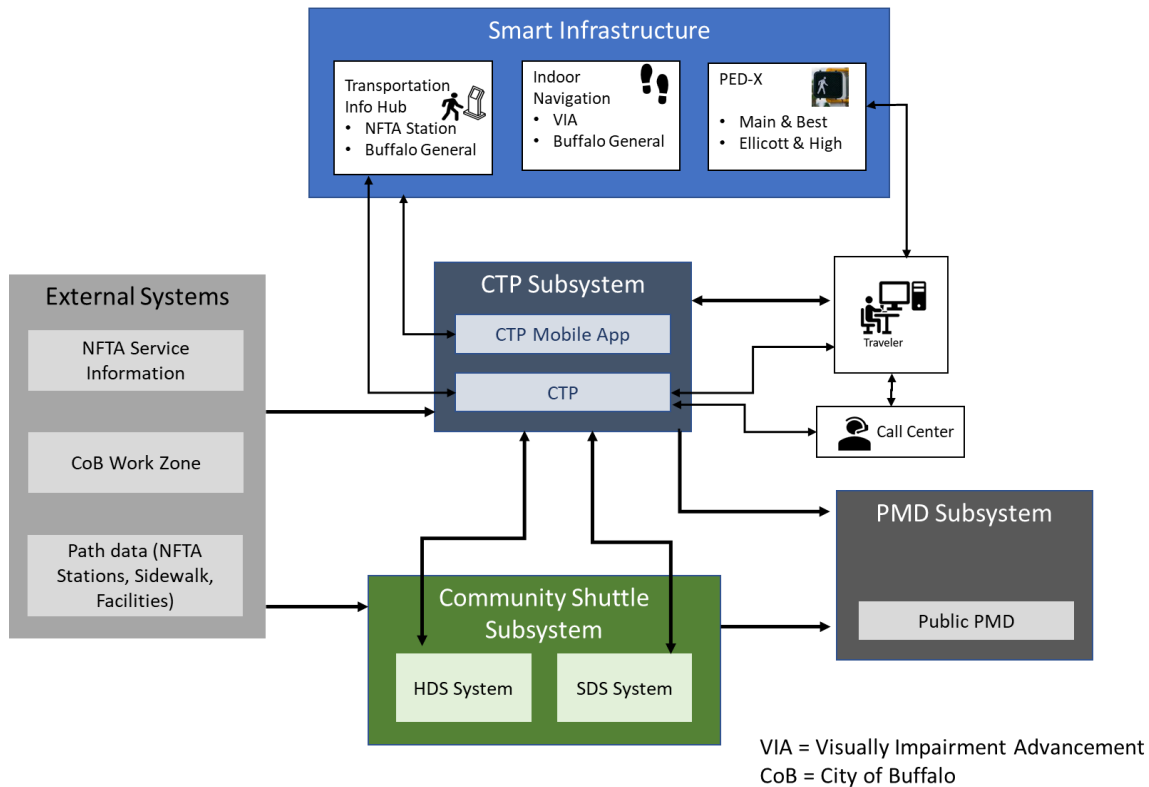


Figure 3. Buffalo Deployment Project Context Diagram

Source: Buffalo, NY ITS4US (2024)

Some of the details in the Concept Context Diagram were refined from the Phase 1 system of interest to Phase 2. Justification for these changes will be documented in the Phase 2 ConOps. The detailed context diagrams for each subsystem and smart infrastructure components are

described in the following four sections (each corresponding to one of the four subsystems). The subsystem and module depictions mirror the details needed to frame the architecture. Where detail is needed, for example, the CTP, the subsystem functions and flows are well documented. Where subsystems are deployed as a service, pre-existing systems, or turn-key, fewer details are needed (e.g., Self-Driving Shuttle, SDS, and Human-Driven Shuttle, HDS).

The following subsections describe the key components of the SOI. The detailed diagrams (**Figure 4** through **Figure 11**) include information flows within and between subsystems and functions. A complete set of these information flows (tagged in the diagrams as [I-n] where n is a number between 1 and 23, is listed in **Table 2**. The table includes the information flow index, name, direction between source and destination, and target source and destination subsystem or component.

Table 2. Information Flows in System of Interest

Information Flow #	Information Flow Name	Information Flow Description
I-1	UI Mobile App APIs	APIs and web services provisioned between the CTP mobile app and server
I-2	UI Web	APIs and web services provisioned to a thin client such as the web or TIH
I-3	Service information	NFTA fixed route GTFS, GTFS-realtime
I-4	BNMC Facility Map Update	BNMC indoor facility pathways
I-5	NFTA Map Update	NFTA station pathways
I-6	(1) SDS Booking transactions (2) SDS Service Information	(1) Reservations, scheduling and status information to book a SDS service. (2) SDS Service information (GTFS-realtime)
I-7	(1) HDS Booking transactions (2) HDS Service Information	(1) Reservations, scheduling and status information to book a HDS service (2) HDS Service information (GTFS-realtime)
I-8	PED-X request transactions	(1) Information exchange between the CTP mobile app (via CTP back office) and Traffic signal gateway to request actuation of the pedestrian crossing (2) Location of PED-X enabled crossing
I-9	BNMC Facility waypoint sensor broadcast	Transactions between mobile app native comm and indoor navigation waypoint sensors (e.g., beacons)
I-10	CTP operational log	Operational and performance data monitored and collected by the CTP
I-11	PED-X operational log	A summary of the requests and their results.
I-12	SDS operational log	Operational and performance information from SDS
I-13	HDS operational log	Operational and performance information from HDS
I-14	Performance measures	Performance Measurement results

Information Flow #	Information Flow Name	Information Flow Description
I-15	Map and graph services	APIs and web services that present performance measures
I-16	Direct access data files	APIs / links to access public data
I-18	External Data (NFTA Performance Data and OSM / path / map updates)	OSM / path / map updates: Map, sidewalk, indoor facility and asset data and updates from external sources NFTA Performance Data: Summary data for fixed route and PAL on time performance and other performance metrics
I-21	Communications between support personnel	Communications to support travelers on the CS SDS. This is a voice interface (e.g., intercom, phone) <i>Note: there is no equivalent interface associated with this information flow.</i>
I-22	Signal Control Exchange	Message from the Traffic signal gateway to a local traffic signal controller. The information flow forwards a request made by a traveler to request signal actuation.
I-23	City of Buffalo (CoB) PROW Work Zone (WZ)	Update of work zone information associated with the public right of way developed and disseminated by the CoB.

2.2 List of Subsystems and Components

The following subsections provide a description of the subsystems and components that comprise the Buffalo, NY ITS4US system.

2.2.1 Complete Trip Platform Subsystem

The CTP provides trip planning and travel functions for travelers. The tool is available for registered and non-registered account users. Account holders will be able to interact (e.g., book a trip reservation, check estimated time of arrival (ETA)) with other mobility partners for which they have accounts (e.g., NFTA paratransit and microtransit shuttle), personalize their trip preferences and customize hands-off turn-by-turn notifications, and access wayfinding assets using components specified in the smart infrastructure subsystem. Non-registered travelers will be able to use the trip planning and travel tools to view accessible paths, transit services and alerts about asset status (e.g., elevator / escalator operations) when available.

The CTP concept was refined from the Phase 1 ConOps, with the functions being described below. The context diagram for the CTP is shown in **Figure 4**, where:

- 1) subsystems are shown in blue boxes and boxes with icons;
- 2) functions depicted in white boxes contained in the blue boxes;

- 3) terminators, which are source or destinations (internal or external subsystems/systems) of the data, are shown in various colored boxes and ovals as designated in the legend;
- and
- 4) information flows as either green line (designated as internal interfaces) or orange lines (designated as external interfaces) tagged with information flow indices (e.g., I-1). These are described in **Table 2**.

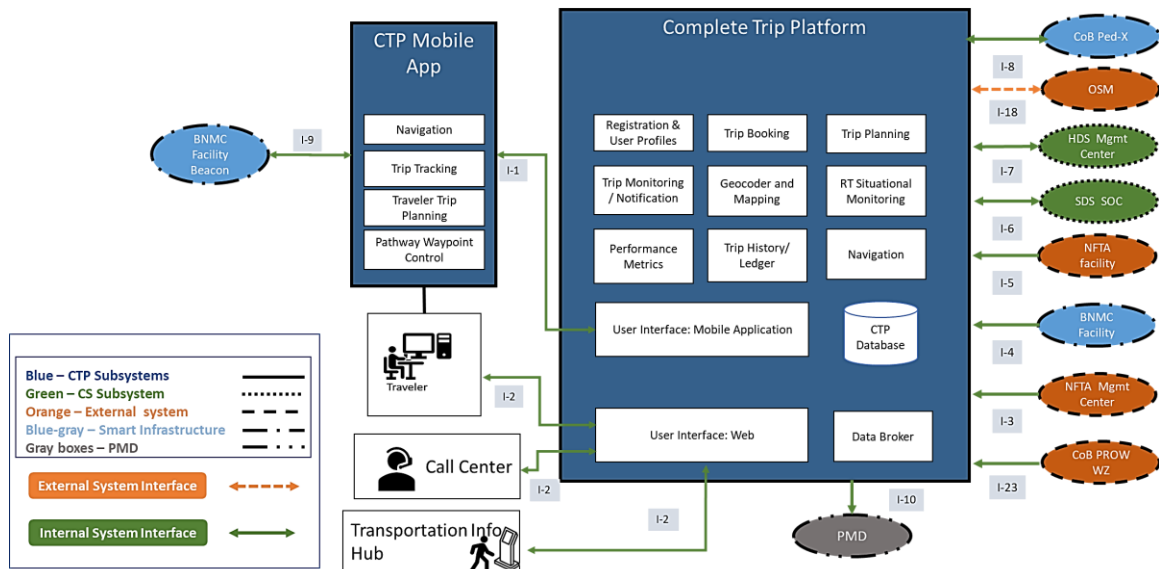


Figure 4. Complete Trip Platform Subsystem
Source: Buffalo, NY ITS4US (2024)

In general, the processing for the CTP is performed on the platform (server side). However, if the mobile app cannot exchange messages with the platform, some functions are replicated to operate independently of the platform. In addition, the app includes other native functions to communicate with infrastructure equipment (indoor navigation) deployed as part of the Buffalo ITS4US project. Details of these will be included in the Agile user story designs and acceptance criteria.

The CTP Subsystem provides the following functions which correspond to those depicted within the white boxes shown in **Figure 4**.

Registration & User Profiles (CTP)

The user profile function provides users with a tool to register and customize their preferences for trip types based on user event triggers (including navigation, wayfinding, and alert notifications), sensory alerts, trip and transition accommodations, in addition to shortest walking distance, fewest transfers, maximum walking distance, crossing zones, indoor navigation preferences, preferred mobility options, and other wayfinding technology interoperation. The user profile function also enables the user to opt-in to share information among other systems such as CS system or other facility systems. The user profile function allows the user to create, update, or delete these preferences and other devices that are associated with the profile. The profile information is protected and preserved under the Personally Identifiable Information (PII) policies.

Trip Planning (CTP) and Traveler Trip Planning (CTP Mobile App)

The trip planning function enables a user to plan a complete trip from origin to destination, as well as the ability to update mobility options/service providers, trigger types, and other preferences based on the current trip. The trip planning function provides the user with the ability to review the turn-by-turn directions of a trip prior to traveling. Based on user preferences, the turn-by-turn directions may provision messages to indoor and outdoor wayfinding assets such as pedestrian crossing requests, and “you are here” locations.

Trip Booking (CTP)

The trip booking function enables a user to reserve and book a trip with the CS service provider requiring pre-booking. Only registered, authorized users are eligible to use these services. The booking function depends on the mobility service (door to door vs. microtransit). The datasets sent to the CS module include booking (and return booking), services required (e.g., companion or service animal, wheelchair, wheelchair type), cancellation, request for arrival time (and delay) messages, payment rules, and availability. The booking function will receive confirmation and other booking details from the service provider, alert the user as needed (based on user preference), and store the information for user lookup.

Geocoder and Mapping (CTP)

The Geocoder and Mapping function is two-fold: (1) collects and generates navigable graphs to support the trip planner based on fixed pathways (including existing maps such as the Open Street Map (OSM)) and their dynamic conditions (acquired through the real-time situation monitoring function), (2) converts address and landmark locations to latitude and longitude.

Navigation (CTP Mobile App)

The navigation function generates a time / spatial graph that may be downloaded into a mobile app that can be used by the native app location awareness functions (including automated location tracking, wrong-side-of-the-street detection, geofencing, and activity recognition) to trigger messages with turn-by-turn directions including indoor navigation features such as stairs, elevators, and escalators. The navigation function also includes information on interfacing with third party communications media to exchange information on wayfinding (such as messages about pathway and walk requests).

Note: real-time notifications are triggered by events that are either time- or location-based and are not associated directly with navigation (e.g., bus time of arrival).

Trip Monitoring and Notifications (CTP)

The trip monitoring and notifications function continually monitors each user who opts-in to tracking and monitoring their current location, revisits trip itineraries based on user trip preferences (provide re-routing when obstacles are detected), and issues triggers based on user notification preferences. The alerts and event messages are sent to the device(s) designated by their profile.

Trip Tracking (CTP Mobile App)

The trip tracking function continuously monitors the user to determine their current location. If they opt not to share their location, the location is not collected and shared with the CTP. The function is similar to the trip monitoring and notifications function of the CTP with the added functionality that the tracking will trigger an event such as a request to the personal pedestrian safety (PED-X) or path waypoint control functions.

Real-time Situational Monitoring (CTP)

The real-time situational monitoring function collects and assesses real-time information acquired from third party sources such as traffic, weather, transit operations, shuttle operations, and other systems that monitor asset and infrastructure conditions and states. This function updates the fixed pathway graphs (i.e., sidewalk, indoor pathways).

Trip History / Ledger (CTP)

The trip history and ledger function stores information about user trip history, as well as logs all transactions and information received by the CTP subsystem.

Performance Metrics (CTP)

The performance metrics function provides CTP performance metrics on system utilization and user selections. These metrics include Google Analytics (e.g., time viewing screen, number of hits on screen, etc.). Additional measures will include preference selections, trip types, and fidelity of using trip plans while traveling. The data is fed to the Performance Measurement Dashboard (PMD) to meet the Phase 1 Performance Measurement and Evaluation Support Plan (PMESP1) (FHWA-JPO-21-878) [5] and Phase 2 Performance Measurement and Evaluation Support Plan (PMESP2) (FHWA-JPO-21-878) [6] requirements. Data are summarized or aggregated to remove PII from the measures prior to being shared with downstream systems.

Data Broker (CTP)

The data broker provides a function to exchange services, methods, and interfaces with other subsystems and external systems in a safe environment. The functionality to ingest, quality check, process, and route the data to the appropriate function exists. Among the existing interfaces include General Transit Feed Specification (GTFS), GTFS-realtime, and GTFS Flex.

User Interfaces: Web (CTP)

The user interface (UI) functions provide universal access to users through multiple channels (including data and call center) and text (web based, font selection, and sizing). The functions that are accessible include the following trip planning functions:

- Registering and updating user profile.
- Selecting and setting preferences for trip planning.
- Reviewing trip history.

User Interface: Mobile Application (CTP)

In addition to similar functionality as the Web UI, the Mobile Application UI functions include the ability of a user to download and synchronize trip planning functions, as well provision the following:

- Real-time notifications and events based on situational awareness when the mobile app is on-line.
- Geo-fencing calculations and stored triggers when the mobile app is off-line (see navigation function).
- Communications between traveler mobile app and indoor / outdoor wayfinding devices.

2.2.2 Community Shuttle Subsystem

The CS Subsystem will provide on-demand mobility services within the Fruit Belt, Masten Park and Allentown neighborhoods and BNMC. Although they share similar interfaces to external components/subsystems, the CS consists of two service types – SDS and HDS services, each designated as a system within this architecture description. The two systems include:

- **SDS System** is composed of one autonomous vehicle and the shuttle operations center (SOC). The SDS will provide microtransit service on a pre-defined set of road segments that satisfy the Operational Design Domain (ODD) of the SDS.
- **HDS System** is composed of human driven, wheelchair accessible vehicles, dispatch, and scheduling software (from the NFTA paratransit fleet) and reservation services from the NFTA PAL Direct software system. The HDS will provide door-to-door, on-demand service similar to the current PAL paratransit service, but available for all registered CTP participants.

The inclusion of HDS and SDS provides options for travelers. In addition, the two types of services:

- 1) Allow the project to contrast the utility and acceptance of shared autonomous vehicles (SAV) vis-à-vis human-driven vehicles.
- 2) Provide insight into the business case for using SAVs within the context of a CS system and especially for underserved populations.
- 3) Offer an educational opportunity for the community to learn about SAVs thereby increasing public acceptance of, and confidence in, the technology over time.
- 4) Lower the risk of the CS element of the project, given some measure of skepticism that still exists among a sizeable portion of our society toward SAVs, along with the current regulatory environment governing SAVs which is still restrictive of some aspects of SAV operations.

The envisioned service area for the proposed CS fleet is shown in **Figure 5**.

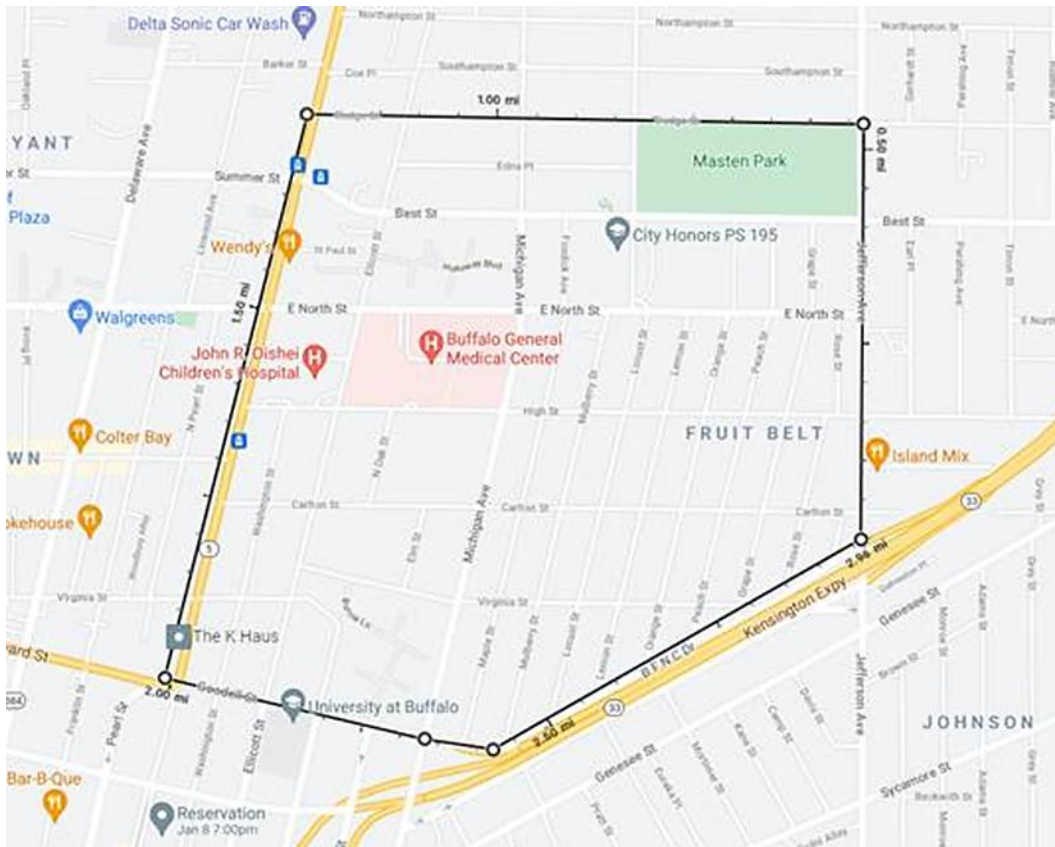


Figure 5. Proposed Service Area for the Community Shuttle

Source: Buffalo, NY ITS4US (2024)

Registered CTP users are able to summon the shuttle through the CTP. The operating subsystems of these shuttles are described in the following sections.

2.2.2.1 CS SDS System

The SDS System is composed of the Autonomous Vehicle and SOC components. The shuttle will operate on an on-demand schedule constrained to travel over a pre-defined route (i.e., a set of streets that satisfy the SDS ODD) and pre-designated pick-up/drop-off locations. The SDS SOC will receive all calls for services and will track the status of each vehicle in the SDS fleet. The SDS system will be procured as a turn-key service exchanging prescribed information flows between the SDS services and SOI subsystems (e.g., PMD, CTP) and external systems (e.g., NITTEC).

Human actors include the SDS's Shuttle Operations personnel who will manage the SOC and manage incidents, Call Center Customer Support (who provide direct support to travelers) and SDS operators / stewards (who will be trained by the SDS vendor).

Figure 6 provides a representation of the SDS information flows with other systems and subsystems. Internal system interfaces are indicated by green lines and oval identification numbers, and external system interfaces are represented with orange lines and oval identification numbers. Black lines represent voice calls.

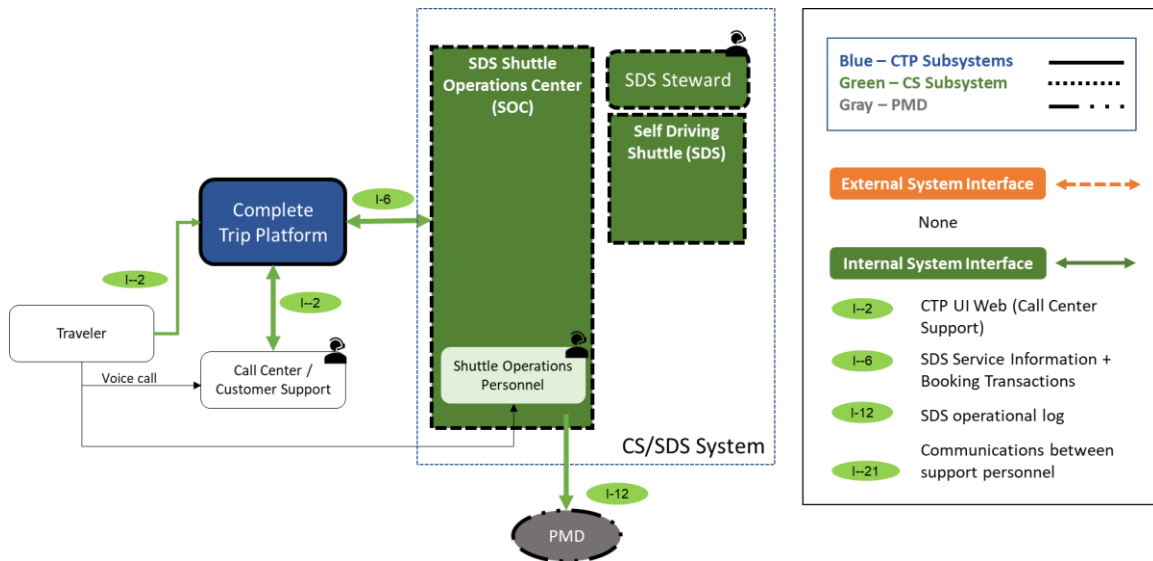


Figure 6. Community Shuttle SDS System

Source: Buffalo, NY ITS4US (2024)

Note that the indexed information flows are described in **Table 2**.

2.2.2.2 CS HDS System

The HDS System (**Figure 7**) is composed of the NFTA Dispatch and Reservations System, HDS vehicle, and HDS operator. The HDS will use the NFTA PAL dispatch and software services and operate from the NFTA PAL dispatch and operations center. To that end, the major components are interfaces to and from the NFTA PAL Direct system.

The HDS will use an existing NFTA system that already provides the appropriate services / Application Programming Interface (APIs) needed to transact customer booking and mobility services. Note that the indexed information flows are described in **Table 2**.

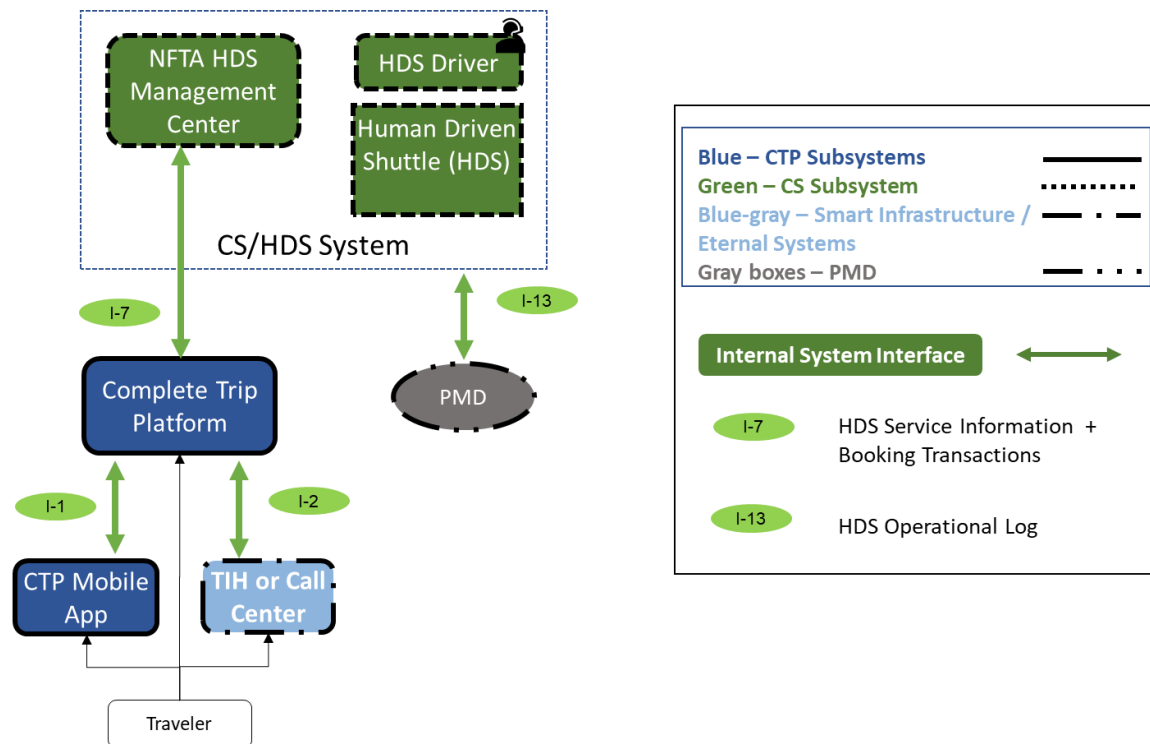


Figure 7. Community Shuttle HDS System

Source: Buffalo, NY ITS4US (2024)

2.2.3 Smart Infrastructure Subsystem

Smart Infrastructure (SI) Subsystem supports personalized wayfinding capabilities for travelers. The technologies (modules) include:

- Transportation Information Hub (TIH) modules
- Indoor Navigation modules
- Pedestrian Intersection Crossing (PED-X) modules

The SI Subsystem provides support technologies for trip planning and wayfinding. The SI will be used for public access to trip planning activities, supplementary sensors to support indoor navigation at building / facilities and Metro rail stations, and broker / gateway services for pedestrians to request pedestrian actuation at selected signalized intersections—Main St. & Best St. and Ellicott St. & High St.

The locations identified for the technology deployments provide a logical traveler journey from arriving at the Metro rail station with a TIH, traveling through a PED-X enabled intersection and proceeding to a facility with indoor navigation capabilities. The two primary complete trip smart infrastructure scenarios are depicted in **Figure 8**.



Figure 8. Smart Infrastructure Complete Trip Examples

Source: Buffalo, NY ITS4US (2024)

2.2.3.1 Transportation Information Hub Module

The TIH provides many of the same trip planning and wayfinding features and information as the CTP. Users can generate a trip plan, save a trip plan, download a plan to their smart phone, request navigation directions and notifications. The TIH will be preloaded with deployed location information and provide detailed information on the offices, centers and platforms in a facility including NFTA station platforms, medical labs, offices and more. The TIH will be configured to provide location-specific information based on the location installed.

Potential interfaces may include audio, three dimensional tactile features, and visual icons (which may vary based on TIH equipment selected during the project). The form factor will be accessible to people with ambulatory, visual and auditory disabilities. The system will be available to people without a mobile device, in multiple languages, and augmented with common icons.

2.2.3.2 Indoor Navigation Module

Using commonly available communications technologies already deployed in mobile handsets (e.g., smartphones), low-cost beacons will be deployed at two indoor spaces to provide indoor navigation (**Figure 9**). These beacons will provide waypoint (location) information for digital wayfinding integrated with the CTP mobile app navigation function. Note that the indexed information flows are described in **Table 2**.

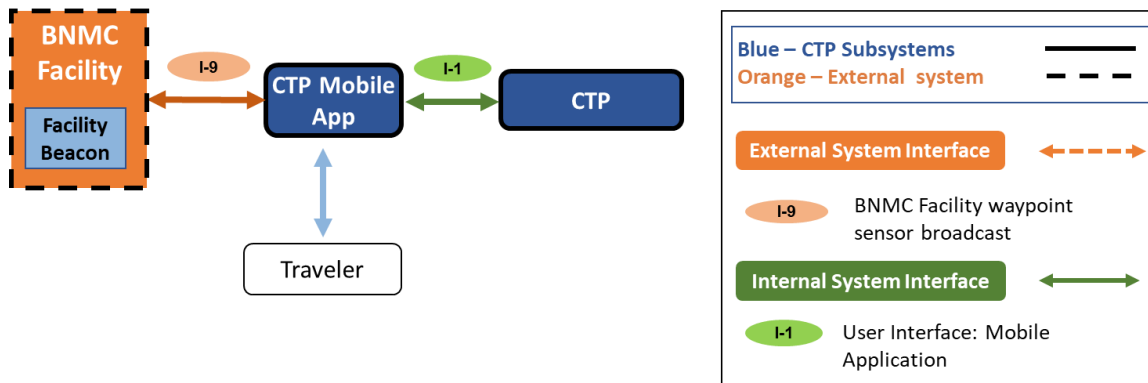


Figure 9. Indoor Navigation Module

Source: Buffalo, NY ITS4US (2024)

2.2.3.3 Pedestrian Signal Crossing Module

The PED-X module will be implemented as a PED-X Gateway. This gateway receives a CTP generated message triggered by their trip plan. The gateway serves as a conduit to authenticate and secure information exchange between the CTP and traffic signal system to actuate the pedestrian request. Information channeled from the pedestrian to the signal system includes the request information.

Note that the Traffic Signal System, using an audible pedestrian signal, will display and announce *walk* and *don't walk* signals at the intersection. This link is not shown in the figure because it is not a physical communications message.

The Pedestrian Signal Crossing module is shown in **Figure 10**. Note that the indexed information flows are described in **Table 2**.

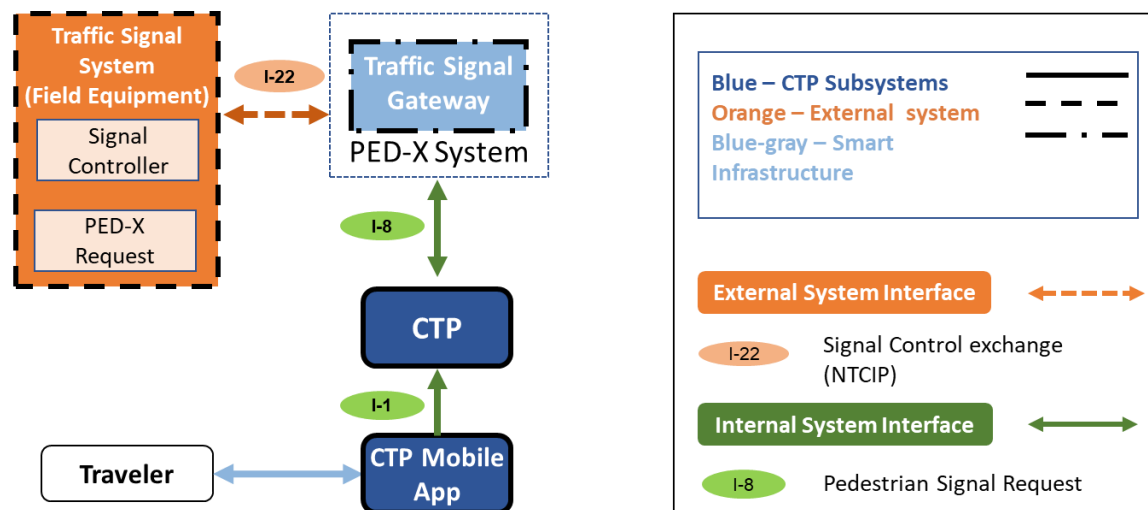


Figure 10. Pedestrian Signal Request (PED-X) Module

Source: Buffalo, NY ITS4US (2024)

2.2.4 Performance Measurement Dashboard Subsystem

The PMD Subsystem monitors, integrates, analyzes, and displays performance measures from other subsystems and external sources. The subsystem includes functions to ingest log files from other subsystems, external data sources, and storage, analytic, and visualization tools to display and access current and historic data sets produced from the integrated system.

The PMD subsystem will be implemented using a three-tier architecture – data (data tier), analytic processes (processing tier), and access / visualization (presentation tier), see **Figure 11**.

Data Tier. The data tier will ingest and store data from the other subsystems and external systems as needed (defined in the Phase 1 PMESP, Phase 1 Data Management Plan (DMP1) (FHWA-JPO-21-868) [7], Phase 2 Data Management Plan (DMP2) (FHWA-JPO-22-973) [8], and subsequent design documents). In addition, metadata management will be included to ensure data integrity as data is ingested and transformed for distribution. The data tier includes the data to be collected from subsystems (including CTP and CS), survey data, metadata and a data catalog for data distribution. The data will be ingested by the PMD and all PII will be removed.

Processing Tier. The processing tier will provide services to curate, transform, parse and query data stores to generate performance and aggregated measures. The processing tier involves data cleaning and transformation that allows for ready to present performance measures in the PMD and post-processed data to a data repository for research use.

Presentation Tier. The presentation tier reflects online PMD with various presentation types including table, charts, and descriptions. Part of the tier involves developing an online data repository that contains the processed data without PII.

The context diagram for the PMD is shown in **Figure 11**, where:

- 1) The PMD subsystem is shown in the box entitled Performance Measurement Dashboard;
- 2) Functions are depicted as rectangles (grey and white) in the PMD tiers;
- 3) Terminators, which are source or destinations, are depicted as databases in the rectangle entitled Performance Datasets; and
- 4) Information flows are depicted as green lines for internal information flows and orange for external information flows. Each information flow is tagged with an index [e.g., I-1]). Note that the indexed information flows are described in **Table 2**.

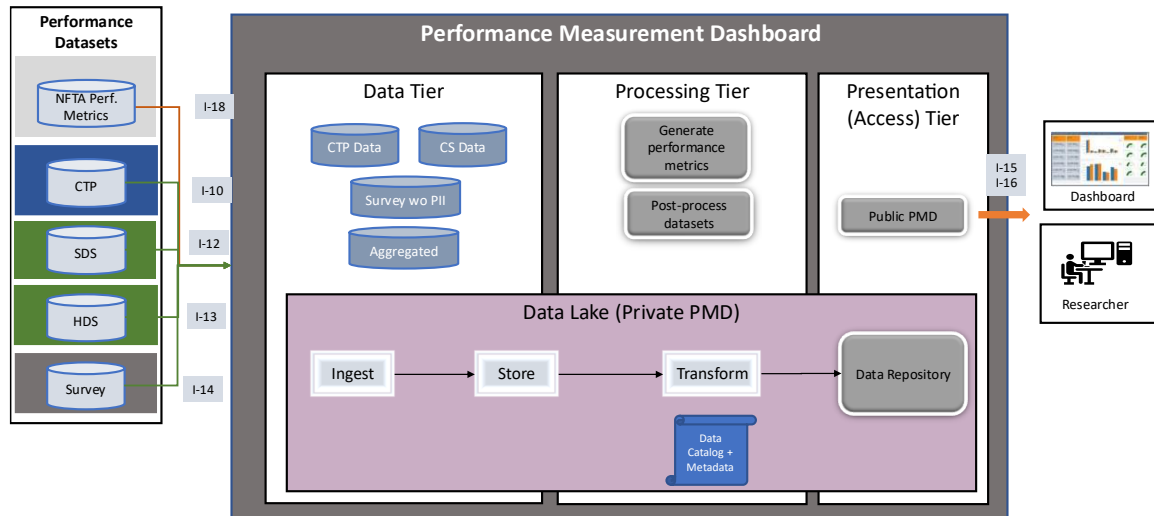


Figure 11. Performance Measurement Dashboard Subsystem
 Source: Buffalo, NY ITS4US (2024)

3 System Design Approach

3.1 Turnkey Systems and Components

As part of this project, only two subsystems will be developed: the CTP and the PMD. **Sections 5 and 6** detail the design approach for each. The following systems/components of the Buffalo, NY ITS4US Deployment will be turnkey or software as a service (SaaS) and are described further in **Section 4**:

- Transportation Information Hub
- Indoor navigation (including the software development kit (SDK))
- Community Shuttle (both the SDS and HDS, and all supporting components)

The Intersection Crossing will leverage the City of Buffalo's (CoB) existing signal system and audible pedestrian systems (APS) and will integrate the Miovision gateway. Since CoB has intersections already outfitted with the equipment, the design elements are restricted to configuration adjustments based on the existing design and installation procedures.

For the components above, the project team will have no design responsibilities beyond hardware and software configuration, which will be detailed in the Comprehensive Installation Plan (CIP) (FHWA-JPO-23-991) [9]. No hardware or software will be developed for these four systems.

These components are proprietary; reference to design information will be provided if not restricted by the vendor agreement.

Procured and leveraged component elements are traced to requirements in **Section 4**. Detailed design elements are proprietary and will not be described in this document.

3.2 Agile Development Process

The CTP and PMD development follow the Agile methodology which is based on iterative and incremental development, where requirements and solutions evolve through collaboration between self-organizing, cross-functional project teams. It promotes adaptive planning, a time-boxed iterative approach, and encourages rapid and flexible response to change.

The CTP and PMD Agile development activities involve the creation, planning and prioritization of epics and related user stories. Each epic covers functions that implement one or more requirements. Each epic is broken down into multiple user stories that drill into the control, procedure, and information flow software code. A user story is assigned one or more sprints in which the *design, code, unit and integration testing* are conducted. Because the process is incremental, the system design is developed incrementally over the course Phase 2 of the project. Each user story is assigned to one or more sprints depending on its size. A user story is used in agile development to describe the functionality of a system from an end user's

perspective. In relation to system design, user stories can be used to convey the requirements and expected behavior of the system. They help in understanding what the users need and how they will interact with the system. Some user stories are directly related to a system requirement and include acceptance criteria that define the conditions that must be met to achieve this requirement as well as dependencies, or relationships between different components or tasks that determine the order or sequencing of events, where appropriate. Other user stories in agile development, however, are not directly tied to a system requirement but are included to provide added value to the end user or to enhance the overall user experience. These user stories often focus on aspects such as usability or optimizing performance which might not be directly specified in the system requirements but enhance the system as a whole.

The Agile approach starts with developing a framework composed of epics and associated requirements (functions and integration activities). The Agile process and Product Backlog Items (PBI) are presented in **Figure 12**, and are described below.

Pre-Dev Process: Epics define the high-level design of the software. These are then decomposed into detailed flow charts, with detailed stories and dependencies identified and staged for development. This occurs during the Agile grooming process. The grooming process will identify not only the flow, but also include UI and experience design elements as well. The product owner (PO) reviews the grooming / design discussions and approves the user story (ticket) for deployment during the sprint.

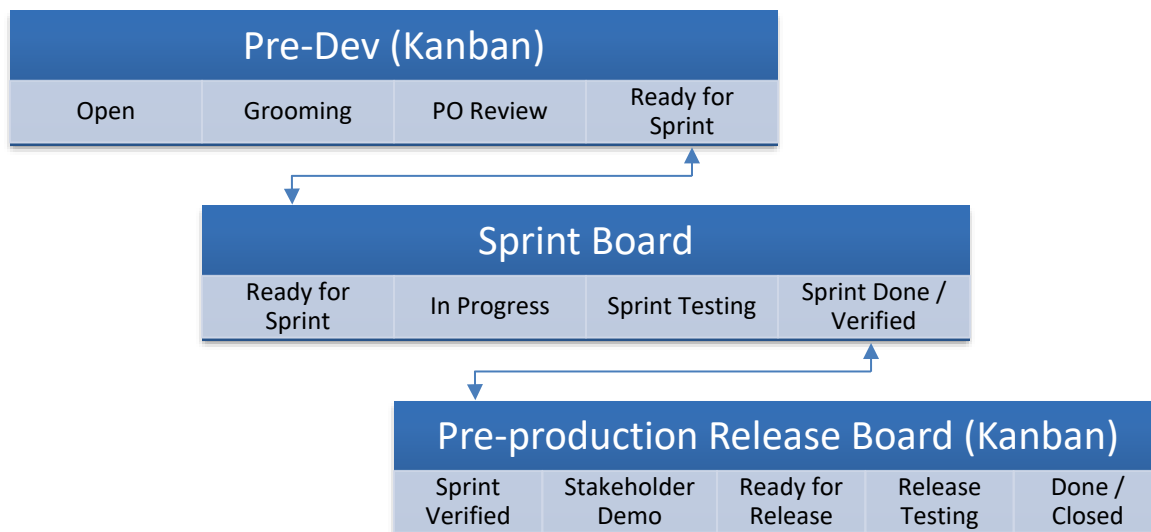


Figure 12. PBI Workflow and Agile Sprint Cycle

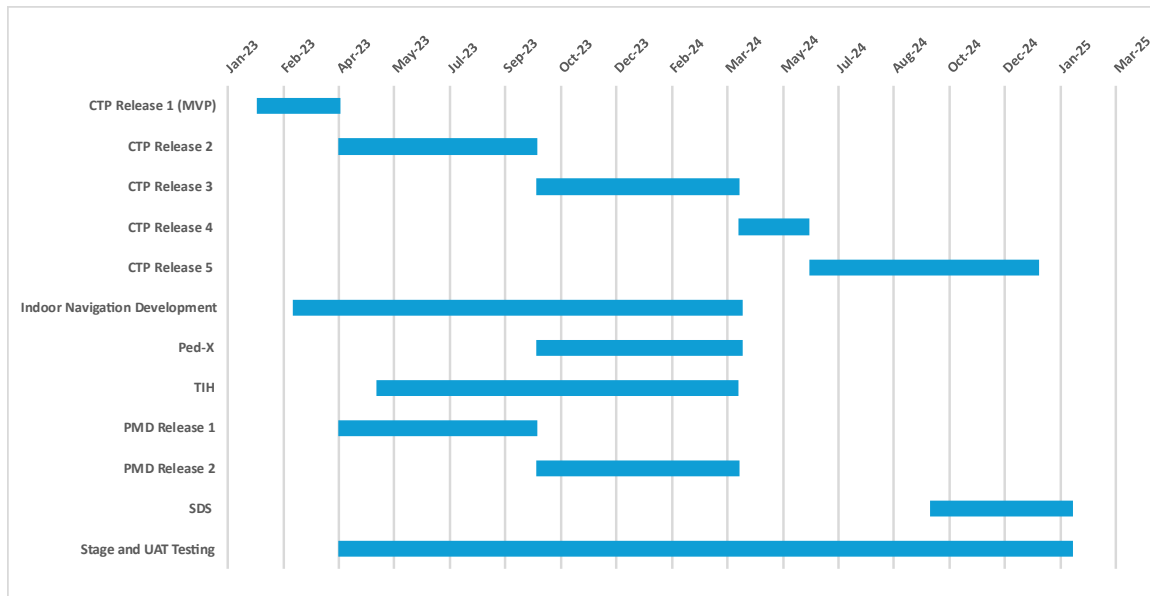
Source: Buffalo, NY ITS4US (2024)

Each ticket is assigned a priority level, see **Table 3**, which is used to establish a backlog (detailed in **Section 5** for CTP and **Section 6** for the PMD) of items (user stories) ready for intake. This backlog is used to plan the sprints and create a roadmap for achieving each release for the CTP and PMD.

Table 3. Priority of Backlog Items

P1 - Critical Ticket	P2 - High Priority Ticket	P3 - Medium Priority Ticket	P4 - Normal Priority Ticket
System is not responding or System outage. Unscheduled downtime.	Major feature or functionality within the system is not working. Causing a critical disruption for users. Must be fixed immediately.	Key defect or functionality that should be embedded into the Active Sprint to be worked and completed before the sprint end date. These are the tickets that were not part of the sprint planning meeting but were identified after the sprint started and must be completed before the sprint end date.	Defect or functionality that should be reported to ICF and go through the grooming process. Work items will be prioritized by Scrum team.

Figure 13 provides the development schedule for the system components that are currently in place.

**Figure 13. System Components Development Schedule**

Source: Buffalo, NY ITS4US (2024)

The sprint schedule for CTP and PMD processes are shown in **Table 4**.

Table 4. Agile Development Schedule for CTP and PMD

Epic / Functions	Start Date	Due Date
CTP Release 1 (MVP)	Jan-23	4/11/2023
User Management Function	Jan-23	4/11/2023
Data Layer	Jan-23	4/11/2023
Trip Planning Functions	Jan-23	4/11/2023
Website MVP	Jan-23	4/11/2023
Mobile App MVP	Jan-23	4/11/2023
Data Feed and Enrichment	Jan-23	4/11/2023
CTP Release 2	Apr-23	10/6/2023
Notifications	Apr-23	10/6/2023
Special Data Feed Integration	Apr-23	10/6/2023
Caregiver/ trusted companion	Apr-23	10/6/2023
Trip Planning: Status	Apr-23	10/6/2023
Account Removal and PII (includes Metric API)	Apr-23	10/6/2023
UI: Website, Mobile	Apr-23	10/6/2023
Reservation API and Dev Environment ready	May-23	5/30/2023
Reservation API integration with CTP	Jun-23	7/31/2023
Indoor Navigation	Jul-23	10/6/2023
Trip Reservations (Integration)	Jul-23	10/6/2023
CTP Release 3	Oct-23	4/5/2024
Service Animal	Oct-23	4/5/2024
Call Center	Oct-23	4/5/2024
Language (English and Spanish)	Oct-23	4/5/2024
Group Travel	Oct-23	4/5/2024
Third party accounts	Oct-23	4/5/2024
Accessibility	Oct-23	4/5/2024
UI: Website, Mobile, Kiosk	Oct-23	4/5/2024
PED-X integration	Oct-23	4/5/2024
CTP Release 4	Apr-24	6/7/2024
O&M	Apr-24	6/7/2024
CTP Security	Apr-24	6/7/2024
CTP Reliability	Apr-24	6/7/2024
Self-monitoring log	Apr-24	6/7/2024
Application and feature Expansion	Jun-24	12/31/2024
CTP Release 5	Jun-24	12/31/2024
SDS Reservations API	Jun-24	12/31/2024
application and feature Expansion	Jun-24	12/31/2024
CTP Reliability	Jun-24	12/31/2024
PMD Release 1	Apr-23	10/6/2023
Design PMD Framework	Mar-23	3/22/2023

U.S. Department of Transportation
Office of the Assistant Secretary for Research and Technology
Intelligent Transportation System Joint Program Office

Epic / Functions	Start Date	Due Date
Create Survey form link for CTP App	Mar-23	3/31/2023
Create Survey Data Storage Environment on UB server	Apr-23	5/1/2023
Collect CTP Performance Metrics (PM) data (from Etch) and survey testing (static) data for the alpha version of PMD development	Apr-23	9/11/2023
Finalize Performance Management Metrics	Apr-24	4/9/2024
Code data ingestion process and API connection server configuration.	Jun-23	7/18/2023
Validate APIs for Performance Management Metrics	Apr-24	4/30/2024
Develop PMD Demo UI and Backend data connection	Jul-23	9/2/2023
Testing 1st release of PMD Demo	Sep-23	9/24/2023
Reviewing the Demo and Approval	Sep-23	10/6/2023
PMD Release 2	Oct-23	4/5/2024
Feedback and Discussion of User Experience of the 1st release of PMD Demo	Oct-23	10/28/2023
Collect HDS sample static (or API) PM data (anything similar to HDS to be deployed for the study) from NFTA	Oct-23	4/5/2024
Collect updated CTP PM data (from Etch) and survey testing API data	Dec-23	4/5/2024
Develop 2nd release of PMD Demo with refinement of functionality and feature from the 1st release with updated CTP/Survey/HDS data	Jan-24	4/5/2024
Code daily Performance Metrics visualization framework with real-time API data ingestion process	Feb-24	4/5/2024
Testing 2nd release of PMD Demo & Reviewing the Demo and Approval	Apr-24	4/26/2024
Feedback and Discussion of User Experience of the 2nd release of PMD Demo	Apr-24	5/21/2024
Collect SDS sample static (or API if available) PM data	Sep-24	12/26/2024
SDS	Sep-24	1/30/2025
SDS system testing w/o passengers	Sep-24	12/26/2024
SDS integration with CTP	Jan-24	9/24/2024
SDS Pre-production Testing	Dec-24	1/30/2025

3.3 Tracking Software Design Elements to Requirements

Traceability is achieved through a well-defined process that links user stories and requirements, which forms the basis for tracking the software design, test cases, and test procedures to validate and verify that the system is built to meet stakeholder needs. Each user story in the backlog is associated with a requirement, establishing a direct connection between the user's needs and the system requirements. This discrete tracing ensures that every aspect of the software's functionality is tied back to a specific requirement, verifying that no critical requirement is left unaddressed during development. The requirement traceability matrix (RTM) also includes traceability to design elements by indicating the section(s) of the SDD that relates to each requirement, providing the ability to do comprehensive verification and validation. **Figure 14** is a screenshot of the RTM in which each requirement is related to a user story and SDD section.

At the end of each system component's section, there is a subsection that includes a requirements traceability table listing the requirements that are met by the design of that component and the specific section in the SDD that each requirement is linked to. The tables also include a status column which indicates whether the requirement is undergoing a change as system requirements may be subject to change based on a number of factors such as changing user needs and priorities, technical readiness, and emerging technical and system level solutions. Any major change to a need or requirement includes an evaluation and approval by the key stakeholder group(s) most affected by the change, such as a configuration control board or product owner. The status of each requirement indicated as one of the following:

- No change – This means that the requirement has not undergone any changes.
- Approved – This means that the requirement has previously been subject to a change request resulting in an evaluation and approval of the change by the key stakeholder group(s) most affected by the change.
- Pending – This means that the requirement is currently undergoing the change control process. A change request form has been filled and the request awaits approval from the change control board or product owner.

NEW Req ID	NEW Title	NEW Description	NEW Need ID	new subsystem	Component	SDD Section (user story)
Req-CS-036.2	HDS on-demand routing and Dispatch	The HDS shall operate door to door, on-demand service managed by their back office scheduling, routing and dispatch services in the BNMC and project region.	UN-E-TP-1	CS	HDS	4.2.2
Req-CS-040.2	Validate HDS Reservation	The HDS shall be equipped with a mechanism to verify boarding passengers have a valid reservation (booked through the CTP) to travel their reserved trip (e.g., boarding / alighting location and time). The validation may be through inspection by the HDS operator.	UN-E-TP-12	CS	HDS	4.2.2.1, 4.2.2
Req-CS-043.2	Track HDS Performance	The HDS operator shall track the location and monitor performance of vehicles in revenue service in real-time.	UN-E-TE-1	CS	HDS	4.2.1, 4.2.2
Req-CS-045.2	HDS Booking API Specification	The HDS reservations provider shall provide API specifications for use by the CTP for booking services.	UN-S-SO-13	CS	HDS	4.2.2
Req-CS-046.2	HDS Booking Status API	The CS HDS operator shall provide APIs for use by the CTP to publish information about reservations status.	UN-S-SO-13	CS	HDS	4.2.2
Req-CS-049.2	HDS Scheduling and Routing	The HDS routing management system shall generate PAL (spontaneous) routing and schedules for on-demand, door to door manifests. These typically will consist of two or more pick-up and drop-off locations, travel times between the stops and estimated arrival and departure times.	UN-E-TE-1	CS	HDS	4.2.2
Req-CS-052.2	CS HDS Notify EMS	Upon the occurrence of an incident, the HSD mobility operator shall notify appropriate emergency management and incident response personnel.	UN-S-BO-12	CS	HDS	4.2.4
Req-CS-055.2	HDS Trip Monitor Management	The HDS system shall continually recalculate HDS service adherence to determine impacts to traveler trip plans in order to provide updates to the traveler about their travel experience.	UN-E-TE-1	CS	HDS	4.2.2

Figure 14. Screenshot of Requirements Traceability Matrix

Source: Buffalo, NY ITS4US (2024)

4 Turnkey Systems and Components

The Turnkey Systems and Components section details the design approach of proprietary systems that are off-the-shelf, operated by external systems, software as a service or turnkey build-operate-maintain systems. The system/component, type of acquisition approach and vendor / supplier roles are described in **Table 5**.

Table 5. Type of System or Component

System / Component	Type of “Proprietary” System or Service and Vendor Roles
SDS components of CS subsystem	Turnkey – design-build-operate-maintain system procured from ADASTEC Corp
HDS systems of CS subsystem	Open scheduling and operations software developed by the New York State Department of Transportation (NYSDOT) Vehicles and services provided by NFTA
Indoor Navigation System	SaaS from CXApp include asset management and SDK Leverage existing equipment from Kaleida Health at Buffalo General Medical Center (BGMC) Procuring and placing equipment (beacons) for Visually Impairment Advancement (VIA) building
Pedestrian Signal / Intersection Crossing	Procured equipment and operations from Miovision at two CoB intersections Installation and integration of equipment provided by CoB
Transportation Information Hub	Procured and installed equipment by RedyRef at two locations (BGMC and NFTA Metro Rail station)
Sidewalk Data Collection	Data collection services and encoding into OSM conducted by University at Buffalo (UB)

For the SDS, turnkey system, the project team will have no design responsibilities beyond verifying and validating testing. The system functionality is described in **Section 4.1**.

For the components with hardware procurements (INS, Ped-X and TIH), the project team will have no design responsibilities beyond hardware and software configuration, which will be detailed in the CIP. High level functionality and a description of each system is provided in their respective sections below.

In addition, the process for collecting sidewalk data is described in **Section 4.6**.

All CTP integration design elements will be described in **Section 5**.

No hardware or software will be developed for these systems. ***These components are proprietary***; reference to design information will be provided if not restricted by the vendor agreement.

4.1 Self-Driving Shuttle – Community Shuttle Subsystem

The Self-Driving Shuttle (SDS) will provide a demand-responsive service to the CTP (Buffalo All Access app) registered users for trips in the vicinity of the BNMC. SDS operations, however, will be constrained to a pre-defined route of pre-selected streets that satisfy the SDS Operation Design Domain (ODD), and at pre-defined pick-up and drop-off locations. The project team will coordinate with the vendor to define safe pick-up and drop-off locations based on the ODD that may include a shelter, if possible.

The SDS subsystem will be developed and deployed by a joint team from ADASTEC Corp. (ADASTEC) and Vicinity Motor (Bus) USA Corp (VMC). ADASTEC will then operate the shuttle, for the Buffalo All Access project, during the last three months of Phase 2, and throughout the 18-month duration of Phase 3. The following subsections will discuss the different components and features of the SDS subsystem.

4.1.1 Hardware

This section describes the hardware associated with self-driving automation, including sensors, computers, and other elements. It is to be noted that the shuttle which will be deployed for the Buffalo All Access project is NOT a retrofitted vehicle, but a ground-up factory fitted automated bus produced by VMC, which means that the drive-by-wire conversion is done by the producer and thus exists prior to deployment.

The shuttle's Autonomous Driving System (ADS), flowride.ai, uses enhanced sensor fusion with map-based priors. Flowride.ai uses maps as an additional sensor that increases the deterministic behavior of the system without ignoring generalization to adapt to different road conditions. Sensors are placed mainly targeting public transportation operations. Pedestrian and animal detection is enhanced with the fusion of thermal cameras.

Multiple sensors have been used to improve the sensors' effectiveness and avoid any misdetection, and their positioning has been optimally adjusted. The sensor suite and other hardware elements of the Vicinity Autonomous Lightning EV, which will be deployed for the Buffalo All Access project, will include the following hardware types (design will be finalized during the engineering and design stage of the bus production) shown in **Table 6**.

Table 6. SDS Sensor Hardware Components

Hardware Type	Quantity	Property
LiDAR (Light Detection & Ranging Sensor)	6	64 Channels

U.S. Department of Transportation
Office of the Assistant Secretary for Research and Technology
Intelligent Transportation System Joint Program Office

Hardware Type	Quantity	Property
LiDAR	1	128 Channels
GNSS/INS (Global Navigation Satellite System + Aided Inertial Navigation System)	1	High Precision GNSS Receiver
RGB (Red-Green-Blue) Camera	8	3 Front facing, 3 Backward facing, 2 T-Junction
Thermal Camera	2	Front Facing, Door
RADAR (Radio Detection and Ranging)	5	Digital Scanning RADAR
V2X OBU (Vehicle-to-Everything Onboard Communication Unit)	1	Dual mode onboard unit – Dedicated Short-Range Communications (DSRC) and cellular
Computers	6	2 GPU (Graphical Processing Unit) based, 4 CPU (Central Processing Unit) based
Network Units	6	3 Switches, 1 Time Master, 1 Router, 1 Firewall
Screens	3	1 for passengers, 1 for the driver, 1 for engineers

4.1.2 Software

The ADS software, called flowride.ai, was developed in-house by ADASTEC's engineers. Flowride.ai delivers an advanced Level 4 automation platform for full-size commercial vehicles and is designed for large-scale public transport along predefined routes on public roads. flowride.ai platform consists of modular automated driving software in the bus and a cloud-based back-office platform. The bus module handles all aspects of the automated operation of the vehicle through an integrated, fault-tolerant set of sensors and HD-Maps, where enhanced sensor fusion and deep learning techniques are utilized.

The autonomous driving stacks in flowride.ai and their relations with each other are shown in **Figure 15**. High-level details of the different modules and functionalities of flowride.ai are provided in the following subsections.

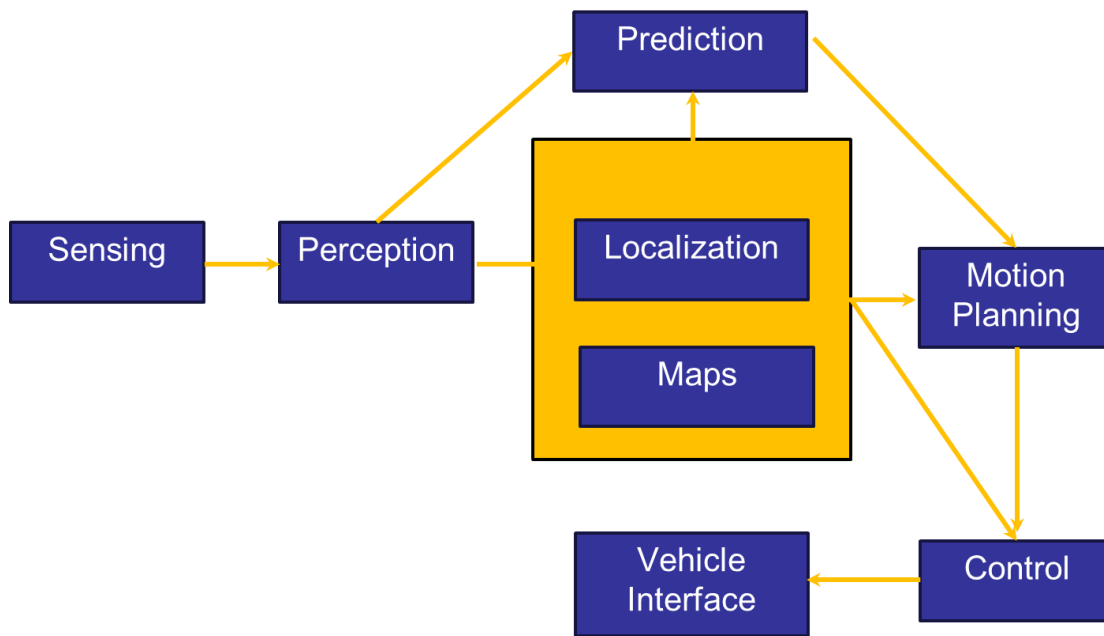


Figure 15. ADASTEC's flowride.ai Autonomous Driving Stack

Source: Used with permission from ADASTEC

4.1.2.1 Object Detection and Response

Object and Event Detection and Response (OEDR) addresses all objects and events directly related to automated vehicles (AV) immediate driving tasks. OEDR is provided during all operating conditions of the AV in its ODD.

4.1.2.2 Localization

The localization stack is based on finding the vehicle's location in the world frame by using real-time sensor data and matching them with high definition (HD) maps. Objects around the vehicle are localized after the vehicle locates itself. The system fuses data from:

- LiDAR: landmark localization
- HD-Maps
- High precision GNSS/INS and satellite-based correction
- Vehicle Controller Area Network (CAN)
- Odometry

By doing so, the shuttle can localize itself (position on a map) in urban canyons, tunnels, and other challenging conditions. Also, the fusion of multiple sensors for localization provides redundancy. As a result, in case of a hardware failure in the localization subsystem, the vehicle continues to operate.

4.1.2.3 Perception

For complex urban scenarios the systems use sensor fusion for perception. The automated driving system uses multi-modal signals for perception, RGB and thermal camera images, LiDAR

points, radar points, ultrasonic sensors, and map information. As a result, it recognizes all relevant traffic participants and objects accurately, robustly, and in real-time.

The system can detect and classify objects around the vehicle from a 360-degree view. It determines the objects' positions and estimates their speeds and directions. It fuses outputs from multiple sensors (LiDAR, RGB Camera, Thermal Camera) for increased precision in detecting objects and scene perception. Using five different sensor modalities aims to create a fault-tolerant, redundant, and robust system. In addition, the perception system can detect traffic lights and traffic signs. Since the system vehicle is a bus, the perception software's other responsibility is to check the surroundings of the vehicle for the safety of all passengers.

4.1.2.4 Prediction

The prediction software module predicts the objects' next states, such as position, speed, and direction. For example, static objects cannot move suddenly, but dynamic objects can. The behavior of a dynamic object can change. For instance, even though most traffic participants' behavior is similar, pedestrians can change their directions suddenly.

Since the bus moves among other dynamic objects on the road, such as cars, bicycles, motorcycles, and pedestrians, the system needs to predict the behavior of these objects to make the best decisions on what the vehicle should do. The behavior of an object is predicted by generating a trajectory for it. Prediction is real-time, which means the latency is less than 40 milliseconds.

4.1.2.5 Planning

The planning software identifies multiple routes for the vehicle to drive from the start of the route to its end, including bus stops. It uses HD maps to define the drivable areas and selects the best trajectory for the trip considering the vehicle's limitations. If there is an object on the road which can affect safe driving, planning decides to brake, swerve, or change lanes depending on the situation and environment. While the planning module plans trajectory, it also obeys traffic rules defined in the HD maps. Planning also decides movement according to the location of other vehicles at intersections.

4.1.2.6 Control

The control module generates control signals for actuators and communicates with the vehicle. It gets commands from the Planning Module and calculates necessary throttle, brake, and steering angle commands to send the bus as inputs, considering predefined jerk and acceleration limits.

4.1.2.7 HD Maps

Flowride.ai uses HD maps to understand the environment in real-time. The maps include a 3-dimensional (3D) point cloud map of the environment, the geometry of the road and curbs, the drivable area, lane boundaries, traffic signs, crosswalks, stop lines, yielding points, speed bumps, traffic signals, and traffic rules. HD maps are created with the help of LiDAR, IMU, GNSS sensors, and cameras.

4.1.2.8 Vehicle-to-everything (V2X) Communications

V2X communications may be used to provide safer and more comfortable rides for passengers, particularly at signalized intersections. Flowride.ai can receive traffic signal communication (SpaT: signal phase and timing) along V2X-equipped routes.

4.1.2.9 Bus Stop Handling

Bus stops handling is a unique feature of flowride.ai ADS. The flowride.ai platform handles the interaction with passengers on the bus stops (pickup and drop-off locations) and automatically checks the safe zone after passengers enter the bus.

4.1.2.10 Software Updates

The software will be updated by a local technical operator when the update decision is made (after acceptance testing and reports).

4.1.2.11 Cyber-security System

ADASTEC's cybersecurity system detects unauthorized communications and provides warnings. SDS vendors or SOC agents can monitor these interventions. The SDS vehicle system access will be secured using advanced authentication methods beyond password and a physical locking mechanism including a two-step verification process.

4.1.3 Interface with the Infrastructure

For the SDS, there are no infrastructure requirements other than Level 2 alternating current (AC) or direct current (DC) chargers for charging the electric shuttle. However, it is noted that the availability of any V2X-enabled traffic signal controllers along the deployment route are expected to enhance rider comfort. At this point, the majority of traffic signals along the deployment route on BNMC are not capable of communicating with vehicles, and therefore this aspect of interfacing with the infrastructure may only be implementable at a future date.

4.1.4 Vehicle Models

The manufacturer of the proposed vehicle is Vicinity Motor Corporation, and the model is the Vicinity Autonomous Lightning EV. The powertrain is battery electric, with 252 kilowatt-hour (kWh) battery size with a 180-mile range. The bus can be charged with either a Level-2 AC charger or a DC charger. The vehicle is not suitable for bidirectional driving. The seating capacity is up to 22 passengers, with seat belts for every passenger seat. It is a dual-mode bus, which means it can be driven manually and operated autonomously. The Vicinity Autonomous Lightning EV buses comply with applicable Federal Motor Vehicle Safety Standards, 49 Code of Federal Regulations (CFR) part 571. Detailed specifications of the bus are outlined below.

4.1.4.1 Functional Specifications

The functional specifications associated with the vehicles include the following:

- Seating Capacity Up to 22 Passengers (2 Doors Configuration)
- Accessibility Capacity Up to 3 Wheelchair Locations (2 Doors Configuration)

- Ramp Angle 6:1 Bi-fold Entry Ramp
- HVAC System Capacity 86,000 British thermal unit (BTU)
- Suspension Air-Ride with Kneeling (an accessibility feature that allows the bus to lower for ingress/egress)
- Traction Motor Power 295 HP
- Top Speed (Manual) 70 Miles Per Hour (MPH)
- Gradeability 20%
- Typical Range Up to 120 Miles / 168 kWh / 4 Battery System

4.1.4.2 Battery Specifications

The Electric Vehicle (EV) specifications include the following:

- Battery Manufacturer Bayerische Motoren Werke (BMW) / LION Smart
- Battery Type Lithium-Ion Lithium Manganese Cobalt (LMC)
- Battery Size 168 kWh
- System Voltage 400V (Nominal)
- Design Life Cycle >4000 @90% depth of discharge (DOD)
- Temp. Range -22 degrees Fahrenheit (°F) to +133° F
(-30 degrees Celsius (°C) to +56° C)

The EV is estimated to run for about 10 hours, subject to variability based on factors including distance traveled and weather conditions.

4.1.4.3 Charging

Specifications for charging includes the following:

- Level 2 (AC Charging J1772) < 8 Hours
- Level 2 DC Fast Charge < 2 Hours

Note: Charging time is dependent on charger capacity, rate, and infrastructure.

Summary specifications of the bus can be found in the Appendix:

- "Attch_2_VMC_Bus_Summary_Specifications"
- "Attch_3_VMC_Bus_Flyer"

4.1.5 Accessibility Features

The Vicinity Autonomous Lightning EV buses comply with the minimum requirements for transportation vehicles required to be accessible by the Americans with Disabilities Act (ADA) of 1990, 49 CFR part 38. In addition, all emergency exits are accessible.

The SDS will be equipped with a Ricon 6:1 power wheelchair ramp, interlocked with the brake system to prevent bus movement when deployed. The vehicles feature three ADA-compliant mobility aid locations comprising of two Q'Straint QPod tie-downs and one Q'Straint Quantum tie-down system. Lighting, signage, grab rails, audible, and visual alert systems are incorporated into the design as required by ADA.

The SDS has both external and internal visual signs and auditory announcements. The external signs show the vehicle Identification (ID), route, and destinations. It is also a programmable sign. The external auditory system makes announcements about the bus approaching the station and the bus ready for action. ADASTEC has two human-machine interfaces (HMI) for interior signage. Auditory signage for passengers is also available. All in-vehicle functions that require passenger interaction will include Braille lettering as well as universal icons for all signs in the vehicle. There will be visual and written content regarding the maintenance, operation, and training of the Safety Driver and Safety Operator. ADASTEC will also provide documented quick guides, user manuals, and training documents.

4.1.6 Operator HMI

ADASTEC Operator HMI is easily activated by either a basic command or automatically. The HMI is designed to control all necessary functions of the automated vehicle quickly and efficiently. The safety steward should proceed with initial check procedures and then click the power button to launch the flowride.ai stack. The operator can confirm bus stops or loads other than the default destinations list. The operator may choose a specific destination(s) from the bus stops selection list, which needs to be confirmed by the operator or control center. The flowride.ai stack identifies incidents and near misses to provide necessary maneuvers (minimal risk maneuver (MRM) to achieve minimal risk condition (MRC)) and logs necessary data to provide information for the authority. ADASTEC has an emergency response plan and will follow all procedures developed in the Law Enforcement Interaction Plan. The system and SOC will be ready to provide necessary actions according to these procedures.

Through the operator HMI, important notifications can be observed, such as information about the system's health (sensor health check, localization, CAN bus). Also, the safety steward can stop the vehicle at any time by pressing the "EMERGENCY BRAKE" button. In addition, a soft brake button is also available to stop the vehicle.

4.1.7 The Shuttle Operations Center (SOC)

The SOC's software (flowride) will be responsible for the following key functions: (1) routing and dispatch of the SDS; (2) monitoring of the SDS to determine their estimated arrival time; and (3) providing the data needed for calculating the SDS subsystem performance metrics. The SOC scheduling and dispatch software will need to interface to provide reservations and trip status with the Buffalo ITS4US project's CTP which will be developed independent of the SDS procurement. Through interactions between the SOC's software and the Buffalo ITS4US CTP, the community shuttle shall execute trip plans within pre-specified time limit from the request (e.g., 60 minutes). The time limit will be determined in Phase 3, once supply and demand of the service is better known.

Flowride SOC will have a reservation management subsystem that interfaces reservations between SDS and CTP—providing Representational State Transfer (REST) API's for reservations. These include Reservation API, Reservation cancellation API, and reservation availability API. SOC will interact with the SDS real-time data stream to search for availability and send reservation command calls to SDS to arrange the schedule. Depending on the result payload from SDS, the reservation API will return the appropriate response code.

ADASTEC's SOC utilizes flowride API to integrate routing and scheduling solutions. ADASTEC takes in scheduling API calls, verifies them with the bus, and returns the appropriate output. To register trips and schedules to an SDS, CTP will call SOC's documented scheduling APIs in a proper format. SOC will validate the given request and return appropriate responses back to the CTP. All communication between the systems is established with Transport Layer Security (TLS), which ensures data is secure during transfer. The scheduling data store will be GTFS compliant. For real-time data stream from SOC to SDS, GTFS-realtime will provide time-sensitive data like trip ETA's, SDS location, seat availability, and trip alerts.

The SDS has a Digital Video Recorder (DVR) system for internal and external monitoring of the vehicle. During an emergency, the SDS will send information about the status of passengers to the SOC, allowing the SOC operators to remotely monitor the situation and communicate with travelers through their UI channel(s).

4.1.8 Passenger Information System

The ADASTEC-VMC shuttle has a large screen inside the vehicle to communicate important information to the passengers onboard. The large screen displays the list of destinations, time of arrival, and the distance the vehicle has traveled. In addition, weather conditions, location-based information, and status information of the vehicle, such as "waiting," "approaching the bus stop," and other announcements, are also provided to the passengers via the screen.

In addition, through the CTP or Buffalo All Access App passengers will be able to see the vehicle's location, the route (on a map), and the arrival time at each bus stop. When the vehicle approaches the selected bus stop, the application notifies the passenger. There is also a clearly labeled emergency button on the main screen of the mobile application for passengers to inform the central authority in case of any emergency.

To ensure passengers' security, the shuttle cabin is permanently monitored by a DVR system throughout the operation. In addition, ADASTEC is currently developing an in-cabin monitoring and warning system. This system will detect and warn the site operator or control center agents about incidents such as harassment, theft, fighting, smoking, and health related issues and emergencies. Given that a safety steward will be onboard the SDS all the time during the current Buffalo All Access ITS4US Deployment project, the automated in-cabin monitoring and warning system is not needed.

4.1.9 Data Logging and Storing

The data recorded from the system during the operation can be used in debugging, development, or improvement studies. The data is collected from the operating systems of the vehicle and will be used to support the development of any needed performance measures in a manner that preserves the privacy of any traveler involved.

4.1.10 SDS Requirements Traceability

The requirements that are met by this design are listed in **Table 7** and **Table 8**. **Table 7** lists the mandatory requirements that need to be met as they relate to safety and operation of the SDS in which the vendor is in complete compliance with the requirements. The desired requirements in

Table 8 relate to the customer experience. The items in the requirements traceability tables for each of the turnkey systems and components are as follows:

- **Req ID:** Requirement Identification Number
- **Req Title:** Requirement Title
- **Status:** indication of whether the requirement has undergone a change. Change details can be found in the RTM.
 - **No change** – the requirement has not been changed
 - **Approved** – the requirement has undergone the change control process, and the requested change has been approved.
 - **Pending** – a change to the requirement is being recommended and it has yet to be approved.
- **SDD Section:** indication of the section in this document that describes this application of the requirement.

Table 8 includes a column indicating whether the vendor fully or partially complies with the desired requirement.

Table 7. SDS Requirements Traceability to Design (Mandatory)

Req ID	Req Title	Status	SDD Section
Req-CS-001	Manual and Autonomous Driving	No change	Section 4.1.4
Req-CS-004	SDS Capacity	No change	Section 4.1.4.1
Req-CS-005	Manual Control	No change	Section 4.1.4
Req-CS-008	Ramp / Lift	No change	Sections 4.1.4.1 and 4.1.5
Req-CS-014	Multiple and Redundant Sensor Systems for Perception and Localization	No change	Sections 4.1.1, 4.1.2.2, 4.1.2.3
Req-CS-014.1	LIDAR Sensor	No change	Section 4.1.1
Req-CS-014.2	RADAR Sensor	No change	Section 4.1.1
Req-CS-014.3	Camera-Centric Computer Vision	No change	Sections 4.1.1 and 4.1.2.3
Req-CS-014.4	Inertial Measurement Unit	No change	Section 4.1.1
Req-CS-014.5	Localization	No change	Sections 4.1.1 and 4.1.2.2
Req-CS-017	Onboard Persistent Storage	No change	Section 4.1.9
Req-CS-024	Detect, classify, measure and Interpret Objects	No change	Sections 4.1.2.1, 4.1.2.3, 4.1.2.4
Req-CS-024.1	Detect Vehicles	No change	Sections 4.1.2.1, 4.1.2.3, 4.1.2.4
Req-CS-024.2	Detect Pedestrians	No change	Sections 4.1.2.1, 4.1.2.3, 4.1.2.4
Req-CS-024.3	Classify Objects	No change	Sections 4.1.2.1, 4.1.2.3, 4.1.2.4
Req-CS-024.4	Driving Rule Compliance	No change	Sections 4.1.2.1, 4.1.2.3, and 4.1.2.7

Req ID	Req Title	Status	SDD Section
Req-CS-025	Motion Planning Algorithm	No change	Sections 4.1.2.4 and 4.1.2.5
Req-CS-026	Operations in Mixed traffic	No change	"Attch_1_ADASTEC ODD" attached, and the video below: https://youtu.be/DZdRAi4bb9A
Req-CS-026.1	ODD Rule Set Compliance	No change	"Attch_1_ADASTEC ODD" attached, and the video below: https://youtu.be/DZdRAi4bb9A
Req-CS-026.2	Operational Specifications	No change	"Attch_1_ADASTEC ODD" attached, and the video below: https://youtu.be/DZdRAi4bb9A
Req-CS-026.3	Driving During Inclement Weather	No change	"Attch_1_ADASTEC ODD" attached, and the video below: https://youtu.be/DZdRAi4bb9A
Req-CS-026.4	Avoid Conflicts with Other Vehicles	No change	"Attch_1_ADASTEC ODD" attached, and the video below: https://youtu.be/DZdRAi4bb9A
Req-CS-026.5	Avoid Conflicts with Pedestrians'	No change	"Attch_1_ADASTEC ODD" attached, and the video below: https://youtu.be/DZdRAi4bb9A
Req-CS-026.6	Avoid Fixed Objects	No change	"Attch_1_ADASTEC ODD" attached, and the video below: https://youtu.be/DZdRAi4bb9A
Req-CS-026.7	Avoid Moving Objects	No change	"Attch_1_ADASTEC ODD" attached, and the video below: https://youtu.be/DZdRAi4bb9A
Req-CS-026.8	Navigate with Minimum Clearance	No change	"Attch_1_ADASTEC ODD" attached, and the video below: https://youtu.be/DZdRAi4bb9A
Req-CS-029	Designated Pickup/Drop off Stops	No change	Section 4.1.2.9
Req-CS-036.1	SDS on-demand routing and Dispatch	No change	Sections 4.1 and 4.1.7
Req-CS-040.1	Validate SDS Reservation	No change	Section 4.1.7
Req-CS-043.1	Track SDS Performance	No change	Section 4.1.7
Req-CS-044	SDS Operational Design Domain (ODD)	No change	"Attch_1_ADASTEC ODD" attached, and the video below: https://youtu.be/DZdRAi4bb9A
Req-CS-045.1	SDS Booking API Specification	No change	Section 4.1.7
Req-CS-046.1	SDS Booking Status API	No change	Section 4.1.7
Req-CS-049.1	SDS Scheduling and Routing	No change	Section 4.1.7
Req-CS-050	Monitoring SDS Environment	No change	Sections 4.1 and 4.1.6

Req't ID	Req't Title	Status	SDD Section
Req-CS-051	Incident Management using Law Enforcement Interaction Plan	No change	Section 4.1.6
Req-CS-052.1	CS SDS Notify EMS	No change	Section 4.1.6
Req-CS-058	Driving Rules / MUTCD	No change	Section 4.1.2.3
Req-CS-059	Authorization to Operate	No change	Section 4.1.4
Req-CS-060	Low Speed Shuttle	No change	"Attch_1_ADASTEC ODD" attached, and the video below: https://youtu.be/DZdRAi4bb9A
Req-CS-075	New Software Releases	No change	Section 4.1.2.10
Req-CS-081.1	SDS Operational and Maintenance Plan	No change	See CMOP Section 8.1
Req-CS-082.1	SDS Operational Performance	No change	Sections 4.1.7 and 4.1.9
Req-CS-083	Mobility Provider Trip Reporting	No change	Section 4.1.7
Req-CS-083.1	SDS Trip Reporting	No change	Section 4.1.7
Req-CS-084.1	Secure SDS Trip Reporting information	No change	Section 4.1.9
Req-CS-89	Accessible Emergency Exits	No change	Section 4.1.5
Req-CS-90	3D Map Updates	No change	Section 4.1.2.10
Req-CS-92	Open Architecture SDS System	No change	Section 4.1.7
Req-INT-011.1	SDS Reservation API Specification	No change	Section 4.1.7
Req-Sy-009.1	Access to SDS Mobility Services via CTP	No change	Section 4.1
Req-Sy-011	CS Geographic Coverage	No change	Section 4.1
Req-Sy-012.1	CS Response Time	No change	Section 4.1.7
Req-Sy-018	Accessible Vehicles	No change	Section 4.1.5
Req-Sy-019	Americans with Disability Act	No change	Section 4.1.5
Req-Sy-036	CS Health Status Communications Action to the PMD	Approved	Section 4.1.9
Req-CS-94	Develop Safety Steward SOP	Approved	See CMOP Section 8.1
Req-CS-95	Manage Safety Steward Operations	Approved	See CMOP Section 8.1
Req-Proj-1	Train Safety Steward SOP	Approved	Section 4.1.5
Req-Proj-5	Buy America Provision	Approved	See Comprehensive Acquisition Plan (CAP) Section 2.3 and CIP Section 2.4
Req-Proj-7	Operational Readiness Testing and Demonstration	Approved	See Test Results and ORP Sections 2 and 3
Req-Proj-8	Test Planning and Reporting	Approved	See Test Results and STP Section 4.2
Req-Proj-6	Passenger Outreach and Training	Approved	See Training Materials and Outreach Plan Section 3.3.5

Table 8. SDS Requirements Traceability to Design (Desired)

Reqt ID	Reqt Title	Vendor Comply	Status	SDD Section
Req-CS-002	Motor Technology	YES	No change	Sections 4.1.4 and 4.1.4.3
Req-CS-003	HVAC System	YES	No change	Section 4.1.4.1
Req-CS-007	Automatic Doors	YES	No change	"Attch_1_ADASTEC ODD" attached, and the video below: https://youtu.be/DZdRAi4bb9A
Req-CS-007.1	Automatic Doors - Open	YES	No change	"Attch_1_ADASTEC ODD" attached, and the video below: https://youtu.be/DZdRAi4bb9A
Req-CS-007.2	Automatic Doors - Close	YES	No change	"Attch_1_ADASTEC ODD" attached, and the video below: https://youtu.be/DZdRAi4bb9A
Req-CS-007.3	Automatic Doors - Malfunction	YES	No change	"Attch_1_ADASTEC ODD" attached, and the video below: https://youtu.be/DZdRAi4bb9A
Req-CS-009	Wheelchair Securement	YES	No change	Section 4.1.5
Req-CS-010	Seat Belts	YES	No change	Section 4.1.4
Req-CS-011	Hand-holds	YES	No change	Section 4.1.5
Req-CS-013	Multiple Redundant Communication Radios	YES	No change	Section 4.1.7
Req-CS-015	Passenger Communication Equipment	YES	No change	Section 4.1.8
Req-CS-016	Accessible Emergency Button	YES	No change	Sections 4.1.6 and 5.5.4
Req-CS-016.1	Emergency stop button misuse	YES	No change	See CMOP Section 8.1
Req-CS-018	CS Vehicle Health Monitoring	PARTIAL	No change	Section 4.1.6
Req-CS-018.1	SDS Sensor Health Monitoring	YES	No change	Section 4.1.6
Req-CS-018.2	SDS Communication Health Monitoring	YES	No change	Section 4.1.6
Req-CS-018.3	SDS Safety Asset Health Monitoring	YES	No change	Section 4.1.6 and Section 4.1.8
Req-CS-019	Monitor Communications	YES	No change	Section 4.1.6
Req-CS-020	Alert Steward of Degraded Communications	YES	No change	Section 4.1.6
Req-CS-022	Incident Management due to Degraded Health	YES	No change	Section 4.1.6

U.S. Department of Transportation
Office of the Assistant Secretary for Research and Technology
Intelligent Transportation System Joint Program Office

Req ID	Req Title	Vendor Comply	Status	SDD Section
Req-CS-028	Emergency Stop Actions	YES	No change	Section 4.1.6
Req-CS-041	SDS User Interface Channels	YES	No change	Section 4.1.8
Req-CS-041.1	SDS UI Channel - in-vehicle status audio	YES	No change	Section 4.1.5 and 4.1.8
Req-CS-041.2	SDS UI Channel - in-vehicle status visual	YES	No change	Section 4.1.8
Req-CS-041.3	SDS UI Channel - in-vehicle situational awareness audio/visual	YES	No change	Section 4.1.5 and 4.1.8
Req-CS-041.4	SDS UI Channel - Braille	YES	No change	Section 4.1.5
Req-CS-041.5	SDS UI Channel - universal icons	YES	No change	Section 4.1.5
Req-CS-041.6	SDS UI Channel - instructional videos	YES	No change	Section 4.1.5
Req-CS-041.7	SDS UI Channel - External announcements and visual cues	YES	No change	Section 4.1.5
Req-CS-041.8	SDS UI Channel - Connection to CTP mobile app	YES	No change	Sections 4.1.7 and 4.1.8
Req-CS-042	Communicate SDS Status	YES	No change	Sections 4.1.6 and 4.1.8
Req-CS-053	Monitor Passenger Safety	YES	No change	Section 4.1.7
Req-CS-054	Emergency Communications to Passengers	YES	No change	Section 4.1.7
Req-CS-055.1	SDS Trip Monitor Management	YES	No change	Section 4.1.7 and 4.1.8
Req-CS-056.1	SDS Update CTP on Trip Management	YES	No change	Section 4.1.7
Req-CS-061	Pick-up/Drop Off Location Announcement	YES	No change	Sections 4.1.5 and 4.1.8
Req-CS-065	Determine occupancy status of wheelchair securement systems	YES	No change	See note [1] below
Req-CS-066	Pickup / Dropoff locations	This requirement is the responsibility of the ITS4US NFTA project team and not the vendor	No change	Section 4.1
Req-CS-068	Pick-up, Drop-off location occupied	YES	No change	See note [2] below
Req-CS-069	Delay or missed stop caused by re-route (SDS)	YES	No change	Section 4.1.7
Req-CS-070	V2X connection lost	YES	No change	Sections 4.1.6 and 4.1.9

Reqt ID	Reqt Title	Vendor Comply	Status	SDD Section
Req-CS-071	Cybersecurity risk assessment	YES	No change	Section 4.1.2.11
Req-CS-072	Access to SDS onboard computers	YES	No change	Section 4.1.2.11
Req-CS-073	Security Breach Response	YES	No change	Section 4.1.2.11
Req-CS-074	Defense against Spoofing Attacks on sensors	YES	No change	Section 4.1.1 and 4.1.2.3
Req-CS-077.1	SDS Hours of Operation		No change	See CMOP Section 8.1
Req-CS-079.1	SDS Multiple Passenger routing	YES	No change	Section 4.1.7
Req-CS-080.1	Monitor SDS travel anomalies	YES	No change	Section 4.1.9
Req-CS-88.1	Report SDS Operating Status to CTP	YES	No change	Sections 4.1.6
Req-CS-91	External/Internal Monitoring	YES	No change	Section 4.1.7
Req-Sy-027	SDS and SOC Technology Review	YES	No change	Section 4.1.2.10

[1] The ADASTEC-VMC will have a passenger count system onboard to track occupancy status.

[2] This may require intervention from the safety steward onboard.

4.2 Human Driven Shuttle

The Human-Driven Shuttle (HDS) provides on-demand, door-to-door service to a Buffalo All Access app registered users who book a trip within the BNMC region.

The HDS is composed of three major components:

- HDS vehicles
- On-demand Reservations, Scheduling and Dispatch (RSD) software including reservations APIs
- NFTA Operations and Dispatch Center

The vehicles will be supplied using NFTA paratransit vehicles and the NFTA Operations and Dispatch Center will manage the vehicles and software.

The on-demand RSD will use existing software developed by NYSDOT with the reservations interface tailored to integrate with the CTP.

4.2.1 HDS Vehicles

The vehicles used to support the HDS service are NFTA vehicles that are currently used for Paratransit Access Link (PAL) service. The vehicles comply with ADA and Federal Transit Agency

State of Good Repair (SOGR) provisions including up to three wheelchairs and other assistive devices. Additionally, there are seats or space for service animals (Req-CS-087) and traveler companions.

Existing operations and maintenance procedures have been developed for NFTA vehicles (Req-Sy-015, Req-CS-081.2). These are available through NFTA. As documented in the vehicle maintenance manuals and SOGR documents, preventive and periodical maintenance is performed. In addition, automated vehicle monitoring systems (AVMS) are implemented in each vehicle to ensure that they are performing to specifications (Req-CS-018).

The AVMS and on-board systems collect real-time information for vehicle monitoring, tracking (Req-CS-043.2) and travel anomalies (Req-CS-080.2).

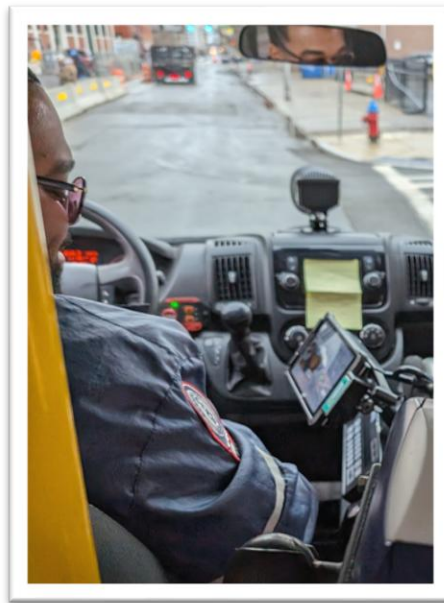


Figure 16. NFTA On-Demand Vehicle with Tablet

Source: NFTA

The operator has access to the information through an on-board tablet to verify boarding, alighting and missed trips of passengers who reserve service (Req-CS-040.2, Req-CS-056.2) as shown in **Figure 16**. These functions are available through the NYSDOT Rural App (see **Section 4.2.2.1**).

4.2.2 On-Demand RSD

The NYSDOT Rural App RSD system was selected to implement the HDS on-demand routing and dispatch function since it implements door-to-door, on-demand services.

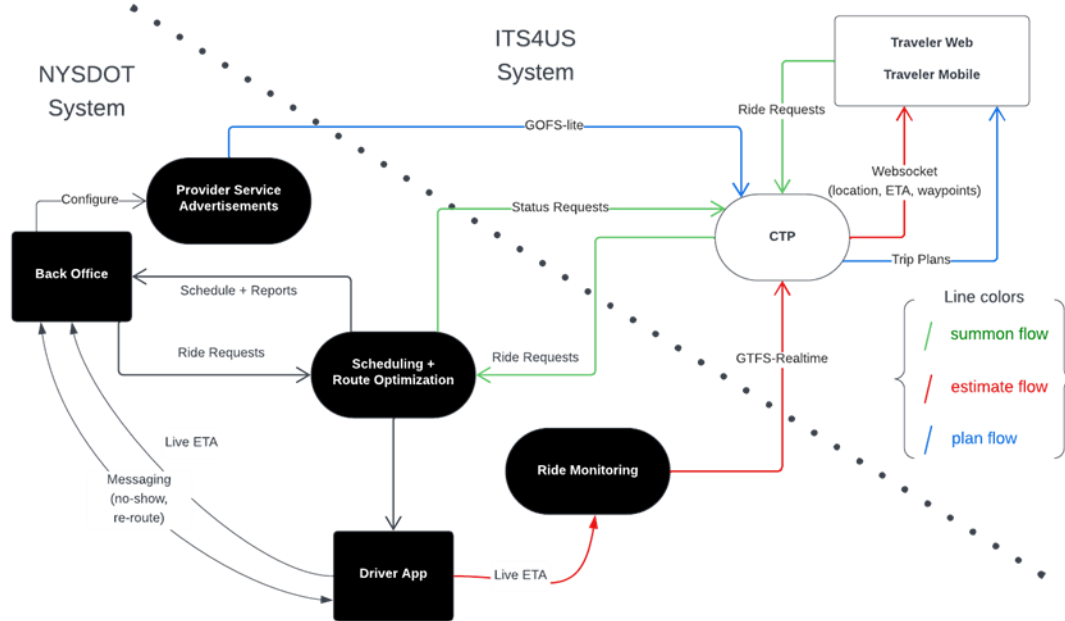


Figure 17. Reservation-Scheduling-Dispatch Architecture and Interfaces

Source: NYSDOT, 2023

As shown in **Figure 17**, the RSD is composed of several components:

- Back Office which manages operator and dispatch functions
- Scheduling and Route Optimization which manages reservations and vehicle schedules
- Driver App which exchanges messages with the Backoffice and monitors and provides live ETA messages to the Backoffice and Ride Monitoring module
- Ride Monitoring which tracks the vehicle and monitors the ETA

The Back Office and Scheduling and Route Optimization software are web-based. The Driver App and Ride Monitoring functions are part of a native app operating on an Android or iPhone Operating System (iOS) platform (tablet or mobile device). The interfaces supported by the RSD are described in more detail in the sections below.

The Reservation APIs that interface with the CTP Back Office exchange ride request (booking) and status information and real-time information. The Reservations APIs are composed of several interfaces.

- GTFS On-Demand Feed Specification– Lite (GOFS-Lite) (for Discovery)
- Ride Request (request, status)
- GTFS-realtime (GTFS-RT TripUpdate)

Note: The Reservations APIs are documented in the ICD Section 3.12 (Int-11) and the real-time updates are documented in ICD Section 3.9 (Int-08). Other interfaces that are exchanged within the RSD application are not included in this system design because they were developed as part of the NYSDOT Rural App development process.

Operations Discovery

CTP receives and reviews the GOFS-Lite file from the RSD to discover the operation period and coverage of the HDS on-demand service. Note: this information is included so available *modes near me* are shown on the Home Page Explore Mode (see **Section 5.4.10**).

Traveler Booking and Validation

The CTP traveler forwards the RideRequest, which is an indexed reservation request (e.g., id) with information on origin/destination, when (arrive-by, leave-at or as soon as possible), time submitted and driver ID (if known).

The RSD validates with the Ride message which contains a response ID, status (PENDING or UNFILLABLE), reservation request id, origin/destination, when, time responded, and if known -- assigned driver, vehicle and ETA.

Since the HDS only books one-way trips, the UNFILLABLE state meets the provision of Req-CS-064 No trip booking available.

The Ride message will be generated when the CTP requests status or validation (Req-CS-040.2) of the trip when requested by the CTP. The RSD responds with the Ride message where the status is assigned to SCHEDULED.

Scheduling Ride and Assigning Driver / Vehicle

The RSD then schedules the trip, generates the driver manifest, vehicle schedule and other key information.

Dispatching a Vehicle

When the RSD dispatches a vehicle/driver, a Ride message is sent to the CTP with status assigned to IN_PROGRESS.

As the RSD schedules rides throughout operations, the RSD generates a RideUpdate (manifest) for the driver. The manifest includes the following fields:

- current timestamp
- status
- location (latitude, longitude)
- array of ordered set of waypoints (locations, description and ETA)
- pickupwaypoint (index in array)

- dropoffwaypoint (index in array)

Ride Monitoring

The Ride Monitoring module generates real-time updates for the CTP (Req-CS-056.2) using the GTFS-RT TripUpdate message. This module also provides situational monitoring and real-time tracking from the driver module and is reflected in the dispatch UI including:

- Tracks vehicle location and status through their on-board operator software and tablet functions (Req-CS-043.2)
- Monitors trips by continuously checking the trip and reroutes them as needed (Req-CS-055.2). The current location of the vehicle is shared with the CTP (Req-CS-056.2)
- Provides ETA to traveler (via CTP) (Req-CS-93)
- If the HDS requires rerouting, trip status updates are sent to the CTP for sharing with traveler based on their preferences (Req-CS-056.2)

NYSDOT provided documentation for the Reservation Status API (Req-CS-046.2) is included in the ICD Section 3.12.

4.2.2.1 Driver App

The driver app provides on-demand services including providing the operator with the route which is calculated based on passenger location and distance from the destination.

The following functions are included in the driver view:

- Driver can view locations and scheduled time of confirmed bookings
- Driver is alerted to changes in booked trips and subsequent changes in route
- Driver can confirm passenger pick-up and drop-off for record keeping
- Drive can message Operations and Dispatch through mobile app or tablet

4.2.2.2 Back Office

The Back Office provides the following processes which are supported for dispatchers:

- Logon / logout (dispatcher / administrator)
- Block and schedule HDS vehicle and operator to daily operations; (replace or cancel HDS vehicle and/or operator from service)
- View current operations including schedule, estimated arrival times, customer tracking in table or map format
- View and export raw data with PII removed

The set of functions for each process is listed in **Table 9**.

Table 9. HDS Dispatcher Functions

Process Name	Functions
Dispatcher Logon	Multifactor Authentication (MFA) Password recovery
View Trips	View scheduled trips (including upcoming trips on driver manifest) View vehicles and trip paths currently in service
Schedule Trip	Select Trip data and time • Change Trip Month • Ensure proper year of trip date is selected. • Select actual date of trip from calendar line Schedule New Pickup Select Rider Name Select Driver Name Identify Pick Up location Identify Drop Off Reverse Pickup Dropoff Location Verify Pickup Date Select Pickup Time Schedule Trip
Driver Management	Add driver Add driver name
Vehicle Manifest	Select available vehicle Assign driver to vehicle
Dispatcher Logout	Logout button

4.2.2.3 Operational Performance and Reporting

The RSD will provide operational service performance information about the HDS services (Req-CS-082.2) and passenger trips (Req-CS-083.2). The information will be summarized from the raw Ride Request and GTFS-RT log files stored in the system.

The system will remove PII such as specific pickup and drop off locations and times, and paths between stops (Req-CS-084.2). Specifically, the system will provide information about:

- Total number of reservations including actual and missed trips
- Total number of revenue miles (by path trace information)
- Ridership by blocks of time and day
- On-time performance (estimated vs. actual pickup/drop-off time variance)
- Total number of incidents reported by driver

The information will be summarized and exported (Req-CS-93) in a comma separated version (CSV) file.

4.2.3 NFTA Operations and Dispatch Center

The existing NFTA operations and dispatch center will provide daily operations, dispatch and communications with HDS operators during HDS hours of operations. The NFTA dispatch staff use a Dispatch module to monitor the schedule, dispatch and send messages to the driver for support.

Existing tools used for PAL operations will also be available including enrolling, transitioning or replacing vehicles into HDS operations, monitoring and reporting health status of a vehicle in revenue service, contacting and managing drivers, and contacting emergency medical services (EMS) upon occurrence of an incident in a HDS (Req-CS-052.2).

Existing standard operation procedures (SOPs) are in place to manage events and incidents for HDS operations. For example, in the case of a vehicle in “degraded mode”, dispatch personnel will dispatch a substitute vehicle and driver to finish the scheduled trips (Req-CS-88.2) and replace the service for the remainder of the shift. The substitution should not affect CTP operations, although the substitution will impact customer trip plans. To that end, the Routing Management module will alert the CTP through the GTFS-RT TripUpdate message that the trip estimated arrival time (at pickup/drop-off) has been delayed.

4.2.4 HDS Requirements Traceability

The requirements that are met by this design are listed in **Table 10**.

Table 10. HDS Requirements Traceability to SDD Section

Req't ID	Req't Title	Status	SDD Section
Req-CS-036.2	HDS on-demand routing and Dispatch	No change	Section 4.2.2
Req-CS-040.2	Validate HDS Reservation	No change	Sections 4.2.1 and 4.2.2.1
Req-CS-043.2	Track HDS Performance	No change	Section 4.2.1 and 4.2.2
Req-CS-045.2	HDS Booking API Specification	No change	Section 4.2.2
Req-CS-046.2	HDS Booking Status API	No change	Section 4.2.2
Req-CS-049.2	HDS Scheduling and Routing	No change	Section 4.2.2
Req-CS-052.2	CS HDS Notify EMS	No change	Section 4.2.3
Req-CS-055.2	HDS Trip Monitor Management	No change	Section 4.2.2
Req-CS-056.2	HDS Update CTP on Trip Management	No change	Sections 4.2.1, 4.2.2, and 4.2.2.1
Req-CS-077.2	HDS Hours of Operations	No change	Section 4.2.3
Req-CS-079.2	HDS Multiple Passenger routing	No change	Section 4.2.2
Req-CS-080.2	Monitor HDS travel anomalies	No change	Section 4.2.1
Req-CS-081.2	HDS Operational and Maintenance Plan	No change	Section 4.2.1
Req-CS-082.2	HDS Operational Performance	No change	Section 4.2.2.3
Req-CS-083.2	HSD Trip Reporting	No change	Section 4.2.2.3
Req-CS-084.2	Secure HDS Trip Reporting information	No change	Section 4.2.2.3
Req-CS-088.2	Report HDS Operating Status to CTP	No change	Section 4.2.3
Req-INT-011.2	HDS Reservation API Specification	No change	Section 4.2.2
Req-Sy-009.2	Access to HDS Mobility Services via CTP	No change	Section 4.2
Req-Sy-018	Accessible Vehicles	No change	Section 4.2.1
Req-Sy-019	Americans with Disability Act	No change	Section 4.2.1

4.3 Indoor Navigation System

The Indoor Navigation System will use commonly available communications technologies already deployed in mobile handsets combined with low-cost Bluetooth Low Energy (BLE) beacons to provide indoor positioning.

The overall solution is represented by the following sections:

- 4.3.1 Hardware Components
 - 4.3.1.1 BLE Beacons – Describes the Bluetooth Beacons, including features and placement considerations.
- 4.3.2 SaaS Computing Platform – Describes the SaaS computing platform that provides indoor navigation asset management (venue maps, waypoints, paths) and the interfaces for connecting with the asset database(s).
- 4.3.3 Interface Components – Describes the software integration features for developing the mobile device app, including on device positioning functions and interacting with the backend SaaS Computing Platform.

- 4.3.4 Asset and Map Update Tools – Describes the web-based tools for managing and maintaining the assets stored in the SaaS Computing Platform.

4.3.1 Hardware Components

4.3.1.1 BLE Beacons

BLE Beacons installed throughout the site(s) will emit short-range radio signals at regular intervals. These signals contain a unique identifier that helps devices identify the specific beacon. The chosen technology used for this purpose is IEEE 802.15, from the original Bluetooth specifications (Bluetooth.com/specifications) which is energy-efficient and well-suited for transmitting data over short distances (Req-INT-002, Req-SI-011).

Physical beacons must be installed throughout the site. Proper placement of beacons is crucial for accurate positioning and communication. Beacons must be strategically placed to cover the desired area and optimize signal strength, area coverage, and battery consumption.

Some complications may arise if the desired (ideal) location of a particular beacon conflicts with customer-specific beacon installation requirements (i.e., visibility of beacon, contrast of beacon color to affixed material, available mounting locations, etc.).

Compromises to the density, location, and mounting style of beacons may reduce the accuracy of the Blue Dot Indoor Positioning experience in effected areas (“Blue Dot” in this context refers to representation of a mobile device location on a map, commonly represented by a blue dot).

The ITS4US Buffalo project will be deploying iBKS Plus BLE Beacons, manufactured by Accent Systems (reference: <https://accent-systems.com/product/ibks-plus/>). Key considerations for this product selection include:

- Extended battery life with user replaceable AA alkaline batteries (est. 84 months) (Req-SI-008, Req-SI-009)
- Compliance with the Apple iBeacon protocol (<https://developer.apple.com/ibeacon/>)
- Compatible with selected SaaS Computing Platform solution

Vendor published technical specifications are available – reference: https://accent-systems.com/wp-content/uploads/iBKS_Plus_datasheet_rev6.pdf (Req-SI-008, Req-SI-009, Req-SI-013).

4.3.1.1.1 Beacon Placement

In general, a denser beacon network will lead to more accurate *on-device position* (location), on average. To achieve uniform accuracy over an area, beacons will be placed with approximately uniform coverage over the entire area, around 10 feet between beacons. Beacon installation locations are provided in Section 3.2.3.1 of the CIP document. The SaaS Computing Platform Technology Provider recommends varying by less than 30% in the grid spacing from beacon to beacon. Additional beacons can be placed for areas that require a higher level of location accuracy (Req-SI-013).

Additional Beacon placement considerations include at a minimum the following:

- Optimization considerations
 - Facility coverage
 - Location positioning accuracy
 - Minimizing interference (line of sight) between beacon position and end user
 - Budget (BLE beacons cost approx. \$50 per unit)
- Physical constraints
 - Obstacles (to beacon placement and future maintenance tasks)
 - Security – placement to deter theft or tampering
 - Signal propagation characteristics
- The beacon installation plan should include only areas relevant to the end-user's access, use case, and the overall purpose of the wayfinding application. For example, if the mobile application is to be used only by the public, beacons should only be installed in areas where the public can physically access the signal.
- Recommended initial beacon installation spacing is on a 7- 8 meter grid (approx. 56 sq. meters per beacon).
- Additional beacons may be desired for potentially increased location accuracy, for example, at high-traffic hallways, intersections of hallways, doorways to heavily used rooms and more.
- Recommended installation height is less than 5 meters above the floor.

4.3.2 SaaS Computing Platform

The SaaS Computing Platform provides key components of the indoor navigation system, including:

- A Content Management System (CMS) for creating, editing, and managing indoor navigation assets.
- API's for retrieving information about the assets stored in the CMS.
- SDKs for use in developing the mobile device application that pulls information from the CMS.
- Proprietary on device positioning libraries that determine the accurate location of a mobile device relative to the CMS assets (BLE beacon positions, defined navigation paths, waypoints, etc.).

All interaction with the CMS system is authenticated by time based security tokens generated based on customer specific clientId / clientSecret credentials.

4.3.2.1 SaaS Solution by CXApp

The chosen SaaS Computing Platform is provided by CXApp (<https://cxapp.com>). The platform provides the following components:

- **CMS (Content Management System):** provides a cloud hosted platform for managing the features of buildings for the purpose of indoor positioning applications (Req-SI-034). Examples of CMS managed items include:
 - Amenities - represent a place of interest that can be navigated to on a map. Examples of amenities include restrooms, elevators, parking lots, etc.
 - Destinations - locations or places on a map to which a user intends to visit. Examples of destinations include meeting rooms, offices, reception areas, kiosk, etc.
 - Floors – a traversable (navigable) level of a building.
 - Paths – a link between waypoints. A user can only travel from waypoint to waypoint if it is connected by a path (note, a path will typically be connected to many waypoints).
 - Path Types - mechanisms used to transport people from one floor to another. Path types have Speed, Weight, and Accessibility parameters, which can be used by the wayfinding algorithms to determine how likely a given path is to be included in the route from source to destination. The parameters will be determined for final in-scope venues and with consultation from local facility representatives. The project will determine which (if any) parameters will be considered by the wayfinding algorithms.
 - Speed parameter:
 - A numerical value between 0 and 99 based on a speed ranking.
 - Represents the speed of a given path type and the likelihood of it being used for wayfinding.
 - A low speed represents a slow path type and is less likely to be used for example a narrow path or path with obstacles (e.g., lounge area).
 - A high speed represents a fast path type and is more likely to be used for example a hallway.
 - Weight parameter:

- A numerical value between 1 and 99, based on a heaviness ranking.
 - Represents the priority of a given path type when wayfinding to a destination.
 - A low weight represents a higher likelihood that the path type will be used for wayfinding.
 - For example, to prioritize elevators over staircases, a lower weight would be assigned to elevators than stairs.
 - A high weight represents a low likelihood that the path type will be used for wayfinding, i.e., that it accommodates a traveler's needs. For example, setting a staircase to 99 would generate paths that consider all path types other than stairs.
- Accessibility parameter:
 - A numerical value between 0 and 99.
 - Represents the desired level of accessibility on a map to assist end users who have challenges with mobility (children, older adults, individuals with disabilities).
 - A lower value represents ease of accessibility. For example, setting this value to 0 will **include** the path type to the accessibility algorithm.
 - A higher value represents limited accessibility. For example, setting the value to 99 will **remove** the path type from the accessibility algorithm.
 - Zones - a collection of several waypoints. A zone typically encompasses a large area within a map. Examples of Zones include parking lots, office wings, large common areas, food court, etc.

The CMS is accessed via a web browser (

Figure 18), and the user is authenticated with a username and password. One (or more) users can have the Administrator role - administrators can add additional users as needed.

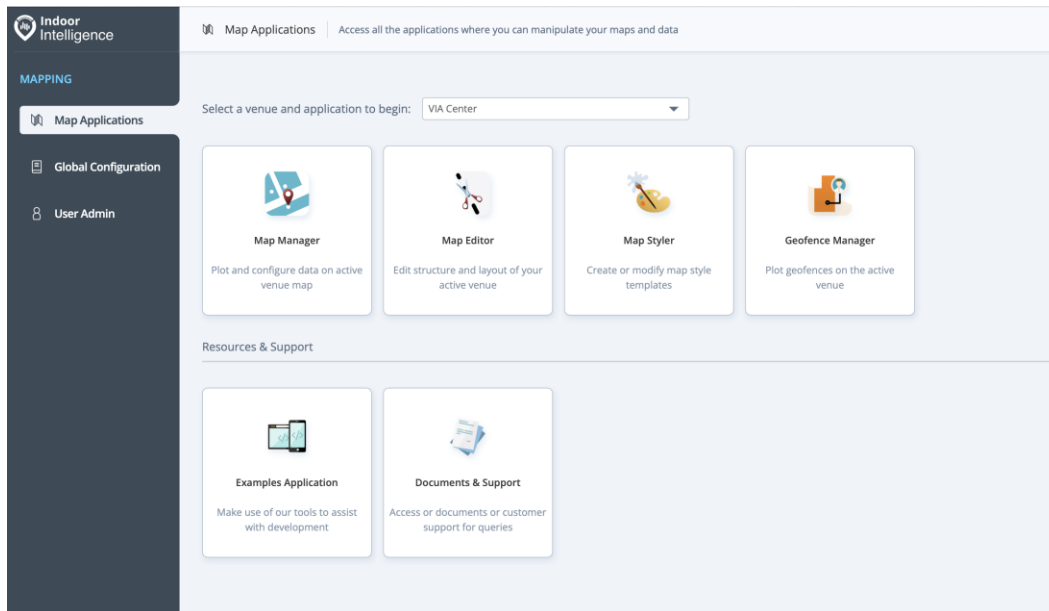


Figure 18. CXApp Content Management Home Page
Source: CXApp

- **Software Development Kit(s) (SDKs):**
 - SDKs provide a set of tools for developers to build and implement maps for the iOS, Android, and Web platforms. Using the tools provided in the SDK, web and mobile developers can build or extend applications to consume complex map data that is managed and configured with the CMS.
 - The SDKs also include proprietary code to implement On Device Positioning (ODP) for indoor navigation. ODP correlates BLE Beacon placement information (from the CMS) with BLE Beacon unique identifiers and Received Signal Strength Indicator (RSSI) data to approximate the location of the handheld mobile device. RSSI is a measure of how strong the BLE beacon signal is as it is received by the handheld device.

4.3.3 Interface Components

The CXApp SDK functions are provided as Apple iOS and Android native libraries. The CTP mobile application is developed using the React Native development platform. At this time, CXApp does not provide a React Native library, so the ITS4US Buffalo project developed an API library bridging the React Native and CXApp native libraries (Req-SI-033).

Functional examples of key SDK functions are available publicly at:

<https://apps.jibestream.com/examples/>

Documentation for all SDK functionality is available with self-serve account creation - reference:

<https://support.cxapp.com/hc/en-us>

CXApp SDK native libraries provide the following features:

U.S. Department of Transportation
Office of the Assistant Secretary for Research and Technology
Intelligent Transportation System Joint Program Office

- Compatibility with iOS 9+ and Android 4.3+ (Jelly Bean).
- Methods are provided to retrieve a destination on a map, display destination details, highlight destinations, and connect two destinations through a path. Note: destinations must be assigned to a waypoint to be included on the map.
- Positioning and Tracking: Indoor location accuracy using universal low-cost beacons and sensor fusion technology.
 - Dead Reckoning: Leverage the sensors available in most smart phones – accelerometers, gyroscopes, magnetometers, and pressure sensors – along with cutting edge mobile processing algorithms (CXApp proprietary) to compute responsive and accurate location, motion, and user context.
 - User Position (Blue Dot): User Position features allow for accurately displaying the user's current location on a map.
- Map Matching: Detailed map data, when available, are used both for aiding the positioning solution down to meter-accurate levels, and for determining way-finding guidance that can be provided to a user seeking out known points of interest within a customer-expandable database.
- Map Display:
 - Scaling: On mobile devices, scaling helps users identify map elements like destinations and amenities. Scaling is a feature that is built into the SDK, allowing users to freely zoom in or out through interactive gestures and/or UI elements such as zoom in/out buttons. The scale of the displayed map can be adjusted to help users focus on a specific portion of the map – the map can be zoomed in or out based on the current view of the map; the map can focus in on a specific element like a destination or path.
 - Map rotation is built into the SDK, allowing users to freely rotate the map to better view map elements. Map rotation can be customized to help users orientate the map in the same direction that the user is facing/moving, which will make features like wayfinding more intuitive (i.e., a heads-up map orientation).
- Navigation: Provides precise step-by-step guidance to people and places, through hallways, across buildings, and between floors.
- Navigation Algorithms: User locations are triangulated using BLE Beacons. The user's x/y location is converted as a latitude and longitude position, and precisely rendered on the map as a Blue Dot. As a user's location changes, the position of the Blue Dot is updated. During navigation, if a user veers from the generated path, the path will update and respond to the user's location, continuing to route them to their chosen destination.
 - Wayfinding: The ability to navigate between two Waypoints on a map or to a particular destination. The Wayfinding algorithm uses Speed, Weight, and Accessibility parameters along with the distance and number of paths in order to generate an optimal path.

- **Trip Planning:** Create a navigation experience by providing end-users with a staged route to reach a list of their curated destinations. End-users can select multiple destinations to create a route, see their location updated in real-time against their planned route, and optionally take static directions with them using Quick Response (QR) Code hand-off from a web application.

Since not all CXApp SDK functions are required in the CTP application, not all SDK functions will be exposed by the bridging library. **Table 11** lists the SDK functions that are planned to have bridging APIs developed (organized similarly to the <https://apps.jibestream.com/examples/> site):

Table 11. SDK Functions by Functional Group

Group	Functions
Mapping	Load Map (from CXApp CMS) Display Map Display My Position on Map Show Icons on Map
Navigation	Draw Path on Map Destination Wayfinding Snap to Wayfinding Path
Rendering	Styling with JSON
Interactivity	Layer Interaction Layer Double Tap Map Gestures
Locales	Load Default Locale
Advanced	Destination Search Advanced Wayfinding Destination Search Blue Dot Blue Dot Navigation Lat/Long Conversion
Device Kit	Wayfinding to Device Apply Device Orientation
Map UI Kit	Navigation with Compass Search
Navigation Kit	Create Text Directions Landmark-Based Directions Distance-Based Directions Auto Reroute Wayfinding
Geofence Kit	Geofence Notifications
Outdoor / Indoor Kit	Single Venue Wayfinding Multi Venue Wayfinding Multi Venue Destination Search

Communication between the CTP mobile application and the CXApp CMS is authenticated by clientId and clientSecret tokens embedded in the mobile application. No end-user specific credentials are required, and no end-user information is transmitted to the CMS system.

4.3.4 Asset and Map Update Tools

Asset and Map Update Tools are included in the CXApp CMS solution to keep track of beacon locations related to the facility layout. The CMS data is the “mapping source of truth” for the indoor navigation solution.

The CMS management solution includes the following web-based tools:

- Map Manager (Req-SI-034)
- Map Editor (Req-SI-034)
- Map Styler
- Geofence Manager

4.3.4.1 Map Manager

The map manager tool provides functions to review, update and delete walking paths and point of interest locations of the indoor facilities layout. To begin the process, up-to-date detailed floor plans are provided to CXApp to generate the initial map. The initial input to this process includes:

- Computer Aided Design (CAD) (.dwg) format diagrams denoting structural map references including as-built drawings denoting the current, physical state of the building to be mapped and a detailed site plan of the surrounding area.
- List of all Unique Points of Interest to be mapped:
 - Naming conventions are audited to match any physical signage or common nomenclature to ensure continuity of the experience.
 - Indication of each Point of Interest as Public, or Private/Internal, or other segregated user group.
 - Keywords for all points of interest for relevant and related search terms that end user may also query.
 - All relevant data is provided in English (locale code: us-EN). Additional languages can be added to the CMS.

Based on the provided CAD diagrams, the Technology Vendor (CXApp) generated a map with the WGS-84 Pseudo Mercator alignment (EPSG Code: 3857), so that Blue Dot (real-time position based) location can be enabled for users in the application.

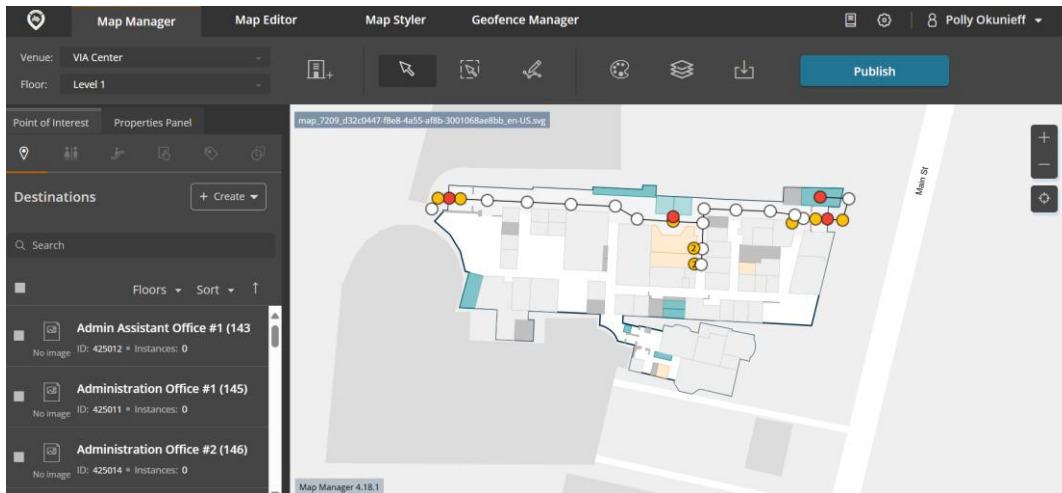


Figure 19. Map Manager Tool with Path and Location Information

Source: CXApp

After the initial map data is populated in the CMS, testers checked the sensitivity of the paths and locations of the beacons. Adjustments were made to the map to simplify the path structure, and additional beacons were installed to cover any gaps or holes in Bluetooth coverage. Future structural or temporary obstructions and changes to the Map assets can be performed using the CMS web “Map Editor” application (**Figure 19**):

Key features of the Map Manager CMS management tool include:

- Incrementally make changes to Map Manager venues or coordinate large changes to be published (for example, expanding the indoor navigation solution to new parts of a building).

4.3.4.2 Map Editor

The map editor shown in **Figure 20** enables the facility owner to make incremental structural changes to the initial map (Req-SI-034). In particular, the facility owner will use this tool to represent temporary service outages, i.e., elevator, escalator, etc. such that alternative accessible paths can be provided temporarily. Key features of the Map Editor CMS management tool include:

- Editing maps on demand – the self-serve tool makes it easy to keep maps up to date for minor structural changes.
- All CMS Map Structure changes are versioned, allowing for the easy restoration of any version of previously saved maps. The CMS system automatically saves point-in-time changes with auto-generated map version name and indicates the date and time that the map was published.

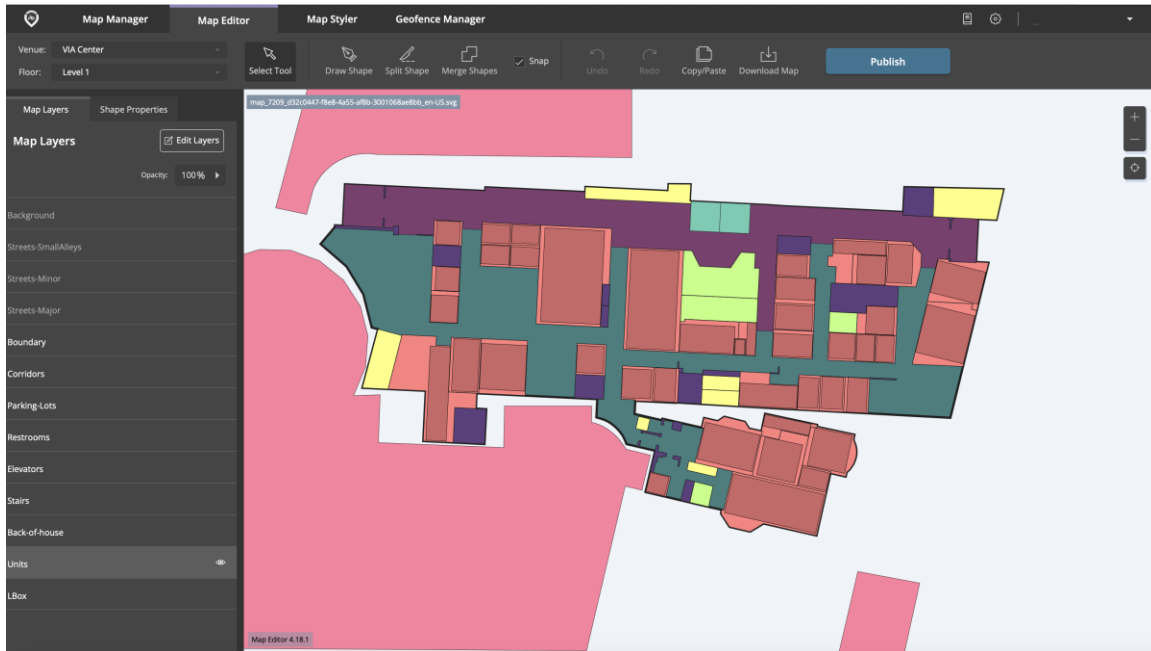


Figure 20. Map Editor Tool viewing Structural Map Layers

Source: CXApp

4.3.4.3 Map Styler

The map styler shown in **Figure 21** enables mapping administrators to customize and manage the appearance of rendered maps by creating Map Styles. Map styles include map color palettes, and map layer colors.

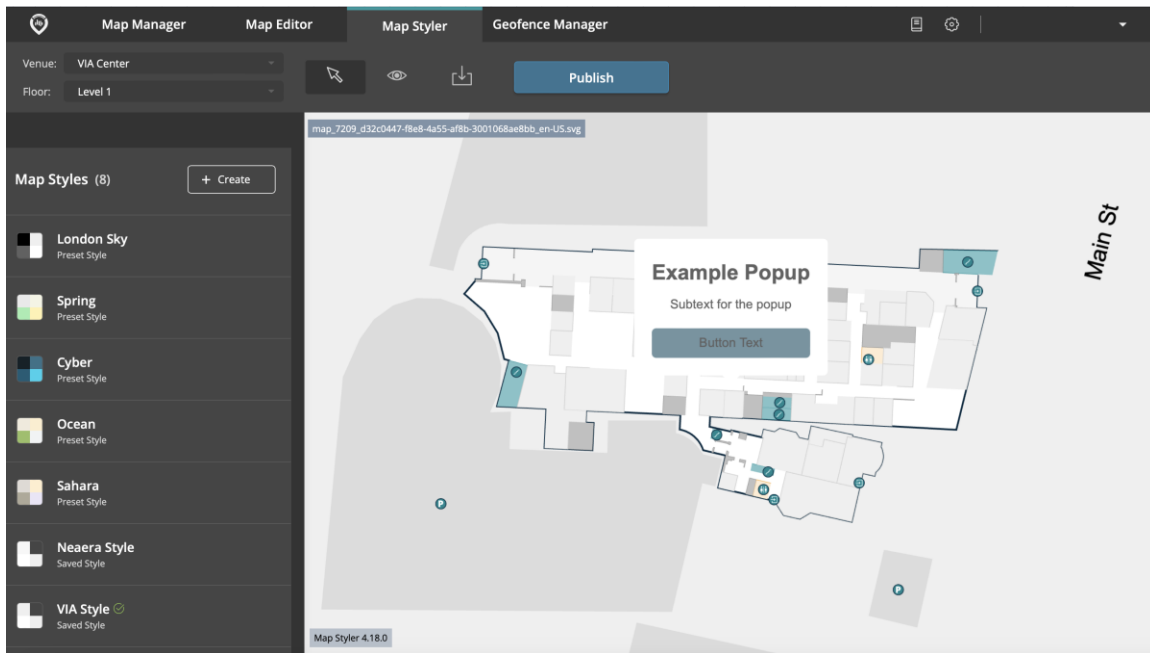


Figure 21. Map Styler Tool Viewing Saved Map Style Page

Source: CXApp

4.3.4.4 Geofence Manager

The Geofence Manager shown in **Figure 22** allows mapping administrators to create and manage Geofence definitions relative to the venues in-scope for indoor navigation. A geofence is a user-defined area of interest that is represented on a real-world map. Geofences are drawn as polygon(s) from a set of real-world longitude-latitude coordinates. The mobile device SDKs provide functions (callbacks) that are triggered when a mobile device enters/leaves the defined Geofence areas (for example, providing a mechanism to switch to/from “indoor” navigation mode and “outdoor” navigation mode).

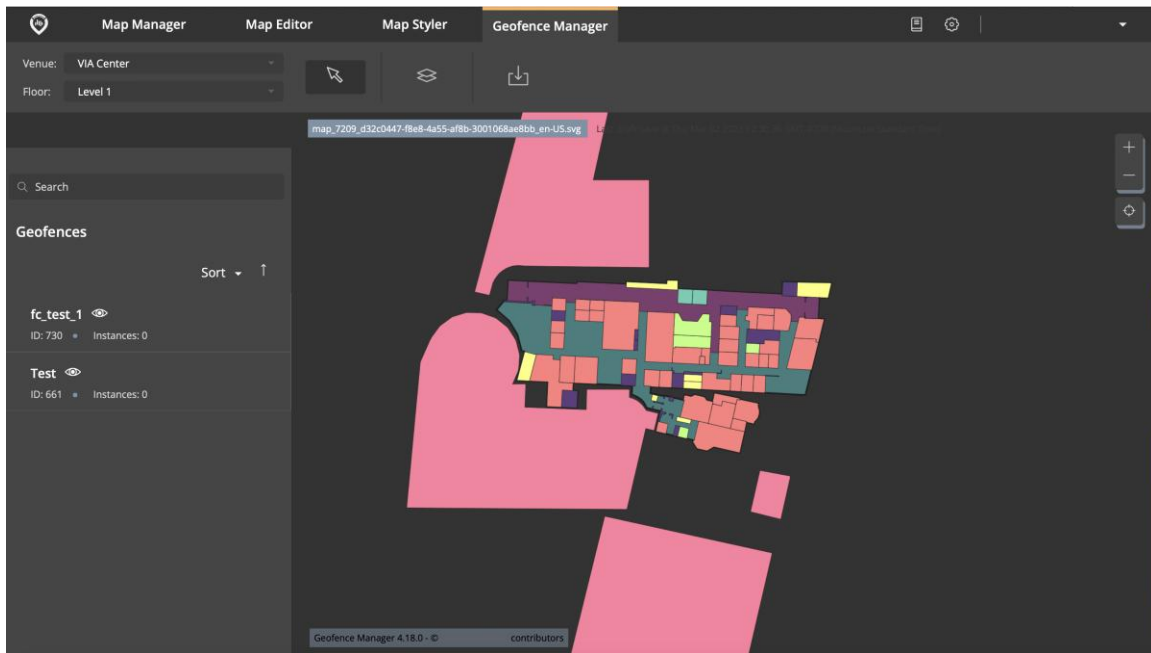


Figure 22. Geofence Manager Viewing Public Areas in the Facility
Source: CXApp

4.3.5 INS Requirements Traceability

The requirements that are met by this design are listed in **Table 12**.

Table 12. INS Requirements Traceability to SDD Section

Req ID	Req Title	Status	SDD Section
Req-INT-002	BLE 5	No change	Section 4.3.1.1
Req-SI-008	Bluetooth Beacon durability	Approved	Section 4.3.1.1
Req-SI-009	Bluetooth Beacon power	Approved	Section 4.3.1.1
Req-SI-011	Smart Signs -- BLE Beacons	Approved	Section 4.3.1.1
Req-SI-013	Bluetooth Beacon installation and mounting	Approved	Section 4.3.1.1 and 4.3.1.1.1
Req-SI-033	Indoor Navigation Software Development Kit (SDK)	Approved	Section 4.3.3
Req-SI-034	Indoor Map Generation	Approved	Sections 4.3.2.1, 4.3.4, and 4.3.4.2
Req-Proj-15	Indoor Nav Buy America Provision	Approved	See CAP Section 2.3 and CIP Section 3.1.4
Req-Proj-18	Indoor Navigation Operational Readiness Testing and Demonstration	Approved	See Test Results and ORP Section 3.4.4
Req-Proj-19	Indoor Navigation Component Testing and Reporting	Approved	See Test Results and STP Section 2.1.2
Req-Proj-20	Indoor Navigation Operations and Maintenance Services	Approved	See CMOP Section 8.2

U.S. Department of Transportation
 Office of the Assistant Secretary for Research and Technology
 Intelligent Transportation System Joint Program Office

4.4 Pedestrian Signal / Intersection Crossing

The Miovision Core Detection and Counts Module (DCM) and SmartView camera will be used as a gateway to the intersection pedestrian signal request module. This PED-X Gateway will serve as a “proxy” between the CTP request for pedestrian signal and the traffic signal controller using a variation of the NTCIP 1211 Signal Control and Prioritization preemption message. This gateway provides a conduit to authenticate and secure the information exchange between the CTP and traffic signal system. Information channeled from the pedestrian to the signal system includes the request information.

Note that the Traffic Signal System, using an audible pedestrian signal will display and annunciate *walk* and *don't walk* signals at the intersection.

The Miovision module consists of hardware installed at each intersection, software and interfaces between the Miovision hardware and existing traffic signal controller system, and cloud services to communicate with and monitor the intersection systems.

In addition, BLE beacons were installed to signal system posts in order to augment the safety provision for travelers at the stops.

4.4.1 Hardware

The hardware installed in the two intersection consists of the Miovision Core DCM Hardware and SmartView 360 camera (see **Figure 23**).



Figure 23. Miovision Intersection Hardware

Source: Miovision

Details of their specifications are included in:

- [Miovision Core DCM Hardware Specifications](#)
- [Miovision SmartView 360 Hardware Specifications](#)

4.4.2 Signal Communications and Traffic Operations Platform

The software package, hosted in the cloud as a service, includes:

Communications: using cellular services between the cloud implementation and the field hardware (Core DCM communications interface). The communications unit provides:

- 4th-Generation Cellular(4G) LTE cellular data service between the Communications Interface and the Server via a national commercial carrier using Bands 2, 4, and 13
- Failover support from 4G to 3rd - Generation Cellular (3G) to 2nd - Generation Cellular (2G) with incremental fallback
- Cellular site survey via a portable unit to determine cellular signal strength (Received Signal Strength Indicator (RSSI) for 3G, Code Division Multiple Access (CDMA)/ United Telecommunications Service (UTS)/ Evolution-Data Optimized (EV-DO), and Reference Signal Received Power (RSRP) for 4G LTE)
- Cellular site survey via a portable unit to determine cellular signal quality Energy to Interference Ratio (ECIO) for 3G, CDMA/UMTS/EV-DO, Reference Signal Received Quality (RSRQ) for 4G LTE, and SINR or Signal to Interference-plus-Noise-Ratio for 4G LTE)

Server: The server provides the following:

- Hosted at a professional cloud hosting facility with redundancy of at least two instances, with automatic load balancing and shall scale to support simultaneous number of connections
- Permanent storage of all Telemetry Data, Alert Data, and Vehicle Identification Data in perpetuity.

Secure Communications: Security provisions include the following:

- Provides a Virtual Private Network (VPN) for secure data transmission between the Core DCM and Server
- Authenticated using public key infrastructure (PKI) and encrypting using PKI and the TLS/ Datagram Transport Layer Security (DTLS) 1.0+ protocol
- Implements HTTPS/SSL (Secure Sockets Layer) communication to the Server from the public internet for access of the User Interface
- Supports revoking of all authenticated user names, passwords, or keys at any time
- Supports simultaneous integration across a heterogeneous mix of different technologies and providers, including different cellular providers, fiber connected networks, and point-to-point radio solutions

Device Monitoring: functions provide a serial-over-LTE connection and appropriate networking support to enable secure communication between cabinet hardware. This is a monitoring function that triggers an alarm to the server.

User Interface: The server side (cloud) enables users the following access and functionality:

- A secure web-based Graphical User Interface (GUI) using SSL
- An unlimited number of concurrent logins by authenticated users
- Fully accessible via desktop, tablet, and mobile products on Chrome, Microsoft Edge and Safari
- All the functionality of Signal Monitoring, Alerts Management, Inventory and Asset Management and Traffic Data Analysis from a single software application requiring a single login
- User login via OAuth Login
- A secure means of verifying account registration via email
- A secure means of password reset
- The addition and management of user accounts for users that are both inside and outside of the organization at no additional cost
- Access to all Telemetry Data and Alert Data

Figure 24 shows the location of the intersection on the map as well as an aerial view of the intersection.

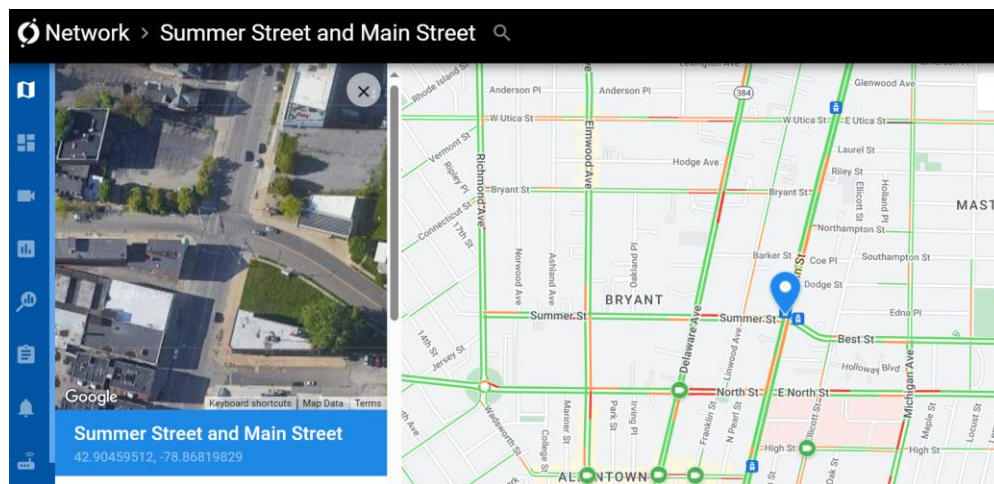


Figure 24. Example UI of Miovision Implementation at Summer and Best Streets.

Source: Miovision

Signal Monitoring: functions include the following:

- Live display of all Telemetry Data with latency not to exceed 1 seconds when LTE connection is active (see a screenshot of telemetry data in **Figure 25** showing the current display from the traffic signals as well as the presence of vehicles detected on channel 2, Dark shades indicate the channels are not in use.)
- Historical display of all Telemetry Data on-demand with load latency not to exceed 1 second
- Viewing mode in which all Telemetry Data is displayed overlaid onto a diagram of the intersection
- Viewing mode in which all Telemetry Data is displayed in a timing diagram format in which interval length is displayed in seconds for each signal phase
- Display of environmental weather conditions, including precipitation and temperature, as part of live and historical viewing of Telemetry Data
- Reporting on signal telemetry, detector and alert data

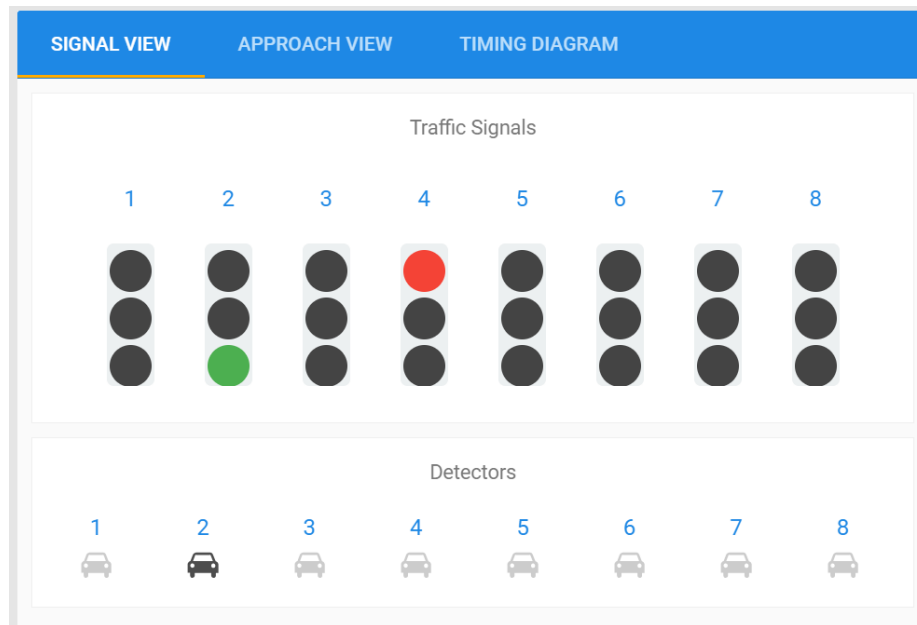


Figure 25. Telemetry Data (Signal View) from Ellicott and High Streets

Source: Miovision

No signal channels are deployed in the Approach View. The Timing Diagram is shown in **Figure 26**.

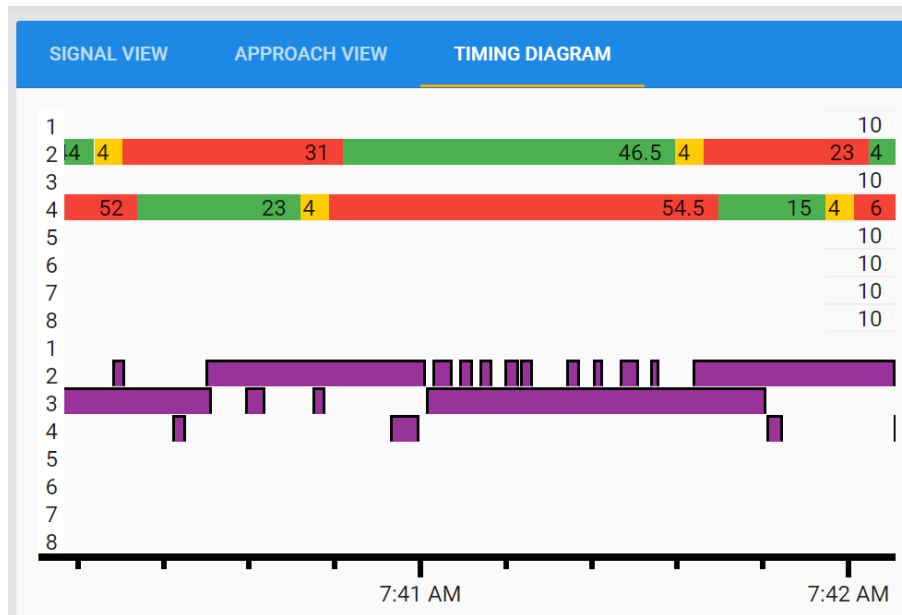


Figure 26. Telemetry Data (Timing Diagram) from Ellicott and High Streets

Source: Miovision

In addition, the system supports Alerts Management and Inventory and Asset Management functions. These functions are used by the CoB, but not by the project.

The system also supports access of data via a REST API that is encoded in JSON or XML (Extensible Markup Language). The project uses the JSON version of the API. The API is discussed in the ICD, Sections 3.2 and 3.3. The Preemption API is used to request pedestrian signal actuation.

4.4.3 Beacon Enhancement at Intersections

The positional accuracy of the GPS was not sufficient to capture the accuracy needed to detect when a traveler was at the corner of an intersection and not in the intersection. In addition, the corner of Ellicott and High posed significant GPS accuracy challenges due to multipath errors. To that end, Bluetooth beacons were installed on each signal pole in the intersection that includes PED-X, Ellicott and High. (Note: Main and Summer/Best will include beacons following construction in 2026). The approach was as follows:

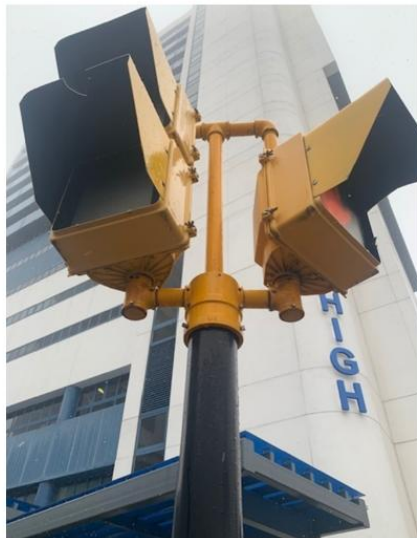
1. Measure pole dimensions to determine height and width of material needed to attach beacon to each corner of the intersection (see **Figure 27**).
2. Test beacons and set their strength to maximum setting so that the signal may be detected from at least 50 feet.
3. Place beacon in NEMA Type 3R enclosure – rated for outdoor use to protect against water (rain, sleet, snow).
4. Install on each post in all four corners of the intersection (see **Figure 28**).

5. Retest the PED-X and the range of the beacon strength settings.

Ellicott and High Northwest Corner



Northwest Corner



Northwest Corner Installation Zone



Northwest Corner Pole Width

-The other three poles on the SW, NW and NE corners are smaller poles. They are 5" at the base but taper slightly and are 4 1/2" at the top where the installation would take place.

Figure 27: Measuring Pole Dimensions for Ellicott and High Northwest Corner

Source: NFTA / BNMC



Figure 28: View of the beacon housing on each of the intersection poles.

Source: NFTA/BNMC

4.4.4 PED-X Requirements Traceability

The requirements that are met by this design are listed in **Table 13**.

Table 13. PED-X Requirements Traceability to SDD Section

Req ID	Req Title	Status	SDD Section
Req-SI-001	PED-X Gateway	No Change	Section 4.4
Req-SI-002	PED-X Gateway operation	No Change	Section 4.4.2
Req-SI-003	Receive PED-X request message	No Change	ICD Section 3.2
Req-SI-004	Log PED-X request	No Change	Section 4.4.2
Req-SI-005	Forward PED-X request	No Change	ICD Section 3.3
Req-SI-006	Send PED-X status	No Change	ICD Section 3.2
Req-SI-007	PED-X Status Message	No Change	ICD Section 3.2
Req-SI-025	PED-X Gateway	No Change	Section 4.4.2
Req-INT-007	NTCIP 1211 Signal Control and Prioritization	No Change	Section 4.4

4.5 Transportation Information Hub

The TIH uses the same software as the CTP web application. To that end, it will offer the same trip planning and information as the CTP. Users can find locations, generate and save a trip plan, request navigation directions and notifications, and find how to download the CTP mobile app.

Since the TIH is a channel for the CTP web version (design described in **Section 5**), this section describes the hardware specifications and management functions available from the procured services. The section is divided into kiosk hardware and Engage IoT software.

4.5.1 Kiosk Hardware

The RedyRef Empire R3.0 with 43-inch free standing touch screen kiosk (see **Figure 29**) was selected to be installed at two sites – NFTA Best and Main Rail Station entrance area and Kaleida Health's Buffalo General Medical Center lobby.



Figure 29. Transportation Information Hub -- RedyRef Empire 3.0

Source: RedyRef

The TIH display will be installed in the portrait position.

Enclosure: Freestanding, ruggedized steel construction, power coat finish (white with black), front access door with key lock, ADA capable

Mount: baseplate or to Floor through baseplate

Display: 43-inch Projected Capacitive Touch Sensors (PCAP) Touch Screen

Media Player: small form factor Central Processing Unit (CPU) i3 Processor with 8 Giga Bytes (GB) Random Access Memory (RAM), 250 GB of Solid State Drive (SSD), Windows 10 IoT (aka embedded system)

Audio: AudioNav™ device (storm interface)

Power: 120v-15 amp maximum power draw

Environment: Indoor temperature rated. Note: the environmental specifications are sufficient for indoor temperatures. Processor was upgraded to provide for operations during low temperature ranges.

Communications: WiFi – external antenna

4.5.2 Engage IoT Software

The management software is composed of the Engage IoT client and server side software components. The server side includes the kiosk and portal software services while the client side includes services that enable the client (aka CTP) to interact with the server as shown in **Figure 30**. The functions associated with the server side are described in **Table 14** and the client side are described in **Table 15**.

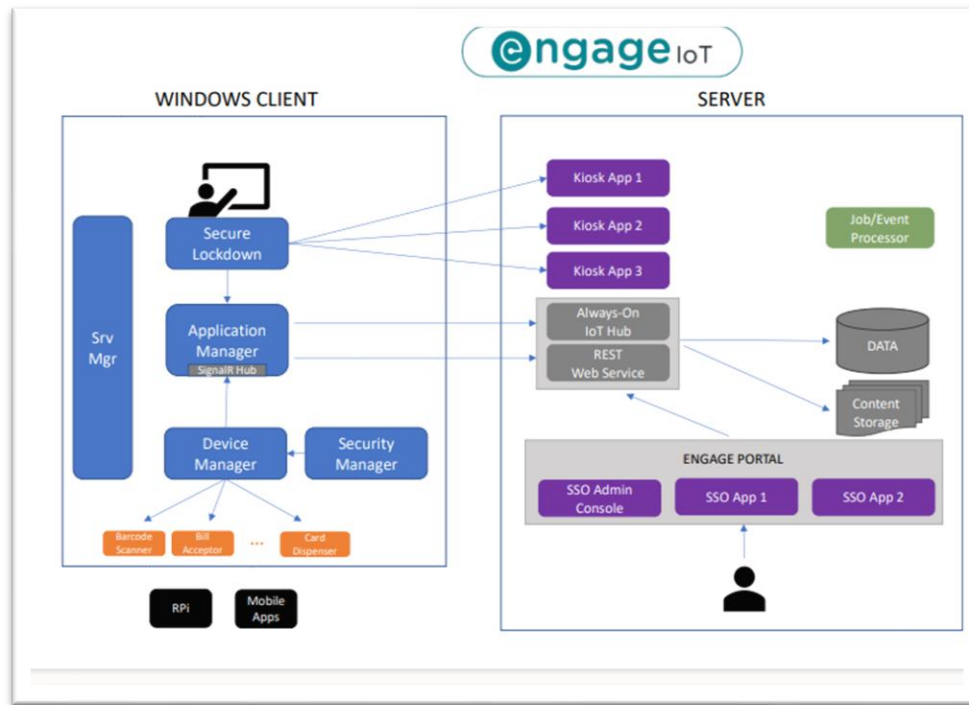


Figure 30. Kiosk Software Architecture

Source: RedyRef

The server-side functions are associated with the Engage Portal functions. The portal provides administrative, configuration, monitoring and management functions that the client accesses through the application manager. As part of their management contract, RedyRef administration staff will manage the kiosks at both sites using the portal functionality. The functions are described in **Table 14**.

Table 14. Functions -- Engage IoT Server

Engage IoT Server	Description
Single sign on (SSO)	Server side access and authentication is managed through a single sign on process.
Custom dashboard	The Dashboard, accessible through the Engage Portal, may be customized by the user. Screenshots of the Administration view is shown in Figure 31 and Figure 32 .

Engage IoT Server	Description
Device configuration and control	The device configuration and control – general and session configuration and control as shown in Figure 31 and Figure 32 below. The Attract Mode and Keyboard will not be used for this project. (note a separate keyboard function was developed as part of the CTP design, see Section 5.5.5).
Device monitoring and alerts	The Device dashboard provides an overview of the status of all devices, with the ability to quickly drill down into hardware component health and to initiate commands such as reboots to the remote devices. One such alert to be configured will be to monitor kiosk health. The kiosk will send periodic heartbeats to the monitoring system and if any heartbeats are missed (i.e. due to power failure or bad internet connection), an email alert will be sent to configurable recipients.

The screenshot displays the 'Admin' interface for the Engage Lockdown browser. The top navigation bar includes 'Settings' and 'Devices' tabs. The 'General Settings' section is active, showing various configuration options. The 'Security Codes' section contains fields for 'Exit Code' and 'Restart Code'. The 'Custom Navigation' section at the bottom features a table with columns for 'Code' and 'Url', and an 'Add More' button.

Figure 31. Engage Lockdown browser – General Settings
Source: RedyRef

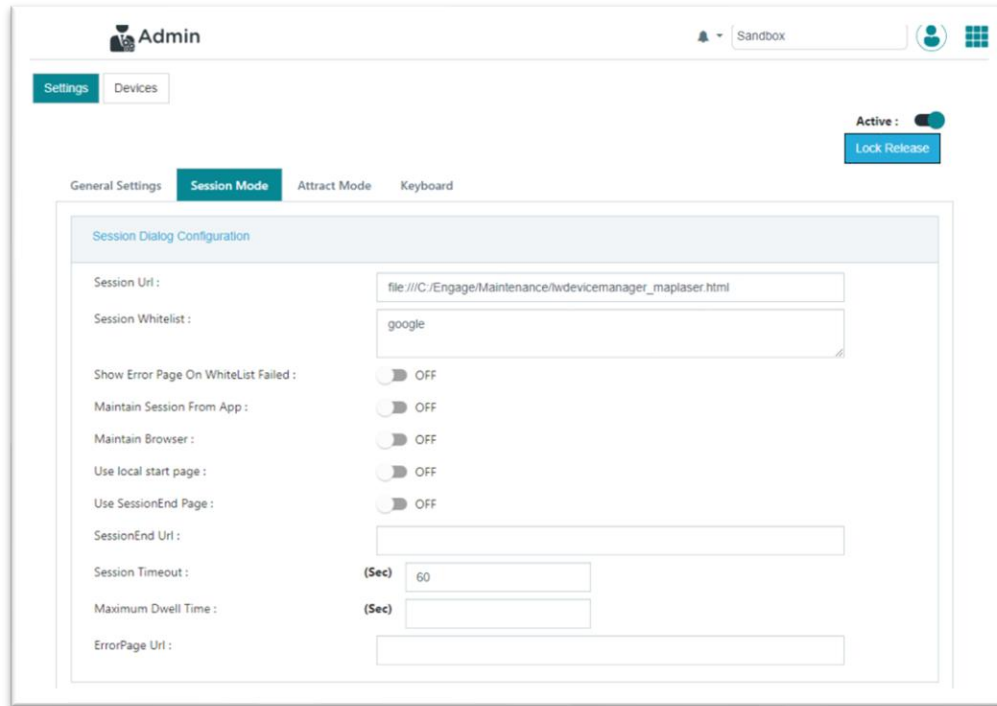


Figure 32. Engage -- Lockdown browser – Session Mode

Source: RedyRef

The client services available to be used by the CTP are described in **Table 15**. These tools support presenting and securing the display for using the CTP app. The design elements of how the CTP uses these tools are discussed in **Section 5.5.5**.

Table 15. Functions -- Engage Client (CTP)

Engage Client	Description
Secure lockdown browser	The Engage Secure Lockdown application secures the device from user access to the desktop and unauthorized web sites. Lockdown also contains all of the features needed, such as session timeouts and on-screen keyboards, to easily deploy an enriched user experience.

4.5.3 TIH Requirements Traceability

The requirements that are met by this design are listed in **Table 16**.

Table 16. TIH Requirements Traceability to SDD Section

Req ID	Req Title	Status	SDD Section
Req-SI-016	TIH thin client for CTP	No change	Section 4.5
Req-SI-017	TIH CTP configuration	No change	Section 5.5.5
Req-SI-018	TIH CTP connection	No change	Section 4.5.1

U.S. Department of Transportation
Office of the Assistant Secretary for Research and Technology
Intelligent Transportation System Joint Program Office

Req ID	Req Title	Status	SDD Section
Req-SI-019	TIH equipment	Approved	Section 4.5.1 Note: keyboard is described in Section 5.5.5.
Req-SI-020	TIH touch model	N/A	Pending Deprecation
Req-SI-021	TIH talking model	N/A	Pending Deprecation
Req-SI-022	TIH touch model language selection	N/A	Pending Deprecation
Req-SI-023	TIH touch model content configuration	N/A	Pending Deprecation
Req-SI-024	TIH CTP and Touch Model operations	N/A	Pending Deprecation
Req-SI-028	Public kiosks	No change	Sections 4.5 and 4.5.1
Req-SI-029	TIH environmental conditions	No change	Section 4.5.1
Req-SI-030	SI durability	No change	Section 4.5.1
Req-SI-035	TIH ADA Compliance	Approved	Section 4.5.1
Req-SI-036	TIH Connectivity	Approved	Section 4.5.1
Req-SI-037	TIH Operating System	Approved	Section 4.5.1
Req-SI-038	TIH Web Access Restriction	Approved	Section 4.5.2
Req-Sy-019	Americans with Disability Act	No change	Section 4.5.1
Req-Proj-13	TIH Installation	Approved	See CIP Section 5.4
Req-Proj-14	TIH Operations and Maintenance	Approved	See CMOP Section 8.3
Req-Proj-9	TIH Buy America Provision	Approved	See CAP Section 2.3 and CIP Section 5.3.1
Req-Proj-10	TIH User Outreach and Training	Approved	See Training Materials and Section 3.3.5
Req-Proj-11	TIH Operational Readiness Testing and Demonstration	Approved	See Test Results and Section 3.4.4
Req-Proj-12	TIH Test Planning and Reporting	Approved	See Test Results, STP Section 4.3.1, and CIP 5.3.1

4.6 Sidewalk Collection

This section describes the sidewalk data collection process. **Figure 33** shows the sidewalks where data was collected. The task collected data on sidewalk accessibility and then entered it into the OpenStreetMap (OSM).

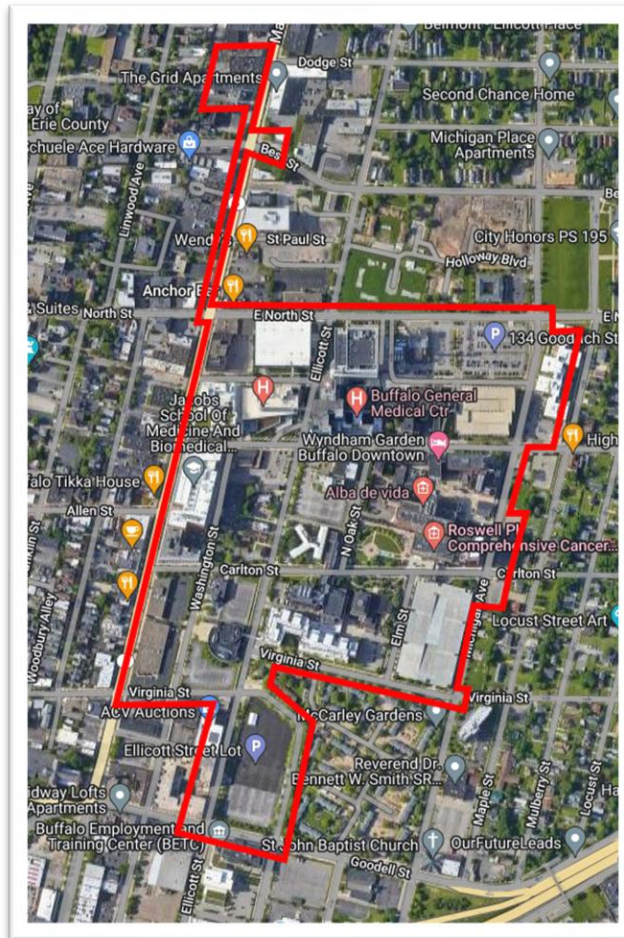


Figure 33. Map of the Sidewalk Data Collection Area at BNMC

Source: Buffalo, NY ITS4US (2024)

4.6.1 Sidewalk Collection Overview

Sidewalk data collection was performed by staff from the Center for Inclusive Design and Environmental Access (IDEA Center), a research unit and service center at UB's School of Architecture and Planning. Specifically, the team conducted an in-person audit of the existing BNMC (see **Figure 33**), focusing on the public realm (i.e., site access, primary pedestrian routes, curb cuts, crosswalks, transit stops, parking, and wayfinding). The team identified barriers to independence for wheeled mobility device users and people with hearing and visual impairments.

The audit was designed to document existing conditions and was not intended to ensure compliance with any particular law or regulation. However, the team also made determinations as to the suitability of the surfaces based on available regulatory guidance such as the 2010 ADA Standards for Accessible Design and U.S. Access Board draft regulations for the accessibility of public rights-of-way.

The work included the following:

- Developing a checklist of features to audit at each intersection and for each block, and for all routes to building entryways, for both sides of streets and buildings along the blocks East of Main St. and West of Michigan Ave., between North St. and Virginia St.
- Attributes collected to include those identified below, where attributes generally complied with regulatory guidance, the feature was simply reported as present. Additional details were provided where such features were observed to be deficient in some way. For example, the curb height was not provided at an intersection where a curb ramp was present and appropriately designed. If the curb ramp did not provide the appropriate slope, the slope was documented. If there were no curb ramps, the curb height was reported.

The audit was performed in the spring of 2023. The findings were documented in an Excel spreadsheet coded to a map of the BNMC campus. Following this, staff from UB's School of Engineering and Applied Sciences (SEAS) undertook the task of coding the collected data in OSM.

4.6.2 Attributes Collected

The following attributes were collected:

- Sidewalks:
 - Estimated width (36+/48+/60+)
 - Incline maximum observed value if over 5% (%)
 - Cross slope maximum value observed if over 2% (%)
 - Smoothness (excellent/good/intermediate/bad)
 - Surface type (paved/asphalt/concrete/paving stones)
- Curbs at highway crossings (flush/raised/lowered), the following attributes were collected:
 - Tactile paving (yes/no/incorrect/partial/contrasted)
 - Incline (%)
 - Counterslope if over 5% (%)
 - landing (36+/48+/60+)
 - direction (parallel/perpendicular/diagonal)
- Highway crossings (traffic signals/uncontrolled/controlled/island/unmarked)
 - Traffic signals (yes/no): sound/vibration/arrow
- Barriers (e.g., Protruding objects, tripping hazards)
- Lighting fixtures provided (yes/no)
- Steps and ramps (including handrails and slope)
- Entrance (main)
 - Automatic door (button/motion)
 - Wheelchair accessible (yes/limited/no)

- Door (hinged/sliding/revolving)
- Amenities: drinking water, bench, shelter, toilets, vending, dog waste (yes/no)
- Wheelchair accessibility of each feature (yes/limited/no)

4.6.3 Encoding Sidewalk Data to OSM

The features were collected and mapped to the OSM attributes in order to ensure consistency with the CTP provisions for map data ingestion. The collection team entered the data in spreadsheets that included eight feature types and their corresponding attributes (see above). These features and attributes correspond to OSM tags in the eight categories shown in **Table 17**. In each category, date collected, person collecting, notes and image file to record lineage information. The notes field was not transferred to OSM however the notes describe the name, instructions for entry, type of accessibility challenge, and other attributes or issues associated with each of the eight categories. Note that the tags labeled custom were inserted as a description in OSM.

Table 17. OSM Tags Used for Sidewalk Feature Set

Category	OSM Tags
Sidewalk	location location_description sidewalk:width= sidewalk:incline= sidewalk:surface= sidewalk:smoothness= sidewalk:lit= sidewalk:wheelchair= (custom) sidewalk:cross_slope=
Barrier	location barrier= (custom) barrier:user_defined=
Amenities	location amenity= parking:capacity:disabled= (custom) amenity:other= amenity:wheelchair=
Entrance	location entrance= entrance:access= entrance:wheelchair= entrance:automatic_door= entrance:door=
Kerb	location kerb= kerb:height= tactile_paving= (custom) kerb:incline= (custom) kerb:counterslope= (custom) kerb:top_landing= (custom) kerb:direction= wheelchair=

Category	OSM Tags
Crossing	location crossing:type= crossing:island= crossing:wheelchair= traffic_signals:countdown= traffic_signals:operated= traffic_signals:sound= traffic_signals:vibration= traffic_signals:arrow=
Steps	location steps:number_of_steps= steps:handrail= steps:lit= steps:ramp=
Ramp	location ramp= ramp :incline= ramp :handrail= ramp:wheelchair=

The collected data was entered into OSM for each of the respective paths (sidewalks) so it can be used by the CTP. The OSM tags and custom tags that were used include the tags included in **Table 17**. The custom tags were inserted as a comma delimited array in the OSM “description” tag.

5 Complete Trip Platform Subsystem

This section details the design of the CTP, which consists of the functional flow diagrams, epics and User Stories that are part of the Agile development process. They describe the functions, flow, and elements that compose the subsystem design.

5.1 CTP Design and Agile Backlog

The design of the CTP is described within the context of the following components which provide the detailed subsystem design:

- Platform – core and base platform design features
- User Management – user access and profile design features
- Trip Planning – trip planning design features
- Trip Management – trip execution and management design features including tracking and Coordinator (aka caregiver) functions
- Enhanced Accessibility Features – features that specialize enhanced access to application features and notifications
- User Interfaces – site maps and navigation features for Web, Mobile and TIH user channels
- Security and Privacy Design Summary

These components are also used to define high level epics. Each epic is further refined by a set of user stories. These components are discussed in detail in the subsections that follow.

5.2 Platform

The platform component describes the infrastructure layer design elements. The elements include:

- Core functionality
- Data layer:
 - Base Platform and System
 - Internal APIs

- Trip indexing approach (i.e., Trip History Unique Identifier)
- Reservations – Functional API
- Ped-X – Functional API

The details of the APIs and data feeds are described in the ICD. This section describes the design details about the ingestion and generation processes for the data feeds and APIs.

5.2.1 Core Functionality

The core functionality of the CTP achieves two high level requirements and a third that leverages existing open-source code from the OpenTripPlanner (OTP). The three requirements (and user stories) associated with describing the core functionality include:

- Multimodal Trip Planner (Req-CTP-014)
- Buffalo and NFTA Service Coverage (Req-CTP-011)
- Core Functionality from OTP (Req-CTP-013)

The user stories are described in **Table 18**.

Table 18. Core Functionality User Stories

User Story	Description and Acceptance Criteria
Req-CTP-014: Multimodal Trip Planner	Description: The CTP shall provide travelers with the option to tailor their trip plans based on their preferences and abilities for the modal services incorporated in this project including indoor and outdoor navigation (via automobile, NFTA bus, light rail and PAL services, Community Shuttle, walking, biking, and other mobility options) which provides underserved populations with door-to-door trip plans. The implementation and rollout will be driven by stakeholder input during the Agile Development process. Dependent on User Management features (see Section 5.3.4) Acceptance Criteria: • Core functionality for the OTP works for trip planning including NFTA transit trip plans. • User schedules a trip for walking, biking, transit, number of transfers, shortest trip, maximum walking and generates one or more trip plans.

User Story	Description and Acceptance Criteria
Req-CTP-011: Buffalo and NFTA Service Coverage	Description: The CTP shall provide existing NFTA transit service information for travelers to plan their trips in the Buffalo area. Transit Service data identified for integration with the CTP includes: (a) Static information (operational times, schedules (GTFS), service coverage (GTFS Flex). (b) Real-time status (GTFS realtime data) Acceptance Criteria: - User schedules a trip for walking, biking, transit (NFTA), number of transfers, shortest trip, maximum walking and generates one or more trip plans. - User cannot generate a trip that is outside of coverage without the Community Shuttle (that only operates within the BNMC area).
Req-CTP-013: Core Functionality from OTP	Description: The CTP shall use the open trip planner (OTP) to provide the core trip planning, routing and monitoring functionality, interfaces and infrastructure. The core OTP system and design elements are described in https://github.com/opentripplanner/OpenTripPlanner. (Note: other functions are executed in Mapbox and other data feeds for monitoring) Acceptance Criteria: Basic trip planning and unit testing of components.

5.2.2 Data Layer: Base Platform / System

As a system, the CTP will use data feed standards and frameworks as the basis for this platform. The platform will use OTP and GTFS as the core of the platform. This enables the system to expand beyond this project, provide interoperability and to be extended to support the needs of future users.

Associated user stories describing the base platform layer include:

- Req-CTP-022: Reference transportation network
- Req-INT-004: GTFS
- Req-INT-005: GTFS Realtime

The user stories are described in **Table 19**.

Table 19. Base Platform Layer User Stories

User Story	Description and Acceptance Criteria
Req-CTP-022: Reference transportation network	Description: The CTP shall relate data from different sources to a reference base map that is used to optimize and generate trip plans. Acceptance Criteria: Multimodal services are shown on the map in the app
Req-INT-004: GTFS (related to Req-CTP-011 and Req-CTP-045)	Description: The system shall conform to GTFS. See https://developers.google.com/transit/gtfs Acceptance Criteria: User can view transit schedules and schedule transit services in the app.
Req-INT-005: GTFS Realtime (related to Req-CTP-011)	Description: The system shall conform to the GTFS real-time specification and encoding method. See https://developers.google.com/transit/gtfs-realtime. Acceptance Criteria: User can view transit real-time transit services and receive real-time updates about the next transit services in the app.

5.2.3 Data Layer: Internal APIs

The data layer has a set of internal APIs that are consumed by the website, mobile, and kiosk interface apps.

Associated user stories describing the Internal APIs epic includes:

- Req-CTP-012: Ingest data to provide trip options
- Req-CTP-017: Ingest non-standardized multimodal data (middleware)
- Req-CTP-021: Validate ingested data
- Req-INT-013: Internal APIs Formats
- Req-SY-026: Dataset Curation Plan

The user stories are described in **Table 20**.

Table 20. Base Platform Layer User Stories

User Story	Description and Acceptance Criteria
Req-CTP-012: As a user, I would like to know my options of traveling to the medical center and surrounding neighborhoods	Description: As a user, I would like to know my options of traveling to the medical center and surrounding neighborhoods. I would like to know: • when schedules are • if there are service delays • what my transport options are currently • where are my possible pick up/drop off locations Acceptance Criteria: • NFTA GTFS data is ingested and curated • NFTA GTFS realtime is ingested and valid • SDS patterns are defined and available (using GTFS) • HDS coverage is defined and enforced
Req-CTP-017: As a system, I need to be able to have a way to ingest multimodal data that could be beyond the functional framework of OTP	Description: As a system, I need to be able to have a way to ingest multimodal data that could be beyond the functional framework of OTP. This data could be non-normalized and in a non-standard format. This data also needs to enrich the data layer and display information that is useful to the user. Dependent on Req-CTP-048 Sidewalk Data features where OSM data was enriched through the Sidewalk Collection process (see Section 4.6). Acceptance Criteria: • OSM data is valid and includes sidewalk data features including accessible entrances, sidewalks without obstacles. • Sidewalk WZDx interface is working (will be implemented during Release 5)

User Story	Description and Acceptance Criteria
Req-CTP-021: As a system, I need to validate that the trip plan is feasible with all of the multiple data sets that are ingested in the platform.	Description: As a system, I need to validate that the trip plan is feasible with all of the multiple data sets that are ingested in the platform. This includes generated sensor data from components in the ITS4US program parameters (e.g., SDS, HDS, NFTA schedules and real-time status). Acceptance Criteria: • NFTA GTFS data is ingested and curated • NFTA GTFS realtime is ingested and valid • SDS reservations interface is working • HDS reservations interface is working
Req-INT-013: Internal APIs	Description: The system shall specify internal APIs and data exchange formats using open interface formats such as REST, JSON, GeoJSON (Geographic JSON), XML (Extensible Markup Language), csv (comma-separated values) formats. Acceptance Criteria: Interfaces are defined using a standard format (see ICD for validation).
Req-SY-026: Dataset Curation Plan	Req-SY-026: [Research] As a Platform, I need clean data that can be collected, ingested, normalized and distributed to be able to support the system. Acceptance Criteria: • Data is ingested, processed and generates trip information accurately

5.2.4 Data Layer – Trip History and Unique Trip Identifier

The system/platform needs to be able to distinguish all trip plans in the system. Since there are multiple permutations of how a trip can be constructed and executed, the system needs a way to be able to link/group all of the possible trip segments together for a user and for execution. This implies that there should be a unique identifier that is assigned to the container of "trip plan" and that each segment references this identifier to be able to display or execute on.

Associated user stories include:

- Req-Sy-006: The System shall assign a common unique identifier to a trip history to link the trip plan and execution, as well as its multiple trip segments.

- Req-Sy-025: Linking trip segments - Subsystem log files

The user stories are described in **Table 21**.

Table 21. Trip History and Unique Trip Identifier

User Story	Description and Acceptance Criteria
Req-Sy-006: The System shall assign a common unique identifier to a trip history to link the trip plan and execution, as well as its multiple trip segments.	Description: The System shall assign a common unique identifier to a trip history to link the trip plan and execution, as well as its multiple trip segments. Trip history will include information about the complete trip associated with each subsystem. The detailed data contained in trip history records will be described for each mode, service, and subsystem during the design processes of each subsystem. Design Elements: No design elements, this requirement is native to OTP code. Acceptance Criteria: • Trip history (output in the CTP Log Data API) shows planned and actual trip histories.
Req-Sy-025: Linking trip segments - Subsystem log files	Description: Linking trip segments - Subsystem log files shall use a common reference (identifier) or a reference that can be associated with the trip plan and reservation used by a traveler in executing their trip. Design Elements: No design elements, this requirement is native to OTP code. Acceptance Criteria: • See Req-Sy-006 acceptance criteria

5.2.5 Data Layer: Booking Interfaces

The system needs a standardized and documented booking approach that will be utilized throughout the system/platform and describes the fundamental data flows incorporated into the platform. The booking interfaces will be used in the trip planning and trip management modules. The booking interfaces should:

- Have a starting point, origin
- Destination end
- Be able to support booking multiple ways to get to the destination end
- Be able to take in preferred booking start of trip times

- Be able to take in preferred booking time to destination
- Be able to consider different mobility preferences and needs into defining the trip

Because the booking APIs provide *on-demand* services, a user does not need to schedule the request or schedule a return trip. Each trip is independently booked. The Explorer mode will provide availability information for a user searching for current mobility needs in the BNMC area.

Associated user stories include:

- Req-INT-011: Reservation API Specifications
- Req-INT-011.1: SDS Reservation API Specification
- Req-INT-011.2: HDS Reservation API Specification
- Req-CTP-008: Mobility Provider Reservations APIs used by CTP
- Req-CTP-019.3: Integrated Trip Planning -- CS SDS

The user stories are described in **Table 22**.

Table 22. Reservation API User Stories

User Story	Description and Acceptance Criteria
Req-INT-011: Reservation API Specifications	Description: The Mobility provider shall document the API specifications for the booking and status APIs including schema, dictionary, and orchestration of API transactions between the reservation modules and third-party user interface (e.g., CTP). Acceptance Criteria: • Documented in the ICD, Section 3.12 and 3.13.
Req-INT-011.1: SDS Reservation API Specification	Description: SDS Reservation API Specification - The SDS Operator shall document the API specifications for the SDS (microtransit) booking and status APIs including schema, dictionary, and orchestration of API transactions between the reservation modules and third-party user interface (e.g., CTP). Acceptance Criteria: Documented in the ICD, Section 3.13.

User Story	Description and Acceptance Criteria
Req-INT-011.2: HDS Reservation API Specification	Description: HDS Reservation API Specification - The HDS Operator shall document the API specifications for the HDS (on-demand, door to door) booking and status APIs including schema, dictionary, and orchestration of API transactions between the reservation modules and third-party user interface (e.g., CTP). Acceptance Criteria: Documented in the ICD, Section 3.12.
Req-CTP-008: Mobility Provider Reservations APIs used by CTP	Description: Mobility Provider Reservations APIs used by CTP - The CTP shall use APIs provided by the Mobility provider for the SDS and HSD reservation management modules. Acceptance Criteria: APIs are described in the ICD and functional operations and orchestration in Section 4.1.7 (SDS) and 4.2.2 (HDS).
Req-CTP-019.3: Integrated Trip Planning -- CS SDS	Description: The CTP shall integrate Community Shuttle SDS options in the integrated trip planning mode options. Acceptance Criteria: APIs are described in the ICD and functional operations and orchestration in Section 4.1.7 (SDS).

5.3 User Management

The User Management epic describes user stories to support user access to the CTP web and mobile applications. The functions provide access to CTP registered users. The major functions (e.g., Epic) include secure login processes to support new and returning users, account troubleshooting (e.g., forget/reset password, reset Multi Factor Authentication), registration and account setting processes, and a logout process (see **Figure 34**).

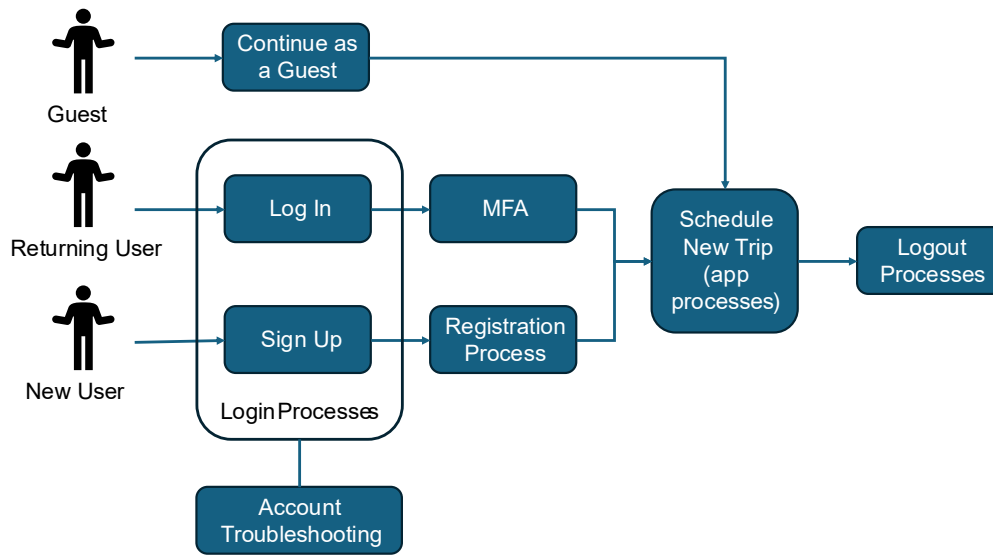


Figure 34. User Management Functional Flow -- high level.

Source: NFTA

The splash screen includes the three methods to access the app as shown in **Figure 35**.



Figure 35. Buffalo All Access App Splash Screen

Source: NFTA

The same functional flow applies to both the web and mobile design versions. The design elements include the Global User Management Function descriptions (**Section 5.3**) and the Security design (**Section 5.8**).

5.3.1 Data Management: Account Removal and PII

The Account Removal and PII consists of four user stories related to a user requesting the removal of their account, confirmation of their request to remove the account and then their account credentials and history. These four user stories are related to the Req-CTP-037.5 As a user, I should be able to delete my account.

The user stories are described in **Table 23**.

Table 23. Account Removal and PII User Stories

User Story	Description and Acceptance Criteria
Req-CTP-133: Account History and PII Removal	Description: The CTP shall remove a registered account holders PII from the CTP storage when an account holder removes their account. Acceptance Criteria: User can click on Profile in the menu and the Delete Account button with confirmation; can be verified by re-logging in and confirming that the CTP shows no account is available.
Req-CTP-134: Account Closure and Removal Process	Description: The CTP shall implement a process for registered account holders to close their account and remove their PII from system-wide storage. Acceptance Criteria User can click on Profile in the menu and the Delete Account button with confirmation; can be verified by looking at the user profile database on the back end of the system and confirming removal of information.
Req-CTP-135: Traveler PII Data Removal Request- CTP	Description: The CTP shall implement a process for registered account holders to close their account and request the removal of their PII from system-wide storage. Acceptance Criteria User can click on Profile in the menu and the Delete Account button with confirmation; can be verified by looking at the user profile database on the back end of the system and confirming removal of information.
Req-CTP-136: Traveler PII Data Removal – CTP	Description: The CTP shall remove a registered account holders PII from the CTP storage when an account holder removes their account. Acceptance Criteria User can click on Profile in the menu and the Delete Account button with confirmation; can be verified by looking at the user profile database on the back end of the system and confirming removal of information.

5.3.2 User Management Process Flows

The User Management CTP Registration processes meet Req-CTP-037. The process flow for login is shown in **Figure 37**. The legend for the diagram and other user management flow diagrams is shown in **Figure 36**.

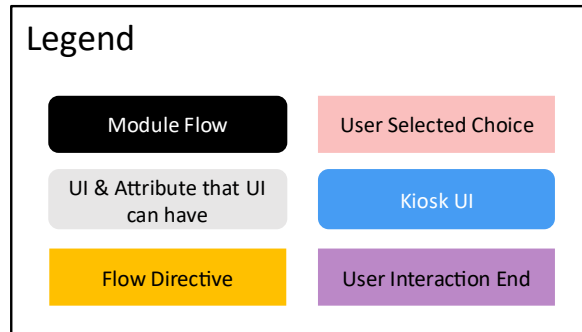


Figure 36. Global User Management Flow Diagram Legend for Figures 25-27.

Source: *Buffalo, NY ITS4US (2024)*

5.3.2.1 Login Process

The login process functional flow is designed as follows:

- User accesses and navigates to the mobile or web CTP. When they do, the system detects the device they are using.
 - If the device is a TIH (kiosk), the system will restrict user management to guest mode although users will be able to book on-demand (HDS) and SDS CS services.
 - If this is a mobile or web site (that is known), then the system requests location information.
 - If the web application, the splash screen asks if they have a log in, want to sign up or continue as a guest.
 - If a mobile application, and the user has signed in previously, the Home Page is displayed which is the Default Trip Planning Screen.
- Any user can remain in Guest Mode and use the trip planning capabilities from the Home Page. Note, account holders can book CS services while guests cannot.
- If **New User**, then the user selects the Sign Up link. The system links to the Registration page. Note that this selection is available from any trip plan screen.
- The link will then open the User Registration process flow (see **Section 5.3.3**).

- If a **Returning User** selects the Login link, the User Name and password fields are shown. After the user enters their User Name and password, the system checks that they match an existing login credentials.
 - If they match, then the system logs them in and transitions to the User's trip planning profile page.
 - If they do not match, they are offered the chance to continue as a Guest or register as a new user.
 - If they do not match, they are given the opportunity to select Forgot User Name or Forgot Password links.

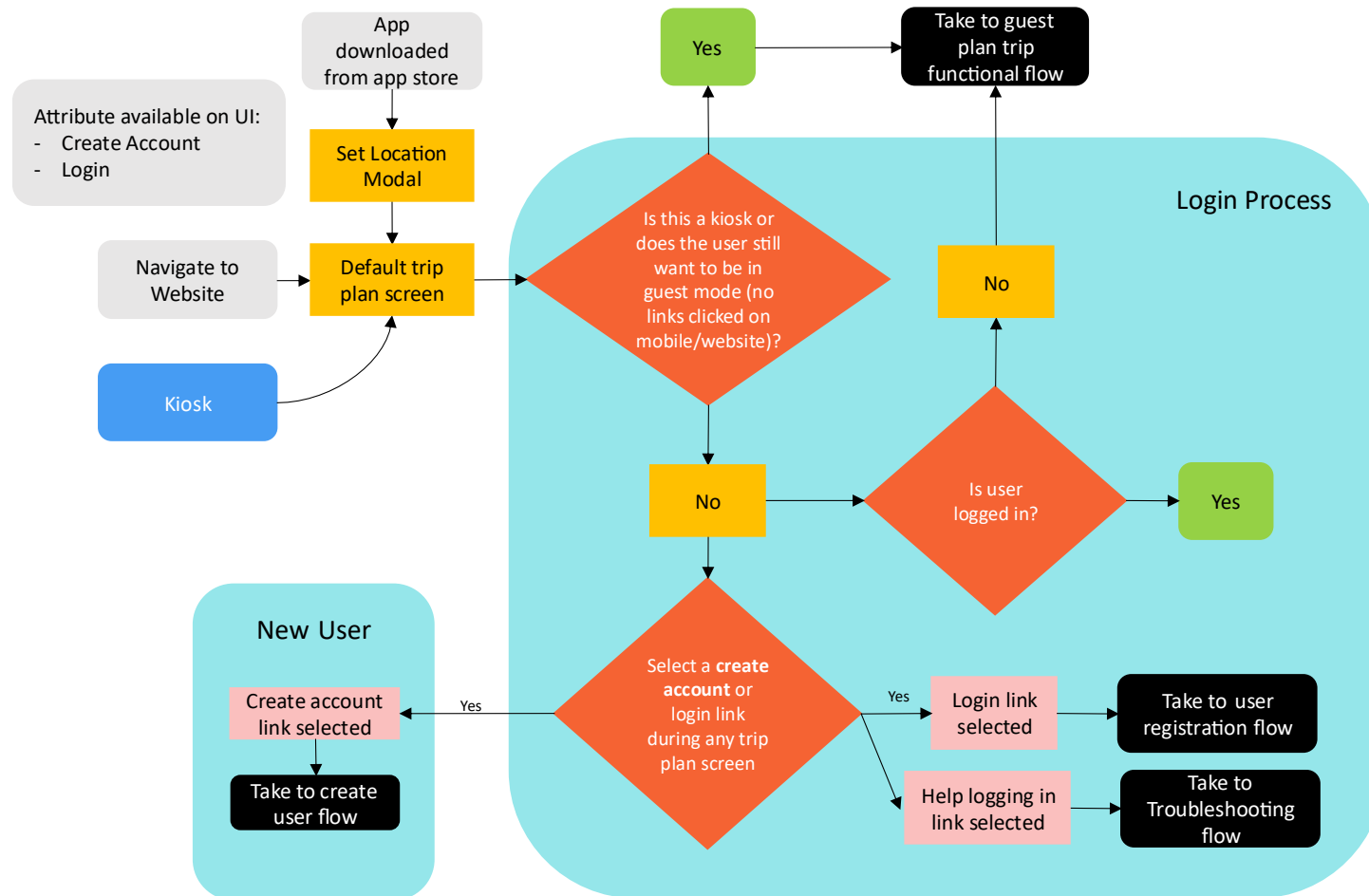


Figure 37. Login Process Flow
Source: Buffalo, NY ITS4US (2024)

5.3.2.2 Logout Process

The Logout process (see **Figure 38**) provides the following logout capabilities:

- Inactivity timeout sessions on Web channels
- Persistent sessions for Mobile channels
- Logout button

The logout functional flow includes three branches.

1. Timeout. When the user is signed on using a web site, the session is timed for inactivity. When the timer expires, a warning is displayed asking the user if they want to extend the session. If they select yes, then the timer is restarted. If the user selects no, then the system logs them out of their session.
2. Mobile Persistence. When the user is signed on using a mobile app, the session remains on until the user needs to reset their password or selects the logout link.
3. Select Logout. When the user selects logout, the system automatically logs out of the session.

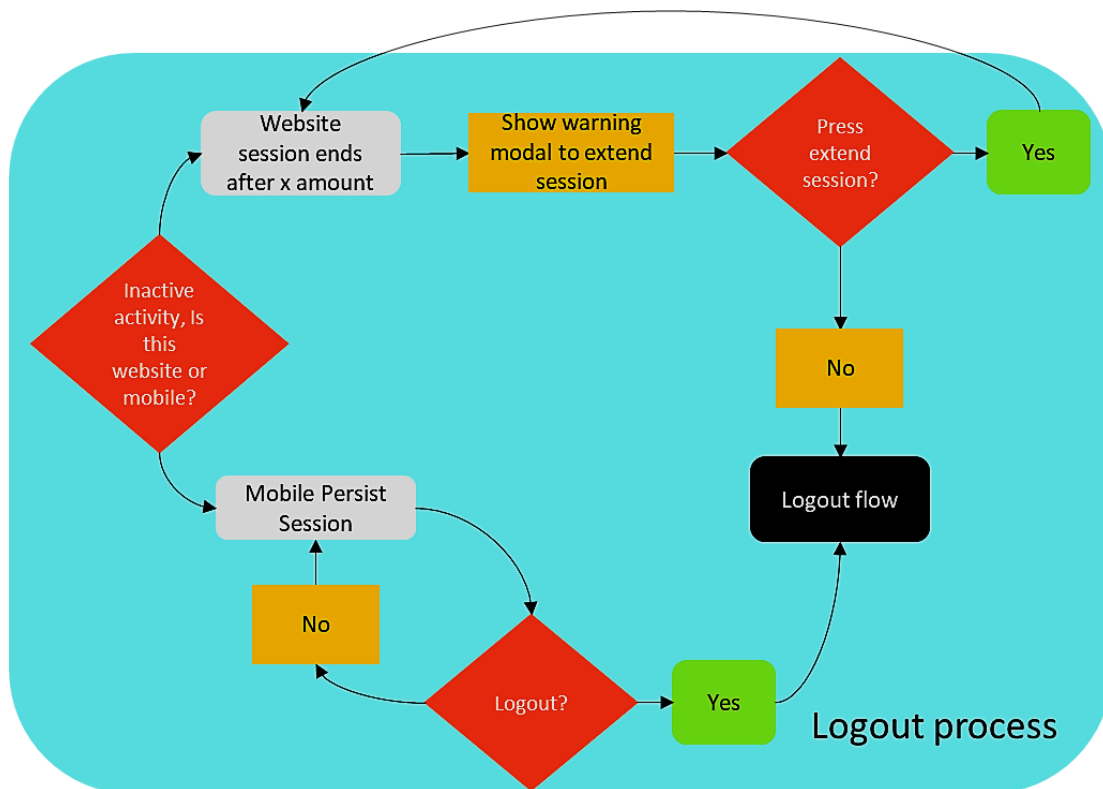


Figure 38. Logout Process Functional Flow

Source: Buffalo, NY ITS4US (2024)

5.3.2.3 Account Troubleshooting Process

The account troubleshooting process (see **Figure 39**) provides account holders with steps to recover their password or reset their MFA. A user can select trouble logging in when they are asked what the problem is – forgot password or reset their MFA. If they want to reset their MFA, identification of the alternative contact information must be included in their profile (i.e., depicted as Reset MFA user flow in **Figure 39**).

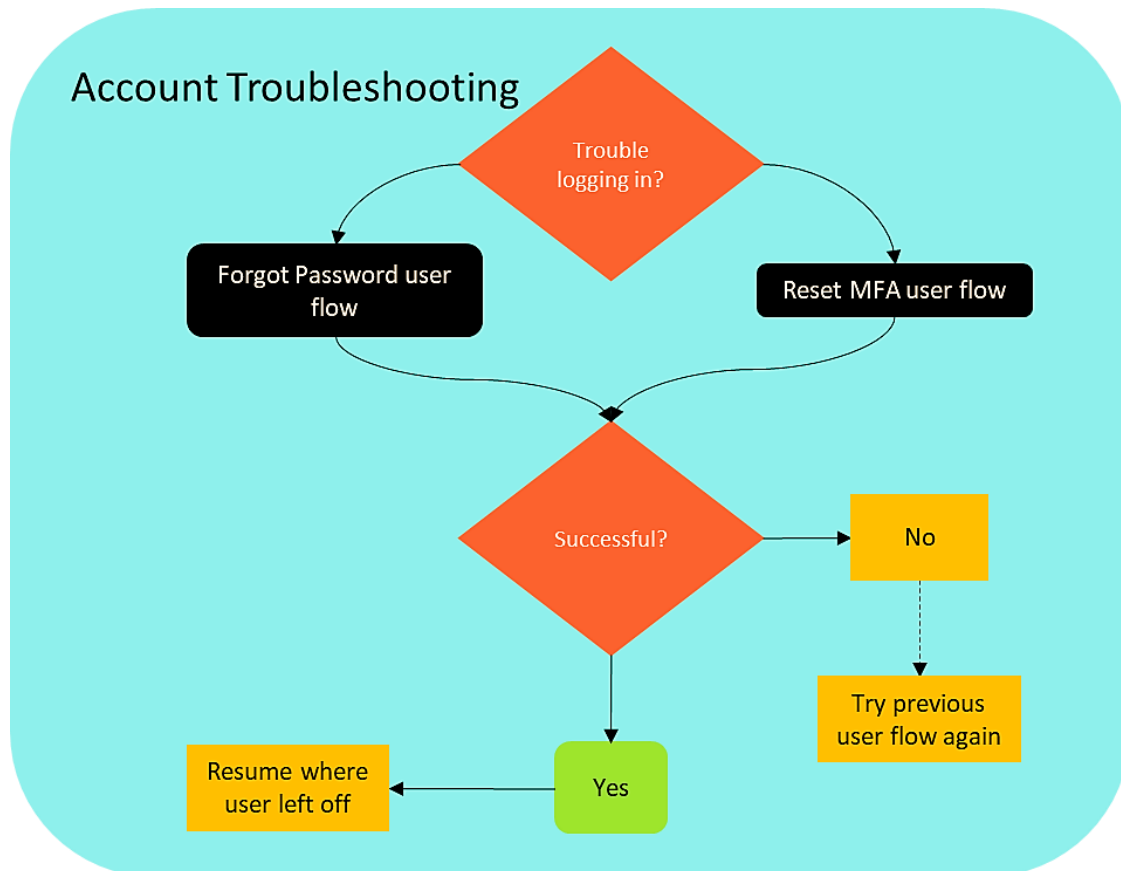


Figure 39. Account Troubleshooting Functional Flow.

Source: Buffalo, NY ITS4US (2024)

When a user has trouble logging in, there is a process to update a password from the Login Page (see **Figure 40**). Specifically, the Login Page includes a link to select when a user forgets their password. The page asks for their User Name. After they submit their User Name, the app asks how they wish to authenticate their account. The authentication method must be included in their profile in order for them to receive the six-digit authentication code. Once received they must insert it into the Change Password page and enter a new password (and verify it). Instructions are included about the appropriate length and characters to include. The red “x” on the right side of the password form will change to green when all the restrictions are met.

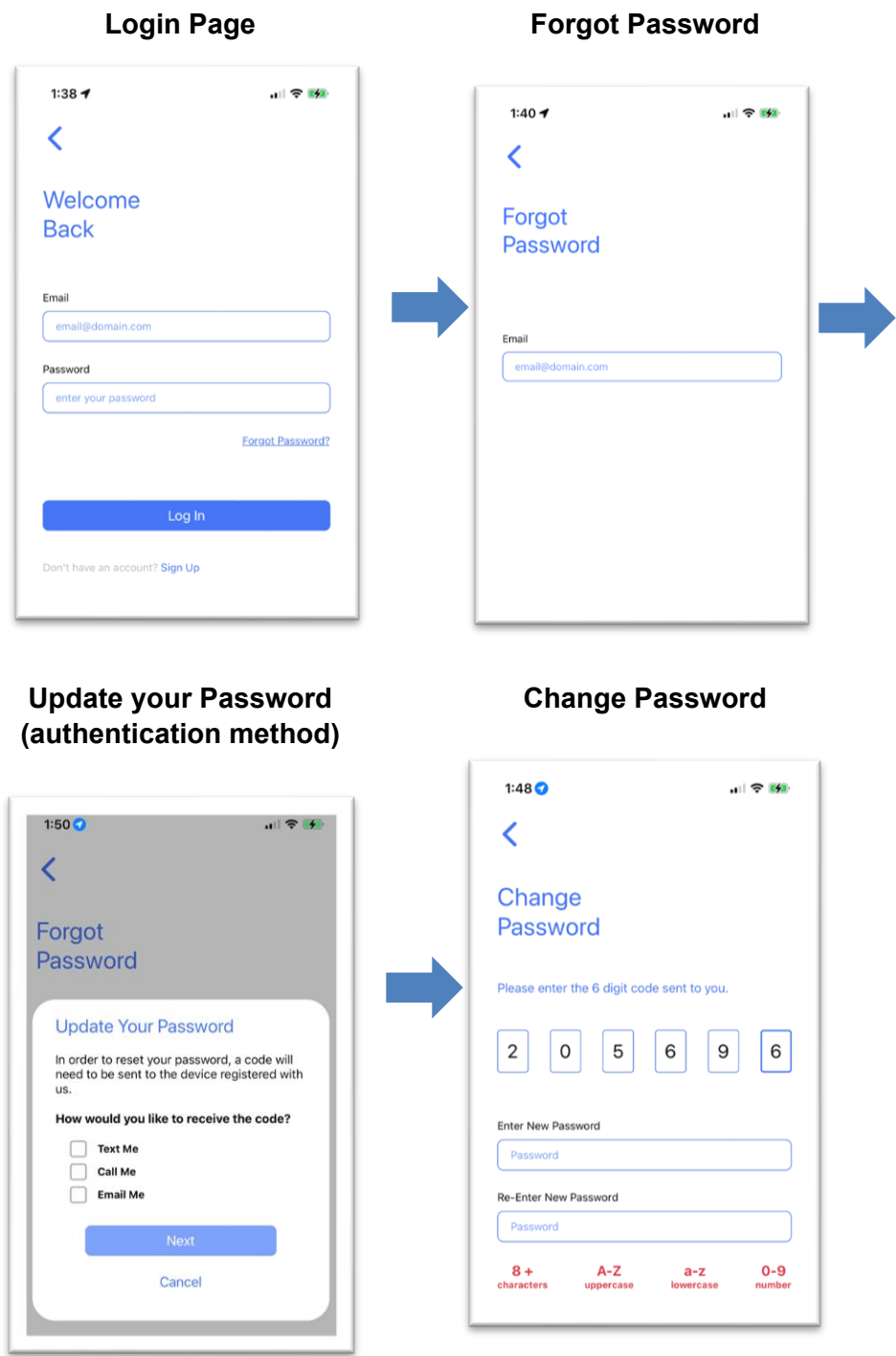


Figure 40. Forgot Password? Flow Process (from login page).
Source: Buffalo, NY ITS4US (2024)

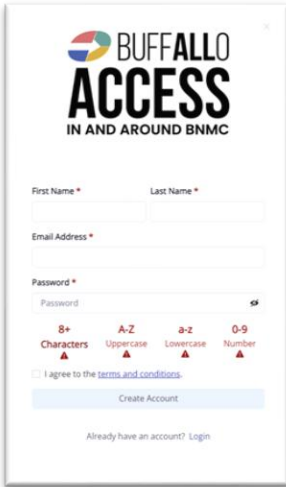
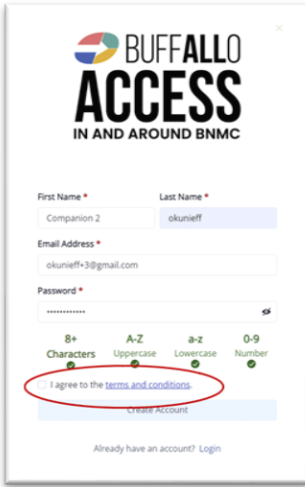
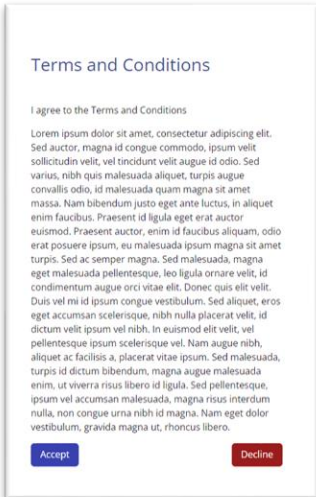
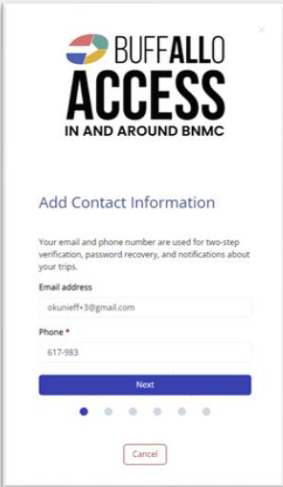
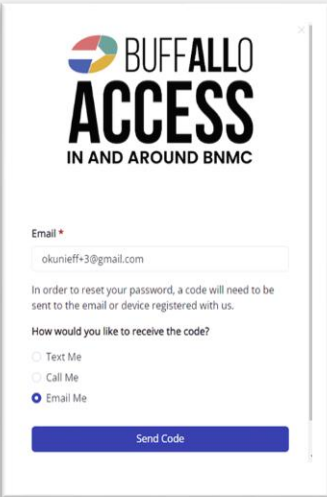
MFA can be sent via Text Me (mobile device only), Call Me or Email Me. The information must be in the user's profile to be activated.

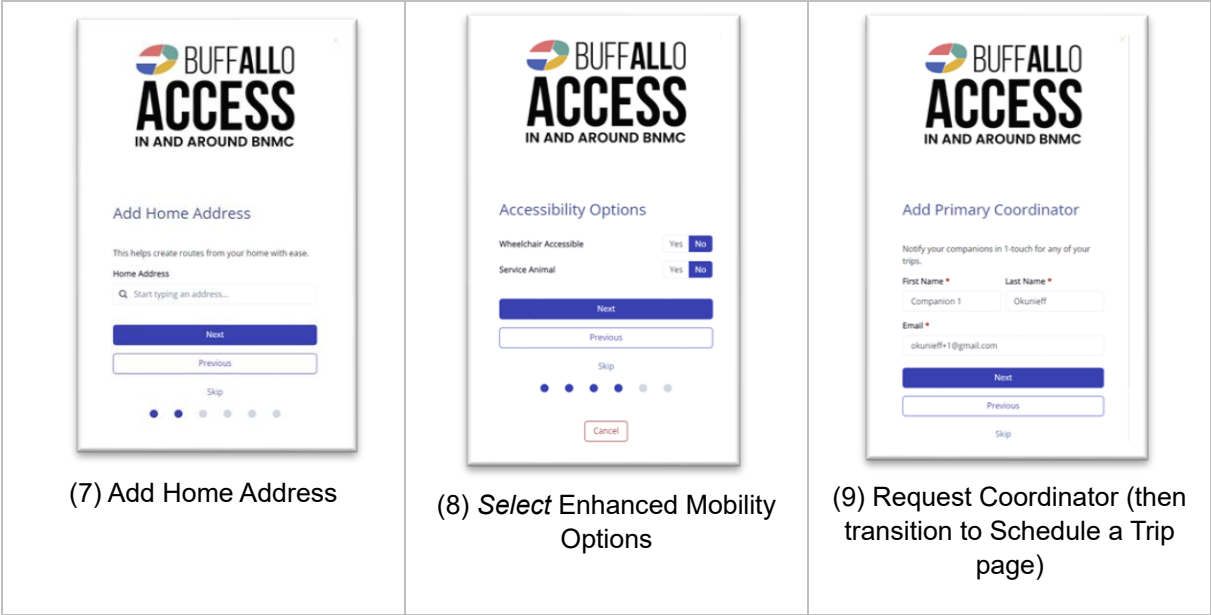
Alternatively, both the MFA and Password may be changed in the Profile tabs using the Account Settings Processes.

5.3.3 User Management: Registration Process

The Registration Processes include configurations to describe the traveler's accessibility preferences. The user interface follows the flow shown in Table 24.

Table 24. Registration Process Web UI Flow
(Source: Buffalo, NY ITS4US (2024))

 (1) Create Account (following Sign Up)	 (2) Select link or check box to agree to Terms and Conditions (opens Ts&Cs page)	 (3) Scroll to end of Ts&Cs page and select box "I agree..."
 (4) Check that "I agree..." is selected. Then select Create.	 (5) Add Contact Information	 (6) Confirm contact information through MFA



5.3.3.1 CTP Registration (Req-CTP-037) User Stories

As described in Section 5.3.1, the CTP registration process includes six user stories:

- Req-CTP-037.1: As a user, I should be able to register an account so I can use the service
- CTP Login User Interface description

The user story descriptions and acceptance criteria are listed in **Table 25**.

Table 25. CTP Registration User Stories

User Story	Description and Acceptance Criteria
Req-CTP-037.1: As a user, I should be able to register an account so I can use the service	Description: This user story provides the registration information that is collected upon being presented with the registration form. The form includes required fields, checkbox to accept terms and conditions, and selection of an active register button. Registration information is collected and stored in the Platform Data Layer (Section 5.2). Acceptance Criteria: • Required fields: First Name, Last Name, Email or Telephone must be completed to allow account creation. • Button: Register/ Create button is required to be selected to allow account creation. • Checkbox: By registering an account, I accept the Terms and Conditions must be agreed to by the user before account creation. ○ <i>Terms and Conditions</i>

User Story	Description and Acceptance Criteria
Terms and Conditions (Req-CTP-037.1)	Description: The terms and conditions were affirmed by the account holder. Req-CTP-037.1 Acceptance Criteria: Terms and Conditions were reviewed by NFTA and BNMC and approved by IRB

5.3.4 User Management Account Setting Processes

The account setting process enables an account holder to select and update their Account Settings as shown in the sidebar, shown in **Figure 41**. The All Access app (web and mobile) uses a head profile to select Account Profile and Settings (see **Section 5.7.2**). When selected in the web app, the user is shown the menu side by side with the content page (e.g., **Figure 42** through **Figure 44**).

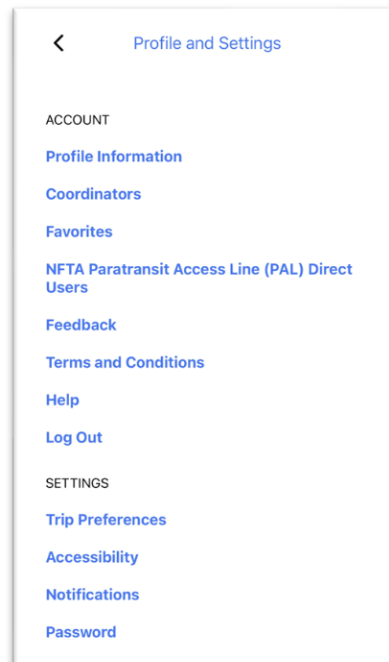


Figure 41. Profile and Settings Web Page

Source: *Buffalo, NY ITS4US (2024)*

Table 26 lists each of the Account Setting selections, setting descriptions and related user stories / requirements.

Table 26. Selections for Account Settings

Title	Description	Related User Story (Requirement ID)
Profile Information	Identifies the information that was provided when registered or last edited. Information includes: • account holder name (mandatory and editable) • telephone number (mandatory) • email address (mandatory) • home address (optional and editable) The following functions are available from this page: • Edit – select to edit account holder name and/or home address • Delete Account – select to delete account	Req-CTP-037.2 Req-CTP-037.5 Req-CTP-037
Coordinators	Identifies any travel coordinator, caregiver or companion (hereafter referred to as Coordinator) who can follow the account holder and receive notifications about their trips. Prior to setting a coordinator, the user can select a link “+ Invite a Coordinator” If assigned, the name and email information about each coordinator are shown. Additional information about Coordinator functions is described in Section 5.5.2.	Req-CTP-028.2 Req-CTP-040 Req-CTP-065 Req-CTP-077 Req-CTP-137
Travelers	For an account holder who is a Coordinator, this list includes the companions, friends or dependents (hereafter referred to as Traveler) who granted the account holder permission to follow their trip plans and journeys. The Coordinator cannot add Travelers; the coordinator must be invited. The Coordinator may remove a Traveler by selecting the Trash icon. This selection does not appear if the account holder is not a Coordinator.	Req-CTP-028.2 Req-CTP-040 Req-CTP-065 Req-CTP-077 Req-CTP-137

Title	Description	Related User Story (Requirement ID)
Favorites	Favorites page shows a list of the account holder's Favorite Locations. A tab is shown for each location. These locations may be used to set places for trip planning. The location tab may be deleted by selecting the trash can icon.	Req-CTP-037.4 Req-CTP-016 Req-CTP-028.6 Req-CTP-028.8
Trip Preferences	The Trip Preferences page lists preferences for: - Minimize Walking Distance (toggle switch) - Max Transfers (select to pop up linear scale from 0 to 8) - Wheelchair Accessibility (toggle switch) - Preferred Mode of Transportation (includes Car, Bike, Bus, Metro Rail, Community Shuttle) Note Enhanced Mobility Options information is described in Section 5.6.	Req-CTP-037.4 Req-CTP-014 Req-CTP-028
Password	This page enables account holders to change their password. They must first enter their current password. Then they can select a new password and verify it. The following functions are available from this page - Submit (to change the password) - Cancel (to cancel the transaction)	Req-CTP-039
Accessibility	Accessibility includes the account holder's language selection (English or Spanish).	Req-CTP-028.3 Req-CTP-028.7 Req-CTP-071 Req-CTP-072
Notifications	Notifications provide the account holder's preferred methods of receiving notifications. Current selections include toggle switches for Push, Short Message Service (SMS) and/or Email. The account holder may select none or more than one method.	Req-CTP-028.4 Req-CTP-028.9

5.3.4.1 User Management: Account User Name and password (Req-CTP-039) User Stories

The CTP Account User Name and password user stories include the following:

- Req-CTP-037.2: As a user, I should be able to manage (add/edit/delete) my profile information
- Req-CTP-039.1: As a user, I should be able to reset my password
- Req-CTP-039.4: As a user, I should be able to manage (add/update) my MFA (multifactor authentication)
 - Req-CTP-039.4: [MFA 30 Days Prompt] As a web user, I should manage (add/update) my MFA every 30 days for web-generated tokens and 90 days for mobile.
 - Req-CTP-039.4: MFA for Account Recovery (As a user, I must be able to request a text, e-mail, or phone call when I am unable to log in using a password.)

These include security and privacy features as well. The user stories and acceptance criteria are described in **Table 27**.

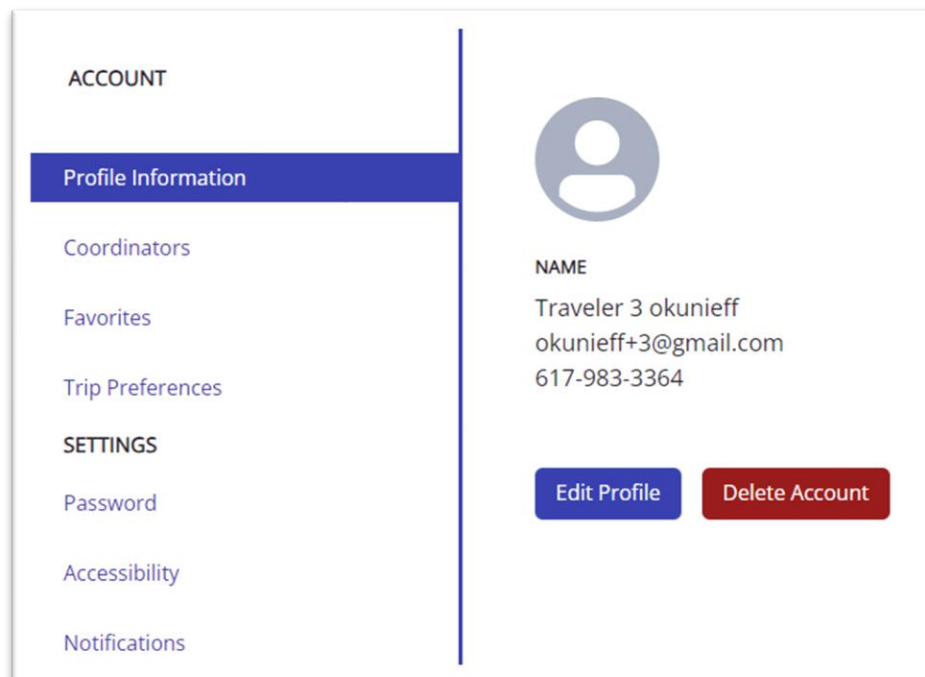


Figure 42. Account Setting - User Name and Contact Information Web UI.
 Source: Buffalo, NY ITS4US (2024)

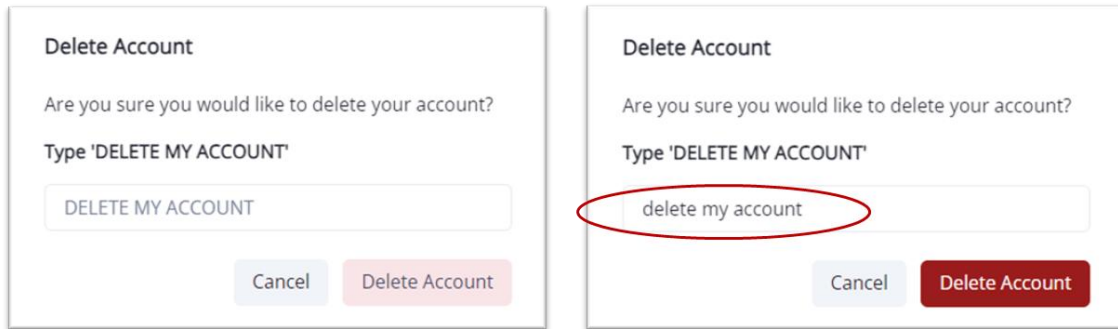


Figure 43. Account Setting: Delete Account Web UI

Source: Buffalo, NY ITS4US (2024)

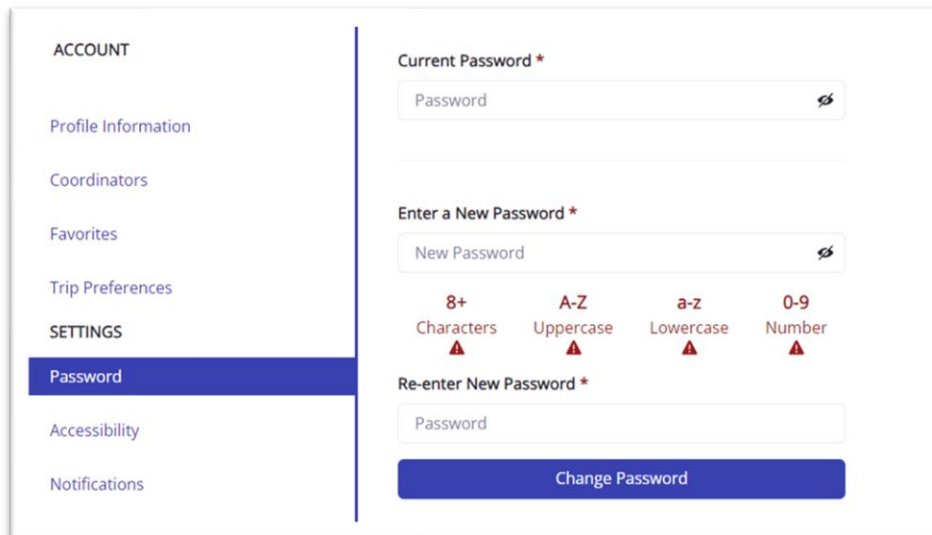


Figure 44. User Settings -- Password Web UI

Source: Buffalo, NY ITS4US (2024)

Table 27. Account User Name and Password User Stories

User Story	Description and Acceptance Criteria
Req-CTP-037.2: As a user, I should be able to manage (add/edit/delete) my profile information	Description: This user story is a form to collect, edit and delete profile information once the user is registered. The profile form includes My Profile. Note – each profile topic includes one or more additional user stories. Profile information is collected and stored in the Platform Data Layer (Section 5.2). Acceptance Criteria: • My Profile: First Name, Last Name, Email, Phone, Home Address, Trip preference, Caretaker information, Change the password, Accessibility needs, notifications preferences are available and functional • The system shouldn't allow the user to delete both email and phone • The system should be compliant and able to navigate with a screen reader on the web • The system will indicate an error if the wrong name/email/address is entered Note: The system will display enhanced mobility options linked to the account, which can also be modified (edited/removed). See Figure 42 for user interface.
Req-CTP-039.1: As a user, I should be able to reset my password	Description: Account holder may reset their password from the account settings menu. Acceptance Criteria: • Require fields: Email or Phone that is associated with the account • System is able to send an email (email), text (phone), or phone call • User will set up their new password in the website and push the user to the login page These criteria will be used for both website and mobile App Note: Once password is reset, the system will log the user out of all sessions and prompt them to re-enter the new password. See Figure 44 for user interface.

User Story	Description and Acceptance Criteria
Req-CTP-037.5: As a user, I should be able to delete my account	Description: This user story allows an account holder to delete their profile and trip history from the data layer. The account holder must actively confirm that they want to delete their account by typing in “Delete my account” in a text form. When they confirm removing the account, the app systematically removes account history, traveler PII and closes the account from the Data Layer. Acceptance Criteria: • The system will verify that user confirms that they are sure they would like to delete their account • The system requires the user to type “Delete My Account” • The system backend can be shown to verify that the user’s current account and related data have been removed Dependencies: • Req-CTP-133: Account History and PII Removal • Req-CTP-134: Account Closure and Removal Process • Req-CTP-135: Traveler PII Data Removal Request-CTP • Req-CTP-136: Traveler PII Data Removal - CTP See Figure 43 for user interface.
Req-CTP-039.4: As a user, I should be able to manage (add/update) my MFA	Description: The system will implement MFA for web and mobile users. Provide MFA notification with a text message, email, or phone voice call. Acceptance Criteria: • User receives MFA authorization code via text, e-mail or phone call
Req-CTP-039.4: [MFA 30 Days Prompt] As a web user, I should manage (add/update) my MFA every 30 days.	Description: Implements a time limitation on how long a user may be signed into their account without logging in again. The time period should be configurable. Acceptance Criteria: • Account should be logged out after 30 days; demonstrate through simulation the passage of 30 days and a prompt appears to sign in through MFA again.

User Story	Description and Acceptance Criteria
Req-CTP-039.4: MFA for Account Recovery	Description: As a user, I must be able to request a text, e-mail, or phone call when I am unable to log-in using a password. Acceptance Criteria: Receive MFA authorization code via text, e-mail or phone call to support account log-in

5.3.4.2 User Management: Account settings -- Favorites (Req-CTP-028.8) User Stories

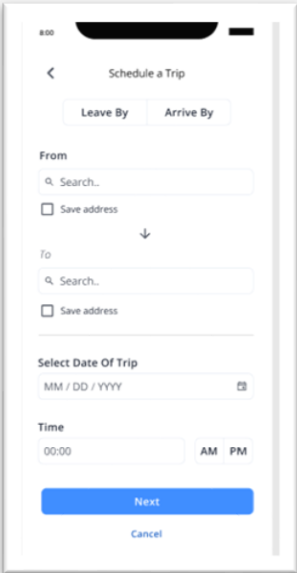
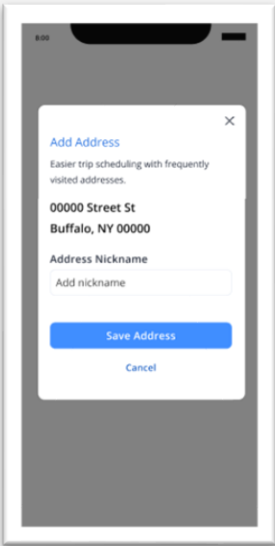
The CTP Account Settings for selecting Favorite Places and Trips include these user stories:

- Favorite Places UI: Add/Edit/Delete
- Req-CTP-016: As a user, I can save a trip as a favorite trip
- Req-CTP-028.8.1: As a user, I should be able to select favorite places from my trip list
- Req-CTP-028.8.2: As a user, I should be able to save my favorite places during my trip creation
- Req-CTP-028.8.3: As a user, I should be able to save my favorite places when I'm editing a trip
- Req-CTP-028.8.4: As a user, I should be able to remove trips from the favorite trip list
- Req-CTP-028.8.5: As a user, I should be able to see and pick my favorite places when I create a new trip
- Req-CTP-028.6: As a user, I am able to set my navigation instruction preferences in my account/profile settings. These options include setting my favorite places for origin, destination or waypoint

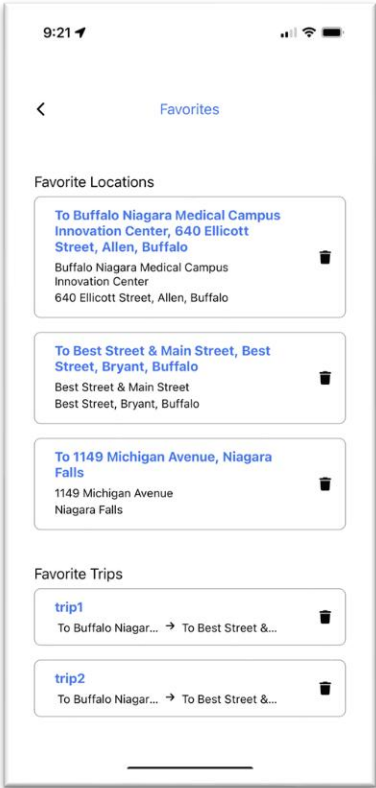
Security and privacy features are incorporated within these user stories as well. The user stories and acceptance criteria are described in **Table 28**.

Table 28. Favorite Places User Stories

User Story	Description and Acceptance Criteria
Favorite Places UI: Add/Edit/Delete	Description: The user can save/unsave their favorite places. The user selects (see Screen #1 in Figure 45) a location from the map or by searching from the From or To fields. Once the place is located, the user checks the box next to the Save address label. When checked, a pop-up screen appears (see Screen#2 in Figure 46) that shows the Add Address screen. User is asked to Save or Cancel the request.

User Story	Description and Acceptance Criteria
Favorite Places UI: Add/Edit/Delete (continued)	Acceptance Criteria: The user story is accepted based on the criteria and capabilities shown in the screenshots below. Screen#1: User is able to search and select From / To locations.  Figure 45. Search to Select From / To Locations Source: <i>Buffalo, NY ITS4US (2024)</i> Screen#2: User is able to save or cancel an address.  Figure 46. Save or Cancel Request to Add Address Source: <i>Buffalo, NY ITS4US (2024)</i>

User Story	Description and Acceptance Criteria
Req-CTP-016: As a user, I can save a trip as a favorite trip	Description: After planning a trip, when asked to Submit, then the next page includes a tab with the trip (Leave and Arrive, mode icon and travel instructions). A star is also displayed on the left most side. When selected, the trip is marked as a favorite. Acceptance Criteria: • The favorite trip includes a star “*” next to the Upcoming Trips list • The favorite trip is included in the Favorites tab in the Trip History tab • The Favorite Trips are listed in the Account Favorites tab
Req-CTP-028.8.1: As a user, I should be able to select favorite places from my trip list	Description: When I am searching, during the planning process, my favorite places will be available in the From and To search boxes. Acceptance Criteria: • From the trip plan page, pull down or select a pre-set favorite location from the From or To fields
Req-CTP-028.8.2: As a user, I should be able to save my favorite places during my trip creation	Description: During trip planning, a user can designate a place as a “favorite location”. Acceptance Criteria: • When I click the save button, the new place should be saved • The location is visible on the Account Favorites page • The star icon is shown next to the location when I create trip plan next time
Req-CTP-028.8.3: As a user, I should be able to save my favorite places when I'm editing a trip	Description: Similar to Req-CTP-028.8.2, the user will be able to change or add a new favorite place while editing a trip plan (e.g., when I use a saved trip and haven't yet designated the place as a “favorite”). Acceptance Criteria: • When I click the save button, the new place should be saved • The location is visible on the Account Favorites page • The star icon is shown next to the location when I create a trip plan next time.

User Story	Description and Acceptance Criteria
Req-CTP-028.8.4: As a user, I should be able to remove trips from the favorite trips list	Description: A user can remove a favorite trip from the Profile and Settings / Favorites tab by tapping the trash can icon (Figure 47).  Figure 47. Favorite Locations and Favorite Trips Source: <i>Buffalo, NY ITS4US (2024)</i> Acceptance Criteria: Favorite trip is removed from list when the trash can icon is selected
Req-CTP-028.8.5: As a user, I should be able to see and pick my favorite places when I create a new trip	Description: A user can select their favorite origin or destination when they plan. They select the From (or To) field and the list of their Favorites appears as a pop-up. They then select the location and it populates the field. Acceptance Criteria: - Tap the From / To fields, and the pop-up with a list of favorite places appears - Select a location, and it is populated in the location field

User Story	Description and Acceptance Criteria
Req-CTP-028.6: As a user, I am able to set my navigation instruction preferences in my account/profile settings. These options include setting my favorite places for origin, destination or waypoint.	Description: Account settings -- navigation instructions. The CTP shall provide the capability for users to select navigation instruction preferences (e.g., user defined favorite places for origin, destination, or waypoints). Acceptance Criteria: - User can set favorite places (location) to use as an origin or destination - User can add favorite trips (origin, destination pairs and trip plan)

5.3.4.3 User Management: Account settings – Trip Preference User Stories

The CTP Account Settings for selecting the user's preferences for travel including mode choices, assistive device or service animal, walking distance and transfers, shown in **Figure 48** Web UI and described in **Table 29** include these user stories:

- Req-CTP-028.1.1: As a user, I should be able to select mode preferences from my trip preference so that it becomes my default when I create new trips.
- Req-CTP-037.4: As a user, I should be able to manage (add/edit/remove) my trip preferences.

The screenshot displays the 'Trip Preferences' section of a web application. On the left, a sidebar contains navigation links under 'ACCOUNT' (Profile Information, Coordinators, Favorites, Trip Preferences) and 'SETTINGS' (Password, Accessibility, Notifications, Terms of Use). The 'Trip Preferences' link is active. The main content area shows four settings: 'Wheelchair Accessible' and 'Service Animal' both set to 'No'; 'Minimize Walking' set to 'Yes'; and 'Max Transfers' set to 4 on a slider ranging from 2 to 6. Below these, a section titled 'Modes of Transportation' lists five options with checkboxes: Car, Bike, Bus, Metro Rail, and Community Shuttle. All checkboxes are currently unchecked.

Figure 48. Account Settings -- Trip Preferences Web UI

Source: Buffalo, NY ITS4US (2024)

Table 29. Preferred Modes Places User Stories

User Story	Description and Acceptance Criteria
Req-CTP-028.1.1: As a user, I should be able to select mode preferences from my trip preference so that it becomes my default when I create new trips.	Description: The user may select mode type from the Profiles and Settings menu. Trip Preferences is a profile setting. The user will navigate to the Trip Preferences page and check as many of the Preferred Modes of Transportation as desired. The preferred modes include car, bike, bus, Metro Rail and Community Shuttle. Walking is the default mode of transportation when no mode is selected. Acceptance Criteria: • Must be a registered user with an account • The system should plan the trip based on the preferred modes and settings from the trip preference settings defined by the user
Req-CTP-037.4: As a user, I should be able to manage (add/edit/remove) my trip preferences	Description: The user should be able to plan, view, cancel their trip plans for their profile and current trip plans. The trips provide complete trips with all active modes (including SDS and HDS services). The information that can be added, edited or removed is listed in the acceptance criteria. Acceptance Criteria: The user preferences are stored by the system and provided trip plans are consistent with the following user account settings regarding: • Wheelchair accessibility • Minimized walking • Max cost (deferred) • Max bus transfers • Preferred modes: bike (personal, public transit, on-demand; automated vehicle shuttle) Dependency: I need to share my trip information with a coordinator.

5.3.4.4 User Management: Account settings –Notification and Accessibility Preference Type User Stories

Notifications are triggered by proximity to a location, event or time (e.g., ETA). The Notifications user story consists of travelers (and coordinators) selecting their preferences for receiving notifications based on their (or their assigned traveler's) trip plan. The preferences are selected as an Account Setting but can be updated during the trip planning process.

Notification User Story Description: The CTP shall provide an enumerated set of preferences for travelers to select for their account, which they can adjust the selections and notifications for each trip. These preferences will be configurable to assign to indoor and outdoor trip plans.

- Req-CTP-063.1: As a user, I'm able to set/manage my trip plan notifications/preferences associated to outdoor wayfinding during my trip planning and booking.
- Req-CTP-063.2: As a user, I'm able to set/manage my trip plan notifications associated to indoor wayfinding in the BNMC during my trip planning and booking. This user story is included in **Section 5.5.1**.

Notification preference type settings are shown in **Figure 49**.

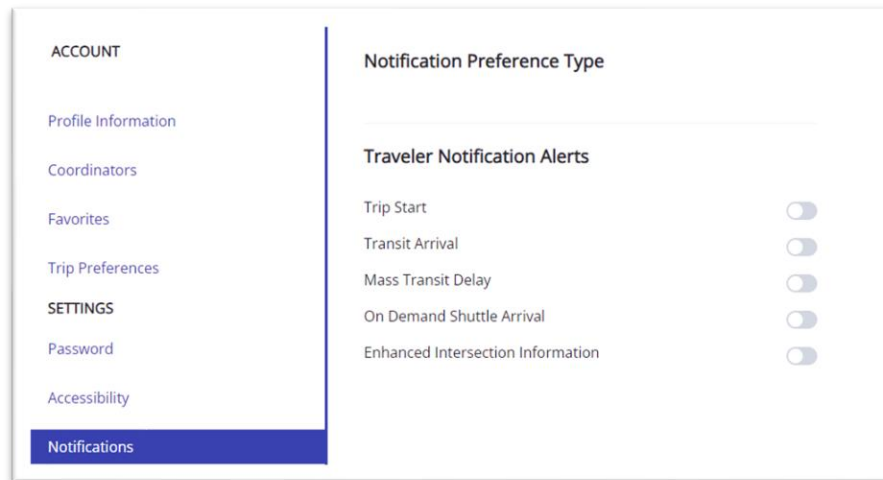


Figure 49. Account Settings – Notification Preference Type Web UI.

Source: Buffalo, NY ITS4US (2024)

The notifications are closely coupled with the Accessibility preferences (see **Figure 50**) which allow the user to set the navigation directions to voice on or off, the display language to English or Spanish, the notification alerts to Push (to app), SMS messages or voice via Phone.

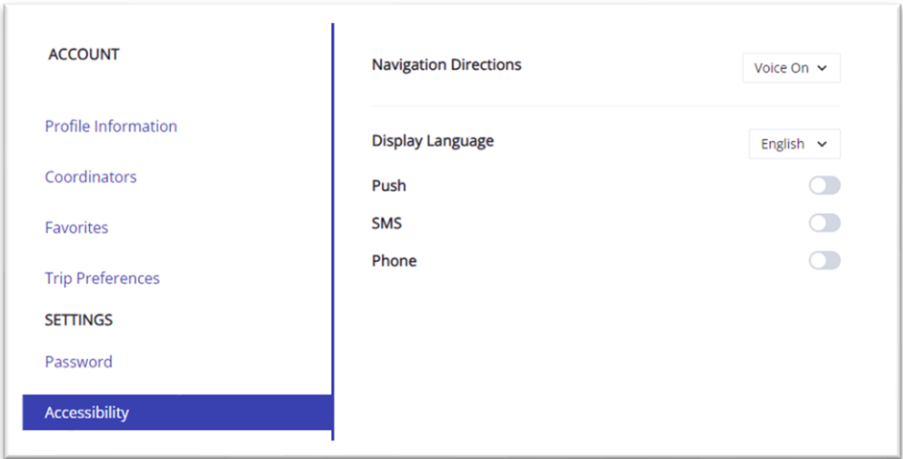


Figure 50. Account Setting Accessibility Web UI.
Source: Buffalo, NY ITS4US (2024)

The Spanish setting changes most of the display language to Spanish as shown in **Figure 51**.

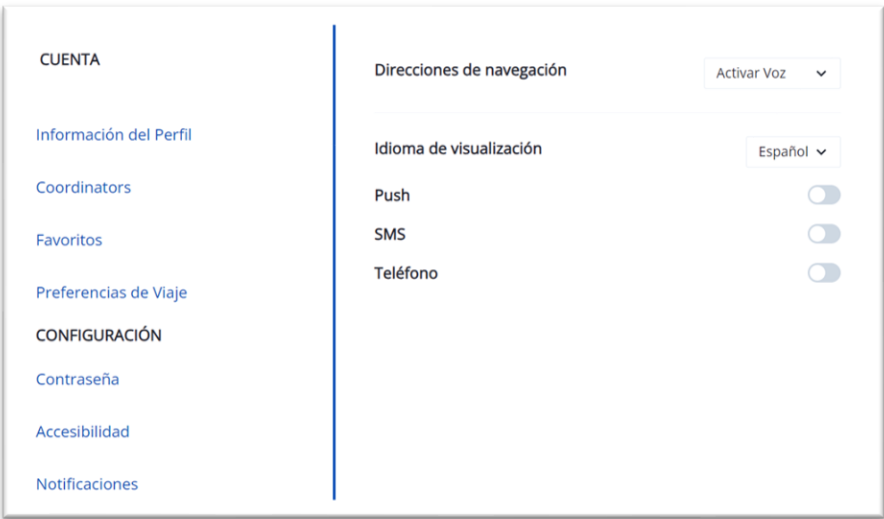


Figure 51. Account Setting Accessibility Web UI (with Spanish Language Set).
Source: Buffalo, NY ITS4US (2024)

The user story descriptions and acceptance criteria are listed in **Table 30**.

Table 30. Accessible Notification User Stories

User Story	Description and Acceptance Criteria
Req-028.7.2: As a user, I am able to set my preferred communications channel [for notifications] in either the web app or the mobile app. These options are: SMS text, phone call or push.	Description: The CTP shall provide the capability for users to select preferences for communications channel to receive trip updates (e.g., web, mobile app, mobile website, call or SMS). The capabilities experienced by the traveler depend on the functions of their receiving devices. Acceptance Criteria • Toggle Notification preferences options including SMS (text), phone call or push in the mobile app • Toggle on Notification preference options including SMS, phone call or push in web app
Req-CTP-028.9: As a user, I can set my preferences on how I want to receive my notifications on my mobile device.	Description As a user, I can set my preferences on how I want to receive my notifications on my mobile device. These options are only allowed on the mobile app and do not exist on the website account/profile pages. I can choose notification methods of haptic/vibration, text or voice read. These functions will be supported in conjunction with the user's native mobile device. The capabilities experienced by the traveler depend on the functions of their receiving devices. Note: these relate to enhanced accessibility features (see Section 5.6). Acceptance Criteria: The CTP shall provide the capability for users to select preferences for methods of receiving notifications and turn by turn directions (e.g., voice, text, haptic/vibration).

User Story	Description and Acceptance Criteria
Req-CTP-028.4: As a user, I should be able to set my preferred notifications in my profile settings. This includes PED-X, ETA for reservation service to start, ETA of when to leave, ETA of arrival time. Note: this list was refined through a stakeholder review meeting.	Description: The CTP shall provide the capability for users to select notifications (e.g., intersection PED-X, conveyance status, ETA for reservation services) they would like to receive. Acceptance Criteria: User can toggle on one or more notifications including Trip Start, Transit Arrival [ETA], Mass Transit Delay, On Demand Shuttle Arrival [ETA for reservation services], Enhanced Intersection Information [PED-X]. The Coordinator can also select their preferred notification types and accessibility features related to notifications.

5.4 Trip Planning

5.4.1 Trip Planning Process Flow

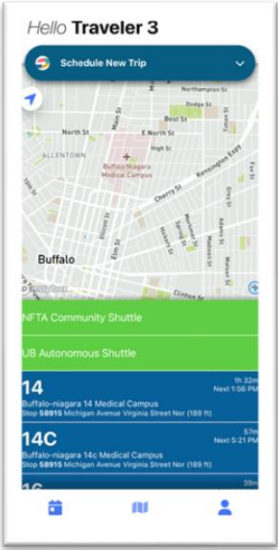
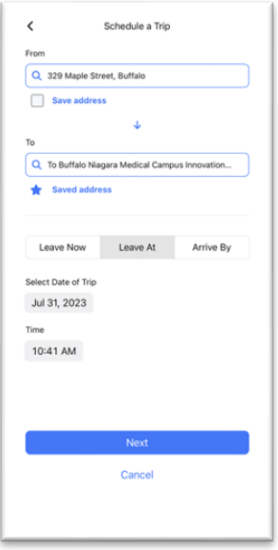
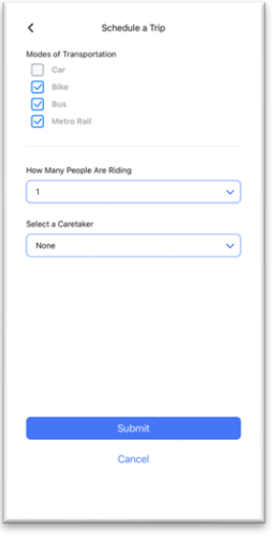
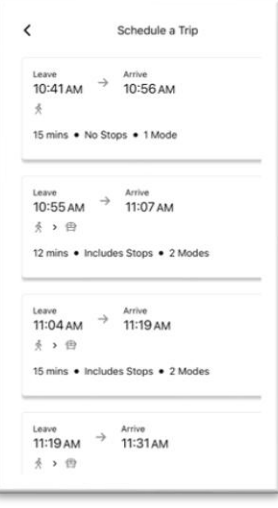
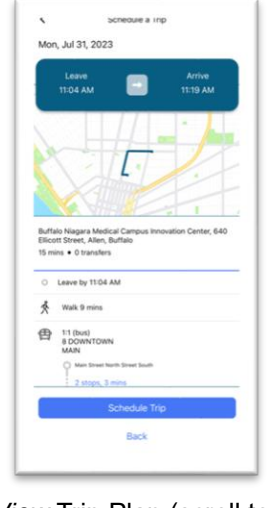
The Trip Planning Process Flow consists of basic trip planning functions to support the traveler including:

- access to a list of mobility services nearby (see Explore Mode, **Section 5.4.10**)
- plan a trip with multiple modes
 - get starting point
 - get destination point
- get a list of stops along each mode of transportation
- get information about a mode of transportation
- get travel options on how a trip can be accomplished

A complete list of API features/functions are located in the OpenTripPlanner GitHub site. Additional information on the OTP is described in the Core Functions (see **Section 5.2.1**). The process flow for planning a trip as shown in **Table 31** includes five steps from the Home page.

Table 31. Trip Planning Process Flow with Screen Shots

Source: *Buffalo, NY ITS4US (2024)*

 (1) From Home Page select Schedule a Trip	 (2) Select From, To, Leave/Arrive, Date, Time; then select Next (Cancel)	 (3) Select Modes, # Travelers, Coordinator; then Submit (Cancel)
 (4) Tap Trip tab (from alternatives)	 (5) View Trip Plan (scroll to see complete trip); then Schedule Trip. Screen which transitions to home screen.	--

The sub epics related to trip planning include:

- Base Trip Planning
- Req-CTP-011: Buffalo and NFTA Service Coverage
- Req-CTP-009: Pre-populate Trip Mode Preferences
- Req-CTP-010: Pre-populate Trip Location (Origin)
- Integrations with transit options

- Req-CTP-123: Contradictory preferences

These are described in **Sections 5.4.2 to 5.4.6**.

5.4.2 Base Trip Planning User Stories

The CTP Base Trip Planning user stories are described in **Section 5.2.1** include the following:

- Req-CTP-013: Core Functionality from OTP - The CTP shall use the open trip planner (OTP) to provide the core trip planning, routing and monitoring functionality, interfaces and infrastructure
- Req-CTP-014: Utilize OTP for Multimodal Trip Planner to provide options for travelers

For details of these user stories see **Table 18**.

5.4.3 Req-CTP-011: Buffalo and NFTA Service Coverage

The Buffalo and NFTA Service Coverage user stories include:

- Req-CTP-011.1: As a user, I would like to know Static information about service coverage (operational times, schedules (GTFS), service coverage)
- Req-CTP-011.2: As a user, I would like to know real-time status (operational times, schedules (GTFS), delays, and service coverage)

Descriptions of these user stories are described in **Table 32**.

Table 32. Service Coverage User Stories

User Story	Description and Acceptance Criteria
Req-CTP-011.1: As a user, I would like to know Static information about service coverage (operational times, schedules (GTFS), service coverage (GTFS Flex))	Description: When using the CTP, the user (guest or account holder) can schedule trips for NFTA bus and metro rail based on their GTFS schedule. Acceptance Criteria: Trip plans will include accurate information on NFTA transit service (bus and rail)
Req-CTP-011.2: As a user, I would like to know real-time status (operational times, schedules (GTFS), delays, and service coverage (GTFS Flex))	Description When using the CTP, the user (guest or account holder) can view schedule real-time status information about their trip. Pre-requisite: The data layer has feeds needed for real-time status and service. Acceptance Criteria: • Be able to view the real-time status of my trip.

5.4.4 Req-CTP-015: Allow travelers to plan and update their trip preferences when they plan their trip

The CTP shall allow travelers to update their trip preferences when they plan their trip. The following user stories describe the functions associated with this requirement:

- Req-CTP-037.3: As a user, I should manage my trips (plan, view, cancel)
- Req-CTP-015: As a user when planning a trip, I should be able to update my trip preferences for the specific trip without going into my account preferences. It should appear to prepopulate prior to trip planning, so I can adjust my preferences
- Req-CTP-063.1: As a user, I am able to set/manage my trip plan notifications/preferences associated to outdoor wayfinding during my trip planning and booking
- Req-CTP-063.2: As a user, I am able to set/manage my trip plan notifications associated to indoor wayfinding in the BNMC during my trip planning and booking

Table 33. Trip Planning Preference Updates User Stories

User Story	Description and Acceptance Criteria
Req-CTP-037.3: As a user, I should manage my trips (plan, view, cancel)	Description: The user should be able to plan, view, cancel their trip plans for their profile and current trip plans. The trips provide complete trips with all active modes (including SDS and HDS services). Dependency: Req-CTP-037.4 User Story and Acceptance Criteria (see Table 29). Process flow is depicted in Table 31. Acceptance Criteria: • Complete trip plan, submit and receive multiple trip itineraries as depicted in Table 31.
Req-CTP-015: As a user when planning a trip, I should be able to update my trip preferences for the specific trip without going into my account preferences. It should appear to prepopulate prior to trip planning, so I can adjust my preferences	Description: As a user when planning a trip, I should be able to update my trip preferences for the specific trip without going into my account preferences. It should appear to prepopulate prior to trip planning, so I can adjust my preferences. Acceptance Criteria: • While scheduling a trip, the system defaults to user's preference. Then user can update their preferences while scheduling their trip.

User Story	Description and Acceptance Criteria
Req-CTP-063.1: As a user, I'm able to set/manage my trip plan notifications/preferences associated to outdoor wayfinding during my trip planning and booking	Description: As a user when planning a trip, I should be able to update my trip preferences for the specific trip without going into my account preferences. It should appear to prepopulate prior to trip planning, so I can adjust my preferences. Acceptance Criteria: While scheduling a trip, the system defaults to user's preference. Then user can update their preferences while scheduling their trip.

5.4.5 Req-CTP-009: Pre-populate Trip Mode Preferences

The Pre-populate Trip Mode Preferences user stories are included in the core OTP functionality. They include:

- Req-CTP-009.1: As a user on the website after I've logged in, I should have my preferred modes pre-populated
- Req-CTP-009.2: As a mobile app user after I've logged in, I should have my preferred modes pre-populated

Descriptions of these user stories are described in **Table 34**.

The pre-requisite for both Req-CTP-009 user stories requires that the user is an account holder who has selected Trip Preferences (see **Section 5.3.4.3**).

Table 34. Pre-populate Mode Preferences User Stories

User Story	Description and Acceptance Criteria
Req-CTP-009.1: As a user on the website after I've logged in, I should have my preferred modes pre-populated	Description: When using the CTP website, an account holder will have their trip preferences pre-populated for all their trip plans. Acceptance Criteria: Trip plans will include the trip preference selections on all new trips scheduled from a website app.
Req-CTP-009.2: As a mobile app user after I've logged in, I should have my preferred modes pre-populated	Description: When using the CTP mobile app, an account holder will have their trip preferences pre-populated for all their trip plans. Acceptance Criteria: Trip plans will include the trip preference selections on all new trips scheduled from a mobile app.

5.4.6 Req-CTP-010: Pre-populate Trip Location (Origin)

The Pre-populate Trip Location user stories are included in the core OTP functionality. They include:

- Req-CTP-010.1: As a user on the website after I've logged in, I should have my location prepopulated with the location that I am nearest or at
- Req-CTP-010.2: As a mobile app user after I've logged in, I should have my location prepopulated with the location that I am nearest or at
- Req-CTP-010.3: As a kiosk user my location is prepopulated with BNMC or the nearest internal location/external entrance that the kiosk is located

Descriptions of these user stories are described in **Table 35**.

Table 35. Pre-populate Trip Location User Stories

User Story	Description and Acceptance Criteria
Req-CTP-010.1: As a user on the website after I've logged in, I should have my location prepopulated with the location that I am nearest or at.	Description: App will detect the user's current location when logging into the CTP web site. Acceptance Criteria: • After logging on, Home screen map displays the user's current location.
Req-CTP-010.2: As a mobile app user after I've logged in, I should have my location prepopulated with the location that I am nearest or at	Description: App will detect the user's current location when logging into or opening the mobile CTP app. Acceptance Criteria: • After logging in or opening App, the mobile device's home screen map displays the user's current location.
Req-CTP-010.3: As a kiosk user my location is prepopulated with BNMC or the nearest internal location/external entrance that the kiosk is located.	Description: App will detect the user's current location opening the kiosk's CTP app. Acceptance Criteria: • After opening App (as Guest), the kiosk's home screen map displays the current location (e.g., Kaleida Health General Hospital or NFTA Summer and Best Station).

5.4.7 Integration with Transit Options User Stories

The Integration with Transit Options user stories include:

- Req-CTP-019: Integrated Trip Planning services
- Req-CTP-019.1: Integrated Trip Planning -- NFTA fixed route
- Req-CTP-019.3: Integrated Trip Planning -- CS SDS (will be implemented during Release 5)
- Req-CTP-019.4: Integrated Trip Planning -- CS HDS
- Req-CTP-019.5: Integrated Trip Planning -- Other mobility provider options (optional)

Descriptions of these user stories are described in **Table 36**.

Table 36. Integration with Transit Options User Stories

User Story	Description and Acceptance Criteria
Req-CTP-019: Integrated Trip Planning services	Description: The CTP shall include multimodal trip planning, routing and monitoring of travelers as they plan and execute their trips to ensure seamless and coordinated transfers between trip segments. Acceptance Criteria: Meets Req-CTP-019.1, Req-CTP-019.3-4 User Stories (see below)
Req-CTP-019.1: Integrated Trip Planning -- NFTA fixed route	Description: As a user, I'd like to know my options of transit, schedule, and length of time within the NFTA metro system when I plan a trip in the specified trip areas for the ITS4US program. Pre-requisite: The CTP shall integrate NFTA transit options in the integrated trip planning mode options. Updates of datasets associated with the service provision will be updated prior to any service change. https://gtfsr.nfta.com/ Acceptance Criteria: Show NFTA data in Schedule a Trip
Req-CTP-019.3: Integrated Trip Planning -- CS SDS	Description: The CTP shall integrate the Community Shuttle SDS options in the integrated trip planning mode options. Acceptance Criteria: - Show SDS options in Schedule a Trip when SDS coverage and operations are available in a trip request - Hail SDS from Explore mode - Show vehicle status (ETA at pickup and dropoff)

User Story	Description and Acceptance Criteria
Req-CTP-019.4: Integrated Trip Planning -- CS HDS	Description: As a user, I'd like to know my options of transit, schedule, and length of time with the community shuttle HDS when I plan a trip in the specified trip areas for the ITS4US program. Requirement: The CTP shall integrate Community Shuttle HDS options in the integrated trip planning mode options. Acceptance Criteria: • Show HDS options in Schedule a Trip when HDS coverage and operations are in trip request • Hail HDS from Explore mode (see Figure 54 and Figure 55) • Show vehicle status (ETA at pickup and dropoff)
Req-CTP-019.5: Integrated Trip Planning -- Other mobility provider options	Description: As needed, the CTP shall integrate other mobility provider options in the integrated trip planning mode options. This is a future requirement to expand mobility options such as bikeshare and other public transit options. The requirement is implemented, but no other mobility providers were included at this time. Acceptance Criteria: This feature is a legacy configuration parameter implemented in the Core OTP. No other mobility provider was included in the app at this time.

5.4.8 PAL Integration

PAL is added as an option for selection by eligible PAL users. The requirements associated with PAL integrated with the CTP includes the following requirements.

- Req-CTP-014: Multimodal Trip Planner
- Req-CTP-019.2: Integrated Trip Planning -- NFTA PAL options
- Req-CTP-122: PAL vs. System Responsibility
- Req-Sy-009.4: Access to PAL Direct services via CTP

The CTP will use the PAL web site request form to submit PAL reservation requests. Trip planning may only occur to and from the BNMC campus. Travel within the campus will be delivered through the HDS unless it is not in service. Trip reservations and services will only be allowed for eligible PAL users.

The design includes the following process (shown in **Figure 52**):

1. Traveler selects Profile and Setting icon

2. Traveler selects *NFTA Paratransit Access Line (PAL)* to link to <https://paldirect.nfta.com/>
3. Traveler will complete web form for reservations through PAL Direct site

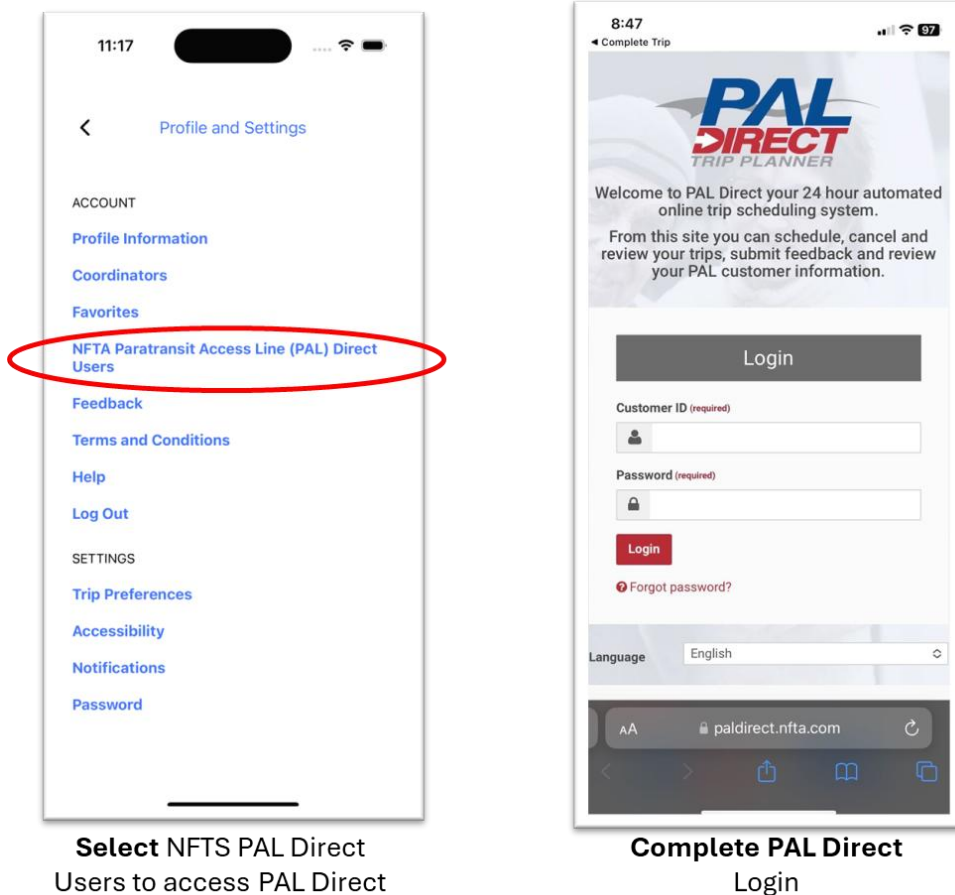


Figure 52. Access to PAL Reservations
Source: Buffalo, NY ITS4US (2024)

A single user story is associated with these requirements.

User Story Description:

- As a registered user, I need to access my NFTA PAL account in order to book a trip within the CTP.

Acceptance Criteria:

- User must be logged in and click on the Profile and Settings icon. There the user can click NFTA Paratransit Access Line (PAL) Users link which will direct the user to the following website <https://paldirect.nfta.com/> to utilize the PAL reservations system.

5.4.9 Contradictory Preferences User Story

The Contradictory Preferences user story, shown in **Table 37**, includes:

- Req-CTP-123: As a user, my origin and destination should output a list of possible permutations of a trip.

Table 37. Contradictory Preference User Story

User Story	Description and Acceptance Criteria
Req-CTP-123: As a user, my origin and destination should output a list of possible permutations of a trip	Description: As a user, my origin and destination should output a list of possible alternative trip plans (permutations of a trip). These choices should include my trip preferences that I have set in my preferences/account pages or my adjusted preferences for this particular trip. Requirement: The CTP shall provide trip plans that do not conflict among the traveler's input preferences when planning a trip and provide suggestions if no trips are available. Acceptance Criteria: • One or more trips plans should be shown following completing Schedule a Trip process flow (see Table 31, Step 5)

5.4.10 Explore Mode

The Epic - View Shuttle options in Explore Mode, is related to the user's ability to view nearby services and associated schedule times. It can be described from the user's perspective as follows:

- As a user who wants to see what's around me, I open the app and see the overhead Explore map centered at my location. Below the map I can see nearby services and their times. When in the BNMC campus area, I have shuttle options presented.

The Explore mode is a default setting that appears on the home page. It not only shows the available CS options, but also includes all the NFTA bus and rail options in the vicinity. When a traveler selects a tab, the current bus/rail schedule or on-demand summon button is shown in the opened tab, and the stops and / or current positions of the revenue vehicles are shown. The tabs are color coded to differentiate the NFTA service from the CS services.

The user stories associated with this function include:

- User Story #1: Summon CS from home view map (Explore Mode)
- User Story #2: Summon shuttle options in Explore Mode

- User Story #3: View NFTA route and live vehicles nearest current location in Explore Mode
- User Story #4: View live vehicles during execution of fixed route trips
- User Story #5: View live vehicles during execution of shuttle trips
- User Story #6: View pickup ETA of shuttle in Explore mode

The user stories are described in **Table 38**.

Table 38. Explore Mode User Stories

Explore Mode User Stories	Description and Acceptance Criteria
Summon shuttle options in Explore Mode	Description: Utilize OTP for Multimodal Trip Planner. The CTP shall provide travelers with the option to tailor their trip plans based on their preferences and abilities for the modal services incorporated in this project including indoor and outdoor navigation (via automobile, NFTA bus, light rail, Community Shuttle, walking, biking, and other mobility options) which provides underserved populations with door-to-door trip plans. Acceptance Criteria: • Present available mobility services near current position including CS and NFTA services • Show current traveler location • Provide trip planning options (see Section 5.4) See Figure 53. Related Requirement: Req-CTP-014

Explore Mode User Stories	Description and Acceptance Criteria
Summon CS from home view map (Explore Mode)	Description: As a user of the rider app who is viewing the CS options on the Explore mode list of services, I need to be able to tap or click on an on-demand shuttle and summon it to my location. Acceptance Criteria: • Present NFTA Community Shuttle tab in Explore Mode • Click Community Shuttle tab and show Summon Shuttle button • Click on Summon button and hail a HDS (send message to HDS Reservations (see Section 4.2.2) See Figure 54. • When Shuttle is not in service, a message is shown that indicates that it is not available See Figure 55. Related Requirements: Req-Sy-009, Req-CTP-010
View live vehicles during execution of fixed route trips	Description: As a user, I'd like to know my options of transit, schedule, and length of time within the NFTA metro system when I plan a trip in the specified trip areas for the ITS4US program. Pre-Requisite: The CTP shall integrate NFTA transit options in the integrated trip planning mode options. Updates of datasets associated with the service provision will be updated prior to any service change. https://gtfsr.nfta.com/ (Req-CTP-011). Acceptance Criteria: • View all NFTA Fixed Route services near the traveler in Explore Mode • View closest stop near the traveler as well as the scheduled and/or ETA of vehicles at the stop for the next series of trips See Figure 56. Related Requirements: Req-CTP-012, Req-CTP-019.1, Req-CS-93, Req-CTP-045

Explore Mode User Stories	Description and Acceptance Criteria
View live vehicles during execution of shuttle trips	Description: As a user of the rider app, I should be able to see the live location of the shuttle both before and during the trip, when viewing the route for a trip that I have planned. Acceptance Criteria: Demonstration of map view in mobile app (or coordinator web view) after summoning and traveling on a shuttle. Related Requirements: Req-CS-042, Req-CS-056, Req-CTP-068
View pickup ETA of shuttle in Explore mode (ITS4US-134)	Description: View the pickup time of the shuttle (HDS and SDS) from the Explore mode when shuttle is booked. Acceptance Criteria: Demonstration of ETA in the tabs for the HDS and SDS Related Requirement: Req-CTP-045

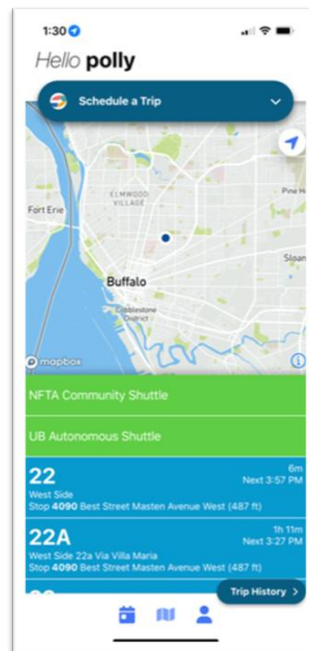


Figure 53. Explore Mode on Home Page (user story #1)

Source: Buffalo, NY ITS4US (2024)

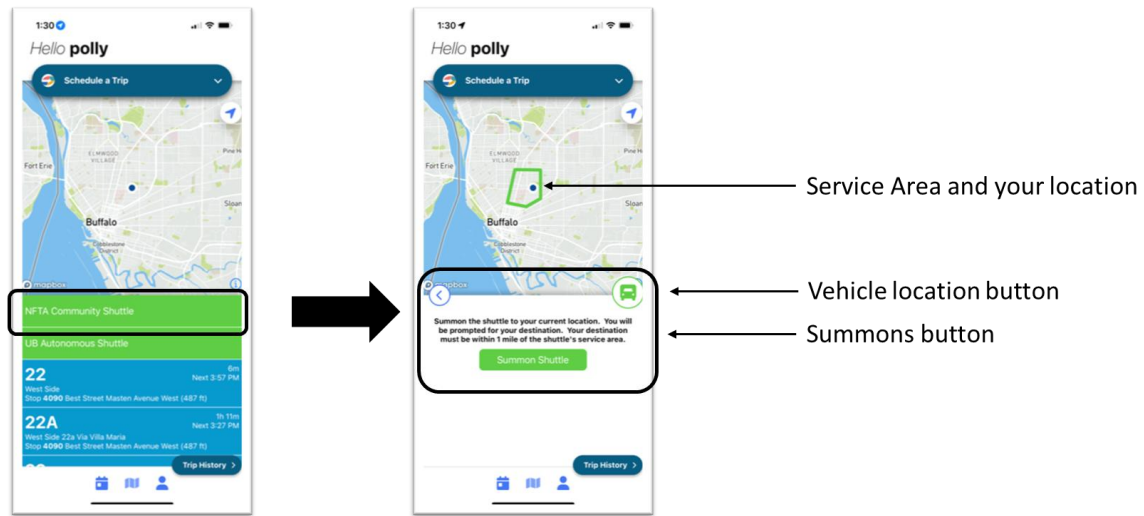


Figure 54. Summon On-demand (HDS) Shuttle (user story #2)
Source: Buffalo, NY ITS4US (2024)

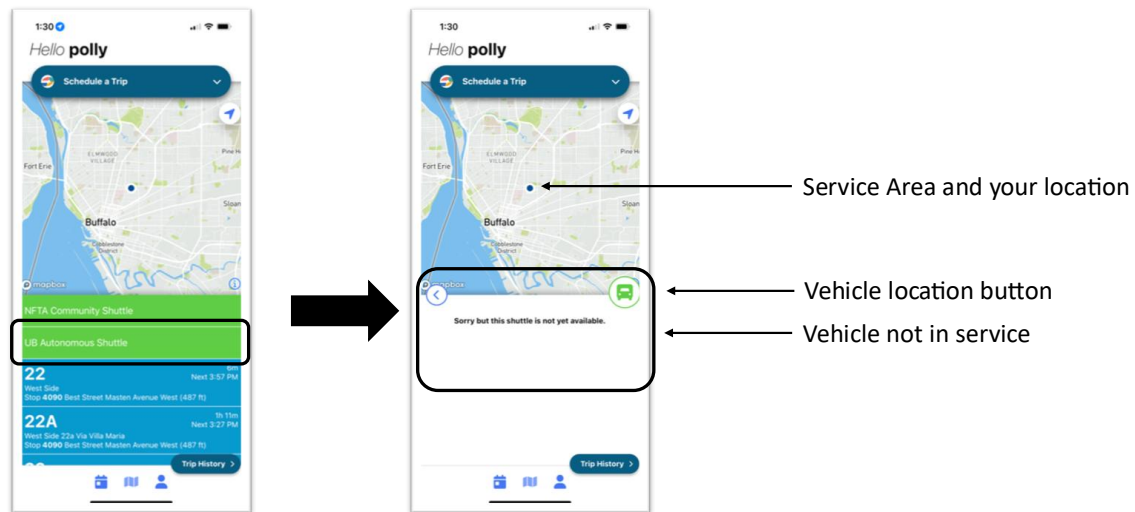


Figure 55. Summon Shuttle Not in Service (user story #2)
Source: Buffalo, NY ITS4US (2024)

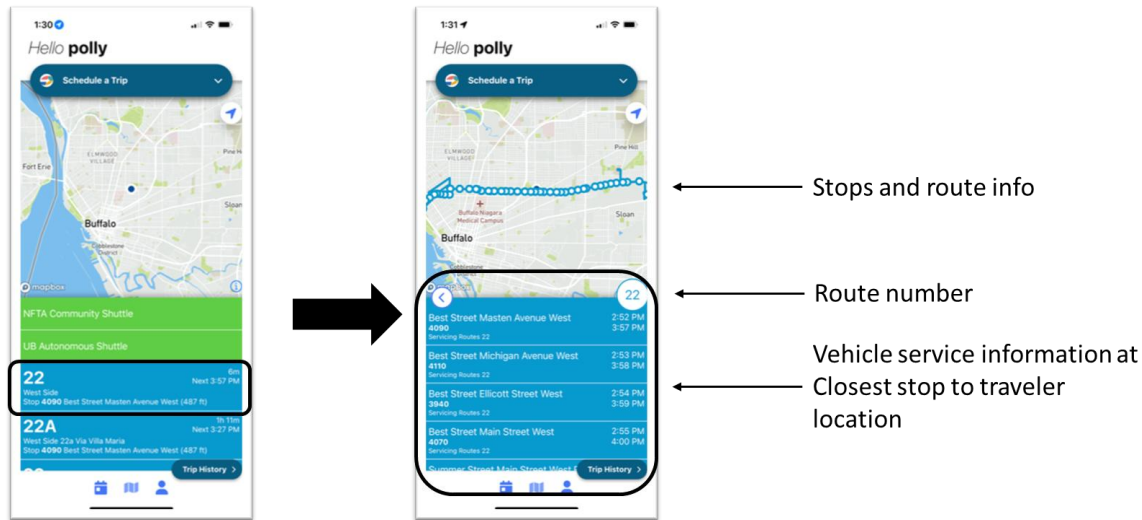


Figure 56. NFTA Fixed Route (user story #3)

Source: Buffalo, NY ITS4US (2024)

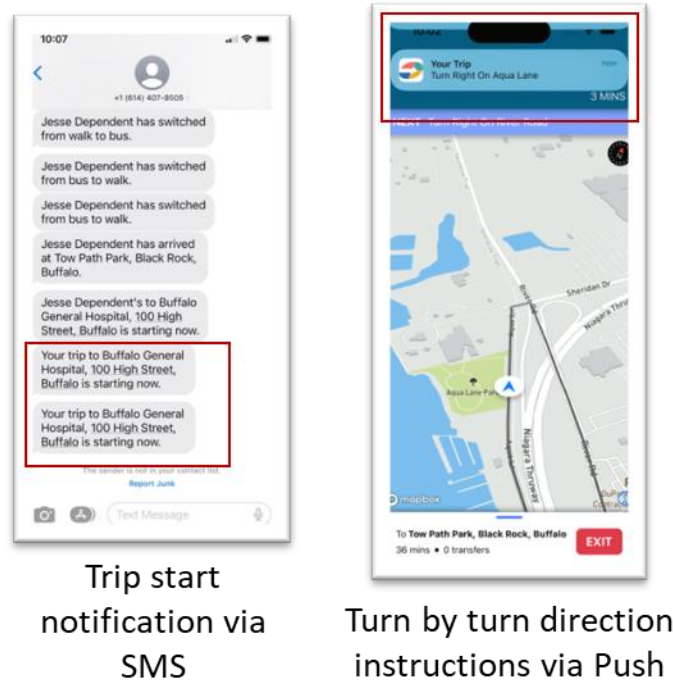
5.4.11 Notification and Navigation Messages

As described in **Section 5.3.4.4**, notifications are triggered by proximity to a location, event or time (e.g., ETA). The Notifications user story consists of travelers (and coordinators) selecting their preferences for receiving notifications based on their (or their assigned traveler's) trip plan. Content and operational implementation are described in this section.

The Notification User Story can be described as follows:

- The CTP shall provide an enumerated set of preferences for travelers to select for their account, which they can adjust the selections and notifications for each trip. These preferences will be configurable to assign to indoor and outdoor trip plans.

Traveler SMS and Push notifications and wayfinding messages are shown in **Figure 57** and Coordinator notifications are shown in **Figure 58**.

**Figure 57. Traveler Notifications and Wayfinding Messages***Source: Buffalo, NY ITS4US (2024)***5.4.11.1 Notification/Wayfinding Messages and Trigger Events**

The list of personas receiving notifications/navigation direction and their associated delivery channels are listed in **Table 39**. **Table 40** lists traveler message events, **Table 41** lists message events that are enhanced to better serve user preferences, and **Table 42** lists message events for coordinators (differentiated by mobile and web-based messages). The tables include the message type, message content, and message trigger. Messages are typically triggered by a spatial or temporal event. Spatial triggers are typically an event that uses a geofence – a virtual perimeter around a location (i.e., measured using GPS). Temporal triggers are events that use time or dynamic events to trigger a notification.

Table 39. Navigation Event Personas

Persona Name	User Persona Type	Delivery Cue (channels)
Traveler	Traveler that does not use a mobility assistive device or require enhanced accessibility features	Visual Verbal Haptic

Persona Name	User Persona Type	Delivery Cue (channels)
Enhanced Mobility Traveler	People who are users of the mobility application that rely on or like to have enhanced accessibility features turned on	Visual with ability for large font Verbal Haptic
Coordinator (3rd party)	People who work for a facility that are responsible for a subset of users because those users are affiliated with the organization	Mobile (accompanying rider) Visual
Coordinator (Companion/Friend/ Relative)	People who are companions to users of the mobility application	Verbal Haptic Web (observing rider) Visual

Table 40. Traveler Message Events

Message Type	Message	Trigger (Geofence or Temporal Value)
Mass Transit	3 min before expected arrival	3 min before expected arrival
Mass Transit	You have arrived	At arrival
Mass Transit	The next 3 arrival times for this route are x, y, z	List next 3 future arrival times
Walking (Indoor/Outdoor)	Turn-by-turn navigation directions	Turn by turn navigation notification
Walking (Indoor/Outdoor)	Turn-by-turn navigation directions	within 10ft
Walking (Indoor/Outdoor)	Turn-by-turn navigation directions	another notification at 5 ft
Walking (Indoor/Outdoor)	Turn-by-turn navigation directions	at turn
HDS Shuttle	You have requested an on-demand shuttle	On demand button pressed to summon shuttle at pickup location

Message Type	Message	Trigger (Geofence or Temporal Value)
HDS Shuttle	Shuttle <name> has arrived	Shuttle arrives
SDS Shuttle	ETA to Shuttle	3 min before expected arrival
SDS Shuttle	Shuttle has arrived	At arrival
SDS Shuttle	The next 3 arrival times for this route are x, y, z	List next 3 future arrival times
Ped-X (Walking and when triggered through app)	Crosswalk signal requested	On demand button press to trigger Ped-X
Ped-X (Walking and when triggered through app)	Turn-by-turn navigation	within 20 ft
Ped-X (Walking and when triggered through app)	Turn-by-turn navigation	another notification within geofence (less than 20 ft)
Ped-X (Walking and when triggered through app)	Turn-by-turn navigation	at requested PED-X crossing/intersection
Transitioning between inside and outside	You are entering a building would you like to switch to the building map? You are exiting a building, would you like to switch to outdoor navigation?	When geofence is detected for transition between outside and inside
Traffic Intersection (Walking)	Turn-by-turn navigation	within 10 ft
Traffic Intersection (Walking)	Turn-by-turn directions	another notification at 5 ft
Traffic Intersection (Walking)	Turn-by-turn directions	at intersection
Mass Transit Delays	Delay – new ETA is XXX	Immediately after delay notification is pushed

Table 41. Enhanced Mobility Traveler Message Events

Message Type	Message	Trigger (Geofence or Temporal Value)
Mass Transit	3 min before expected arrival	3 min before expected arrival

Message Type	Message	Trigger (Geofence or Temporal Value)
Mass Transit	You have arrived	At arrival
Mass Transit	The next 3 arrival times for this route are x, y, z	List next 3 future arrival times
Walking (Indoor/Outdoor)	Turn-by-turn navigation directions	Turn-by-turn navigation notification
Walking (Indoor/Outdoor)	Turn-by-turn navigation directions	within 10ft
Walking (Indoor/Outdoor)	Turn-by-turn navigation directions	another notification at 5 ft
Walking (Indoor/Outdoor)	Turn-by-turn navigation directions	at turn
HDS Shuttle	You have requested an on-demand shuttle	On demand button press to summon shuttle at pickup location
HDS Shuttle	Shuttle <name> has arrived	Shuttle arrives
SDS Shuttle	ETA to Shuttle	3 min before expected arrival
SDS Shuttle	Shuttle has arrived	At arrival
SDS Shuttle	The next 3 arrival times for this route are x, y, z	List next 3 future arrival times
Ped-X (Walking and when triggered through app)	Crosswalk signal requested	On demand button press to trigger Ped-X
Ped-X (Walking and when triggered through app)	Turn-by-turn navigation	within 20 ft
Ped-X (Walking and when triggered through app)	Turn-by-turn navigation	another notification within geofence (less than 20 ft)
Ped-X (Walking and when triggered through app)	Turn-by-turn navigation	at requested Ped-X crossing/intersection
Ped-X (Walking and when triggered through app)	Crosswalk signal has expired	missed signal cycle

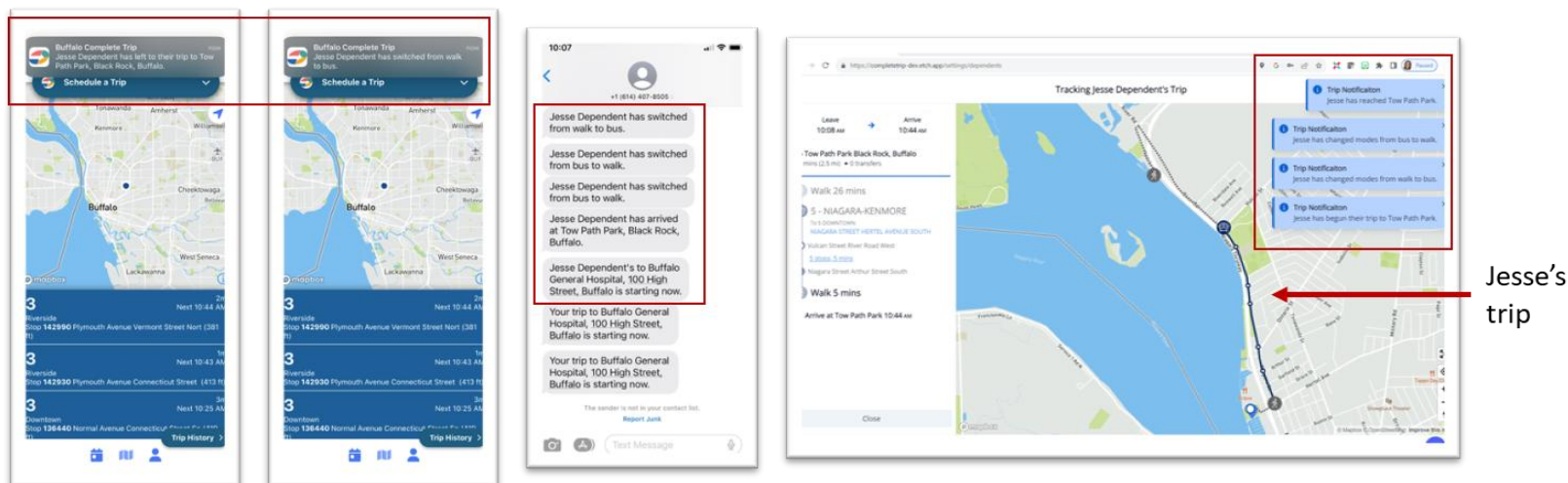
Message Type	Message	Trigger (Geofence or Temporal Value)
Transitioning between inside and outside	You are entering a building would you like to switch to the building map? You are exiting a building, would you like to switch to outdoor navigation?	When geofence is detected for transition between outside and inside
Traffic Intersection (Walking)	Turn-by-turn navigation	within 10 ft
Traffic Intersection (Walking)	Turn-by-turn directions	another notification at 5 ft
Traffic Intersection (Walking)	Turn-by-turn directions	at intersection
Mass Transit Delays	Delay – new ETA is XXX	Immediately after delay notification is pushed

Table 42. Coordinator (3rd Party or companion) Message Events

Message Type	Channel	Message	Trigger (Geofence or Temporal Value)
Mass Transit	Mobile	3 min before expected arrival	3 min before expected arrival
Mass Transit	Mobile, Web	Your companion has arrived	At arrival
Mass Transit	Mobile	The next 3 arrival times for this route are x, y, z	List next 3 future arrival times
Walking (Indoor/Outdoor)	Mobile	Turn-by-turn navigation directions	Turn by turn navigation notification
Walking (Indoor/Outdoor)	Mobile	Turn-by-turn navigation directions	within 10 ft
Walking (Indoor/Outdoor)	Mobile	Turn-by-turn navigation directions	another notification at 5 ft
Walking (Indoor/Outdoor)	Mobile	Turn-by-turn navigation directions	at turn
Walking (Indoor/Outdoor)	Mobile, Web	Your companion has arrived	At arrival

Message Type	Channel	Message	Trigger (Geofence or Temporal Value)
HDS Shuttle	Mobile	You have requested an on-demand shuttle	On demand button press to summon shuttle at pickup location
HDS Shuttle	Mobile, Web	Your companion has arrived	Shuttle arrives
SDS Shuttle	Mobile	ETA to Shuttle	3 min before expected arrival
SDS Shuttle	Mobile, Web	Your companion has arrived	At arrival
SDS Shuttle	Mobile	The next 3 arrival times for this route are x, y, z	List next 3 future arrival times
Ped-X (Walking and when triggered through app)	Mobile	Crosswalk signal requested	On demand button press to trigger Ped-X
Ped-X (Walking and when triggered through app)	Mobile	Turn-by-turn navigation	within 20 ft
Ped-X (Walking and when triggered through app)	Mobile	Turn-by-turn navigation	another notification within geofence (less than 20 ft)
Ped-X (Walking and when triggered through app)	Mobile, Web	Your companion has arrived	at requested Ped-X crossing/intersection
Ped-X (Walking and when triggered through app)	Mobile	Crosswalk signal has expired	missed signal cycle
Transitioning between inside and outside	Mobile	You are entering a building would you like to switch to the building map? You are exiting a building, would you like to switch to outdoor navigation?	When geofence is detected for transition between outside and inside
Transitioning between inside and outside	Mobile, Web	Your companion has arrived	at facility arrival

Message Type	Channel	Message	Trigger (Geofence or Temporal Value)
Traffic Intersection (Walking)	Mobile	Turn-by-turn navigation	within 10 ft
Traffic Intersection (Walking)	Mobile	Turn-by-turn directions	another notification at 5 ft
Traffic Intersection (Walking)	Mobile	Turn-by-turn directions	at intersection
Traffic Intersection (Walking)	Mobile, Web	Your companion has arrived	At intersection
Mass Transit Delays	Mobile	Transit Delay	Immediately after delay notification is pushed



Push to Mobile

SMS

Push to Web

Figure 58. Example of Coordinator Notifications*Source: Buffalo, NY ITS4US (2024)*

5.4.11.2 GPS Signal Warning

When GPS services operate between tall buildings or under concrete canopies, it becomes degraded through multipath error (signals are received out of order) or degraded measurements. In both cases, the location on the traveler's mobile device may jump around the screen, showing the person first on one side of the street, then on the other.

The app applies several approaches to detect and mitigate the effects.

1. The App detects the trend of the last several GPS measurements (received on a second-by-second basis) and smooths the measurements.
2. The App uses native functions in the mobile app to measure the confidence level of the horizontal measurement of the GPS signal.
3. When signal is determined to be degraded, the App triggers a warning to the traveler that the trip path they are taking may be degraded.

Specifically, the design consists of using native mobile platform functions that detect GPS and cellular signal strength confidence levels. The confidence level provides the radius of confidence within 60%. When the radius is large, the quality is reduced. The confidence level detection will indicate the quality of the signal and assume the positioning accuracy. When the app detects the traveler is deviating from the trip path, it determines whether the cause is due to GPS error or user behavior. When the traveler's path is out of range of the confidence level there is a higher probability that the cause is due to a GPS error. When the confidence level is within normal range yet the app detects that the traveler is not on their planned path, then the app determines that they are no longer on their planned path and requires a reroute. For example, in the case where the northern crosswalk would make the trip longer, the app will register that the GPS error probability is high, and the probability of the user taking the longer route is low.

When the GPS error is detected, the app triggers a warning on the app that informs the user that the GPS is degraded. The notification states, "Warning: GPS accuracy issues in this area may impact trip planning and navigation. Please take caution." as shown in

Figure 59 illustrates the warning icon shown on maps while traversing in areas of GPS degradation.

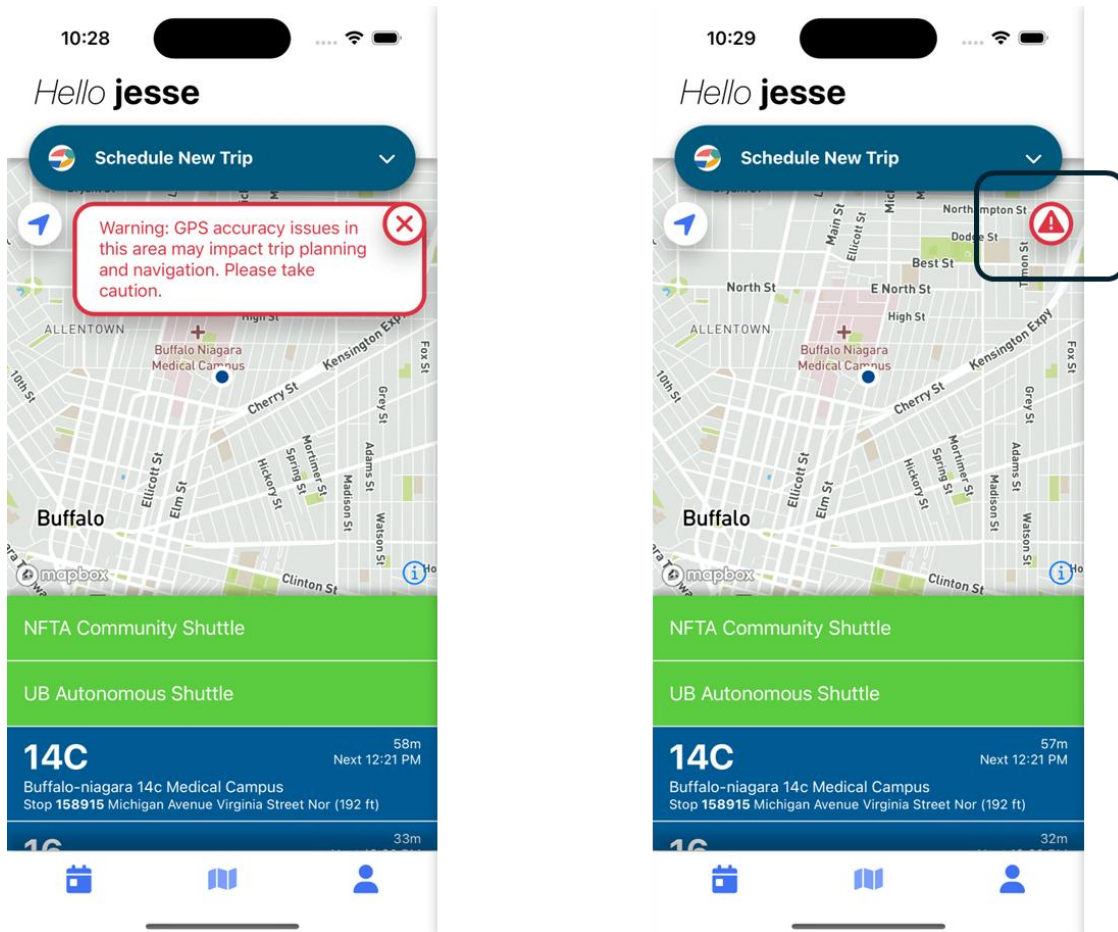


Figure 59. GPS Signal Warning
Source: Buffalo, NY ITS4US (2024)

5.5 Trip Management

The Trip Management Epic includes user stories related to navigation and wayfinding activities. The prerequisite for trip management is for the CTP server process to download a trip plan to the app when the traveler is ready to start a trip. Many integration elements are included in the trip management function including:

- Indoor and Outdoor Navigation
- Coordinator View of Traveler Trips
- Pedestrian Actuation Request

In addition, other functions such as the help, survey and TIH functions are also included in this function.

Several trip management functions are detailed in the Trip Planning Epic.

5.5.1 Indoor / Outdoor Navigation

The Indoor / Outdoor Navigation functionality is composed of providing turn-by-turn navigation instructions, transitioning from outdoor to indoor (and *vice versa*), and indoor navigation. All the user stories are operated on the mobile app exclusively. To that end they depend on ensuring that the mobile location settings are tuned properly. The user story and requirements associated with tuning location is listed first in the Indoor / Outdoor User Stories table (**Table 43**).

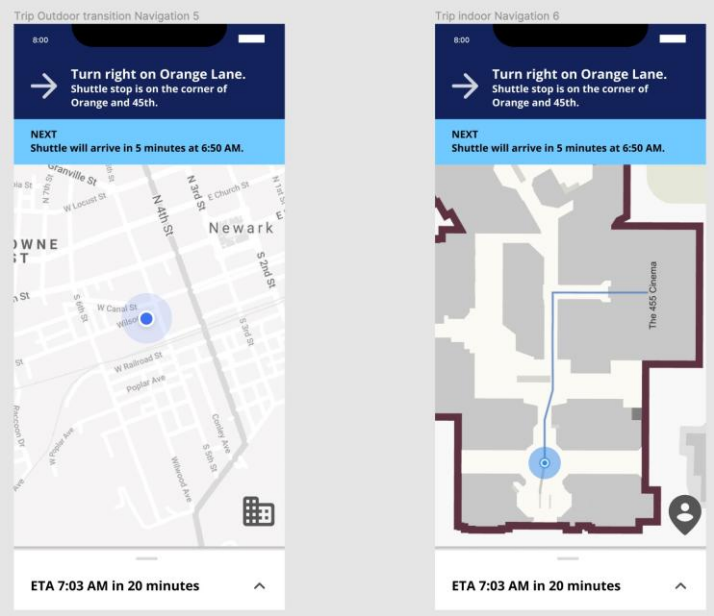
Table 43. Indoor / Outdoor User Stories

User Story	Description and Acceptance Criteria
Req-CTP-101: Tune location settings	Description: As a user, when I am prompted to use location services native to my mobile phone, it will calibrate my location correctly according to my mobile network. Acceptance Criteria: The CTP shall provide instructions in the Help section that describe how to configure and calibrate their location sensors to achieve the most accurate location and positioning performance from their mobile app.
Outdoor Navigation in Mobile App	Description: As a mobile application user who is ready to embark on a trip, or is in the middle of a trip, I can start turn-by-turn navigation for outdoor directions. Acceptance Criteria: - User is logged into their account - User selects origin, destination, and time of departure - User selects mode(s) - User selects trip plan - User activates trip plan and clicks go to get turn-by-turn directions that include upcoming stops (if using bus/train)

User Story	Description and Acceptance Criteria
Req-CTP-027 On-line / off-line data usage and tracking	Description: As a mobile user who is ready to embark on a trip and would like to have off-line access (i.e., can turn off their data while navigating through the mobile app), I must load my mobile app with the trip using data prior to starting my trip. Related to Req-CTP-132 Monitor for Mobility Provider connectivity. When the user is not connected, the mobile app reverts to planned information. Acceptance Criteria: • Same acceptance criteria as Outdoor Navigation in Mobile app (above) • User traveling with data off mode on their mobile devices receive turn-by-turn messages without any real-time notifications. Note: PED-X, INS and real-time notifications are not enabled without data turned on.
Req-CTP-047 Rerouting trip plan	Description: As a mobile user, I want to be rerouted on a more optimized path as I travel off the planned route. Acceptance Criteria: • User is registered and started navigation • User trip plan does not go on planned path • User trip plan and navigation will automatically recalculate and notify the user • User will see new arrival time (if applicable)

User Story	Description and Acceptance Criteria
Indoor Navigation - Outdoor / Indoor Turn-by-Turn Directions	Description: As a traveler that is traveling from my home to an indoor destination, or vice versa, I need a complete door-to-door trip plan to follow. This ticket relates to Indoor Navigation - Stitched Complete Trip Plan. Once a complete trip plan is available between outdoor and indoor locations, turn-by-turn directions can be generated and spoken/displayed to the traveling app user and any monitoring Coordinators. Acceptance Criteria: If indoor navigation is available at a location, the building icon will appear on the lower left corner of the map for the user to click on to see the overall indoor navigation path.
Indoor Navigation - Stitched Complete Trip Plan	Description: As a traveler that is traveling from my home to an indoor destination, or vice versa, I need a complete door-to-door trip plan to follow. The CTP's current trip plans include modes for pedestrian movement, cars, bikes, shuttles, buses, and trains. The plan stops at the exterior of buildings. This task will result in combined indoor-outdoor plans. Dependencies: - Indoor Navigation Plan trip to indoor location - Indoor Navigation - My location on map - Indoor/Outdoor Transition Acceptance Criteria: - If indoor navigation is available at a location, the building icon will appear on the lower left corner of the map for the user to click on to see the overall indoor navigation path. As the user is closer to the destination, the user will be prompted to click on the indoor navigation icon to begin turn by turn indoor navigation.

User Story	Description and Acceptance Criteria
Indoor Navigation - Plan trip to indoor location	Description: As a traveler, I want to see indoor points of interest in the app search results and navigate directly to the selected point. Dependent: on designating and exporting destinations from INS (see Section 4.3) and importing them into the CTP. Acceptance Criteria: Points of interest are labeled within the indoor floorplan as well as during navigation.
Indoor Navigation - My location on map	Description: As a mobile app user, I need to see my “blue dot” location and direction displayed on the map, using CX App’s On-Device Positioning (ODP) SDK. Dependent: <i>loading the SDK into the Android and iOS mobile operating systems</i> Acceptance Criteria: While navigating indoors, the user can see his or her location indoors.

User Story	Description and Acceptance Criteria
Indoor Navigation - Toggle between indoor and outdoor map UI	Description: As a traveler in the mobile app who is traveling to or from VIA or the hospital, I want to be able to switch between indoor and outdoor map views when navigating to or from the facility.  Figure 60. Toggle between Outdoor and Indoor User Interface Source: <i>Buffalo, NY ITS4US (2024)</i> Acceptance Criteria: • Provide information that is shown on Figure 60 including indoor and outdoor toggle icons (see bottom right).

User Story	Description and Acceptance Criteria
Indoor Navigation - Indoor/Outdoor Transition	Description: As a user moving into a supported facility or leaving a facility, I would like to easily toggle to the indoor or outdoor map. Sprint 13 added the capability to switch between an indoor and outdoor map. This sprint refines the process using geofencing. Dependent: on a Toggle between Indoor/Outdoor Acceptance Criteria: • The screen changes from an outdoor map to an indoor map when the indoor toggle is selected • The screen changes from an indoor map to an outdoor map when the outdoor map is selected. • The indoor icon appears when the Outdoor map is shown on the screen. • The outdoor icon appears when the indoor map is shown on the screen.
Indoor Navigation - Outdoor / Indoor Turn-by-Turn Directions	Description: As a traveler that is traveling from my home to an indoor destination, or vice versa, I need a complete door-to-door trip plan to follow. This JIRA ticket relates to Indoor Navigation - Stitched Complete Trip Plan (above). Once a complete trip plan is available between outdoor and indoor locations, turn-by-turn directions can be generated and spoken/displayed to the traveling app user and any monitoring coordinator. Acceptance Criteria: • Same as Indoor Navigation - Stitched Complete Trip Plan and Indoor Navigation –Indoor/Outdoor Transition.

User Story	Description and Acceptance Criteria
Req-CTP-063.2: As a user, I'm able to set/manage my trip plan notifications associated to indoor wayfinding in the BNMC during my trip planning and booking	Description: As a user, I'm able to set/manage my trip plan notifications associated to indoor wayfinding in the BNMC during my trip planning and booking. Acceptance Criteria: • User receives notifications for turn-by-turn directions while traversing the indoor trip.

User Story	Description and Acceptance Criteria
API Layer Development	Description: Develop CXApp SDK service to React Native and React Native to mobile OS calls (iOS and Android). Services include: • Load / Display Map from CXApp • Display My Position on Map • Destination Wayfinding • Draw Path on Map • Blue Dot Location and Navigation • Show Icons on Map • Snap to Wayfinding Path • Styling with JSON • Layer interaction • Load Default Locale • Map Gestures (follow, overview, search results and step through navigation instructions) • Destination Search • Latitude and Longitude Conversion • Wayfind to device • Apply Device Orientation • Navigate with Compass • Create Text Directions • Landmark based directions • Distance based directions • Auto re-routing wayfinding • Geofence Notifications • Single Venue Wayfinding • Multi Venue Wayfinding • Multi Venue Destination Search The services that implement these functions are described in the ICD (Section 3.25, Int-18). Acceptance Criteria: • The API Layer is developed (translation from React Native CXApp SDK native OS calls). • Demonstration of the functionality on Android. • Demonstration of the functionality on IOS.

5.5.2 Coordinator View

A Coordinator is a trusted friend, companion or caregiver to whom a traveler has granted permission to view their travel when planning or taking a trip on the app. The Coordinator may view current or recurring trips, receive notifications through an on-going trip, and track a traveler's trip.

The epic is based on the high-level requirements and user stories as follows:

- **Req-CTP-077: Manage Assigned Coordinators in Mobile App:** As a user who receives care from a medical profession or family member, I need to add and manage coordinators who have access to my account information.
- **Req-CTP-077: Manage Assigned Coordinators in Web App:** As a user who receives care from a medical profession or family member, I need to add and manage coordinators who have access to my account information.

The Coordinator View includes user stories that enable a user to designate one or more coordinators to track their trips and journeys using the CTP app. The Rider and Coordinator Functional Flow includes the process to on-board a coordinator. Once included, the coordinator has access to the traveler's planned and current trips that are assigned to the coordinator. In addition, the coordinator will receive notifications (see **Section 5.4.11**) prior to and during the traveler's journey.

Furthermore, the traveler who granted permission can remove a Coordinator at any time. A Coordinator can accept or remove their relationship with the traveler at any time, as well. **Figure 61** shows the end-to-end process from requesting a coordinator to confirmation of their agreement to serve as coordinator.

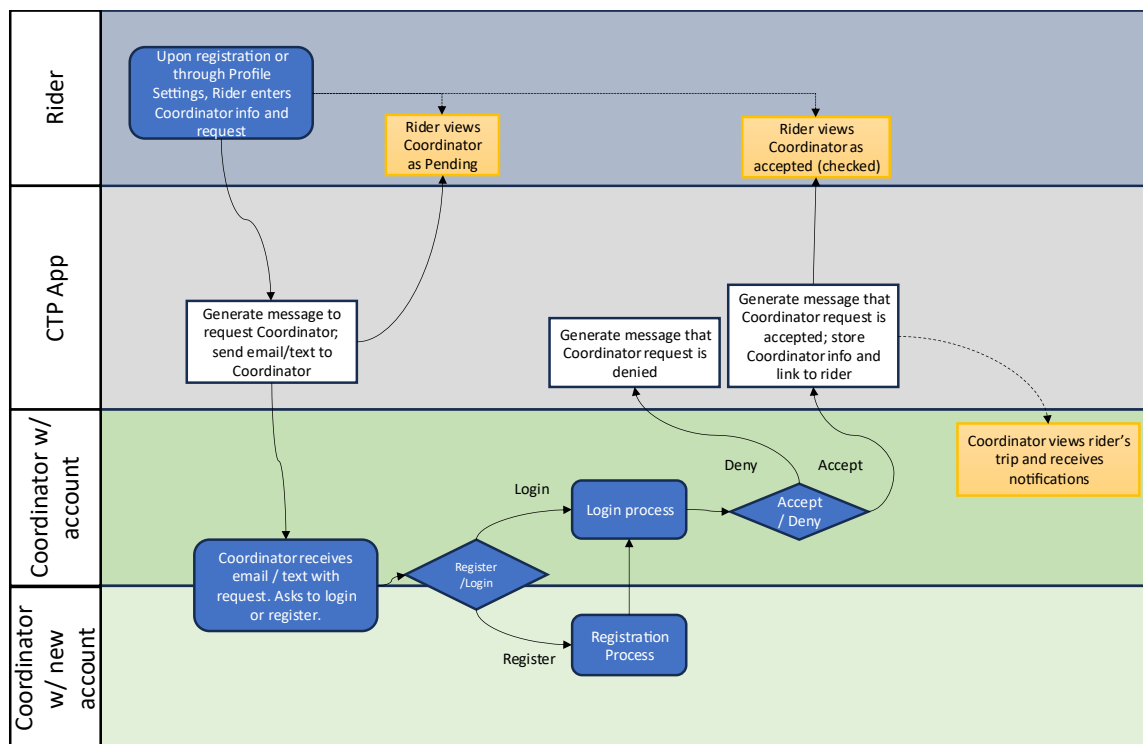


Figure 61. Rider and Coordinator Request Functional Flow

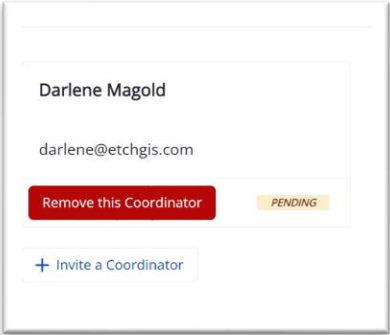
Source: Buffalo, NY ITS4US (2024)

The blue boxes in **Figure 61** indicate a process flow, the white boxes indicate an internal function of the CTP; and the yellow boxes indicate a UI function available to a user (rider or coordinator).

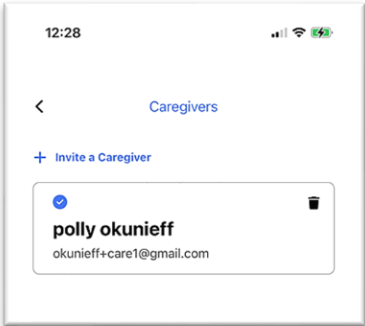
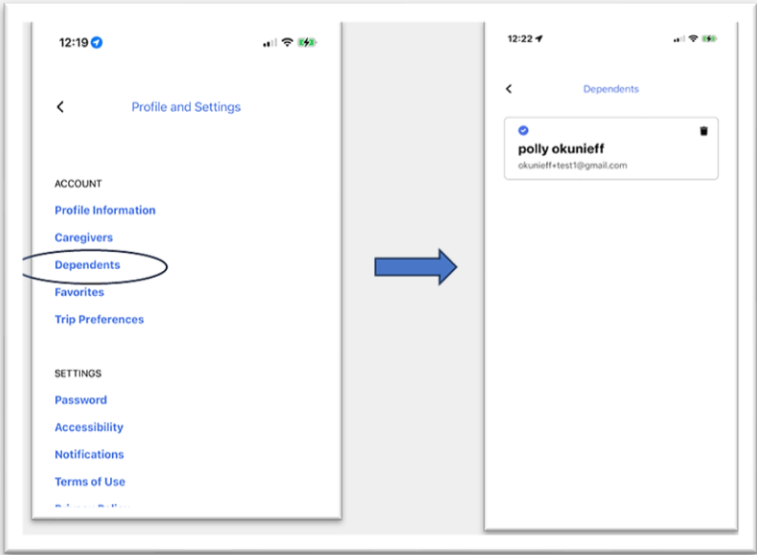
The functional flow includes four actors –

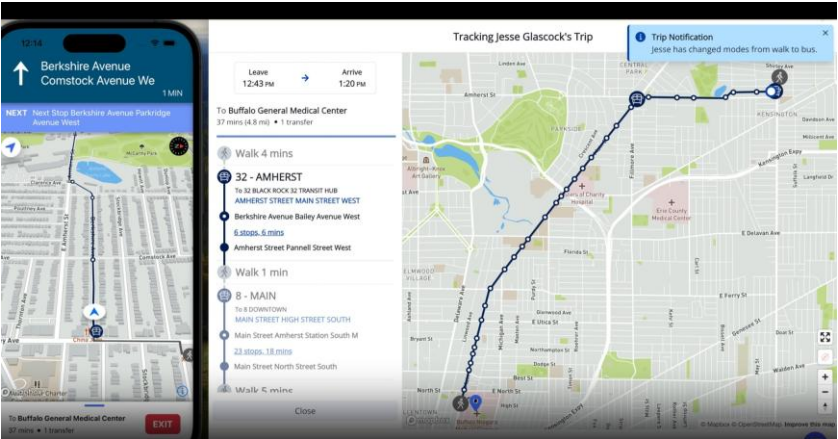
- **Traveler** – Account holder who owns the account. The account holder may designate one or more coordinators.
- **Mobility Platform** – the CTP app.
- **Coordinator with New Account** – A new account that was opened by the coordinator. A coordinator must have an account to become a rider’s coordinator.
- **Coordinator with (existing) Account** – The primary account associated with a coordinator.

Table 44. Rider / Coordinator Request Functional Flow Description

Step	Rider and Coordinator Login Functional Flow Part A --Description
1	Rider enters the name and contact information (email or phone) of a coordinator in the Profile Settings or during their registration processes (see Section 5.3). They may also assign (update) a coordinator to a trip when they schedule the trip (see Section 5.4.4). The CTP will show a PENDING request on the Rider’s app (Figure 62).  Figure 62. Pending Request to Add Coordinator <i>Source: Buffalo, NY ITS4US (2024)</i>
2	The CTP generates a message (email or text) to the coordinator requesting their agreement to act as a coordinator (Figure 63).  Figure 63. Email Message Requesting Coordinator <i>Source: Buffalo, NY ITS4US (2024)</i>

Step	Rider and Coordinator Login Functional Flow Part A --Description
3	If the coordinator does not have an existing account, they can create one through the registration (Register) process (see Section 5.3.3). Otherwise, they can login through the Login process (see Section 5.3.4) (Figure 64). You have been requested to be a caregiver for All Access App. Please login to view the request. If you do not have an account, please register and you can review the request once you complete the registration. Login Register Figure 64. Screen Prompting Coordinator to Login or Register for an Account <i>Source: Buffalo, NY ITS4US (2024)</i>
4	When the coordinator logs into their account, they are requested to accept or deny the invitation (Figure 65). You have been requested to be a caregiver for polly okunieff. Do you want to accept it? Accept Request Deny Request Figure 65. Coordinator Invitation Request <i>Source: Buffalo, NY ITS4US (2024)</i>

Step	Rider and Coordinator Login Functional Flow Part A --Description
5	Rider views coordinator in Coordinators account settings (Figure 66).  Figure 66. Coordinator Account Setting Screen <i>Source: Buffalo, NY ITS4US (2024)</i>
6	Coordinator views rider in “Traveler” account settings (Figure 67).  Figure 67. Coordinator View of List of Dependents <i>Source: Buffalo, NY ITS4US (2024)</i>

Step	Rider and Coordinator Login Functional Flow Part A --Description
7	Coordinator can view rider trips in Traveler settings (Figure 68).  Figure 68. Coordinator View of Traveler Trips Source: Buffalo, NY ITS4US (2024)

The user stories shown in **Table 45** for the Coordinator View include the following:

- Req-CTP-040: E-mail to View and Accept Coordinator Requests
- Req-CTP-137: View and Manage Assigned Travelers in Web App
- Req-CTP 137: Coordinator Can View Trip Schedule
- Req-CTP 137: Coordinator Can Track Trip Progress
- Req-CTP 137: Coordinator Can Track Traveler Location
- Req-CTP-077: Manage Assigned Coordinators in Mobile App
- Req-CTP-077: Manage Assigned Coordinators in Web App

Table 45. Coordinator View User Stories

User Story	Description and Acceptance Criteria
Req-CTP-040: E-mail to View and Accept Coordinator Requests	Description: As a potential coordinator, I will receive a request to be assigned coordinator rights for someone who has entered my e-mail into their mobile app or web app account. I can click a link in the e-mail to go to a web page that displays the request. I can accept the request and the traveler's app will show my name as an accepted coordinator. Acceptance Criteria: The Coordinator receives email request as shown in Figure 61.
Req-CTP-137: View and Manage Assigned Travelers in Web App	As someone who is registered as the coordinator for one or more dependents, I need to view and manage my list of travelers on the web site. Acceptance Criteria: The Coordinator is able to view and manage assigned travelers as shown in Figure 61 and Table 44.
Req-CTP 137: Coordinator Can View Trip Schedule	Description: As a coordinator who provides assistance for one or more travelers, I can choose a traveler to view a list of upcoming trips with departure times. Acceptance Criteria: The Coordinator is able to choose and view a traveler's schedule as shown in Figure 61 and Table 44.
Req-CTP 137: Coordinator Can Track Trip Progress	Description: As a coordinator who provides assistance for one or more travelers, I can view the directions for a traveler's trip and see what upcoming steps remain along the full journey. Acceptance Criteria: Demonstration of a traveler moving on a map in Coordinator app and see Figure 58 for map view of trip progress.

User Story	Description and Acceptance Criteria
Req-CTP 137: Coordinator Can Track Traveler Location	Description: As a coordinator who provides assistance for one or more travelers, I can choose a traveler to view live location and route on the map. Acceptance Criteria: Demonstration of a traveler location on a map in Coordinator app and see Figure 58 for traveler trip location and notifications.

5.5.3 Pedestrian Crossing Actuation Request (PED-X)

The PED-X request is one of the hands-off functions that is included in the App. Two intersections have the Miovision system installed to provide a gateway to request pedestrian actuation. The features and equipment are described in **Section 4.4**. This section describes how the capabilities are made available to the traveler.

The process available to the traveler is as follows:

Precondition: Traveler generates a trip plan that includes crossing an intersection outfitted with the Pedestrian Crossing Actuation Request function. Then the traveler begins his journey using the Buffalo All Access App.

- (1) As the traveler arrives within 50 feet of the intersection (the geofence area), a button appears on the mobile app that asks, "Request to cross the intersection." (Req-CTP-050 Geolocate traveler near intersection)
 - a. Note: geofence and influence of the location beacons on user location tracking can be reconfigured to better operational performance.
- (2) When selected, the App sends a request via Miovision server to the Core DCM to forward the request to the traffic controller PED-X activation.
- (3) Once sent, the App button changes into a bright label that indicates that the request was sent.
- (4) When the traveler walks out of the geofence area, the label is removed and returns to journey turn-by-turn directions.

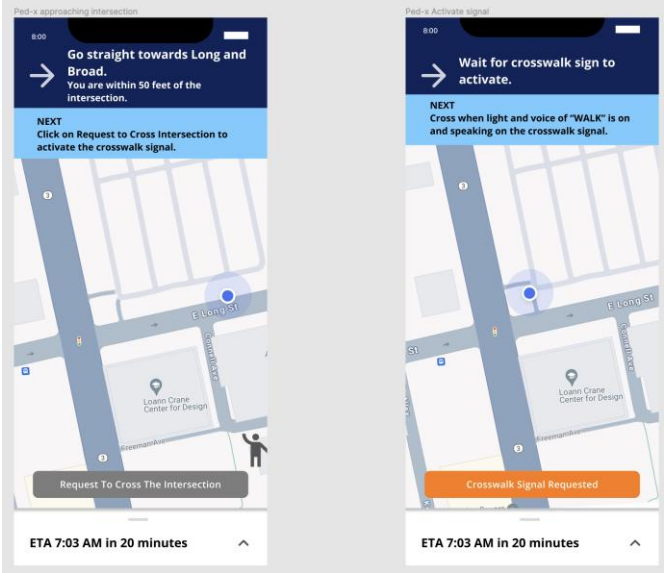
Alternative #1: request automatically clears when the PED-X is activated.

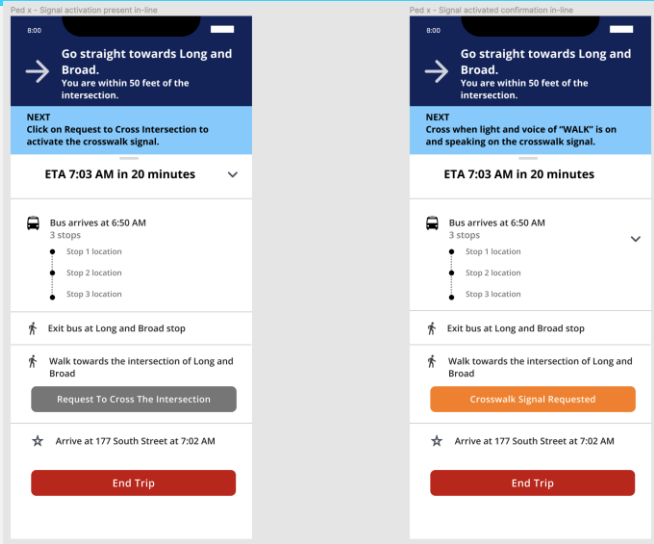
Alternative #2: the request is cancelled after 300ms (time to live).

These steps are described as user stories in **Table 46**.

Table 46. PED-X Integration User Story Descriptions

User Story	Description and Acceptance Criteria
Middleware for Ped-X API (1)	Description: For pedestrian crossing (Ped-X), the CTP will communicate with the CoB's traffic signal infrastructure. As users approach a signalized intersection during navigation, the mobile app will send a crossing command to the signal controller in order to express the user's intention to cross, without the user having to push a physical button. In this sprint, we will create a middleware service capable of talking to the Miovision API for signal actuation. This service will wrap the communication so that the user is not exposed to the Miovision credentials, and it could be adapted to other PED-X infrastructure. The middleware supports the following requirements: Req-CTP-051, Req-CTP-052, Req-CTP-053, Req-CTP-054, Req-CTP-055, Req-CTP-057, Req-CTP-058, Req-CTP-059. Acceptance Criteria: As the user approaches an intersection, while in navigation mode, the user will see a button pop up on their app when the user is within 50 feet of the signal. The user can select the button in the app, to activate the walk sign. The user should see the walk sign activated at the next cycle.
Ped-X - Use crosswalk button to send preemption request (2)	Description: As a mobile app user who is crossing one of the smart intersections, I want to press the "Request to cross the intersection" button in the app and cause a signal to be sent to the Miovision API. The app should show if the request is still pending and reset when it is not, either because of time or because of error. Acceptance Criteria: As the user approaches an intersection, while in navigation mode, the user will see a button pop up when the user is within 50 feet of the signal. The user can select the button in the app, to activate the walk sign. The user should see the walk sign activated at the next cycle. The button will be deactivated or grayed out if not activated.

User Story	Description and Acceptance Criteria
Ped-X - Display crosswalk button in navigation (3)	Description: As a mobile app user who is crossing one of the smart intersections, I want to see an option to request the crosswalk signal from within the app when I get close (Figure 69 and Figure 70).  The figure consists of two side-by-side screenshots of a mobile navigation app. The left screenshot, titled 'Ped-x approaching intersection', shows a map with a blue line indicating the route. A blue circle highlights the intersection of E Long St and Broadway. A blue button at the bottom of the map area says 'Request To Cross The Intersection'. The right screenshot, titled 'Ped-x Activate signal', shows the same map view. A blue button at the bottom of the map area says 'Crosswalk Signal Requested'. Both screenshots show a 'NEXT' instruction at the top and an 'ETA 7:03 AM in 20 minutes' at the bottom. Figure 69. Map View with Option to Request Crosswalk Signal <i>Source: Buffalo, NY ITS4US (2024)</i>

User Story	Description and Acceptance Criteria
Ped-X - Display crosswalk button in navigation (3) (continued)	 Figure 70. Navigation View with Option to Request Crosswalk Signal <i>Source: Buffalo, NY ITS4US (2024)</i> Acceptance Criteria: Includes similar functions as shown in UI mockups
PED-X Communications	Description: As a user, I want to know if my request was acknowledged, or if I can activate a request. The user story is related to the following requirements: • Req-CTP-111 Monitor for PED-X connectivity • Req-CTP-112 Alert Lack of communications for PED-X connectivity • Req-CTP-113 PED-X anomalies • Req-CTP-114 Alert Traveler to PED-X anomalies Acceptance Criteria: If the signal is unavailable or not within the geofence, the button on the app is grayed out. There are no alerts other than the button appearing – the button turning active – then inactive if it times out.

5.5.4 Help and Feedback Functions

This section describes the HELP and FEEDBACK function design. The Help and Feedback functions are included in the Profile and Settings functions. In addition, a *customer satisfaction survey* pops up at the end of each trip.

The HELP function for the mobile and website application can be found in the Profile and Settings section under ACCOUNT on the mobile app and on the Web view (see **Figure 71**). This includes information organized by each feature e.g., trip planning, coordinator, preferences, etc. In addition, help functions include a link to call the Call Center including an emergency call number for the Self-Driving Shuttle (Req-CS-016).

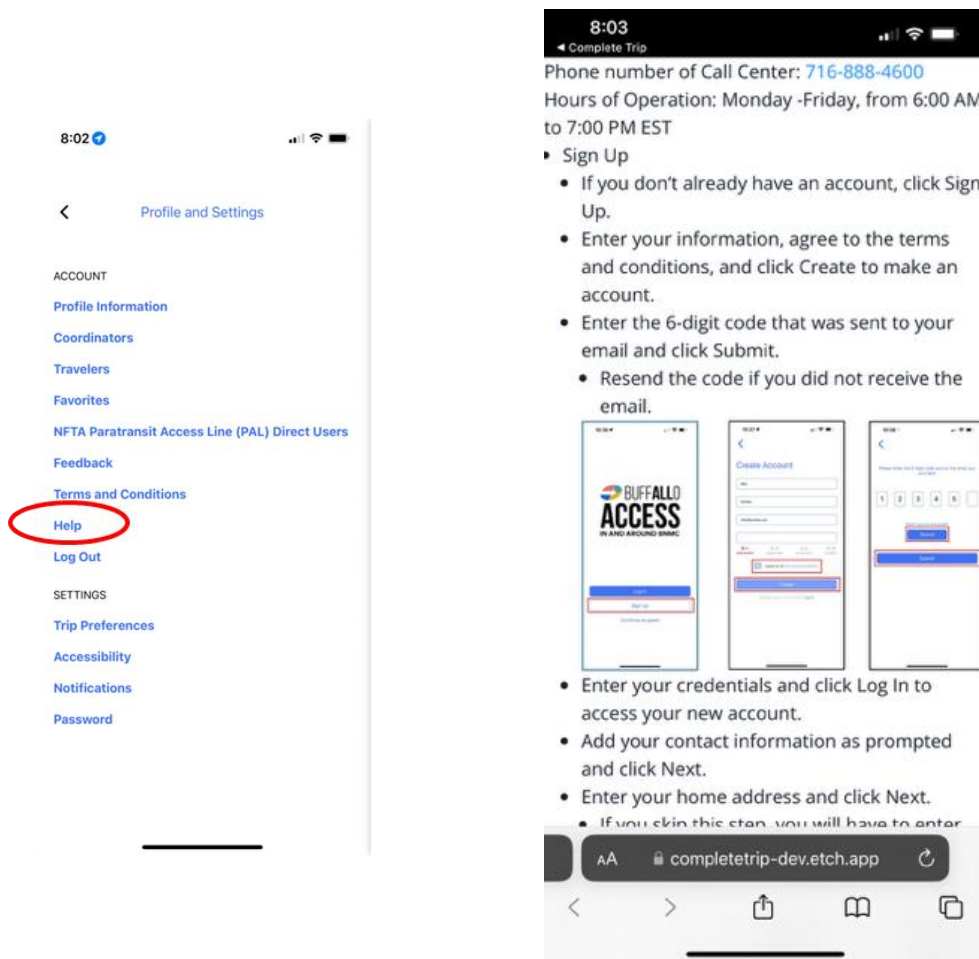


Figure 71. Help Selection and Support

Source: Buffalo, NY ITS4US (2024)

The FEEDBACK function for the application and website can be found in the Profile and Settings section under ACCOUNT on the mobile app, and through the comment bubble (on the icon menu) on the Web view (see **Figure 72**). The feedback includes a drop down so the user can select the category most appropriate and can be organized for quantifying by the performance measurement processing (see **Section 6**). There is also a text box where a user can enter

comments. This information will be collected by the application development team and provided via the CTP Log Data API (ICD Section 3.4) on a daily basis after removing all PII information.

The figure displays two versions of a web-based feedback form. The left version shows the form with a 'Submit' button. The right version shows the form with a dropdown menu open, displaying a list of categories. The categories listed are: Trip Scheduling, Community Shuttle, Autonomous Bus, Smart Intersections, Transit, Outdoor Navigation, Indoor Navigation, Coordinator and Traveler, Accessibility, General Mapping, and Other.

Figure 72. Feedback Form and Categories List (web view)

Source: *Buffalo, NY ITS4US (2024)*

A *customer satisfaction survey* will be presented to the user at the end of each trip with a 5-star rating for several elements for the Performance Measurement Dashboard.

These design elements meet the following requirements:

- Req-CTP-080 Traveler feedback form
- Req-CTP-086 Report Traveler feedback issue
- Req-CTP-088 UI to Call Center
- Req-CS-016 Emergency Call Button (for SDS)

Table 47. Help and Feedback User Stories

User Story	User Story Description
Req-CTP-127 Call Center calls and Req-CS-016 Emergency Call	Description: As a user, I should have access to a phone number to call if my shuttle does not show up. When I click on the number, it should place the call for me. Note: The call will be sent to the call center where it will be directed to appropriate recipients including emergency call number. Acceptance Criteria: • Call center button is displayed in the UI. • Selecting the call center button connects the user with the call center or appropriate party Note: Call center processes to be included in training and CMOP will include the call tree and appropriate recipients.
Req-CTP-080 Feedback form	Description: As a user, I can provide feedback on multiple categories in the application or website. Acceptance Criteria: • The user is able to enter information through the feedback UI which then populates the feedback form entries and categories.
Req-CTP-086 Report Traveler feedback issue	Description: As a user, I should be able to complete and submit my form to be processed. Acceptance Criteria: • Complete entries in the feedback form. • Submit, clear, or cancel the feedback form.

5.5.5 TIH Functions

The kiosk or Transportation Information Hub functions will be in Guest Mode only. However, the functions will include the ability to summon the HDS (on-demand) and SDS services.

The TIH function designs include configuring the kiosk administration function and kiosk functions such as the keyboard and guest mode / specialized kiosk functions.

5.5.5.1 Kiosk Configuration Functions

The kiosk configuration functions are described in **Table 48**.

Table 48. Kiosk Configuration Functions User Story Descriptions

User Story	Description and Acceptance Criteria
Kiosk – Content Management System (CMS) setup	Description: As a kiosk administrator, I need to go into the kiosk CMS web page and add a new kiosk URL with other necessary device settings. Acceptance Criteria: - The administrator is able to log on to the RedyRef CMS portal (Engage IoT Software). - See Section 4.5.2 for additional information.
Kiosk - Test in Kiosk Environment	Description: As a kiosk user, I need a UI experience that is well suited to the physical screen dimensions and operating behavior. In this task, the kiosk web app will be tested within the Engage CMS platform software that runs on the physical kiosks. Acceptance Criteria: The user will have the same experience with the kiosk web app as with the web app for CTP with no login or registration information.
Kiosk - Onscreen keyboard	Description: As a kiosk user, I need a UI experience that includes an onscreen keyboard to perform trip planning activities. Acceptance Criteria: The user will have the same experience with the kiosk web app as with the web app for CTP with no log in or registration information and is able to use an onscreen keyboard to enter information.

User Story	Description and Acceptance Criteria
Kiosk - UI	Description As a kiosk user, I need UI experience that is well suited to the physical screen dimensions and operating behavior. Acceptance Criteria: The user will have the same experience with the kiosk web app as with the web app for CTP with no log in or registration information.

5.5.5.2 TIH Traveler Functions

The TIH traveler functions are the same as those described in Guest Mode. The user stories are described in **Table 49**.

Table 49. TIH User Story Descriptions

User Story	Description and Acceptance Criteria
Trip Planning (Req-CTP-018 Augmented functionality) – Schedule a trip	Description: As a user of a public kiosk, I would like to plan a trip. Acceptance Criteria: Plan a complete trip, submit and receive multiple trip itineraries as depicted in Table 31 but for the web version.
Trip Planning (Req-CTP-018 Augmented functionality) – Schedule a Community Shuttle trip	Description: As a user of a public kiosk, I would like to plan a trip using the SDS or HDS (on-demand). Acceptance Criteria: Plan a complete trip, submit and receive multiple trip itineraries with CS reservations (as depicted in Table 31 but for the web version.) Note: this feature will not be available in Guest mode except on the kiosk.

User Story	Description and Acceptance Criteria
Req-CTP-010 Pre-populate Trip Location (Origin)	Description: As a user of a public kiosk, when I schedule a trip, I want the origin to default to the kiosk location. Acceptance Criteria: View the schedule a trip screen with the origin appearing at the location of the kiosk. (see Figure 73)
User Security / Guest User	Description: As a user of a public kiosk, I should not be able to have an option to create an account or log in. Acceptance Criteria: Only guest function flows appear (see Figure 37 process) on the kiosk.
Email Planned Trip	Description: As a user that is not logged in, I am able to email a link of this trip to any email I input. Acceptance Criteria: Send and receive a selected trip plan to myself
Kiosk – QR Code	Description: As a kiosk user, I need to download the mobile application to my personal device. Acceptance Criteria: The user will have access to the CTP mobile app by capturing a QR code to download the app from either iOS or Android device. Note: add QR codes when app is uploaded to app stores.

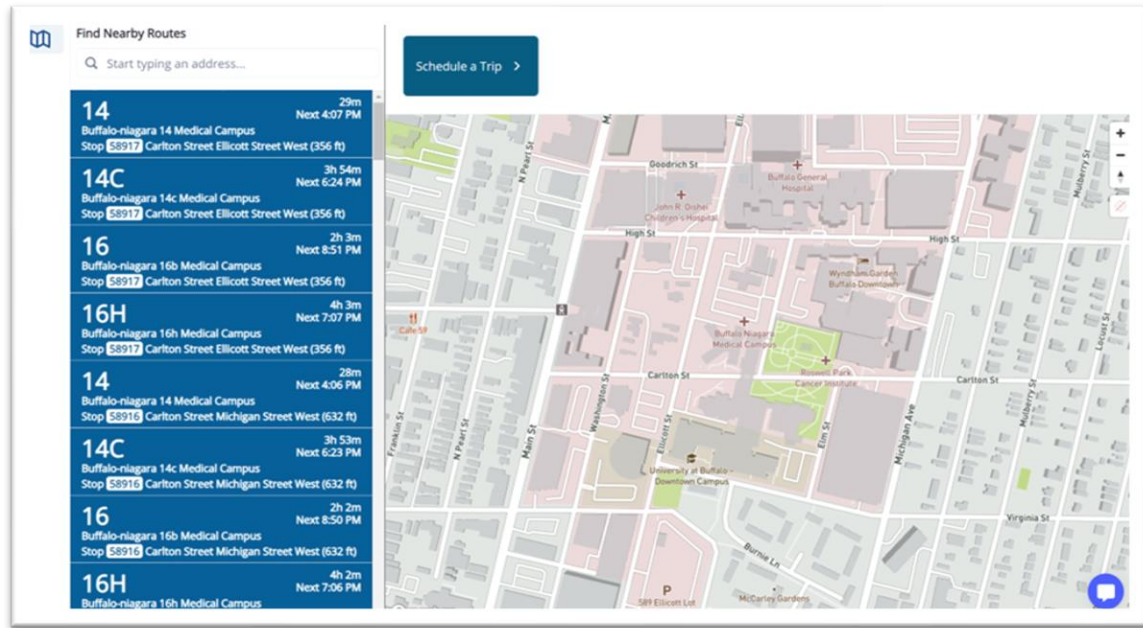


Figure 73. Screenshot of Splash Page for TIH and Guest Mode

Source: Buffalo, NY ITS4US (2024)

5.5.6 Trip History

The Trip History is included in the CTP Log Data API (see **ICD Section 3.4**). The Log Data consists of all legs (modes) of the trip based on planned time versus actual. The data is stored in flat files in the CTP server; key data is anonymized and obfuscated to disguise the traveler. At a configurable frequency, the data is generated into a CSV file for upload to the PMD server (see **Section 6.2.2.1**). The current frequency is set to a weekly upload.

The Performance Measurement processing uses this information to compare how a planned trip related to the actual trip time and distance. This requires travelers to use navigation in their mobile app to generate the performance. Types of data that will be provided in trip history include trip plans and executions, user preferences and other log files that provide insight into traveler usage and utilization of services. The data also includes utilization of the UI channels (web, mobile, call center). The log file is extensible, able to add new usage and performance metrics as the system expands.

The origin and destination locations and times are rounded to obfuscate the trip details. The Traveler ID will be assigned a hash code that replaces the account identifier (i.e., email address).

5.6 Enhanced Accessibility Features

This epic adds services to enhance accessibility for users including:

- Manage preferences for accessibility needs during trip planning and navigation
- Honor global device settings for accessibility

The epic services address global and CTP requirements with the Accessibility Features proposed design and listed in **Table 50**.

Table 50. Enhanced Accessibility Features associated with System Requirements

Req ID	Title	Description	Design Element
Req-Sy-002	Web and mobile user interface (UI) accessibility	The system shall comply with Web Compliance Accessibility Guidance (WCAG) 2.1 for all digital information presentation including mobile and web browsers.	• Screen reading • Large font • Alternative colors • UI w/ natural language processing capabilities
Req-CTP-024	Accessibility Feature Compliance	The CTP shall comply with Web Content Accessibility Guidelines (WCAG 2.1) accessibility features (on both the web and mobile platforms).	• Screen reading • Large font • Alternative colors • UI w/ natural language processing capabilities
Req-CTP-028.2	Account settings - - accessibility and support services	The CTP shall provide the capability for users to select accessibility and support service preferences (e.g., travel companion, service animal, and call to third party -- guardian/caregiver). <i>Note: Guardian/caregiver are branded as "coordinator"</i>	• Coordinate feature set • Configurable support phone number feature • Service animal companion option in trip booking
Req-CTP-028.3	Account settings - - language	The CTP shall provide the capability for users to select language choice. – Spanish Only	• Multilingual support screen reading - Spanish Only • Multilingual text support in CTP app - Spanish Only

Req ID	Title	Description	Design Element
Req-Sy-005	Vehicle Accessibility Information Collection	The system shall inventory information on accessibility information available from each CS vehicle used in the system. The information shall include attributes that support the demographic populations using mobility devices (e.g., lift/ramp, type of securement), hearing aids, visual support (text to speech), etc. The data supporting the types of assistive devices will be driven by stakeholder input during the Agile development process. Based on NTFA options.	• Preference option for accessible equipped vehicle or bus when booking trip or in profile
Req-CTP-118	Reservation accommodating traveler assistive devices	The CTP shall include information on traveler assistive devices when booking CS services to ensure that the vehicle accessibility features match traveler needs. The types of assistive devices will be driven by stakeholder input during the Agile development process.	• Preference option for accessible equipped vehicle or bus when booking trip or in profile
Req-CTP-120	Reservation accommodating traveler preferences	The CTP shall provide an option for travelers to identify their preferred traveler assistive devices when booking CS services to ensure that the vehicle accessibility features match traveler needs. The types of assistive devices will be driven by stakeholder input during the Agile development process (see research spike).	• Haptic enabled on phone • Speech to text/text to speech controlled by OS screen reader

Through our research we identified the capabilities and limitations of several enhanced accessibility features as listed in **Table 51**.

Table 51. Selected Enhanced Accessibility Feature Capabilities and Limitations

Feature	Features	Limitations
In-App Haptic	Haptics and Smartphone - Proposed in app to accentuate voice-over speech as a baseline - Sensory overlay to enhance navigation and alert notifications	Limitations of Smart Technology of Assistive Devices/Accessible Wearables - Most manufacturers (~90%+) found in the assistive and accessible device/wearable like to control their device and experience in device - Controlled by their own app and are mostly a closed system - With these limitations we can only control the CTP in-app experience and only pass through inherent functionality in the device (i.e., audio for earpieces) - Unable to control access to things like haptic vibration in a smart cane
Natural Language Processing	Chat Capabilities - Building chat type capabilities as an alternate to the multi-step forms for scheduling a trip - Enables different types of interactions that a traditional form does not allow - Unlocks the ability to speak in a natural multi sentence form to schedule a trip - Example verbal prompt to schedule a trip in CTP app - "I have an appointment at 11am, on Tuesday the 12th at VIA and I need wheelchair accessibility"	"Verbal Assistant" Chat Target persona is a visually and physically challenged traveler

The enhanced accessibility features include Language Preferences and Hearing and Sight Enhancements including:

- Hearing and Sight Enhancements User Stories

- Support High Contrast (Mobile)
- Support High Contrast (Web)

These user stories are defined for both web and mobile platforms in **Table 52**.

Table 52. Enhanced Accessibility Feature User Stories

User Story	Description and Acceptance Criteria
Accessibility Onboarding	Description: As someone signing up for the app or managing preferences, either for myself or as a caregiver, I need to be able to specify the app usage and travel accommodations I require. This includes, but may not be limited to: - Pedestrian need: walk, wheelchair, walker, cane - English or Spanish - Support animal - Guided natural language assistant Part of this effort is designing the presentation of these options. Acceptance Criteria: • See User Stories from Section 5.3.4. • Related requirements: ○ Req-CTP-028.3 ○ Req-CTP-028.7 ○ Req-CTP-071 ○ Req-CTP-072 ○ Req-CTP-079 ○ Req-CTP-078
Req-CTP-118: When I book a trip as a user who has preferred accommodations selected in trip preferences in my profile/settings or in the trip preferences ad-hoc screen when I planned my trip	Description: When I book a trip as a user who has preferred accommodations selected in trip preferences in my profile/settings or in the trip preferences ad-hoc screen when I planned my trip - they should be honored and taken into account when the trip is booked and executed. The CTP shall include information on traveler assistive devices when booking CS services to ensure that the vehicle accessibility features match traveler needs. Dependency on Accessibility Onboarding Use Case. Acceptance Criteria: • Demonstrate that the settings remain from login to login. • Demonstrate that preferences may change for an on-demand trip.

User Story	Description and Acceptance Criteria
Accessibility - Support High Contrast - Mobile	Description: As a user who requires visual enhancement, I have my phone configured to use high contrast. The app should support this mode to display all content without usability issues. Acceptance Criteria: • Demonstrate settings in mobile app (Android and iOS).
Accessibility - Support High Contrast - Web	Description: As a user who requires visual enhancement, I would like to configure my profile to use high contrast. The site should support this mode to display all content without usability issues. Acceptance Criteria: • Demonstrate setting selection as seen in Figure 74.
Accessibility - Support Large Text - Web	Description: As a user who requires visual enhancement, I have my browser configured to use large text. The app should support the large text to avoid screen run-off and other side effects that would prevent usability. Acceptance Criteria: • Demonstrate setting selection as seen in Figure 74.
Accessibility - Support Large Text - Mobile	Description: As a user who requires visual enhancement, I have my phone configured to use large text. The app should support the large text to avoid screen run-off and other side effects that would prevent usability. Acceptance Criteria: • Demonstrate settings in mobile app (Android and iOS).
Natural Language Assistant - Web	Description: As a web user, I would like to schedule a trip using a natural language interface that lets me specify my trip request in a freeform way, with follow-up questions and confirmation. Acceptance Criteria: • Demonstrate setting selection as seen in Figure 74.

User Story	Description and Acceptance Criteria
Research Spike: Haptic Feedback	Description: Users need to be able to navigate using a smartphone without being required to use the screen or audio. Haptic feedback will be added to the mobile app to provide instructions derived from the existing turn-by-turn navigation feature. During this research spike, the team will review current state of the art research in haptic feedback for navigation. We will explore the possible “language” that could be used to communicate distance and direction with vibration. The research spike identified several haptic code approaches, however, when asked, our stakeholders indicated that the feature was not necessary as long as verbal or textual information is available once alerted by a vibration from the smartphone. Acceptance Criteria: Feedback from stakeholders. Held interviews and focus groups with stakeholders to request feedback.
Screen Reading for Web (v1)	Description: As a user of the web application who requires visual enhancements for using the application interface, I expect to be able to navigate the site with Accessible Rich Internet Applications (ARIA) compliant screen readers, entirely using audio output. Acceptance Criteria: Demonstrate setting selection as seen in Figure 74.
Screen Reading for Mobile (v1)	Description: As a user of the mobile application who requires visual enhancements for using the application interface, I expect to be able to navigate the app features with the mobile operating system's screen reader, entirely using audio output. Acceptance Criteria: Demonstrate settings in mobile app (Android and iOS).

Users can select their preferred enhanced mobility settings by clicking on the icon with the person with outstretched arms shown in **Figure 74**.

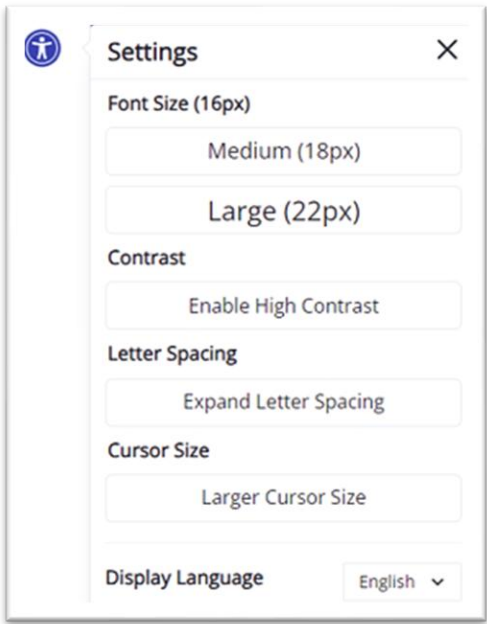


Figure 74. Enhanced Accessibility Settings in Web UI
Source: Buffalo, NY ITS4US (2024)

Language translations to Spanish use an existing OTP function. However, all the terms were extracted and translated into Spanish. The files were reviewed and agreed upon by Spanish speakers from different backgrounds including Puerto Rican, Mexican and Dominican. **Table 53** provides the internationalization of user stories.

Table 53. Internationalization of User Stories

User Story	Description and Acceptance Criteria
Extract all text into internationalization file	Description: The mobile and web applications use English text for the UI elements. During this sprint, all text that appears in the UI will be extracted to an English internationalization (i18n) file so that future sprints can incorporate multilingual capability. Acceptance Criteria: User can review csv file from the application development team and add languages as the CTP expands to more than Spanish.

User Story	Description and Acceptance Criteria
Produce CSV of all application text for translation	Description: The internationalization text extracted from the web and mobile app (ticket #194) will be used to produce a Spanish translation of the UI. For this task, the i18n text will be turned into a CSV file that can be shared with translators. Note: this was a manual process performed by extracting every word from the mobile and web sites and inserting them into an Excel document for translation and reviewed by several Spanish-dialect speakers (i.e., Mexican, Puerto Rican and Dominican). Acceptance Criteria: The user can compare the translation sheet csv file from the application development team to the translation in the website and mobile app and it matches.

Examples of typical screenshots that show the Spanish language selection are shown in **Figure 49** and **Figure 50**.

5.6.1 Natural Language Assistant

The natural language assistant (NLA) provides voice instructions to schedule a trip. The NLA is composed of the OpenAI chat assistant especially useful for users with visual challenges to schedule a trip, review trip options and book the preferred trip.

This chat assistant is built on top of the OpenAI ChatGPT platform (<https://chatgpt.com/>). OpenAI is an artificial intelligence platform which utilizes deep learning generative models to leverage large amounts of data to train the chat assistant. The same system that powers ChatGPT helps travelers schedule trips by giving them feedback on origin, destination, date and time, preferred travel modes, and accessibility preferences. The assistant then feeds the machine learning natural language model the trip parameters and returns a list of best options for travel based on the traveler's requested schedule. The model will consider least travel time, minimum number of transfers, and accessibility concerns if applicable. **Table 54** provides the descriptions and acceptance criteria for the related user stories.

Table 54. Natural Language Assistant User Story Descriptions

User Story	User Story Description
Natural Language Assistant - Mobile	Description: As a user with a smartphone, I would like to schedule a trip using a natural language interface that lets me specify my trip request in a freeform way, with follow-up questions and confirmation (Figure 75). Figure 75. Natural Language Assistant <i>Source: Buffalo, NY ITS4US (2024)</i> Acceptance Criteria: • Demonstrate scheduling a trip on the mobile platforms using the natural language assistant with multiple trip options. • Select one of the many trips.
Natural Language Assistant - Web	Description: As a web user, I would like to schedule a trip using a natural language interface that lets me specify my trip request in a freeform way, with follow-up questions and confirmation. Acceptance Criteria: • Demonstrate scheduling a trip on the web platform using the natural language assistant with multiple trip options. • Select one of the many trips.

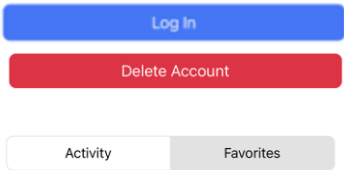
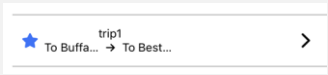
5.7 User Interface (UI)

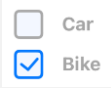
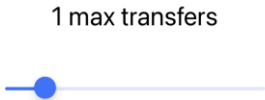
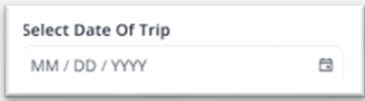
This section describes the UI navigation features including iconography, buttons and site maps for the web and mobile app channels.

5.7.1 Navigation Features

Navigation features are found on every page of the UIs. **Table 55** shows an example of the link graphic and description of the navigation feature.

Table 55. Buttons and Link graphics

Link / Button Graphic	Description
>	Greater than sign is used to open a page related to the page or label is associated with
<	Less than sign is used to go back to a previous page
X	X (top right corner of page or label) closed the page or pop-up
▼ (▲)	Down (up) carat is used to open (close) a list of selections. Close pull-down list by selecting the downward facing carat.
	Interactive label is used as a function button to activate or cancel a function. • Blue – opens new page or form button • Red – delete account button • Grey – when grey, view is selected • White (no color) – when white or no color, view or action is not selected
	Toggle Button – when shaded the toggle is off and when highlighted, toggle indicates on.
+	Plus signs are used to add a feature. Select the plus sign to open a form that enables you to add an entry (e.g., coordinator).
	Star indicates that the trip or place is a favorite. To set, tap the star outline. To unselected, tap the filled in star.

Link / Button Graphic	Description
	Trash can – to delete the entry, tap the trash can.
	Check box – select one or more options. To select option, tap a grey box. To unselect, tap a checked box.
	Scale line – as user moves dot, the number (of max transfers on bus routes) increases or decreases when moved to the right or left.
	Calendar to set date in form field

5.7.2 Icons

Icon graphics and descriptions used by the CTP app are similar for all UIs – mobile, web and kiosk. The iconography and description are described in **Table 56**. Column are defined as follows:

- **Icon Graphic:** iconology used by the CTP
- **Icon Description:** a description of the icon and the function accessed by the icon
- **Source Page:** the page and location on the page where the icon is positioned
- **Destination Page:** the page that opens when the icon is selected

Table 56. CTP Application Iconography

Icon Graphic	Icon Description	Source Page	Destination Page
	The folded document icon is used to return to the Home page	Home page and other pages. When displayed on the home page, the icon is not available and shown in a lighter shade of blue.	Home page (also called Explore Mode page)
	The calendar icon is used to view trips that have been scheduled but not yet taken	On Home Page (located on the bottom of page)	Upcoming Trips

Icon Graphic	Icon Description	Source Page	Destination Page
	The person icon is used to access the profile and settings menu items	On Home page (located on the bottom of page)	Profile and Settings menu items
	The green building icon showing an indoor navigational map is available.	On overview map once trip is executed and the traveler is within the geofenced area close to the building.	Indoor map
	The gray map icon denoting the user can go back to outdoor navigation map.	Available on the indoor map once trip is executed.	Outdoor map
	Person with arms outstretched	Displays accessibility settings selections	Enhanced Accessibility
	Blue icon with white bus outline	Displays bus mode	Trip planning and navigation mode
	Light blue icon with dark blue outside circle with white bus outline	Displays moving bus	Seen on map showing location of bus on route.
	Teal blue icon with white car outline	Displays car mode	Trip planning and navigation mode
	Green icon with white shuttle outline	Displays CS mode	Trip planning and navigation mode
	Light blue icon with green outside circle with white shuttle outline	Displays moving community shuttle	Seen on map showing live location of community shuttle
	Gray icon with white outline of a person walking	Displays walk mode	Trip planning and navigation mode
	Gray icon with white outline of a person rolling	Displays roll mode	Trip planning and navigation mode

Icon Graphic	Icon Description	Source Page	Destination Page
	The blue map icon with black dot in the center	Displays destination	Trip planning and navigation mode

5.7.3 User Interface and Platforms

The System Test Plan (STP) Section 4.3.2 identified several platforms and web browsers upon which the application is to be tested. The STP identified that the application would be tested on Web UI browsers including Chrome, Edge, Safari, Firefox and deployed on Android and iOS mobile platforms. Tested platforms are listed in **Table 57**.

Table 57. Buffalo All Access User Interfaces and Platforms

Device Platform	Device Model	Version
Apple (iOS)	iPhone 14 pro	16.4.1(a)
Apple (iOS)	iPhone 14 pro	17.5.1
Apple (iOS)	iPhone 13 pro	16.3.1
Apple (iOS)	iPad 9 th Generation	16.3.1
Apple (iOS)	iPad 9 th Generation	16.3
Apple (iOS)	iPhone Series 6	15.7.9
Apple (iOS)	iPhone Series 6	13.0.2
Apple	MacOS – Safari	16.5.2
Apple	MacOS – Safari	17.2.1
Apple	MacOS – Safari	17.0
Apple	MaxOS – Chrome	Not recorded
Android	Pixel 5a	Android 13
Android	OnePlus 6T	Android 11
Samsung (Android)	Galaxy Z Fold 4	Android 13
Google (Android)	Pixel 5A	Android 14
Microsoft	Windows 11 – Firefox	Not recorded
Microsoft	Windows 11 - Edge	Not recorded
Microsoft	Windows 11 – Chrome	Not recorded

5.7.4 Differences between Android App, iOS Mobile App and Web

There are no differences among the various platforms except the web UI does not support wayfinding and trip management functions.

In addition, the web version includes enhanced accessibility features while the mobile app integrates the settings already set on their mobile device.

5.8 Security and Privacy Design Summary

This section summarizes the security and privacy design features that secure access to account information and protect account PII. These design descriptions are incorporated into other subsections of **Section 5**. **Table 58** lists a summary of the user story, description and related requirements for user management security and privacy features. In addition, the CTP server system security feature is implemented using AWS security functions. It is described below the table.

Table 58. User Management Security and Privacy User Story Trace to Requirements

User Story	User Story Description	Requirement ID
Multifactor Authentication (MFA)	As a user, I am required to have MFA on my account.	Req-CTP-039
No user management on Kiosk UI	As a user of a public Kiosk (TIH), I should not be able to have an option to create an account or log in.	Req-SI-028/ Req-SI-017
User session should persist until logout on mobile app	As a user, I should not have to continually log in to my mobile app. The only time I should have to log back in to the mobile app is if I intentionally log out of the mobile app or after 30 days.	Req-CTP-046
User session should be terminated after configurable amount of time (configuration in global settings)	As a user, I will be logged out of the mobility website after a configurable amount of inactivity. • There will be a warning modal 5 minutes before inactivity threshold. • If I click on extend session, an additional 10 minutes will be added onto the session • If I ignore/do nothing to the extend session modal, session expires.	Req-SI-017
Password (token) should be reset at least every 30 days for web-generated tokens and 90 for mobile	As a user, I will be required to reset my password (token) every 30 days for web-generated tokens and 90 for mobile	Req-Sy-013

User Story	User Story Description	Requirement ID
Remove Account and PII	Req-CTP-037.5: As a user, I should be able to delete my account	Req-CTP-037.5
Close and remove account	Req-CTP-133: Account History and PII Removal	Req-CTP-133
Delete account history	Req-CTP-134: Account Closure and Removal Process	Req-CTP-134
Delete traveler PII (profile data)	- Req-CTP-135: Traveler PII Data Removal Request- CTP - Req-CTP-136: Traveler PII Data Removal - CTP	Req-CTP-135 Req-CTP-136

The design implements AWS security features for the CTP server. All user information is encrypted enroute with Amazon AWS API Gateway, which validates each request using a JSON Web Token (JWT). Information is encrypted at rest in AWS DynamoDB. Because of the “serverless” nature of AWS API Gateway and DynamoDB, there are no customized machines that could be compromised by something like a Linux operating system exploit. The only infrastructure that accesses the data is the underlying physical systems managed by AWS. The custom machines that are involved run containers on Kubernetes, such as OpenTripPlanner, but they do not have access to user data. Security practices implemented by AWS are documented in <https://docs.aws.amazon.com/amazondynamodb/latest/developerguide/best-practices-security.html>.

5.9 Operational Performance and Reliability

This section describes how the CTP handles anomalies in operations including communications disruptions with integration elements. The section covers detecting communication disruptions through openAPI status codes:

- 200 Success: Successfully retrieved API information
- 401 Unauthorized: API key missing or invalid
- 400 Bad Request – If the URL parameters are not formatted correctly.
- 404 Not Found – If a POST or DELETE request and the provided “id” cannot be found.
- 503 Service Unavailable – The server is not ready to handle the request.
- 509 Bandwidth Limit Exceeded – If the OSM server returns this error as a result of the query.
- No response: communication down

The following requirements are subject to communications with implementation elements:

- Req-CTP-112

- Req-CTP 115
- Req-CTP-128

The other requirements relate to capturing operational transactions and discussions. They will be implemented in and tested during Release 5.

- Req-CTP-094
- Req-CTP-095
- Req-CTP-096
- Req-CTP-105

The design elements in this section are scheduled for Release 5.

5.10 CTP Requirements Traceability

The requirements that are met by this design are listed in **Table 59**.

Table 59. CTP Requirements Traceability to SDD Section

Req ID	Req Title	Status	SDD Section
Req-CTP-001	Reservation Planning Services	Approved	ICD Section 3.12, 3.13, 3.18
Req-CTP-001.1	Reservations -- check service	No change	ICD Section 3.12, 3.13, 3.18
Req-CTP-001.2	Reservations -- booking service	No change	ICD Section 3.12, 3.13, 3.18
Req-CTP-001.3	Reservations -- confirm service	No change	ICD Section 3.12, 3.13, 3.18
Req-CTP-001.4	Reservations -- change service	No change	ICD Section 3.12, 3.13, 3.18
Req-CTP-001.5	Reservations -- cancel service	No change	ICD Section 3.12, 3.13, 3.18
Req-CTP-001.6	Reservations -- view service	No change	ICD Section 3.12, 3.13, 3.18
Req-CTP-008	Mobility Provider Reservations APIs used by CTP	Approved	Section 5.2.5
Req-CTP-009	Pre-populate Trip Mode Preferences	No change	Sections 5.4.1 and 5.4.5
Req-CTP-010	Pre-populate Trip Location (Origin)	No change	Sections 5.4.1 and 5.4.6
Req-CTP-011	Buffalo and NFTA Service Coverage	Approved	Sections 5.2.1, 5.4.1, 5.4.3, and 5.4.10
Req-CTP-012	Data of Mobility Services in Project Region	Approved	Section 5.2.3
Req-CTP-013	Core Functionality from OTP	No change	Sections 5.2.1 and 5.4.2

Req ID	Req Title	Status	SDD Section
Req-CTP-014	Multimodal Trip Planner	Approved	Sections 5.2.1, 5.3.3, 5.4.2, and 5.4.8
Req-CTP-015	Updating Trip Plan	No change	Section 5.4.4
Req-CTP-016	Save Trip Information	Approved	Sections 5.3.3 and 5.3.3.2
Req-CTP-017	Multimodal Data	No change	Sections 5.2.3
Req-CTP-018	Augmented functionality	No change	Section 5 Note: this is an overarching requirement that includes all requirements beyond core OTP functionality.
Req-CTP-019	Integrated Trip Planning services	No change	Section 5.4.7
Req-CTP-019.1	Integrated Trip Planning -- NFTA fixed route	No change	Section 5.4.7
Req-CTP-019.2	Integrated Trip Planning -- NFTA PAL options	No change	Section 5.4.8
Req-CTP-019.3	Integrated Trip Planning -- CS SDS	No change	Sections 5.2.5 and 5.4.7
Req-CTP-019.4	Integrated Trip Planning -- CS HDS	No change	Section 5.4.7
Req-CTP-019.5	Integrated Trip Planning -- Other mobility provider options (optional)	No change	Section 5.4.7
Req-CTP-021	Trip Planning Data validation and processing	No change	Section 5.2.3
Req-CTP-022	Reference transportation network	No change	Section 5.2.2
Req-CTP-023	Trip plan optimization for different traveler groups	No change	Section 5.4.4
Req-CTP-024	Accessibility Feature Compliance	No change	Section 5.6
Req-CTP-025	End-User Driven User Experience	No change	Stakeholder demos and meetings.
Req-CTP-026	Communications Channels	No change	Section 5.3.3.4
Req-CTP-027	On-line / off-line data usage and tracking	No change	Section 5.5.1
Req-CTP-028	Account settings	No change	Section 5.3.3
Req-CTP-028.1	Account settings -- mode	Approved	Section 5.3.3.3
Req-CTP-028.2	Account settings -- accessibility and support services	No change	Sections 5.3.3 and 5.6
Req-CTP-028.3	Account settings -- language	Approved	Sections 5.3.3 and 5.6
Req-CTP-028.4	Account settings -- notifications	No change	Sections 5.3.3 and 5.3.3.4
Req-CTP-028.5	Account settings -- automated request	No change	Sections 5.3.3 and 5.3.3.4
Req-CTP-028.6	Account settings -- navigation instructions	Approved	Sections 5.3.3 and 5.3.3.2
Req-CTP-028.7	Account settings -- communications channels	Approved	Section 5.3.3
Req-CTP-028.8	Account settings -- favorite places	No change	Sections 5.3.3 and 5.3.3.2
Req-CTP-028.9	Account settings -- user interface methods	Approved	Sections 5.3.3, and 5.3.3.4

Req ID	Req Title	Status	SDD Section
Req-CTP-037	CTP Registration	No change	Sections 5.3.1, 5.3.2.1, 5.3.3, 5.3.3.1, 5.3.3.3, 5.4.4, and 5.8
Req-CTP-039	CTP Account user name and password	No change	Sections 5.3.3, 5.3.3.1, and 5.8
Req-CTP-040	Third party access to Traveler Accounts	No change	Sections 5.3.3, 5.5.2, and 5.8
Req-CTP-041	Assistive Technology Compatibility	Approved	Section 5.3.3.4
Req-CTP-045	Transit and mobility service status information	Approved	Section 5.3.3.4
Req-CTP-046	Continuous trip planning	No change	Section 5.8
Req-CTP-047	Rerouting trip plan	No change	Section 5.5.1
Req-CTP-048	Sidewalk Data features	No change	Section 5.2.2
Req-CTP-049	Indoor Pathway features	No change	Section 4.3.4
Req-CTP-050	Geolocate traveler near intersection	No change	Section 5.5.3
Req-CTP-051	Generate PED-X request message	No change	Section 5.5.3
Req-CTP-052	Transmit PED-X request message	No change	Section 5.5.3
Req-CTP-053	Trusted connection for Ped-X actuation	No change	Section 5.5.3
Req-CTP-054	Generate and transmit PED-X request cancel message	No change	Section 5.5.3
Req-CTP-055	Generate and transmit PED-X request clear message	No change	Section 5.5.3
Req-CTP-056	CTP countdown	No Change	Pending Deprecation
Req-CTP-057	PED-X Request Message	No change	Section 5.5.3
Req-CTP-058	PED-X Request Cancel Message	No change	Section 5.5.3
Req-CTP-059	PED-X Request Clear Message	No change	Section 5.5.3
Req-CTP-060	Trip Notification Triggers	Approved	Section 5.4.1.1
Req-CTP-061	Trip Notification of Trip Anomalies	No change	Section 5.4.11.1
Req-CTP-062	Trip notification to preferred user interface	No change	Section 5.3.3.4
Req-CTP-063	Trip notification preferences	Approved	Sections 5.3.3.4, 5.4.4, and 5.5.1
Req-CTP-065	Traveler Assistance	No change	Section 5.3.3
Req-CTP-066	Trip Planning and mobility options	No change	Section 5.4.4
Req-CTP-067	CTP Help Feature	No change	Section 5.5.4
Req-CTP-068	CTP Services on Communications Channels	Approved	Sections 5.7.3 and 5.7.4
Req-CTP-069	CTP User Interface method	No change	Section 5.4.11.1
Req-CTP-071	CTP language notification selection	Approved	Section 5.3.3
Req-CTP-072	CTP language planning selection	No change	Section 5.3.3
Req-CTP-073	Trusted third party access	No change	Section 5.5.2 (trusted third party refers to coordinator)
Req-CTP-074	User-based access to Traveler Account	No change	Sections 5.5.2 and 5.8
Req-CTP-075	Audit Third Party Access	No change	Section 5.5.2
Req-CTP-076	Group Travel	No change	Section 5.4.1 (Table 30)
Req-CTP-077	Coordinator Designation	No change	Sections 5.3.3 and 5.5.2
Req-CTP-079	Mobility operator service animal policies	Approved	Section 5.3.3

U.S. Department of Transportation
Office of the Assistant Secretary for Research and Technology
Intelligent Transportation System Joint Program Office

Req ID	Req Title	Status	SDD Section
Req-CTP-078	Traveling with a service animal	No change	Section 5.3.3
Req-CTP-080	Traveler feedback form	No change	Section 5.5.4
Req-CTP-081	CTP ingestion of feedback (OPTIONAL)	Approved	Section 5.5.4
Req-CTP-083	Access to Traveler satisfaction survey results	No change	Section 5.5.4
Req-CTP-084	CTP ingestion of event datasets	No change	Section 5.2.1
Req-CTP-085	CTP ingestion of traffic signal control operation data	-	Pending Deprecation
Req-CTP-086	Report Traveler feedback issue	No change	Section 5.5.4
Req-CTP-087	Traveler Feedback priority	No change	Section 5.5.4
Req-CTP-088	UI to Call Center	No change	Section 5.5.4
Req-CTP-090	Data Use Disclosure policy	No change	Section 5.2.1 (these are in the terms and conditions)
Req-CTP-092	Trip History and Unique Reference Identifier	No change	Section 5.2.4
Req-CTP-093	CTP Security	No change	Section 5.8
Req-CTP-094	CTP Reliability	No change	Section 5.9
Req-CTP-095	Self-Monitoring Log	No change	Section 5.9
Req-CTP-096	Self-Monitoring Log Transmission	No change	Section 5.9
Req-CTP-098	Processing and Load Scalability	No change	See Testing Results
Req-CTP-099	Application and Feature Expansion	No change	Section 5.1
Req-CTP-100	Data Broker	No change	Deployed for integration elements: INS, PED-X, TIH
Req-CTP-101	Tune location settings	No change	Section 5.5.1
Req-CTP-102	Test for accuracy	No change	See Testing Results
Req-CTP-103	CTP Operational Modes	No change	See CMOP Section 4.3.1
Req-CTP-104	CTP publish operational alerts	No change	Section 5.4.11 Based on available data sources
Req-CTP-104.1	CTP publish operational alert timing	No change	Section 5.4.11 Based on traveler's mobile device or data source accuracy
Req-CTP-105	System operational alert tool	Approved	Section 5.9
Req-CTP-106	CTP Marketing Design Guidance	No change	Section 5.7
Req-CTP-107	CTP Maintenance levels	No change	See CMOP Section 4.3
Req-CTP-108	Ingest Work Zone Event data	No change	Section 5.2.2
Req-CTP-110.2	Transmit to Traveler Time to Cross (Don't Walk) -- Countdown	No change	Pending Deprecation
Req-CTP-111	Monitor for PED-X connectivity	No change	Section 5.5.3
Req-CTP-112	Alert Lack of communications for PED-X connectivity	No change	Section 5.5.3 and Section 5.9
Req-CTP-113	PED-X anomalies	No change	Section 5.5.3
Req-CTP-114	Alert Traveler to PED-X anomalies	No change	Section 5.5.3

Req ID	Req Title	Status	SDD Section
Req-CTP-115	Alert Lack of communications with SDS Passenger Information Systems	No change	Section 5.9
Req-CTP-117	Indoor Navigation Beacons using BLE Common communications protocols	Approved	ICD Section 3.24
Req-CTP-118	Reservation accommodating traveler assistive devices	No change	Section 5.6
Req-CTP-120	Reservation accommodating traveler preferences	No change	Section 5.6
Req-CTP-122	PAL vs. System Responsibility	Approved	Section 5.4.8
Req-CTP-123	Contradictory preferences	Approved	Sections 5.4.1 and 5.4.9
Req-CTP-125	Trip plan alternatives	No change	Section 5.4.4
Req-CTP-126	Reservations process	No change	Section 5.4.4
Req-CTP-127	No-show vehicles	No change	Section 5.5.4
Req-CTP-128	Traveler mobile device not linking with indoor/outdoor Smart Signs	No change	Section 5.9
Req-CTP-132	Monitor for Mobility Provider connectivity	No change	Section 5.5.1
Req-CTP-133	Account History and PII Removal	No change	Sections 5.2.6, 5.3.3.1, and 5.8
Req-CTP-134	Account Closure and Removal Process	No change	Sections 5.2.6, 5.3.3.1, and 5.8
Req-CTP-135	Traveler PII Data Removal Request- CTP	No change	Sections 5.2.6, 5.3.3.1, and 5.8
Req-CTP-137	Preferences for Coordinators	No change	Sections 5.3.3 and 5.5.2
Req-INT-004	GTFS	No change	Section 5.2.2
Req-INT-005	GTFS Realtime	No change	Section 5.2.2
Req-INT-011	Reservation API Specifications	No change	Section 5.2.5
Req-INT-011.1	SDS Reservation API Specification	No change	Section 5.2.5
Req-INT-011.2	HDS Reservation API Specification	No change	Section 5.2.5
Req-INT-013	Internal APIs	No change	Section 5.2.3
Req-INT-014	OpenStreetMap	Approved	Sections 5.2.3 and 4.6
Req-SI-017	TIH CTP configuration	No change	Section 5.8
Req-SI-028	Public kiosks	No change	Section 5.8
Req-Sy-001	Web browser support	No change	Section 5.7.3
Req-Sy-002	Web and mobile user interface accessibility	No change	Section 5.6
Req-Sy-005	Vehicle Accessibility Information Collection	No change	Section 5.6
Req-Sy-006	Trip History and Unique Reference Identifier	No change	Section 5.2.4
Req-Sy-007	Traveler PII Data Removal	No change	Section 5.8
Req-Sy-008	Call Center	No change	Section 5.5.4
Req-Sy-009.4	Access to PAL Direct services via CTP	No change	Section 5.4.8
Req-Sy-013	Data security	No change	Section 5.8
Req-Sy-025	Linking trip segments	No change	Section 5.2.4
Req-Sy-026	Dataset Curation Plan	No change	Section 5.2.3

6 Performance Measurement Dashboard

6.1 Overview

This section presents a high-level overview of the PMD for the Buffalo, NY ITS4US system. As shown in **Figure 76**, a three-tier architecture will be employed in PMD development, comprised of a data tier, a processing tier, and a presentation tier. The data tier includes the data to be collected from subsystems (including CTP and CS), survey data, metadata and a data catalog for data distribution. The processing tier involves data cleaning and transformation to enable performance measures to be presented in the PMD and a data repository for research. Finally, the presentation tier reflects the online PMD with various presentation types including table, charts, and descriptions. Part of the tier involves developing an online data repository that contains the processed data without PII.

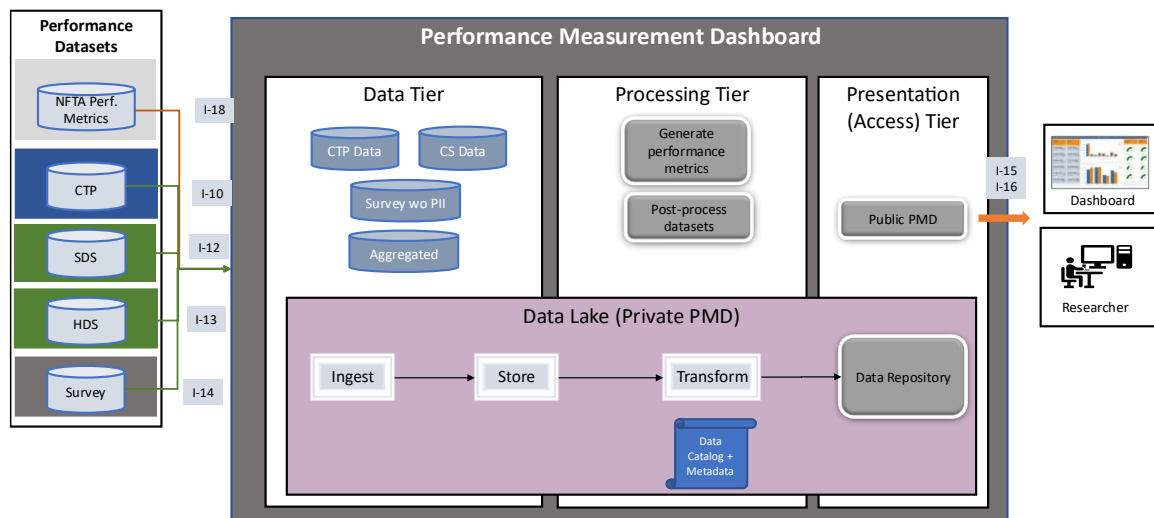


Figure 76. Performance Measure Dashboard Subsystem
Source: Buffalo, NY ITS4US (2024)

The PMD will use an open-source R Project and the Shiny for R package to develop an accessible and user-friendly online PMD (Req-PMD-010). An R package is a collection of functions, data sets, and documentation bundled together for a specific purpose in the R programming language. Shiny is an open-source R package for building web applications directly from R. This streamlined approach will enable efficient data ingestion, processing, and visualization tasks.

The PMD will ingest five key datasets, including data collected during baseline (pre-deployment) and post-deployment surveys, CTP user registration and trip data, and user ratings and operation performance of the CS (including SDS and HDS) trips (Req-PMD-001). The project team will collect the baseline and post-deployment survey data and store them in the secure server. To comply with Institutional Review Board (IRB) regulations and protect PII, the survey data collection team will take necessary steps to anonymize the survey data for PMD development and share the data in UB's secure server that only qualified project team members with UB account credentials can access. CTP- and CS-related data will also be shared to the UB secure server via a data push (ICD-INT-013). Each subsystem will remove or anonymize PII, with the exception of email addresses from CTP registration data. Email addresses will only be used for survey notifications via MailChimp and CTP data matching for surveys (Req-PMD-003), but once data collection is complete, they will be removed from the secure server.

The collected data will be processed to show the performance metrics defined in the PMESP. This involves quality checking (Req-PMD-002) and applying analytical techniques, algorithms, and statistical methods to transform the data into valuable information. During this stage, the data will be cleaned, organized, and transformed as necessary to ensure accuracy and consistency (Req-PMD-014). Potential PII will also be double-checked and removed (Req-PMD-003). In addition, metadata on all datasets stored in the PMD data layer will be developed (Req-PMD-005).

The processed performance metrics will be presented in the online dashboard, featuring interactive data visualization capabilities (Req-PMD-009). This will enable users to explore and understand the performance metrics in a user-friendly and engaging manner. More detailed data sets, devoid of PII, will also be available to researchers through the data repository to conduct in-depth analysis and exploration.

All tools described in the Detailed Design are password protected and authenticated using role-based access methods.

6.2 Detailed Design

All data will be collected and prepared, as described in this section, prior to publication via the public PMD and data repository for researchers.

6.2.1 Survey Processing

The baseline and post-deployment surveys are to evaluate system users' ratings of the three sub systems: HDS, SDS, and CTP. A draft baseline survey and post-deployment survey questionnaires were developed in Phase 1. In Phase 2, the draft baseline survey questionnaire was revised based on refined performance metrics, and an online survey, using SurveyMonkey platform was developed to collect the data. **Table 60** shows the steps associated with the survey data processing.

Table 60. Survey Data Collection Process

Step	Step Description	Contents	Note
1	Finalize Survey Content	(1) Baseline (pre-deployment) survey in Phase 2 and (2) post-deployment survey questionnaire in Phase 3*	Questionnaire will be fine-tuned to evaluate the finalized Performance Metrics (PMs) to report on.
2	Develop Survey in Survey Monkey	Online Survey Monkey survey	Survey team member, UB uses its own Survey Monkey subscription license to create the online survey based on the finalized questionnaire in Step 1.
3	Share Survey On-line	Online survey links	The survey link (e.g., https://www.surveymonkey.com/r/CTP_Baseline), for the baseline survey is generated after step 2 on Survey Monkey admin page and the link will be ready to send CTP app subscribers who complete study enrollment. A link to the baseline survey will be sent to CTP subscribers via MailChimp within a week. In Phase 3, a Post-deployment survey will be sent to those who use the service. Note that only a project specific MailChimp license, which can only be accessed from the UB secure server will be used.
4	Collect Survey Responses	Survey responses	All recruited participants can take the online survey on their mobile device (phones, tablets). Once the survey is completed, the collected data will be automatically stored in the SurveyMonkey database.
5	Monitor Survey Responses	Initial data review of collected survey in csv format; automated reminder emails using MailChimp software	Only authorized team members can access the raw survey data for initial quality review. A reminder email via MailChimp will be sent to the participants with incomplete surveys. For (2) post-deployment surveys, periodic reminders will be emailed via MailChimp.
6	Process Survey Data	Processed survey data files	Data that passes the initial review in Step 5 will be stored in UB's secured server folder and processed for PMs evaluation. Data review routines developed in R will be applied as part of quality control. (Req-PMD-001)

* Unless specified, all steps apply to both (1) baseline and post-deployment surveys.

6.2.1.1 Survey Configuration and Loading

SurveyMonkey will be used to develop online surveys for both baseline and post-deployment surveys. It is a well-known and established online survey platform that makes it easy to develop a set of survey questions with answer choices. **Figure 77** shows the SurveyMonkey admin page for

the Buffalo NY ITS4US baseline survey, where the project team creates and manages the online surveys.

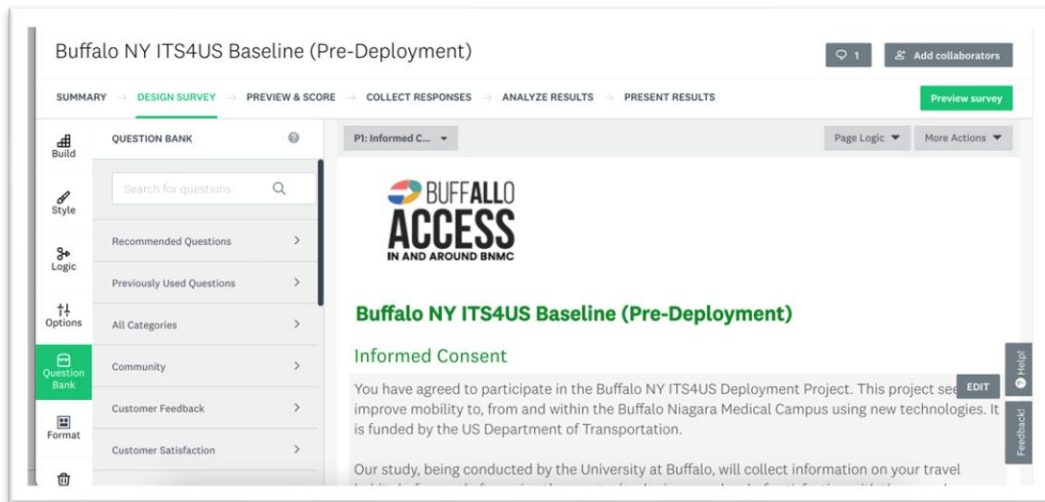


Figure 77. Screenshot of Baseline Survey Admin Page

Source: Buffalo, NY ITS4US (2024)

A survey link, https://www.surveymonkey.com/r/CTP_Baseline, is generated in the admin page after all the survey questions / answer choices are added to the online survey form. The survey form is designed to be accessible through web browsers on both computers and phones. It is automatically optimized for mobile device screen sizes, ensuring a user-friendly experience for participants via mobile phones. This feature is particularly beneficial for CTP app users, as they can conveniently click on the survey link within the app itself to directly link to the survey.

6.2.1.2 User Interface for Survey

6.2.1.2.1 Web User interface

A draft version of the web UI accessed using Edge is shown below in **Figure 78**. It can also be accessed through other web browsers such as Chrome, Safari and Firefox.

BUFFALO ACCESS
IN AND AROUND BHM

ITS4US_CTP_Baseline

1. Have you used the CTP over the past week?

☐ Yes

☐ No

Done

Powered by
SurveyMonkey
See how easy it is to create a survey.

Figure 78. Web User Interface of Baseline Survey – example question
Source: Buffalo, NY ITS4US (2024)

The web UI allows survey participants to complete the survey questionnaire presented on the screen. A survey complete message will be displayed after the respondent answers all questions as shown in **Figure 79**. Participants who have already completed the survey cannot retake the survey. This ensures that each participant's response is recorded only once, maintaining the integrity and accuracy of the collected data.

You have already taken this survey

SurveyMonkey

Want to create your own surveys?

Gather opinions from customers, employees, prospects, and more.
Use your insights to make better, data-driven decisions.

Email Address
you@example.com

Password
(at least 8 characters)

Create Free Account

Figure 79. Web User Interface of Baseline Survey – completion message
Source: SurveyMonkey (2024)

6.2.1.2.2 Mobile User Interface

A mobile survey UI for the draft survey accessed via Chrome and Safari from an iPhone is shown in **Figure 80**. The mobile UIs of Android phones are very similar, if not identical.

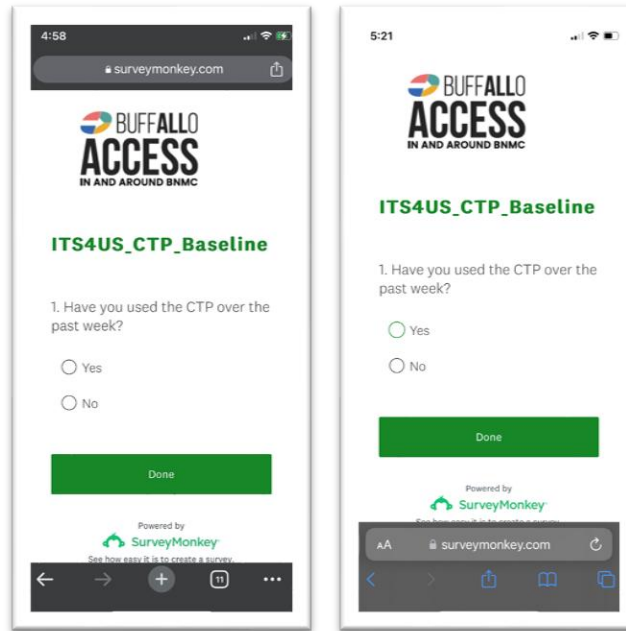


Figure 80. Mobile User Interface of Baseline Survey (via Chrome and Safari from iPhone)
Source: Buffalo, NY ITS4US (2024)

6.2.1.3 Survey Collection and Curation

A frequent monitoring of data collection progress will be undertaken by the project team (refer to **Table 60**, step 5). The project team will review and conduct quality checks on data collected through SurveyMonkey and generate weekly updates, keeping all stakeholders informed about the status of data collection. SurveyMonkey allows the project teams to perform efficient data reviews and quality checks on collected data (see **Figure 81**).

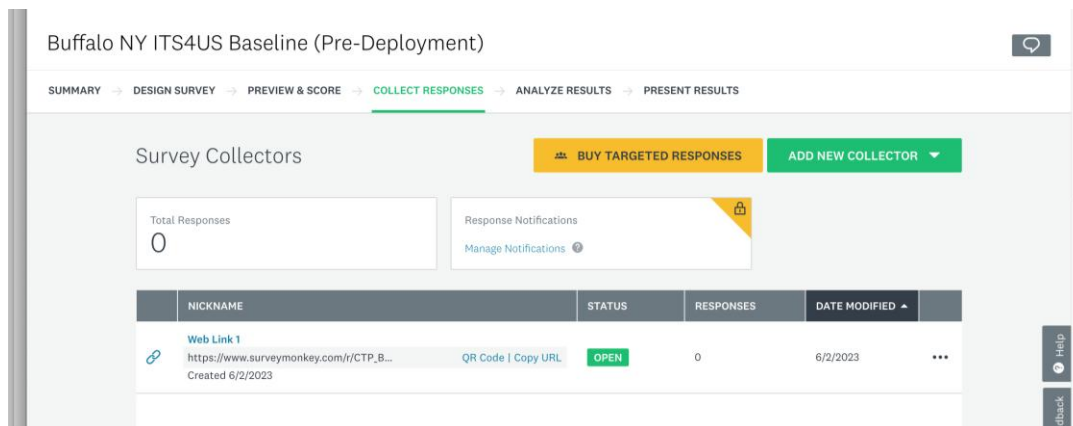


Figure 81. Screenshot of Survey Monkey Admin Page
Source: Buffalo, NY ITS4US (2024)

To ensure high participation and response rates during the baseline data collection effort, the team will encourage participants who have not completed the survey to do so through weekly reminder emails via Mailchimp software. This approach will also be applied to the post-deployment survey data collection efforts.

Survey data will be updated weekly via a survey folder in a secured UB server. The UB survey team will download the collected survey responses from the SurveyMonkey's cloud server to their secure server. The raw data will be securely stored until the end of the project. Before sharing the survey data for performance metrics data processing and presentation, UB team will take necessary steps to remove any PII from the raw data. This task ensures compliance with data protection regulations and safeguards the privacy of participants.

6.2.1.4 Survey Metrics and Processing

In the early stage of Phase 2, the project team finalized six performance measures and related metrics¹. The six performance measures are:

1. Improved the ability of the CTP users to make satisfactory Complete Trips in the study area.
2. Usefulness of the CTP registration and trip preferences process.
3. Usefulness of the CTP trip planning and booking process.
4. Improved ability to find destinations efficiently using the CTP wayfinding functionality.
5. Improved ability to cross specific intersections safely using CTP smart-signal functionality.
6. Provision of an efficient, reliable, and safe new on-demand transit shuttle system.

The project has developed a comprehensive set of 32 metrics that align with the six performance measures. Out of these metrics, 26 will be collected through the baseline survey, post-deployment surveys, or a combination of both to evaluate the CTP trip planning app user's experience, overall system satisfaction with CS service and smart signal performance. **Table 61** provides an overview of the performance metrics that will be collected through survey data.

To assess most of these metrics, survey questions are prepared to rate each metric on a 5-point Likert scale. Participants will be asked to provide their rating by selecting one of the following options:

1. Strongly disagree

¹ Detailed metrics are developed for each measure. More information on performance measures, related metrics and data sources can be found in the "PMESP metrics and data summary.xlsx" file.

2. Somewhat disagree
3. Neither agree nor disagree
4. Somewhat agree
5. Strongly agree

By utilizing a Likert scale, the survey aims to gather participants' subjective evaluations of each metric, allowing for a quantifiable assessment of performance based on their perceptions and experiences. This approach enables the project team to analyze and interpret the collected data to gain insights into the various performance measures. There are also a few non-Likert scale questions designed to measure sub-system's performance.

Table 61. Performance Metrics collected from Surveys

ID	Data Source	Target System	Metric	Data Description
1	Survey	Overall System	System user ratings of how accessible door-to-door travel is for trips to, from and within the BNMC.	Ratings from the Baseline and Periodic Post-Deployment Surveys, on 5-point Likert scale
2	Survey	Overall System	System user ratings of how safe door-to-door travel paths are for trips to, from and within the BNMC, including level, slip-resistant paths.	Ratings from the Baseline and Periodic Post-Deployment Surveys, on 5-point Likert scale
3	Survey	Overall System	System user ratings of the availability of information for making trips to, from and within the BNMC	Ratings from the Baseline and Periodic Post-Deployment Surveys, on 5-point Likert scale
4	Survey	Overall System	System user ratings of the usefulness of information for making trips to, from and within the BNMC	Ratings from the Baseline and Periodic Post-Deployment Surveys, on 5-point Likert scale
5	Survey	Overall System	System user ratings of the ability to make trips using integrated transit services. To, from and within the BNMC	Ratings from the Baseline and Periodic Post-Deployment Surveys, on 5-point Likert scale
6	Survey	CTP (Registration)	System user ratings of the ease of the registration process	Aggregate daily responses across CTP users from a rating question in the CTP app at the end of the registration process about ease of use, on a 5-point Likert scale
7	Survey	CTP (Registration)	System user ratings of the extent to which the options available during registration served their needs	Aggregate daily responses across CTP users from a rating question in the CTP app at the end of the registration process about perceived relevance of preference questions, on a 5-point Likert scale
8	Survey	CTP (Route Planning)	System user ratings of the ease of planning a door-to-door trip route/path	Ratings from the Periodic Post-Deployment Surveys about ease of planning trips, on 5-point Likert scale

ID	Data Source	Target System	Metric	Data Description
9	Survey	CTP (Route Planning)	System user ratings of the satisfaction with the specific route/path options provided by the CTP	Aggregate daily responses across CTP users from a rating question in the CTP app at the end of the planning a trip, on a 5-point Likert scale
10	Survey	CTP (CS Booking)	System user ratings of the ease and convenience of booking on-demand transit trips via the system	Aggregate daily responses across CTP users from a rating question in the CTP app at the end of the CS booking process about satisfaction with the process, on a 5-point Likert scale
11	Survey	CTP (Reporting Conditions)	The percent of CTP users who use the CTP to report incidents or travel conditions during their trips	Answers from the Periodic Post-Deployment Surveys about frequency of using reporting function
12	Survey	CTP (Reporting Conditions)	System user ratings of the ease of reporting incidents or conditions encountered during a trip in the CTP	Ratings from the Periodic Post-Deployment Surveys about ease of reporting incidents, etc. (if user has used the capability), on 5-point Likert scale
13	Survey	CTP (Trip History)	The percent of CTP users who use the CTP function to review past trip history	Answers from the Periodic Post-Deployment Surveys about frequency of reviewing trip history
14	Survey	CTP (Trip History)	System user ratings of the usefulness of reviewing past trip history in the CTP	Ratings from the Periodic Post-Deployment Surveys about usefulness of reviewing trip history (if user has used the capability), on 5-point Likert scale
15	Survey	CTP (Wayfinding)	The fraction of CTP users who elect to receive outdoor wayfinding notifications	Answers from the Periodic Post-Deployment Surveys about frequency of using outdoor navigation
16	Survey	CTP (Wayfinding)	System user self-reported frequency of using outdoor wayfinding notifications	Answers from the Periodic Post-Deployment Surveys about frequency of using outdoor navigation
17	Survey	CTP (Wayfinding)	The fraction of CTP users who elect to receive indoor wayfinding notifications	Answers from the Periodic Post-Deployment Surveys using indoor navigation
18	Survey	CTP (Wayfinding)	System user self-reported frequency of using indoor wayfinding notifications	Answers from the Periodic Post-Deployment Surveys about frequency of using indoor navigation
19	Survey	CTP (Wayfinding)	System user ratings of how useful the outdoor wayfinding functionality is in reaching their trip destination on time	Ratings from the Periodic Post-Deployment Surveys (if user has used the capability), on 5-point Likert scale
20	Survey	CTP (Wayfinding)	System user ratings of the how useful the indoor wayfinding functionality is in reaching their trip destination on time	Ratings from the Periodic Post-Deployment Surveys (if user has used the capability), on 5-point Likert scale

ID	Data Source	Target System	Metric	Data Description
21	Survey	CTP (Wayfinding)	User ratings of various dimensions of using the CTP outdoor wayfinding functionality using the rapid assessment of product usability and universal design (RAPUUD) method	Ratings from the Periodic Post-Deployment Surveys (if user has used the capability), on 5-point Likert scale
22	Survey	CTP (Wayfinding)	User ratings of various dimensions of using the CTP indoor wayfinding functionality using the rapid assessment of product usability and universal design (RAPUUD) method	Ratings from the Periodic Post-Deployment Surveys (if user has used the capability), on 5-point Likert scale
23	Survey	CTP (Smart Signals)	Self-reported fraction of people who cross at the relevant intersections who use the CTP smart signal activation functionality	Answers from the Periodic Post-Deployment Surveys about frequency of crossing intersections and activating smart signals
24	Survey	CTP (Smart signals)	Perceived ease of use and ratings of various aspects of using the smart signals, using the RAPUUD method	Ratings from the Periodic Post-Deployment Surveys (if user has used the capability), on 5-point Likert scale
25	Survey	CTP (Smart signals)	Self-reported frequency of crossing at the intersections with smart signals	Answers from the Baseline and Periodic Post-Deployment Surveys about frequency of crossing intersections
26	Survey	CTP (Smart signals)	Perceived safety of crossing the intersections with smart signals	Ratings from the Baseline and Periodic Post-Deployment Surveys, on 5-point Likert scale

With data stored on UB's secure server, the PMD development team will access and process post-processed (PII removed) survey data on a weekly or bi-weekly basis. **Figure 82** shows the flow of an UB server access. Secure VPN and Remote Desktop connections using UB account login credentials allow authorized PMD development team members to access the secure server for this project. Within the server, data processing routine developed in R will be implemented to automate data processing (Req-PMD-014.3). Additional coding lines will be added for survey data quality checks (Req-PMD-002). Part of the survey metrics and data processing effort includes developing metadata (Req-PMD-005) and data dictionaries that can be accessible from the public PMD. Data will also be transformed into a format that includes the level of geography and aggregation suitable for effective PM visualization and analysis (Req-PMD-009). A configuration file will also be developed, which records how the data (including other subsystem data collected) is accessed and preprocessed to evaluate the defined PMs. Once the survey data is processed to provide performance measures, the output data will be stored in an output folder, which will be used for PMD development (see **Figure 83**).

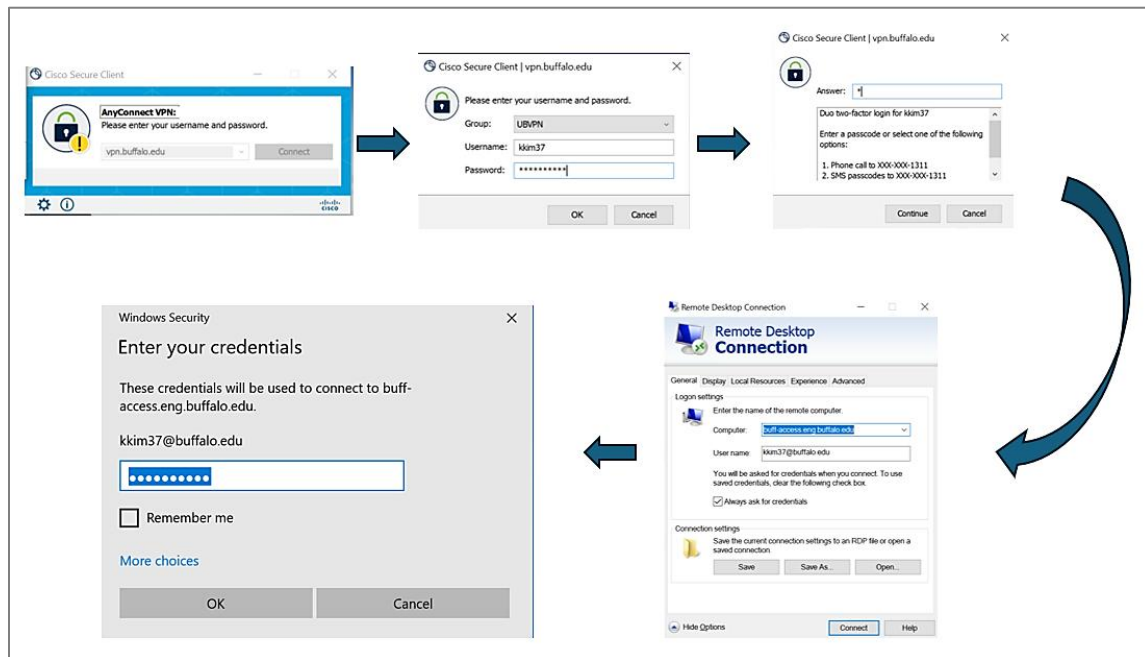


Figure 82. Survey Data Access Flow
Source: Buffalo, NY ITS4US (2024)

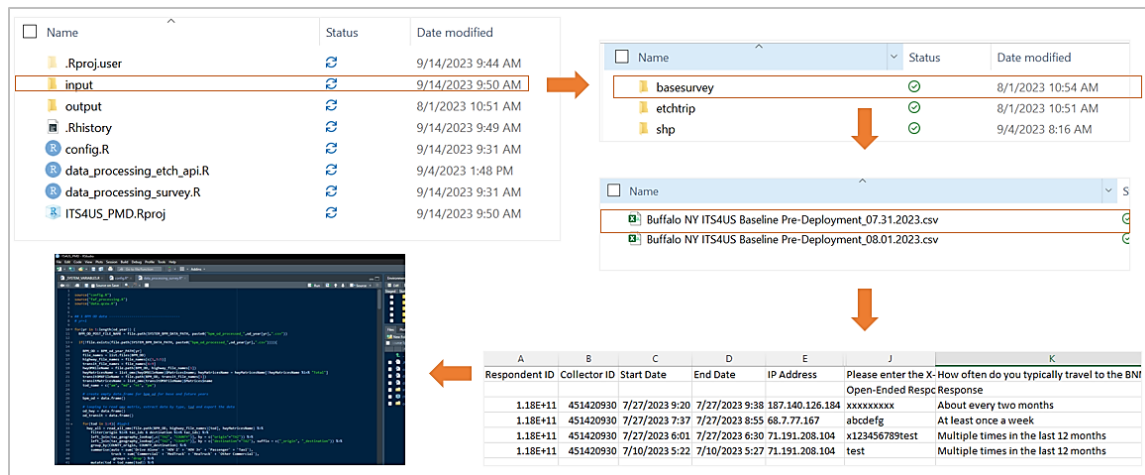


Figure 83. Survey Data Processing Flow
Source: Buffalo, NY ITS4US (2024)

6.2.1.5 Survey Visualization

Given that the performance metrics collected from the surveys are mostly measured on a 5-point Likert scale, the four commonly used visualization charts for Likert scale data will be developed (Req-PMD-009) (see example charts in **Figure 84** below).

1. **Bar Charts:** Bar charts are suitable for comparing and representing the distribution of responses for each metric. The chart can display the frequency or percentage of participants choosing each response option (e.g., 1. Strongly disagree, 2. Somewhat disagree, 3. Neither agree or disagree, 4. Somewhat agree, and 5. Strongly agree) using vertical or horizontal bars.
2. **Stacked Bar Charts:** Stacked bar charts can be employed to display the composition of responses for each metric. Each response option is represented as a different segment within a bar, allowing for a comparison of the proportion of different responses.
3. **Pie Charts:** Pie charts can be used to illustrate the proportion or percentage of responses for each metric category. Each response option (e.g., 1. Strongly disagree, 2. Somewhat disagree, 3. Neither agree or disagree, 4. Somewhat agree, and 5. Strongly agree) can be represented as a segment of the pie, providing a visual representation of the distribution.
4. **Radar Charts:** Radar charts (also known as spider charts) can be utilized to show the overall performance across multiple metrics. Each metric is represented as a spoke on the chart, and the distance from the center to the data point on each spoke indicates the rating or score for that metric. This type of chart provides a visual comparison of the performance across various metrics.

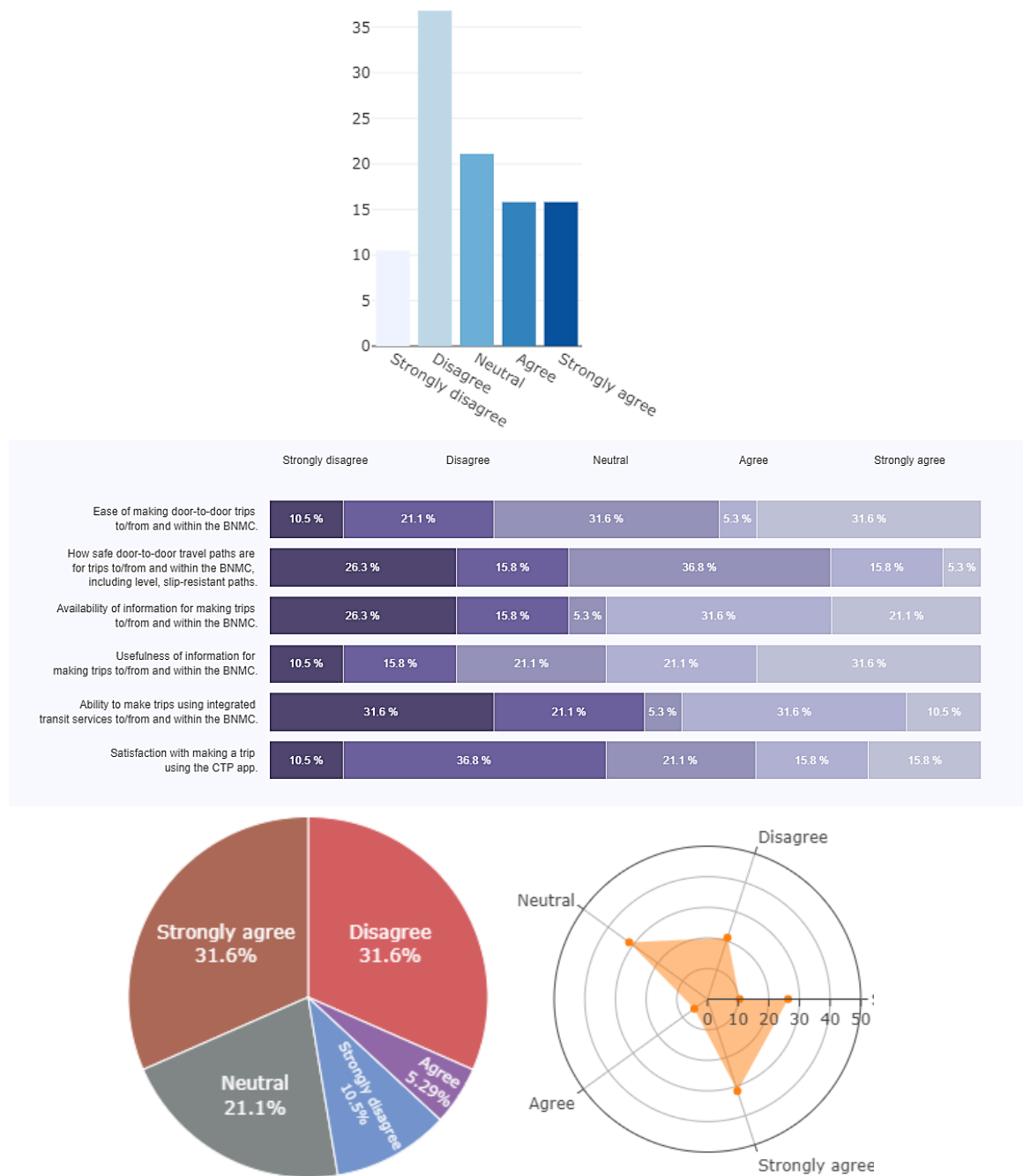


Figure 84. Examples of PM Visualization for Survey Data

Source: Buffalo, NY ITS4US (2024)

6.2.2 Data Ingestion

6.2.2.1 CTP Metrics and Processing

There are 26 metrics related to the CTP (trip planner) app user experience and trip data. Five metrics will aggregate CTP data to evaluate CS, travel conditions, and trip-related CTP user experience. The level of aggregation, which will be available in the PMD, will be identified and standardized during Phase 2 development (Req-PMD-008). **Table 62** shows the detail of the metrics including data source and target system. Post-processed CTP data with each participant's email address but no other PII such as trip latitude/longitude will be pushed to UB's secured server (Req-PMD-014.3). Email address will also be deleted from the secure server, once data collection, including post-deployment survey, is complete.

Table 62. Performance Metrics related to CTP User Experience and Trip Data

ID	Data Source	Target System	Metric	Data Description
1	CTP	Overall System	The satisfaction with making a trip using the CTP app	Ratings from CTP user data, on 5-point Likert scale
2	CTP	CTP (CS Booking)	The percent of CTP users who use the system to book on-demand transit trips (HDS or SDS)	Aggregate daily data across CTP users of number of new trips booked (a) on the HDS and (b) on the SDS
3	CTP	CTP (Smart Signals)	The percent of CTP trips crossing at the relevant intersections who use the smart signal remote activation function	Aggregate daily data across CTP users of (a) the number of trips that traverse each of the smart signal intersections and (b) the number of times the smart signals are activated from the CTP
4	CTP	CS (HDS and SDS)	The percent of CS trips that arrive at the boarding stop within the targeted time allowance of the scheduled arrival time	Aggregate daily data across CTP users of the number of trips of trips that for which the differences between the scheduled and arrival times fall in different ranges (30+ min early, 20-30 min early, etc., 30+ min late)
5	CTP	CS (HDS and SDS)	The percent of CS trips that arrive at the alighting stop within the targeted time allowance of the scheduled arrival time	Aggregate daily data across CTP users of the number of trips of trips that for which the differences between the scheduled and arrival times fall in different ranges (30+ min early, 20-30 min early, etc., 30+ min late)
6	Survey	CTP (Registration)	System user ratings of the ease of the registration process	Ratings from the Periodic Post-Deployment Surveys about ease of reporting incidents, etc. (if user has used the capability), on 5-point Likert scale
7	Survey	CTP (Registration)	System user ratings of the extent to which the options available during registration served their needs	Ratings from the Periodic Post-Deployment Surveys about ease of reporting incidents, etc. (if user has used the capability), on 5-point Likert scale

ID	Data Source	Target System	Metric	Data Description
8	Survey	CTP (Route Planning)	System user ratings of the ease of planning a door-to-door trip route/path	Ratings from the Periodic Post-Deployment Surveys about ease of planning trips, on 5-point Likert scale
9	Survey	CTP (Route Planning)	System user ratings of the satisfaction with the specific route/path options provided by the CTP	Ratings from the Periodic Post-Deployment Surveys about ease of reporting incidents, etc. (if user has used the capability), on 5-point Likert scale
10	Survey	CTP (CS Booking)	System user ratings of the ease and convenience of booking on-demand transit trips via the system	Ratings from the Periodic Post-Deployment Surveys about ease of reporting incidents, etc. (if user has used the capability), on 5-point Likert scale
11	Survey	CTP (Reporting Conditions)	The percent of CTP users who use the CTP to report incidents or travel conditions during their trips	Answers from the Periodic Post-Deployment Surveys about frequency of using reporting function
12	Survey	CTP (Reporting Conditions)	System user ratings of the ease of reporting incidents or conditions encountered during a trip in the CTP	Ratings from the Periodic Post-Deployment Surveys about ease of reporting incidents, etc. (if user has used the capability), on 5-point Likert scale
13	Survey	CTP (Trip History)	The percent of CTP users who use the CTP function to review past trip history	Answers from the Periodic Post-Deployment Surveys about frequency of reviewing trip history
14	Survey	CTP (Trip History)	System user ratings of the usefulness of reviewing past trip history in the CTP	Ratings from the Periodic Post-Deployment Surveys about usefulness of reviewing trip history (if user has used the capability), on 5-point Likert scale
15	Survey	CTP (Wayfinding)	The fraction of CTP users who elect to receive outdoor wayfinding notifications	Answers from the Periodic Post-Deployment Surveys about frequency of using outdoor navigation
16	Survey	CTP (Wayfinding)	System user self-reported frequency of using outdoor wayfinding notifications	Answers from the Periodic Post-Deployment Surveys about frequency of using outdoor navigation
17	Survey	CTP (Wayfinding)	The fraction of CTP users who elect to receive indoor wayfinding notifications	Answers from the Periodic Post-Deployment Surveys using indoor navigation
18	Survey	CTP (Wayfinding)	System user self-reported frequency of using indoor wayfinding notifications	Answers from the Periodic Post-Deployment Surveys about frequency of using indoor navigation
19	Survey	CTP (Wayfinding)	System user ratings of the how useful the outdoor wayfinding functionality is in reaching their trip destination on time	Ratings from the Periodic Post-Deployment Surveys (if user has used the capability), on 5-point Likert scale

ID	Data Source	Target System	Metric	Data Description
20	Survey	CTP (Wayfinding)	System user ratings of the how useful the indoor wayfinding functionality is in reaching their trip destination on time	Ratings from the Periodic Post-Deployment Surveys (if user has used the capability), on 5-point Likert scale
21	Survey	CTP (Wayfinding)	User ratings of various dimensions of using the CTP outdoor wayfinding functionality using the rapid assessment of product usability and universal design (RAPUUD) method	Ratings from the Periodic Post-Deployment Surveys (if user has used the capability), on 5-point Likert scale
22	Survey	CTP (Wayfinding)	User ratings of various dimensions of using the CTP indoor wayfinding functionality using the rapid assessment of product usability and universal design (RAPUUD) method	Ratings from the Periodic Post-Deployment Surveys (if user has used the capability), on 5-point Likert scale
23	Survey	CTP (Smart Signals)	Self-reported fraction of people who cross at the relevant intersections who use the CTP smart signal activation functionality	Answers from the Periodic Post-Deployment Surveys about frequency of crossing intersections and activating smart signals
24	Survey	CTP (Smart signals)	Perceived ease of use and ratings of various aspects of using the smart signals, using the RAPUUD method	Ratings from the Periodic Post-Deployment Surveys (if user has used the capability), on 5-point Likert scale
25	Survey	CTP (Smart signals)	Self-reported frequency of crossing at the intersections with smart signals	Answers from the Baseline and Periodic Post-Deployment Surveys about frequency of crossing intersections
26	Survey	CTP (Smart signals)	Perceived safety of crossing the intersections with smart signals	Ratings from the Baseline and Periodic Post-Deployment Surveys, on 5-point Likert scale

In a similar manner to the survey data processing described above (**Figure 83**), CTP data that are pushed to the server by the CTP app developer will be processed weekly or bi-weekly with data processing routine R scripts. The data will be only accessed and processed through the University of Buffalo secure server only by qualified project team members with university credentials (see **Figure 85**).

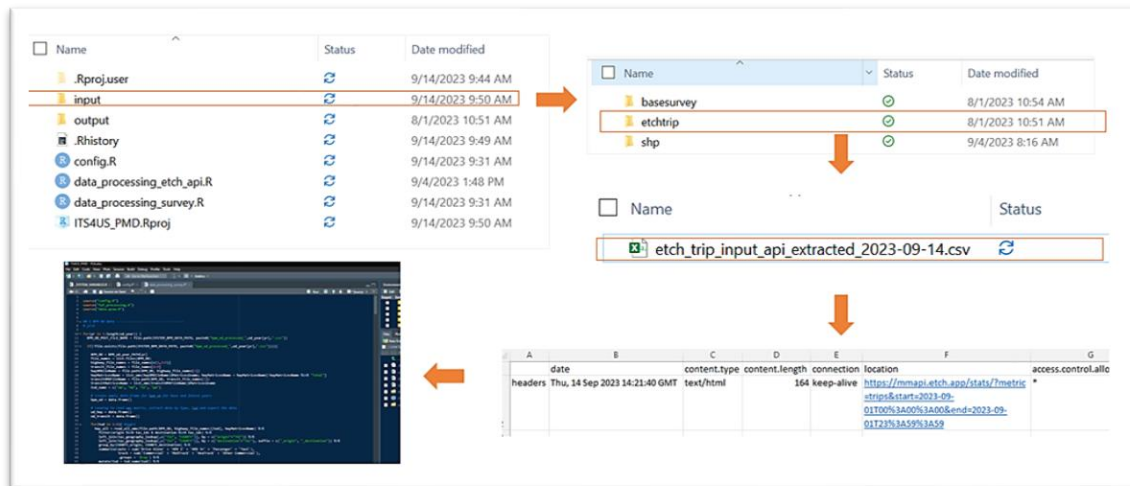


Figure 85. CTP Data Access/Processing Flow

Source: NFTA (2024)

Although participants' email addresses will be used to link survey data to registration, trip planning, and trip performance data, the email address will not be saved when it is stored on the server. An automatic quality control (QC) routine, coded in R, will be run each time that data is ingested and processed. QC checks will include range checks for each data item, checks for missing data, and logic checks for combinations of data items. Once the data is processed to provide CTP-related performance measures, the output data will be stored in an output folder, which will be used as input to the PMD to display metrics to team members and system evaluators. Each time that performance metrics are calculated, they will be tagged with the date for the specific week and added to a cumulative database that can be queried by the PMD code to calculate performance measures over a period specified by the PMD user.

The PMD development team will incorporate additional coding lines to process the data and make the performance metrics data ready to visualize in PMD. Relevant metadata will be developed to allow access to this information from the public PMD.

6.2.2.2 NFTA PAL

There are two metrics designed to rate the performance measure of "(6) the provision of an efficient, reliable and safe new on-demand transit shuttle system". The PAL metrics are a small portion of determining the provision of efficiency and customer satisfaction comparing PAL to CS services. Other performance metrics evaluating performance measure 6 are included in **Section 6.2.2.3**. The two PAL related metrics are below in **Table 63** will be collected from surveys but will also require trip usage of NFTA PAL services as described in the Data Description column.

Table 63. Performance Metrics related to NFTA PAL Data

ID	Data Source	Target System	Metric	Data Description
1	Baseline and post-deployment surveys	CS	Self-reported frequency of using all transit services, including the CS as well as PAL services and NFTA bus and rail lines.	Data is from the pre- and post-deployment surveys comparing registered users' "before and after" self-reported frequency of making trips on PAL.
2	CTP User data and Shuttle Operations data, supplemented by PAL Direct bookings data	CS	Percent of transit trips made by PAL-eligible CTP users within the CS service area that are made via the CS or PAL-spontaneous versus regular PAL trips.	Data is based on CS trip frequency made by people who are PAL-eligible, along with aggregate data on PAL ridership. (Note: NFTA has stated that they cannot provide disaggregate data on PAL ridership by individual users, so that is asked in the surveys.)

6.2.2.3 CS SDS and HDS

Four performance metrics aim to evaluate the SDS (and HDS) shuttle services as shown in **Table 64**. One metric will be evaluated with data collected from the survey. One metric requires CS operations data supplemented by additional system cost data. The other two will be measured with CTP data. The CS subsystem management team will work with a CS operating contractor to prepare the data without PII and push the data to UB's secure server. The PMD development team will develop data ingestion and processing routines accordingly in R to rate the metrics below (Req-PMD-014.4, Req-PMD-014.5, Req-PMD-014.7).

Table 64. Performance Metrics Related to SDS and HDS Trip and Operation Data

ID	Data Source	Target System	Metric	Data Description
1	HDS and SDS Operations data, supplemented by additional system cost data	CS	Cost efficiency of the HDS and SDS shuttle services in terms of operating cost per passenger trip	Aggregate data from the CS Operations System on the actual number of boardings on the HDS and SDS during several periods of the day on each day
2	Survey	CS	System user ratings of the ease of booking on-demand (CS) transit trips via the system	Ratings from the Periodic Post-Deployment Surveys about ease of reporting incidents, etc. (if user has used the capability), on 5-point Likert scale
3	CTP	CS	Percent of CS trips that arrive at the boarding stop within the targeted time allowance of the scheduled arrival time	Aggregate data from the CTP trip data
4	CTP	CS	The percent of CTP users who use the system to book on-demand transit trips (CS)	Aggregate daily data across CTP users of number of new trips booked (a) on the HDS and (b) on the SDS

6.2.2.4 Other Metrics

There are fourteen performance metrics measuring systemwide performance, smart signals, or travel condition of ITS4US Buffalo system as shown in **Table 65**. All of them except two will be collected through the surveys so data processing and metadata will be developed as described in **Section 6.2.1.4** and **6.2.2.1**.

Table 65. Performance Metrics to rate overall System

ID	Data Source	Target System	Metric	Data Description
1	Survey	Overall System	System user ratings of how accessible door-to-door travel is for trips to, from and within the BNMC	Ratings from the Baseline and Periodic Post-Deployment Surveys, on 5-point Likert scale
2	Survey	Overall System	System user ratings of how safe door-to-door travel paths are for trips to, from and within the BNMC, including level, slip-resistant paths	Ratings from the Baseline and Periodic Post-Deployment Surveys, on 5-point Likert scale
3	Survey	Overall System	System user ratings of the adequacy and usefulness of information for making trips to, from and within the BNMC	Ratings from the Baseline and Periodic Post-Deployment Surveys, on 5-point Likert scale
4	Survey	Overall System	System user ratings of the ability to make trips using integrated transit services. to, from and within the BNMC	Ratings from the Baseline and Periodic Post-Deployment Surveys, on 5-point Likert scale
5	Survey	Overall System	System user ratings of how reliable the transit system is in reaching their BNMC trip destination on time	Ratings from the Baseline and Periodic Post-Deployment Surveys, on 5-point Likert scale
6	Survey	Overall System	Self-reported frequency of using all transit services, including the CS as well as PAL services and NFTA bus and rail lines	Answers from the Baseline and Periodic Post-Deployment Surveys about frequency of using various transit services
7	CTP	Overall system	The satisfaction with making a trip using the CTP app	Ratings from CTP user data, on 5-point Likert scale
8	CTP	CTP (Smart Signals)	The percent of CTP trips crossing at the relevant intersections who use the smart signal remote activation function	Aggregate daily data across CTP users of (a) the number of trips that traverse each of the smart signal intersections and (b) the number of times the smart signals are activated from the CTP
9	Survey	CTP (Smart Signals)	Self-reported fraction of people who cross at the relevant intersections who use the CTP smart signal activation functionality	Answers from the Periodic Post-Deployment Surveys about frequency of crossing intersections and activating smart signals
10	Survey	CTP (Smart signals)	Perceived ease of use and ratings of various aspects of using the smart signals, using the RAPUUD method	Ratings from the Periodic Post-Deployment Surveys (if user has used the capability), on 5-point Likert scale
11	Survey	CTP (Smart signals)	Self-reported frequency of crossing at the intersections with smart signals	Answers from the Baseline and Periodic Post-Deployment Surveys about frequency of crossing intersections
12	Survey	CTP (Smart signals)	Perceived safety of crossing the intersections with smart signals	Ratings from the Baseline and Periodic Post-Deployment Surveys, on 5-point Likert scale

ID	Data Source	Target System	Metric	Data Description
13	Survey	CTP (Reporting Conditions)	The percent of CTP users who use the CTP to report incidents or travel conditions during their trips	Answers from the Periodic Post-Deployment Surveys about frequency of using reporting function
14	Survey	CTP (Reporting Conditions)	System user ratings of the ease of reporting incidents or conditions encountered during a trip in the CTP	Ratings from the Periodic Post-Deployment Surveys about ease of reporting incidents, etc. (if user has used the capability), on 5-point Likert scale

6.2.3 Processing

The Buffalo ITS4US PMD relies on six primary data sources for rating the 32-performance metrics. These data sources include: 1) baseline surveys, 2) post-deployment surveys, 3) CTP user data, 4) CS booking and operations data, 5) HDS system data and 6) SDS system data. These data sources will be collected from surveys, user data, and trip data from the implementation of each subsystem, and stored on UB's secure server for PMD development as described in the Performance Metrics tables listed in **Section 6.2.2** (see **Table 62** through **Table 65**).

The PMD development team will utilize R programming language and R Studio as the integrated development environment (see **Figure 86**), to streamline the data ingestion, perform quality control routines (discussed in **Table 60**), and process the data (Req-PMD-014).

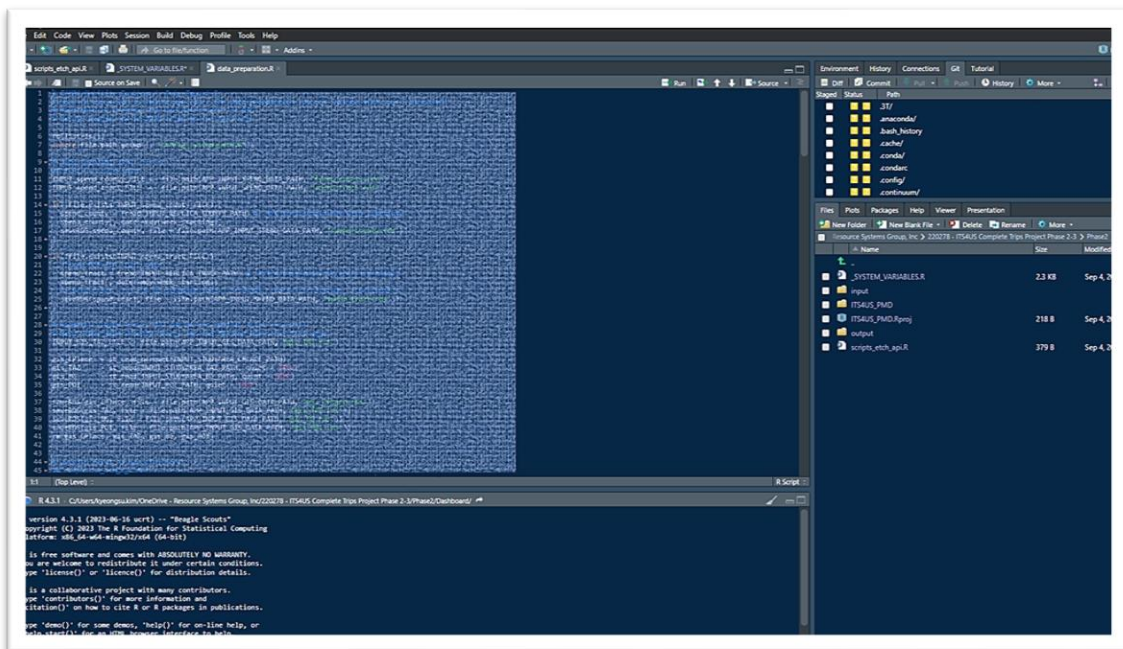


Figure 86. Screenshot of R Studio
Source: Buffalo, NY ITS4US (2024)

Figure 87 illustrates a high-level overview of data sources and data flow within the PMD system.

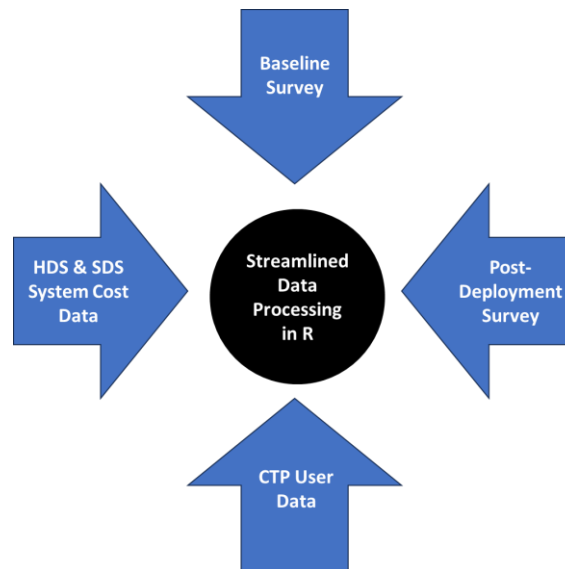


Figure 87. Performance Metrics Data Sources and Data Processing Flow
Source: Buffalo, NY ITS4US (2024)

6.2.4 Performance Measurement Dashboard (Visualization and Distribution)

The Buffalo ITS4US PMD will be developed using Shiny, an open-source online application platform (Req-PMD-010). Shiny, an R package, enables the creation of user-friendly interfaces with advanced features for interactive visualization of performance metrics. While Shiny has its unique coding style, the R scripts developed for data ingestion and performance metric development can be easily integrated into the Shiny dashboard development process.

The PMD will incorporate the charts mentioned earlier, such as bar, pie, radar charts, and other appropriate visualizations (Req-PMD-009), to represent the metrics related to survey data (refer to **Figure 84**). Additionally, it will include report tables that present the results of performance metrics (refer to **Figure 88**). The PMD will also enable users to export results to Excel and image (e.g., png, jpg) files (Req-PMD-007).

Due to concerns regarding the exposure of PII, the PMD will not display any trip-related Origin-Destination (OD) information on a map. However, for informational purposes, it will include an interactive map featuring study site locations such as BNMC, fixed routes for community shuttles, and intersections with smart signals.

The PMD will offer interactivity to navigate through the results. It will provide a dropdown menu for selecting different performance measure types (as depicted in **Figure 89**). Additionally, the PMD will feature interactive customization options through dropdown menus, allowing users to analyze data based on different time scales and user types as shown in **Figure 90**. The PMD will also include a user guide tab that contains data dictionary and metadata info (Req-PMD-013).

Example report for Shuttle and Transit Operations		Values by Month		
User Type = All users	Target	May	June	July
% of CS trips that arrive at boarding stop within 5 min of schedule	>90%	87%	91%	92%
% of CS trips that arrive at alighting stop within 5 min of schedule	>90%	82%	87%	89%
Cost efficiency of CS service in terms of \$ per passenger-trip	<\$20	\$22	\$19	\$19
Increase in rating of using transit to arrive at the destination on time	>0.4	0.50%	0.40%	0.50%
Increase in total use of transit in the study area in trips/person-mo	>1.0	1.1	1	1.1
% of trips by Pal-eligible users in the study area made by CS	>25%	19%	23%	27%
Average user rating of CS service:				
Convenience	>3.0	3.4		3.5
Affordability	>3.0	3.1		3.1
Assessment of CS Service Usability and Design:				
High ease of use	>3.0	2.8		3
High independence	>3.0	3.8		3.6
Low safety risk	>3.0	2.7		2.9
Low risk of user mistakes	>3.0	3.7		3.4
High efficiency of time use	>3.0	4.1		3.9
Low physical effort required	>3.0	3.1		3.2
Low mental effort required	>3.0	3.9		3.7
Low level of unwanted attention	>3.0	4.1		4.2
Low risk of embarrassment	>3.0	3.9		3.7

Figure 88. Example of PM Table
Source: Buffalo, NY ITS4US (2024)

Select Performance Measurement Type
CTP Overall Satisfaction Summary
CTP Registration and Preferences
CTP Trip Planning and Booking
CTP Indoor and Outdoor Wayfinding
CTP Smart Signal Activation
Shuttle and Transit Operations
Generate Composite Summary Report

Figure 89. Example of Main Performance Measurement Type Dropdown Menu
Source: Buffalo, NY ITS4US (2024)

Time Scale of Analysis
Select a specific month
Show values month by month
Show change versus baseline
Show change between months
Breakout by User Type
None (all users)
By type of disability
By income level
By age group
By residence area
By BNMC visitor type

Figure 90. Example of Customization Dropdown Menu

Source: Buffalo, NY ITS4US (2024)

Finally, the PMD will provide a link to a GitHub repository containing all (post-processed without PII) data presented in PMD, data dictionary, metadata, Geographic Information System (GIS) layers, and PMD user guide. This allows researchers to access the post-processed surveys, CTP, and CS data for future studies (Req-PMD-012).

Figure 91 shows examples of dashboards and online applications the PMD development team has developed with a variety of data.

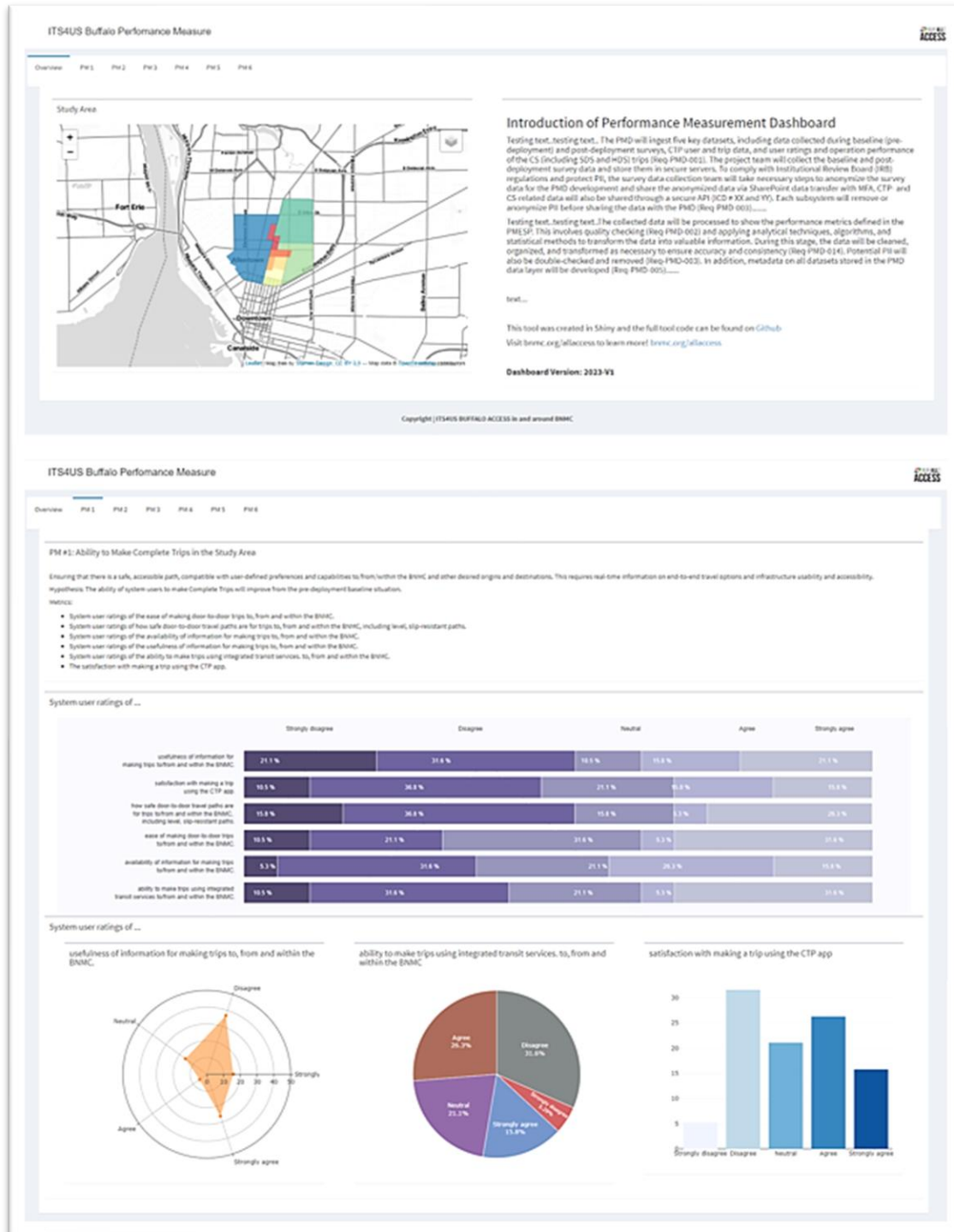


Figure 91. Shiny Dashboard Examples

Source: Buffalo, NY ITS4US (2024)

The PMD for the Buffalo ITS4US system will be published using shinyapps.io, a Secure Sockets Layer (SSL) encrypted environment designed for dashboard deployment via the web (Req-PMD-011). This environment eliminates the need to set up a dedicated Shiny server to the project team's own server while providing a user-friendly platform that simplifies the maintenance of the dashboard for system engineers (see **Figure 92**). With shinyapps.io, the PMD remains secure and encrypted but may be securely accessed over the internet.

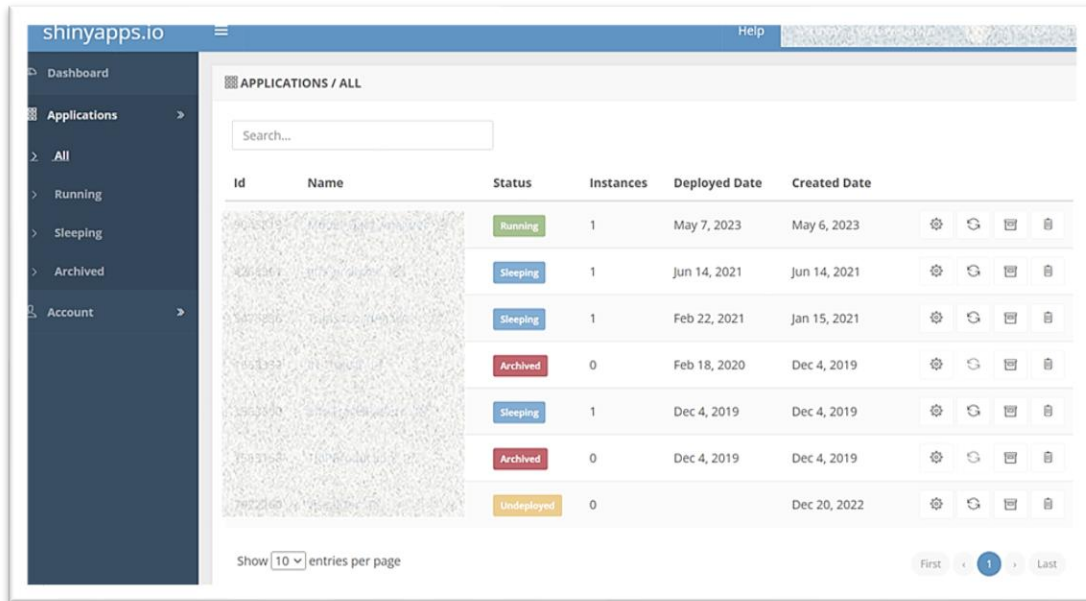


Figure 92. Screenshot of Shinyapps.io Admin Page
 Source: Buffalo, NY ITS4US (2024)

6.3 PMD Requirements Traceability

The requirements that are met by this design are listed in **Table 66**.

Table 66. PMD Requirements Traceability to SDD Section

Req ID	Req Title	Change	SDD Section
Req-PMD-001	Ingesting data	No change	Sections 6.1 and 6.2.1.1
Req-PMD-002	Quality checking data	No change	Sections 6.1 and 6.2.1.5
Req-PMD-003	Anonymizing data	No change	Section 6.1
Req-PMD-005	Metadata	No change	Sections 6.1 and 6.2.1.5
Req-PMD-006	Role based access	No change	Section 6.1
Req-PMD-007	Analytic tools	No change	Section 6.2.4
Req-PMD-008	Data aggregation	No change	Section 6.2.2.1
Req-PMD-009	Presentation formats	No change	Sections 6.1, 6.2.1.5, 6.2.1.6, 6.2.4
Req-PMD-010	Web based presentation	No change	Sections 6.1 and 6.2.4
Req-PMD-011	Cloud base infrastructure	No change	Section 6.2.4

U.S. Department of Transportation
 Office of the Assistant Secretary for Research and Technology
 Intelligent Transportation System Joint Program Office

Req ID	Req Title	Change	SDD Section
Req-PMD-012	On-premise data storage	No change	Section 6.2.4
Req-PMD-013	Discovery	No change	Section 6.2.4
Req-PMD-014	Data Curation of Metric Data	No change	Sections 6.1 and 6.2.3
Req-PMD-014.2	Data Curation of satisfaction (post-deployment survey) data	Approved	Sections 6.1.3, 6.1.2.5, and 6.2.3
Req-PMD-014.3	Data Curation of CTP performance data	No change	Sections 6.2.1.5 and 6.2.2.1
Req-PMD-014.4	Data Curation of reservation data	Approved	Section 6.2.2.3
Req-PMD-014.5	Data Curation of shuttle reporting data	Approved	Section 6.2.2.3
Req-PMD-014.7	Data Curation of additional data	No change	Section 6.2.2.3
Req-Sy-014	PII data use policy and IRB	No change	Section 6.1

7 References

This section provides the references used to create this document:

- [1] [ICD] Okunieff, P., et al. (2024). *Phase 2 Interface Control Document (ICD) – Buffalo, NY ITS4US Deployment Project (FHWA-JPO-22-981)*. Federal Highway Administration.
- [2] [SyRS] Gopalakrishna, D., et al. (2021). *Phase 1 System Requirements Specification (SyRS) – Buffalo, NY ITS4US Deployment Project (FHWA-JPO-21-883)*. Federal Highway Administration.
- [3] [ConOps] Gopalakrishna, D., et al. (2021). *Phase 1 Concept of Operations (ConOps) – Buffalo, NY ITS4US Deployment Project (FHWA-JPO-21-860)*. Federal Highway Administration.
- [4] [SAD] Okunieff, P., et al. (2023). *Phase 2 System Architecture Document (SAD) – Buffalo, NY ITS4US Deployment Project (FHWA-JPO-22-981)*. Federal Highway Administration.
- [5] [PMESP1] Gopalakrishna, D., et al. (2021). *Phase 1 Performance Measurement and Evaluation Support Plan (PMESP) – Buffalo, NY ITS4US Deployment Project (FHWA-JPO-21-878)*. Federal Highway Administration.
- [6] [PMESP2] Bradley, M., et al. (2023). *Phase 2 Performance Measurement and Evaluation Support Plan (PMESP) – Buffalo, NY ITS4US Deployment Project (FHWA-JPO-21-878)*. Federal Highway Administration.
- [7] [DMP1] Gopalakrishna, D., et al. (2021). *Phase 1 Data Management Plan (DMP) – Buffalo, NY ITS4US Deployment Project (FHWA-JPO-21-868)*. Federal Highway Administration.
- [8] [DMP2] Gopalakrishna, D., et al. (2023). *Phase 2 Data Management Plan (DMP) – Buffalo, NY ITS4US Deployment Project (FHWA-JPO-21-868)*. Federal Highway Administration.
- [9] [CIP] Okunieff, P., et al. (2024). *Phase 2 Comprehensive Installation Plan (CIP) – Buffalo, NY ITS4US Deployment Project (FHWA-JPO-23-991)*. Federal Highway Administration.
- [10] [CAP] Okunieff, P., et al. (2024). *Phase 2 Comprehensive Acquisition Plan (CAP) – Buffalo, NY ITS4US Deployment Project (FHWA-JPO-XX-XXX)*. Federal Highway Administration.
- [11] [CMOP] Okunieff, P., et al. (2024). *Phase 2 Comprehensive Maintenance and Operations Plan (CMOP) – Buffalo, NY ITS4US Deployment Project (FHWA-JPO-23-107)*. Federal Highway Administration.

- [12] [ORP] Okunieff, P., et al. (2024). Phase 2 Operational Readiness Plan (ORP) – *Buffalo, NY ITS4US Deployment Project (FHWA-JPO-XX-XXX)*. Federal Highway Administration.
- [13] [STP] Okunieff, P., et al. (2024). Phase 2 System Test Plan (STP) – *Buffalo, NY ITS4US Deployment Project (FHWA-JPO-23-995)*. Federal Highway Administration.

8 Requirements Traceability Matrix

Each section includes traceability to requirements incorporated in the associated component. The Master requirements traceability matrix (RTM) is documented in a Needs to Requirements Matrix which traces requirements to the design elements in this document.

The Master RTM is located in Phase 2 System Requirements Document (SyRS).

Appendix A. Acronyms

Table 67 summarizes the acronyms used in this document.

Table 67. List of Acronyms

Acronym	Description
2G	2 nd -Generation Cellular
3D	3 Dimensional
3G	3 rd -Generation Cellular
4G	4 th -Generation Cellular
AC	Alternating Current
ACS	American Census Survey
ADA	Americans with Disabilities Act
ADASTEC	ADASTEC Corp.
ADS	Autonomous Driving System
API	Application Programming Interface
APS	Audible Pedestrian Systems
ARIA	Accessible Rich Internet Applications
AV	Automated Vehicles
AVMS	Automated Vehicle Monitoring System
BLE	Bluetooth Low Energy
BMW	Bayerische Motoren Werke
BNMC	Buffalo Niagara Medical Campus
BTU	British Thermal Unit
C	Celsius

Acronym	Description
CAD	Computer Aided Design
CAN	Controller Area Network
CAP	Comprehensive Acquisition Plan
CDMA	Code Division Multiple Access
CIP	Comprehensive Installation Plan
CFR	Code of Federal Regulations
CMOP	Comprehensive Maintenance and Operations Plan
CMS	Content Management System
CoB	City of Buffalo
ConOps	Concept of Operations
CPU	Central Processing Unit
CS	Community Shuttle
CSV	Comma-separated values
CTP	Complete Trip Platform
DC	Direct Current
DCM	Detection and Counts Module
DMP	Data Management Plan
DOD	Depth of Discharge
DSRC	Dedicated Short-Range Communications
DTLS	Datagram Transport Layer Security
ECIO	Energy to Interference Ratio
EMS	Emergency medical services
ETA	Estimated Time of Arrival
EV	Electric Vehicle

Acronym	Description
EV-DO	Evolution-Data Optimized
F	Fahrenheit
FHWA	Federal Highway Administration
ft	feet
GB	Giga Byte
GeoJSON	Geographic JSON
GIS	Geographic Information System
GNSS	Global Navigation Satellite System
GPU	Graphical Processing Unit
GOFS-Lite	GTFS On-Demand Feed Specification– Lite
GTFS	General Transit Feed Specification
GTFS-RT	GTFS-realtime
GUI	Graphical User Interface
HD	High definition
HDS	Human Driven Shuttle
HMI	Human-Machine Interfaces
HP	Horse Power
HTTP	Hypertext Transfer Protocol
HTTPS	Hypertext Transfer Protocol Secure
HVAC	Heat, Air Ventilation, and Cooling
i18n	Internationalization
ICD	Interface Control Document
ID	Identification
IDEA Center	Center for Inclusive Design and Environmental Access

Acronym	Description
IEEE	Institute of Electrical and Electronics Engineers
IMU	Inertial Measurement Unit
INS	Indoor Navigation System
iOS	iPhone Operating System
IoT	Internet of Things
IRB	Institutional Review Board
ITS JPO	Intelligent Transportation Systems Joint Program Office
ITS4US	IT'S TRANSPORTATION FOR ALL OF US
JSON	JavaScript Object Notation
kWh	Kilowatt-hour
LiDAR	Light Detection & Ranging Sensor
LMC	Lithium Manganese Cobalt
LTE	Long Term Evaluation
MFA	Multifactor Authentication
min	minute
MPH	Miles Per Hour
MQTT	Message Queuing Telemetry Transport
MRC	Minimum Risk Condition
MRM	Minimal Risk Maneuver
MSA	Metropolitan Statistical Area
MVP	Minimum Viable Product
NFTA	Niagara Frontier Transportation Authority
NITTEC	Niagara International Transportation Technology Consortium
NTCIP	National Transportation Communications for ITS Protocol

U.S. Department of Transportation
Office of the Assistant Secretary for Research and Technology
Intelligent Transportation System Joint Program Office

Acronym	Description
NYSDOT	New York State Department of Transportation
OD	Origin-Destination
ODD	Operational Design Domain
ODP	On Device Positioning
OEDR	Object and Event Detection and Response
OS	Operating System
OSM	OpenStreetMap
OTP	Open Trip Planner
PAL	Paratransit Access Line
PBI	Product Backlog Items
PCAP	Projected Capacitive Touch Sensors
PED-X	Pedestrian Crossing
PII	Personally Identifiable Information
PKI	Public Key Infrastructure
PM	Performance Metrics
PMD	Performance Measurement Dashboard
PMESP	Performance Measurement Evaluation Support Plan
PO	Product Owner
PROW	Public Right of Way
QC	Quality Control
QR	Quick Response
RADAR	Radio Detection and Ranging
RAPUUD	Rapid Assessment of Product Usability and Universal Design
RAM	Random Access Memory

Acronym	Description
REST	Representational State Transfer
RGB	Red-Green-Blue
ROW	Right of Way
RSD	Reservations, Scheduling and Dispatch
RSRP	Reference Signal Received Power
RSRQ	Reference Signal Received Quality
RSSI	Received Signal Strength Indicator
RTM	Requirement Traceability Matrix
SaaS	software as a service
SAD	System Architecture Document
SAV	Shared Autonomous Vehicles
SDK	Software Development Kit
SDD	System Design Document
SDS	Self-Driving Shuttle
SEAS	School of Engineering and Applied Sciences
SI	Smart Infrastructure
SINR	Signal to Interference-plus-Noise-Ratio
SMS	Short Message Service
SOC	Shuttle Operations Center
SOGR	State of Good Repair
SOI	System of Interest
SOP	Standard Operating Procedure
SpaT	Signal Phase and Timing
SSD	Solid State Drive

Acronym	Description
SSL	Secure Sockets Layer
SSO	Single sign-on
SyRS	System Requirements Specification
TIH	Transportation Information Hub
TLS	Transport Layer Security
UB	University at Buffalo
UI	User Interface
UMTS	Universal Mobile Telecommunications Service
USDOT	United States Department of Transportation
UTS	United Telecommunications Service
V2X	Vehicle-to-Everything
V2X OBU	Vehicle-to-Everything Onboard Communication Unit
VIA	Visually Impairment Advancement
VMC	Vicinity Motor (Bus) USA Corp
VPN	Virtual Private Network
WCAG	Web Content Accessibility Guidelines
WZ	Work Zone
XML	Extensible Markup Language

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

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

FHWA-JPO-23-999



U.S. Department of Transportation