Phase 2 System Architecture Document (SAD)

Buffalo, NY ITS4US Deployment Project

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Final Report (Rev 1.0) — January 4, 2023

Final Report (Rev 1.1) – February 21, 2024

FHWA-JPO-22-981

ITS4US

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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

Technical Report Documentation Page

1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.
FHWA-JPO-22-981		

4. Title and Subtitle	5. Report Date
Phase 2 System Architecture Document (SAD) Buffalo, NY ITS4US Deployment Project	February 28, 2024
	6. Performing Organization Code (Delete and insert information here or leave blank)

7. Author(s)	8. Performing Organization Report No.
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12. Sponsoring Agency Name and Address	13. Type of Report and Period Covered
U.S. Department of Transportation ITS Joint Program Office 1200 New Jersey Avenue, SE Washington, DC 20590	Final Report
	14. Sponsoring Agency Code HOIT-1

15. Supplementary Notes

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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. Examples of the technologies to be deployed are electric and 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 navigate intersections, and Smart Infrastructure to support outdoor and indoor wayfinding. 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 Architecture Document (SAD), provides the implementation architecture for the proposed deployment system. This architecture provides the framework to plan, define, and integrate ITS solutions with the proposed system.

17. Keywords	18. Distribution Statement
ITS4US; Complete Trip; Deployment; ITS; Intelligent Transportation Systems; participant training; stakeholder education; System Architecture Document	

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of Pages	22. Price
Unclassified	Unclassified	110	

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

Revision History

Name	Date	Version	Summary of Changes	Approver
Buffalo ITS4US Phase 2 System Architecture Document	January 4, 2023	1.0	Final	Kelly Dixon
Buffalo ITS4US Phase 2 System Architecture Document	February 21, 2024	1.1	Updated to be consistent with Interface Control Document	Kelly Dixon

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1 Introduction

The Buffalo, New York 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. Examples of the technologies to be deployed are electric and self-driving shuttles, a trip planning app that is customized for accessible travel, intersections that use mobile technologies to enable travelers with disabilities to navigate intersections, and Smart Infrastructure to support outdoor and indoor wayfinding. 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, people with disabilities including vision, hearing, mobility challenges and older adults).

This document, the System Architecture Document (SAD), provides the system architecture description for the proposed deployment system. The architecture provides the framework to plan, define, and integrate ITS solutions with the proposed system. The architecture describes 4 viewpoints – enterprise, physical, functional and communications viewpoints.

1.1 Document Purpose

The SAD provides the enterprise, physical, functional and communication architecture views for the Buffalo ITS4US deployment.

The Interface Control Document (ICD), a separate document which supplements the architecture document, details the information flows with their interface specification, network and communications protocols and information standards used by the interface when available. The Standards Plan, which details the standards used by the interfaces, is attached to the ICD (forthcoming).

1.1.1 Organization of this Document

The SAD is organized as follows:

- Section 2 lists the stakeholders and summarizes their user needs.
- Section 3 describes the system of interest.
- Section 4 provides the different architectural views for the system.
- Section 5 lists the documents referenced in the SAD.
- Appendix A details the acronyms and terms used in the SAD.
- Appendix B provides information on the Standards Plan.

- Appendix C lists the changes made on the system's diagrams from Phase 1 to Phase 2.

The conventions used by this document are detailed in each section to help describe the notations associated with each architecture view.

1.2 Identifying Information

Below is the identifying information of the architecture and system of interest that will carry throughout the remainder of this document.

Architecture Name: Buffalo ITS4US Project Architecture where view name is designated as the Enterprise, Physical, Functional or Communications.

System-of-Interest: Buffalo ITS4US Deployment.

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

Technical Subsystem (System) Name	Branded Name
Complete Trip Platform (CTP)	Buffalo All Access App
Human Driven Shuttle (HDS)	Buffalo All Access On-demand Service

1.3 Background

Buffalo is moving toward a sustainable future at all levels of society, 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 **Error! Reference source not found.**.

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.

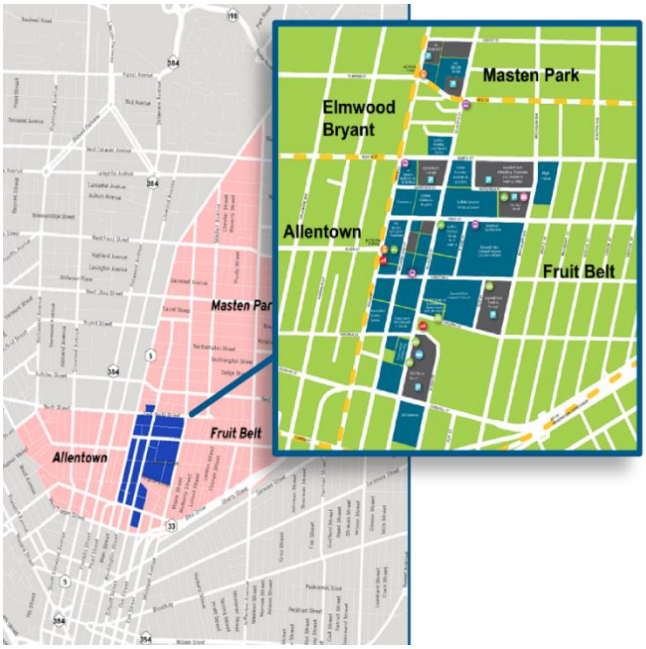

Figure 1. Buffalo Niagara Medical Campus relative to the neighborhoods of focus: Allentown, the Fruit Belt, and Masten Park.
Source: Buffalo, NY ITS4US

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 (ACS 2018tracts)	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 yrs 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**

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 ½ 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 still are 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.

1.4 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, Smart Infrastructure and Performance Measure Dashboard (PMD). Figure 2 provides an overview of each of these components. A more detailed explanation of the system is provided in Section 3.

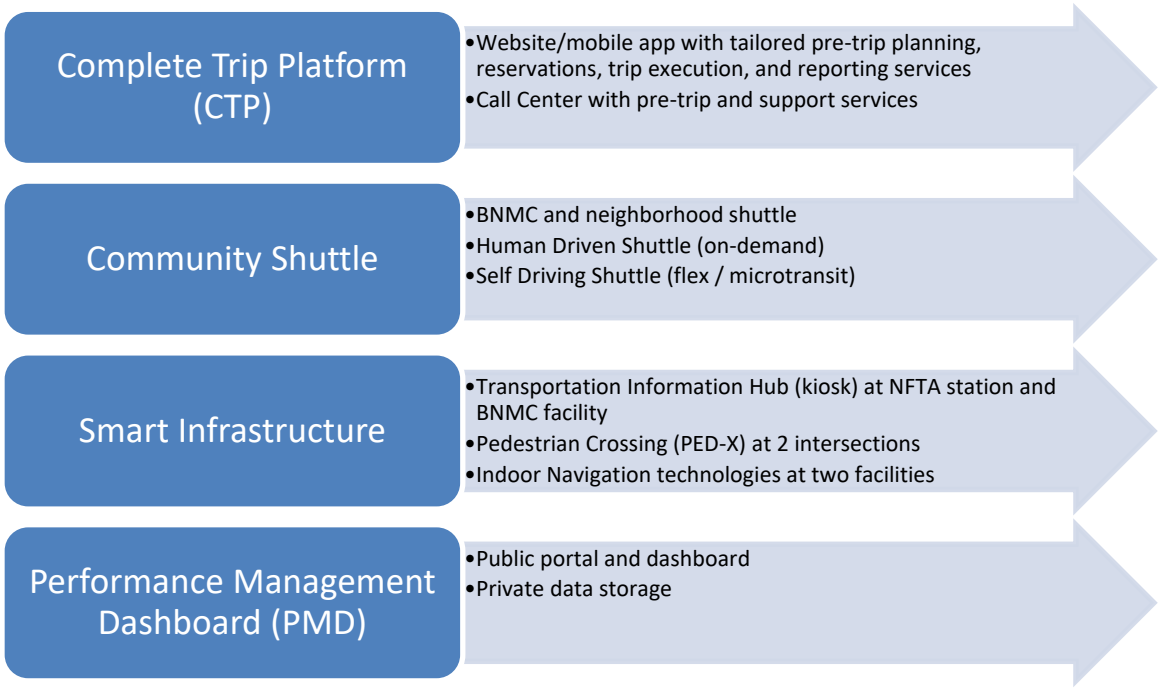

Figure 2. Components the Buffalo, NY ITS4US System
Source: Buffalo, NY ITS4US

1.5 Approach

Each architecture view will be depicted using a methodology and object descriptions promulgated by established practices. To the extent possible, the SAD objects will use the classes and object types included in the Architecture Reference for Cooperative and Intelligent Transportation (ARC-

IT) Version 9.1 to describe related physical, enterprise and communications viewpoints. Below is a summary of the approach for each view.

- **Enterprise.** The Enterprise view approach defines the roles, resources and agreements among stakeholders. The role-based model that details stakeholder roles in developing, operating and maintaining the system and relationships between the systems to inform, govern, and manage the resources.

- **Physical.** The Physical view approach uses the reference ARC-IT physical objects and extensions to model the actual physical objects and high-level flows between them.

- **Functional.** The Functional view combines ARC-IT service packages to represent larger system descriptions, specifically the Trip Planning and Related Subsystems. This combination shows combined service packages from ARC-IT that describe all the functions and related systems that compose the CTP trip planning and wayfinding functions. The functional view includes a description of each functional object and their relationship to the functions described in the System of Interest (SOI).

- **Communications.** The Communications view for the Buffalo ITS4US project represents the communications between elements using Open Systems Interconnection (OSI) model to designate the sets of communications protocols between physical objects. The majority of communications use internet protocols (i.e., Transmission Control Protocol/Internet Protocol) applying best practice security protocols. The communications view generates a set of classes of communications.

1.6 Rationale for Key Decisions

Key decisions were made prior to the development of the architecture. These are reflected in the updated SOI (Section 3).

2 Stakeholders and Concerns

This section defines the stakeholders, user needs, and concerns of the proposed system. The concerns provided at the end of this section describe the stakeholder concerns of the SOI as defined by ISO/IEC/IEEE 42010 standard.

2.1 Stakeholders

Stakeholders of the Buffalo ITS4US deployment project are described below.

2.1.1 User Profiles

Users, owners, operators, and maintainers of the Buffalo ITS4US deployment are described in **Table 2** and **Table 3**. Roles and responsibilities are described for each stakeholder participating in the project deployment. The architecture does not include training and outreach for users unless they interact with the system.

Table 2. Traveler Stakeholder

Stakeholder	Short Description	Roles and Responsibilities
Travelers	End-users of the complete trip platform and services provided.	• Travel using the services provided as part of the system. • Responsibilities include providing feedback using the CTP.
Caregiver	External party designated by traveler to have access to the traveler's account information or receive alerts about a traveler from the complete trip platform.	• Monitor traveler travel using services provided as part of the system. • Responsibilities include providing feedback using the CTP.

Table 3 provides the list of operator/partner users, as well as their roles and responsibilities.

Table 3. Owner / Operator / Maintenance Stakeholders

Stakeholder	System Component	Role	Description
BNMC	Call Center, BNMC Campus Entities	Manages	Organization that contracts, manages and facilitates the Buffalo ITS4US project.
BNMC Entities (VIA and Kaleida Health)	Smart Infrastructure (Transportation Information Hub (TIH) and Indoor Navigation)	Owner / Operator / Maintainer	Facilities that support travel support equipment including TIH and Indoor Navigation equipment for the Buffalo ITS4US project.

Stakeholder	System Component	Role	Description
City of Buffalo (CoB) Operations	Pedestrian Signal System	Owner / Operator / Maintainer	The city in which the Buffalo ITS4US project is deployed. The CoB owns, operates, and plans signal operations of the two designated pedestrian signal crossings and sidewalks in the project coverage area. They manage the roads over which the Self Driving Shuttle (SDS) / Human Driven Shuttle (HDS) will be deployed.
NFTA	Complete Trip Platform PMD HDS Community Shuttle Operations Center NFTA Paratransit Operations (PAL) Provision of General Transit Feed Specification (GTFS) datasets for NFTA TIH	Owner / Operator	The USDOT awardee. They provide transit services in the project service area. Project Owner / Operator. Owns and operates HDS, NFTA Paratransit Access Line (PAL) operations, Provision of GTFS, and TIH at Metrorail stations.

2.1.2 Other Involved Personnel

Table 4 provides the list of other involved personnel, service and equipment providers and their descriptions.

Table 4. Other Involved Personnel Stakeholders

Stakeholder Name	Stakeholder Description
Call Center Personnel	Human actors involved in call center operations to support the phone-based access of the CTP or the community shuttle.
CTP System Administrator	System Administrator for CTP trip planner and mobile app. The team that operates and maintains the software and infrastructure services.
CTP Vendor	Developer, operator, and maintainer of Complete Trip Platform.

Stakeholder Name	Stakeholder Description
Emergency and Law Enforcement Entities	City, state, transit law enforcement, and emergency systems and personnel responsible for monitoring emergencies, as well as the safety of traffic and transit operations. Includes CoB, NFTA, and NY State Police that may have jurisdiction in the deployment area.
Facility Manager	Manager of a facility (generic definition) that includes traveler support systems like a touch model, kiosk (transportation information hub), or indoor navigation services.
HDS Driver	Drivers of the human driven shuttle.
Independent Evaluation	The USDOT independent evaluation team.
PMD System Administrator	Developer, operator, maintainer of PMD.
Self Driving Shuttle (SDS) Steward	The guardian on the SDS who oversees vehicle operations and safety.
SDS Vendor	Service provider of turnkey SDS and Shuttle Operations Center (SOC).
SOC Personnel	Personnel working as part of the SOC.
Traffic Signal Control Gateway Vendor	Integrator, operator, maintainer of Gateway to Pedestrian Signal System.
University at Buffalo (UB)	Subsystem oversight of SDS and the SOC. Also, operator/maintainer of secure database with Personally Identifiable Information (PII) data.
USDOT	The USDOT AO of the ITS4US project.

2.2 User Needs

The end-user related system needs are organized by the complete trip chain starting with planning needs, followed by trip execution needs and finally by travel support needs. The user needs are complemented by system owner needs. The complete set of needs are summarized into three guiding needs (GN), presented below. A complete list of User Needs can be found in the Buffalo NY ITS4US Deployment Project – Concept of Operation (FHWA-JPO-21-860).

- **GN1 – Trip Planning:** The system needs to provide the ability to create indoor and outdoor trip plans that are spontaneous (executable in a timely manner), inclusive of the traveler's needs, integrate all available modes, and have comparable or lower costs to existing modes.

- **GN2 – Trip Execution:** The system needs to allow users to execute and complete their trip plans in a safe, efficient, and reliable manner, while being provided (near) real time turn-by-turn, hands-off updates on key progress status of and changes to their trip.

- **GN3 – System Owner**: The system needs to integrate, share, and store selected datasets (external and internal) in a secure and scalable manner, operate at defined levels of performance, and maintain expected durability.

2.3 Concerns

There are no concerns at this time.

3 System of Interest (SOI)

This section provides a high-level description of the four subsystems of the Buffalo, NY ITS4US system. The following SOI diagrams are updated versions of the Context Diagrams described in the Concept of Operations (ConOps) (FHWA-JPO-21-860) and System Requirements Specification (SyRS) (FHWA-JPO-21-883).

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

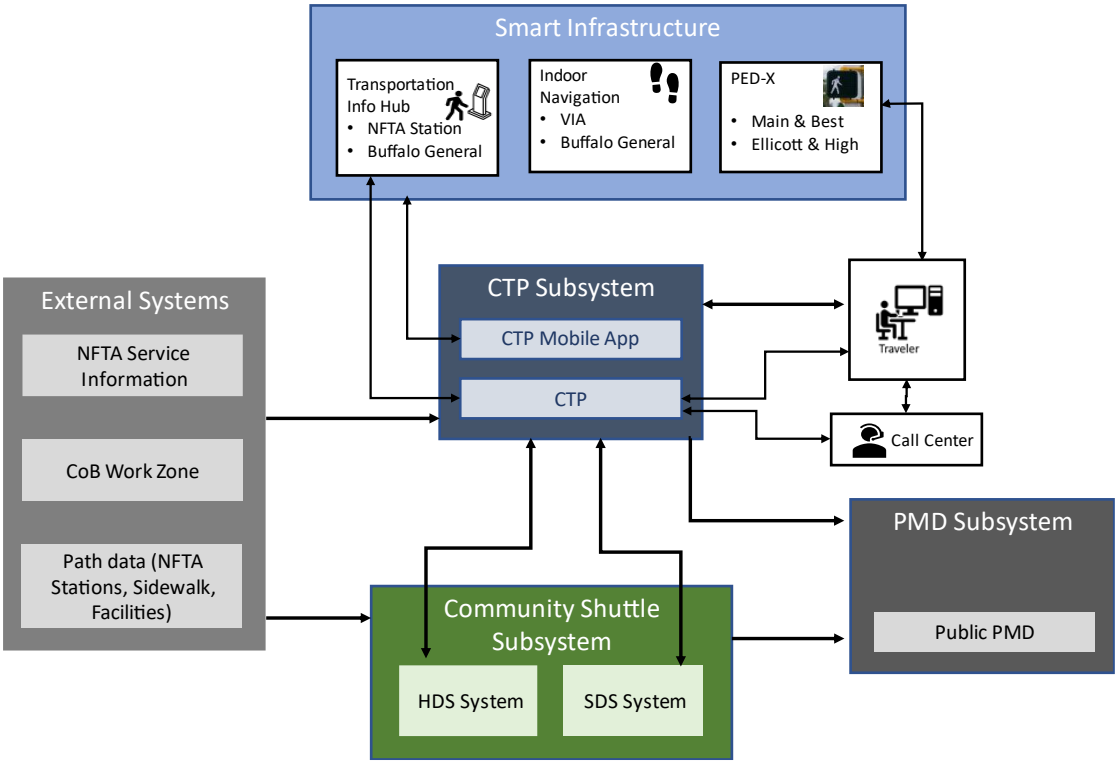

Figure 3. Buffalo Deployment Project Context Diagram
Source: Buffalo, NY ITS4US

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 are documented in **Appendix C: System of** Interest Change Log. 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., SDS and 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 5**. The table includes the information flow index, name, direction between source and destination, and target source and destination subsystem or component.

Table 5. Information Flows in System of Interest (detailed diagrams)

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, on-demand and flex route service reservations
I-4	BNMC Facility Map Update	BNMC indoor facility pathways
I-5	NFTA Map Update	NFTA station pathways (GTFS-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 and PED-X 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. This data also includes trip data that includes PED-X actuation requests.
I-12	SDS operational log	Operational and performance information from SDS
I-13	HDS operational log	Operational and performance information from HDS
I-14	Survey Data feeds	Results from surveys distributed to travelers and app users.
I-15	Web services	Web services that present performance measures in charts and graphics

Information Flow #	Information Flow Name	Information Flow Description
I-16	Direct access data files	APIs / links to access public data
I-17	Queries (requires authentication)	APIs and web services that require authentication
I-18	External Data (NFTA Performance Metrics))	NFTA Performance Data: Summary data for fixed route and other performance metrics External data also includes data that identifies impact to travel (for example weather, work zone information)
I-21	Communications between support personnel	Communications to support travelers on the CS SDS.
I-22	Signal Control Exchange	Message from the PED-X gateway to a local traffic signal controller. The information flow forwards a request made by a traveler to request signal actuation.
I-23	CoB PROW WZ	Update of work zone information associated with the public right of way developed and disseminated by the City of Buffalo

3.1 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) with other mobility partners for which they have accounts (e.g., NFTA paratransit and micro transit 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).

The CTP concept was refined from the Phase 1 ConOps. The functions are described in the following sections.

The context diagram for the CTP is shown in **Figure 4**, where:

1) the 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 5**.

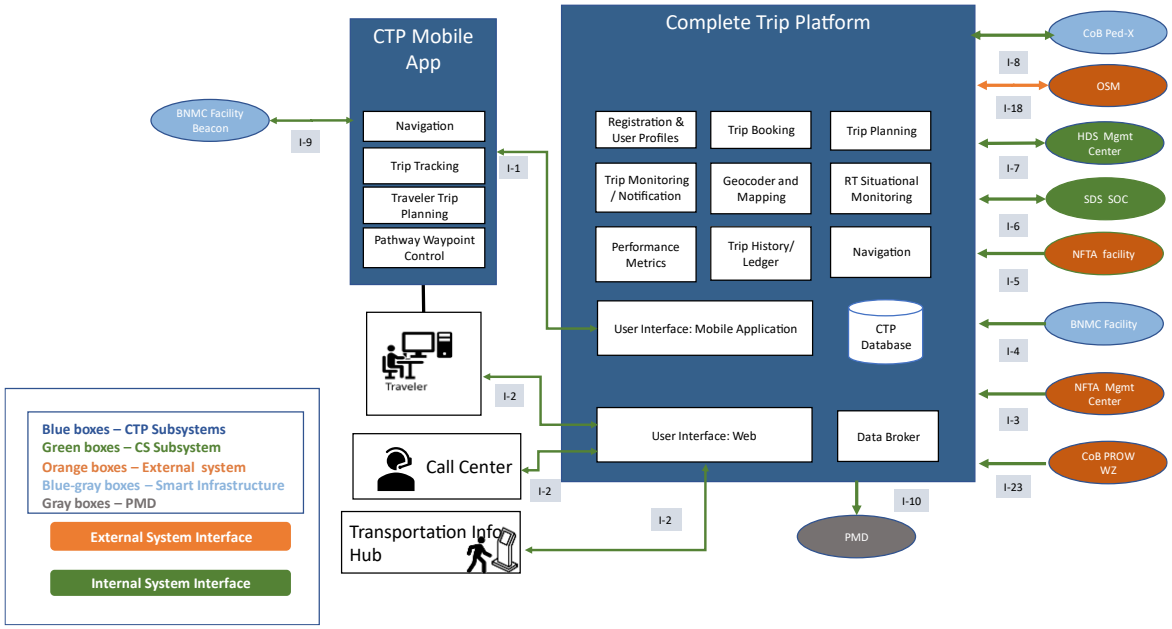

Figure 4. Complete Trip Platform Subsystem
Source: Buffalo, NY ITS4US

In general, the processing for the CTP is performed on the platform (server side). However, in the event that 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 community shuttle 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 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 Community Shuttle 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). Among the data sent to the Community Shuttle (CS) module include booking (and return booking), services required (e.g., caregiver 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) and their dynamic conditions (acquired through the real time situation monitoring function), (2) converts address and landmark locations to latitude and longitude.

Navigation (CTP and 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, blocked path).

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 situation 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) with dynamic conditions.

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 PMD to meet the Performance Measurement and Evaluation Support Plan (PMESP) requirements (Phase 1: FHWA-JPO-21-878; Phase 2: TBD). 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 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 User Interface, the Mobile Application User Interface 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.

3.2 Community Shuttle Subsystem

The Community Shuttle (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 – Self Driving and Human Driven services, each designated as a system within this architecture description. The two systems include:

- **SDS System** is composed of two autonomous vehicles 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 reservations services. The HDS will provide door-to-door, on-demand service similar to 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 community shuttle fleet is shown in **Figure 5**.

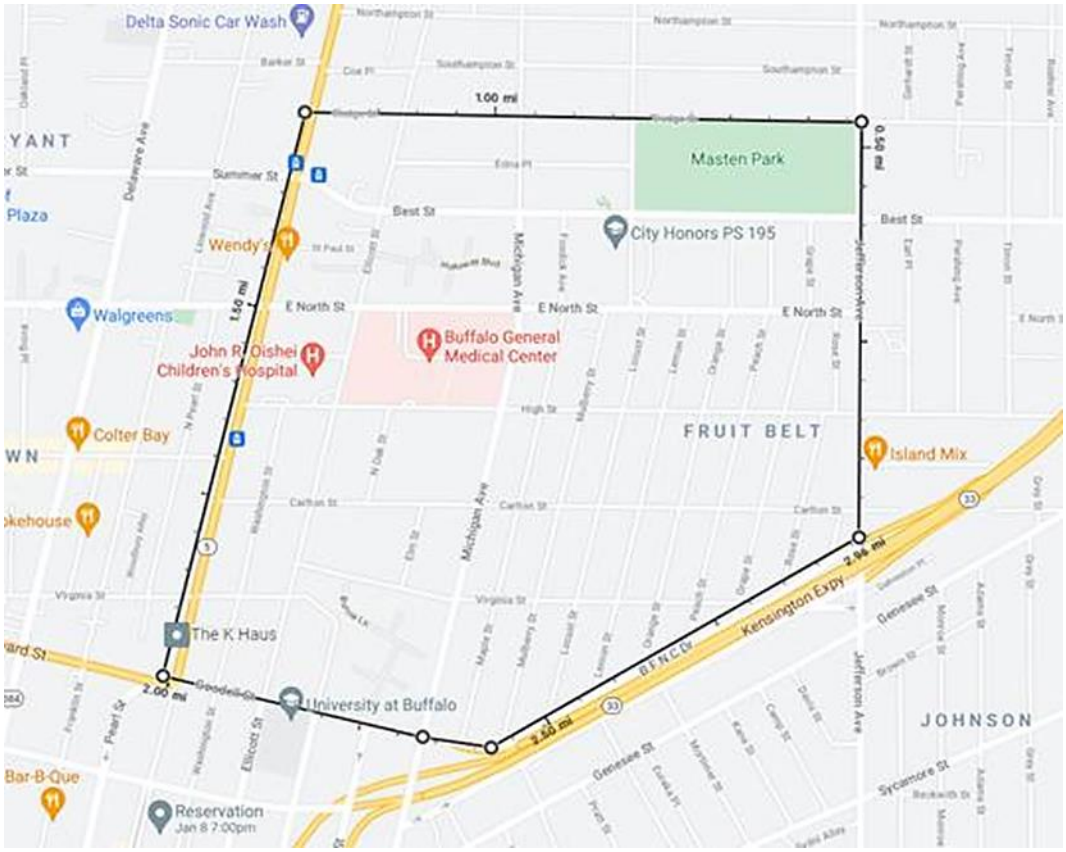

Figure 5. Proposed Service Area for the Community Shuttle
Source: Buffalo, NY ITS4US

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

3.2.1 CS SDS System

The SDS system is composed of the Autonomous Vehicle and Shuttle Operations Center (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 Operations Center (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).

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.

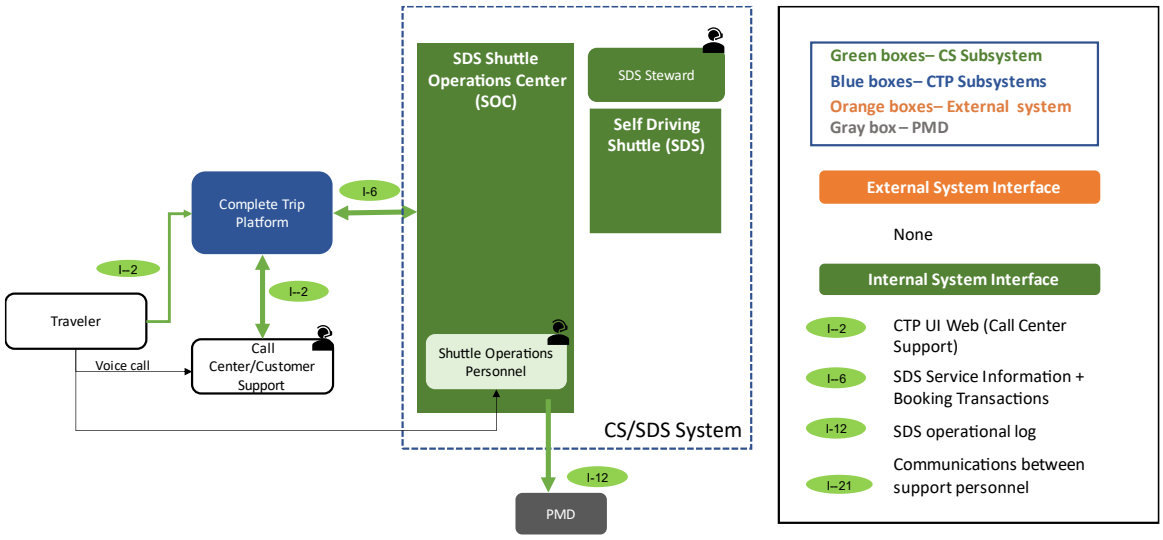

Figure 6. Community Shuttle SDS System
Source: Buffalo, NY ITS4US, 2024

Note that the indexed information flows are described in **Table 5**Error! Reference source not found..

3.2.2 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 NYSDOT Rural App reservations, dispatch and software services (a virtual system) and the vehicles will operate from the NFTA PAL dispatch and operations center.

The HDS will use an existing software APIs that are needed to transact customer booking and mobility services. Note that the indexed information flows are described in **Table 5**.

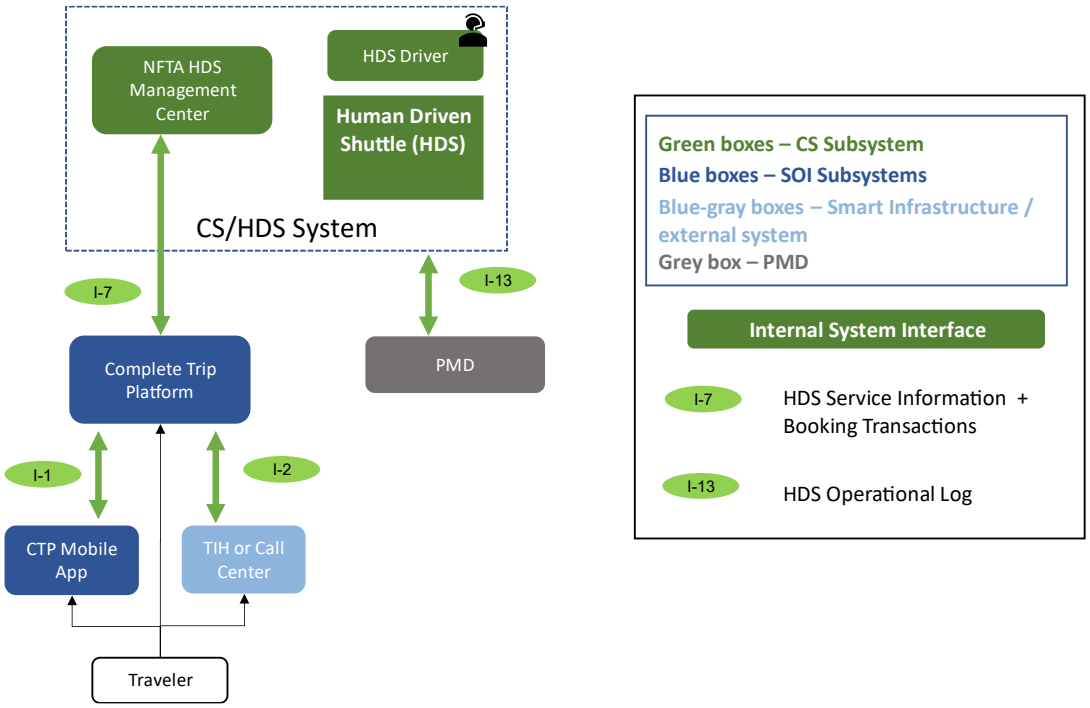

Figure 7. Community Shuttle HDS System
Source: Buffalo, NY ITS4US

3.3 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

SI 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
Buffalo, NY ITS4US

3.3.1 Transportation Information Hub Module

The TIH provides many of the same trip planning and wayfinding information as the CTP. Users can access their CTP account, 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.

3.3.2 Indoor Navigation Module

Using commonly available communications technologies already deployed in mobile handsets, 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 5**.

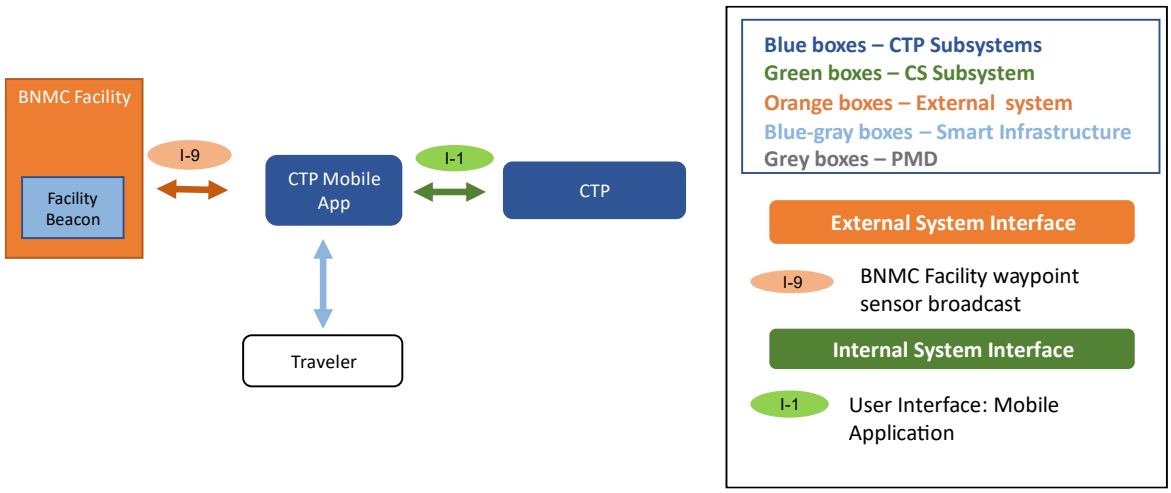

Figure 9. Indoor Navigation Module
Source: Buffalo, NY ITS4US

3.3.3 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 annunciate *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 5**.

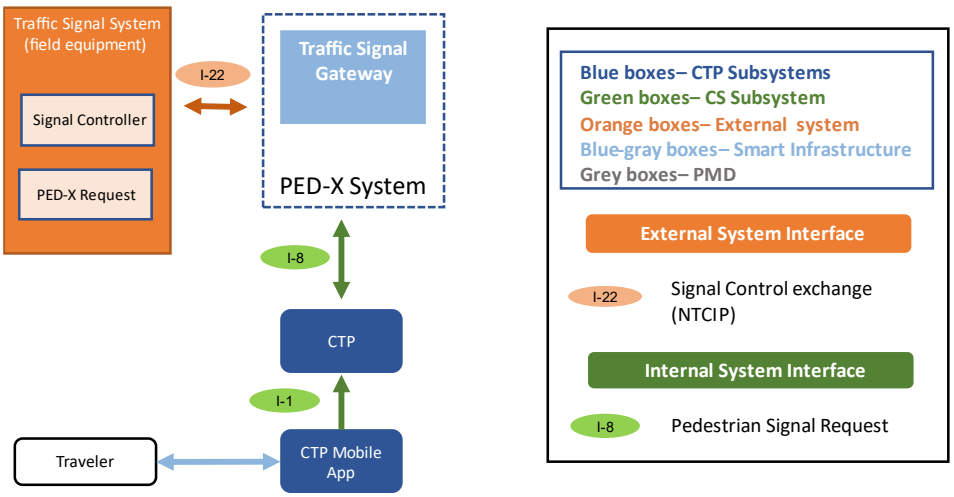

Figure 10. Pedestrian Signal Request (PED-X) Module
Source: Buffalo, NY ITS4US, 2024

3.4 Performance Measure 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 and external data sources, 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 (FHWA-JPO-21-878), Phase 1 Data Management Plan (DMP) (FHWA-JPO-21-868), 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 Management 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 5**.

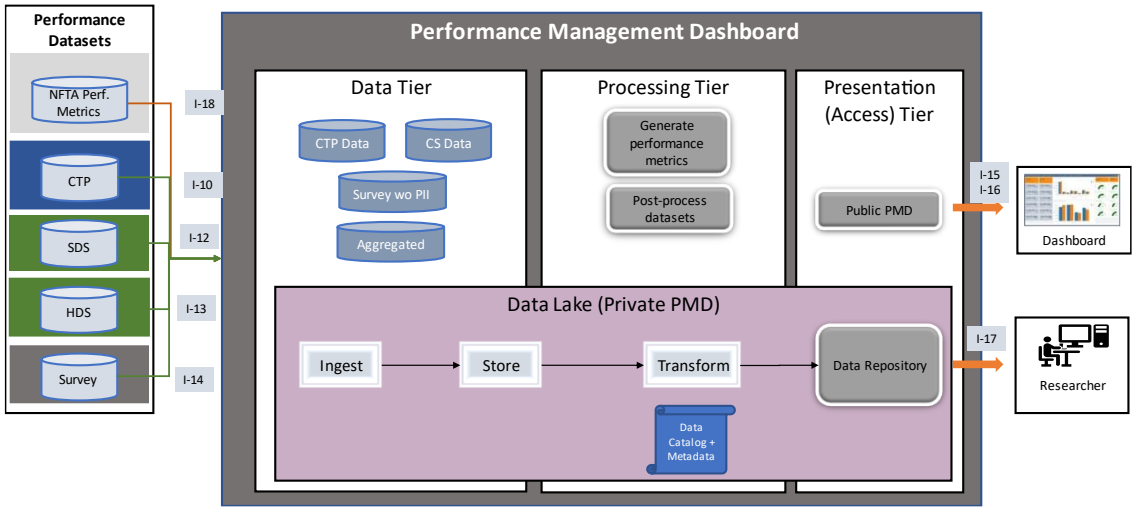

Figure 11. Performance Measure Dashboard Subsystem
Source: Buffalo, NY ITS4US, 2024

4 Architectural Views

This section describes the conceptual model of the proposed system using the ARC-IT v9.1 [1] reference architecture Enterprise, Physical, Functional and Communications viewpoints.

Please note that ARC-IT provides a list of architecture terminology, objects, and acronyms. These terms are not explained in detail in this document. The names of the stakeholders, subsystems and external systems may differ slightly from the stakeholders described in the ConOps and SOI. When introduced, the correlation to previous titles and labels are provided.

All Architecture View diagrams were generated by the Systems Engineering Tool for Intelligent Transportation (SET-IT) Version 9.1 (September 2022). SET-IT includes reference service packages (level 2 diagrams). These service packages may be customized to generate user defined objects (information flows and physical objects). These detailed diagrams may be summarized or aggregated into level 0 or 1 diagrams. Although elements in level 0 and 1 diagrams may be moved, they cannot be changed or augmented.

4.1 Enterprise View

The Enterprise view describes the relationship between stakeholders. Stakeholders that participate and interact with the system are represented as enterprise objects and the enterprise view describes their role in the “delivery and consumption” of mobility services. The enterprise view shows the roles between an enterprise object and their resources (represented by physical objects defined in the Physical and Functional views) by describing the enterprise object’s role with respect to the resource. Interactions between enterprise objects are defined by expectations, contracts, and agreements. These interactions are defined as relationships. The relationships between enterprise objects and enterprise and physical objects are largely determined by the roles.

There are four object types that are defined by ARC-IT and are represented in the Enterprise View in ARC-IT v. 9.1.

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

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

3. **Relationship:** Formal or informal coordination between enterprise objects; e.g., agreements, contracts, funding, expectations.

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

4.1.1 Project Partners and Stakeholders

The project partners and stakeholders are defined in the three tables described in Section 2.1. The tables include:

- Table 2. Traveler Stakeholder
- Table 3. Owner / Operator / Maintenance Stakeholder
- Table 4. Other Involved Personnel Stakeholder

4.1.2 Enterprise Object Relationship to Resource Objects

An inventory of the elements considered resources are listed in **Table 6**. This inventory includes the Resource Name that are included in each ARC-IT diagram from among the six physical object classes (first column). The Description (second column) describes the purpose of each element. The role assumed by each stakeholder is listed in **Table 7**. The relationship between the resource name to the ConOps designated stakeholder (as listed in SOI context diagrams) are included in the Resource Description and notated as *Context Diagram Element*. For example, *CS HDS Management Center* resource is shown as *NFTA HDS Management Center* object in the ConOps.

Table 6. Resource Inventory

Name	Description	Context Diagram Element
BNMC Facility	A facility on the BNMC campus	BNMC Facility
BNMC Facility Personnel	Maintenance personnel that manage a BNMC facility	Not included
Call Center	Call Center for travelers where a CTP call center module is located	Call Center
Call Taker	Call center call taker	Depicted as icon in Call Center
CS HDS Management Center	The community shuttle human driven shuttle center where reservations, scheduling and dispatch activities occur	NFTA HDS Management Center
CS SDS Management Center	SDS operations center	SDS Shuttle Operation Center (SOC)
CTP	The Complete Trip Platform. The sever side of the CTP that provisions APIs and the web site	Complete Trip Platform
CTP Mobile App	The mobile app that is provisioned with APIs from the CTP	CTP Mobile App
CTP System Administrator	System Administrator for CTP trip planner and mobile app	Not included
Facility Manager	Building or facility manager for traveler equipment (indoor navigation or TIH) located in a facility	Not included
HDS	The human driven shuttle.	Human Driven Shuttle (HDS)

Name	Description	Context Diagram Element
HDS Driver	The driver of the HDS shuttle	HDS Driver
Human Driven Shuttle	The Onboard Equipment (OBE) of the HDS vehicle	Human Driven Shuttle (HDS) (Vehicle and OBE are combined)
Independent Evaluation Reporting System	Location to transfer performance data to USDOT	Depicted as icon in Researcher/IE
Indoor Facility Map Update System	The system that supports updating the indoor mapping product that is used by the indoor navigation system	Combined with BNMC Facility
MetroRail Update System	System / tool that updates GTFS Pathway dataset	NFTA facility (depicted as external data source)
NFTA dispatch and operator	The NFTA dispatch and operations personnel who manage the CS HDS Management Center	Not Included (personnel)
NFTA Transit Management Center	Center where transit management service information is generated and provided to the Buffalo ITS4US system	NFTA Management Center (external data source)
PED-X and Traffic Signal Field Equipment	Traffic equipment including the PED-X actuation device at the intersection	PED-X and Traffic Signal Field Equipment
Performance Management Dashboard	A data repository for the performance data of the Buffalo ITS4US project	Performance Management Dashboard (PMD)
Personal Web Application	Traveler's display to present the CTP web application	Depicted as icon in Traveler
PMD Administrator	Developer, Operator, Maintainer of PMD	Not included
SDS	The self-driving shuttle vehicle	Self Driving Shuttle (SDS)
SDS SOC Personnel	Personnel who operate the SDS system operating center	Shuttle Operations Personnel
SDS Steward	The custodian onboard the SDS to ensure that it is operating safely	SDS Steward
Secure Performance Management Center	Secure system to store and analyze survey and metrics. System will also generate reports for delivery and presentation through the PMD	Secure Performance Management Center
Self-Driving Shuttle OBE	The on board equipment (safety and traveler information) installed and operating on the SDS	Self Driving Shuttle (SDS) combined with vehicle
Traffic Signal Gateway (Cloud)	Cloud service to certify appropriate credentials to request pedestrian signal actuation and data collection	Traffic Signal Gateway (Cloud)

Name	Description	Context Diagram Element
Transportation Information Hub	Kiosk providing a thin client interface of the CTP to traveler	Transportation Information Hub
Traveler	A traveler / volunteer who signs up and registers to use the equipment and services associated with the project	Traveler
UB data collection team	UB students who collect and encode GTFS-Pathway data	Not included

The role of the Enterprise object (e.g., stakeholder) is described in **Table 7**. Personnel are not included as a resource in this table.

Table 7. Enterprise Object Relationship to Resource Objects

Enterprise Object	Role	Resource
BNMC	Manages [Note 1]	Call Center
BNMC Facility	Manages, Owns	BNMC Facility
BNMC Facility	Manages (updates)	Indoor Facility Map Update System
City of Buffalo	Manages, Owns	PED-X and Traffic Signal Field Equipment
City of Buffalo	Manages	Traffic Signal Gateway (Cloud)
CTP System Administrator	Manages	CTP, CTP Mobile App
CTP Vendor	Manages	CTP, CTP Mobile App
NFTA	Manages, Owns	CS HDS Management Center, HDS, Human Driven Shuttle, MetroRail Station Update System, NFTA Transit Management Center
NFTA (Project)	Owns	CTP, CTP Mobile App, MetroRail Station Update System, Performance Management Dashboard, Transportation Information Hub
PMD System Administrator	Manages	Performance Management Dashboard
SDS Vendor	Manages	CS SDS Management Center [Note 2], SDS, Self-Driving Shuttle OBE
SDS Vendor	Owns	SDS, Self-Driving Shuttle OBE
Traffic Signal Control Gateway Vendor	Owns, Manages	Traffic Signal Gateway (Cloud)
Travelers	Manages, Owns	Personal Web Application
University at Buffalo	Manages	UB data collection team
University at Buffalo	Manages	Evaluation / Performance Management System, Secure Performance Management Center
University at Buffalo	Owns	CS SDS Management Center (Note 1), Secure Performance Management Center
USDOT	Manages, Owns	Independent Evaluation Reporting System

Note [1]: BNMC will coordinate the call center operator.

Note [2]: The systems and software associated with the CS SDS Management Center are owned and managed by the SDS Vendor. The local facility may be located in a University at Buffalo facility or at the vendor location.

4.1.3 Relationships

The relationships (agreements) between enterprise objects (stakeholders) are described in **Table 8**.

Table 8. Agreements/Expectations between Stakeholders

Number	Agreement or Expectation	Agreement Type	Description	Source Stakeholder	Destination Stakeholder
01	USDOT and NFTA Award Agreement	Contract	This is a contract between USDOT and NFTA for the ITS4US Deployment Project in Buffalo.	USDOT	NFTA
02	NFTA and BNMC Contract Agreement	Contract + Information Provision Agreement	This is a contract between NFTA and BNMC to deliver Phase 2 and 3 of the NFTA ITS4US Deployment Project (hereafter referred to as the NFTA Project).	NFTA	BNMC
03	BNMC and RSG Contract Agreement	Contract + Information Provision Agreement	This is a contract between BNMC and RSG to deliver performance management services for the NFTA project.	BNMC	RSG
04	BNMC and ICF Contract Agreement	Contract + Information Provision Agreement	This is a contract between BNMC and ICF to deliver project management, outreach and technical services for the NFTA project.	BNMC	ICF
05	BNMC and UB Contract Agreement	Contract + Information Provision Agreement	This is a contract between BNMC and UB to deliver the self-driving shuttle subsystem and performance management services for the NFTA project.	BNMC	UB
06	UB and SDS Vendor Operations and Maintenance Agreement	Operations Agreement / Contract + Information Exchange Agreement	This is an Operations Agreement and contract between UB and the SDS Vendor to deploy, operate and maintain the SDS subsystem and integration services for the NFTA project. It also includes an agreement to provide data on a regular and recurring basis based on the contract agreement.	UB	SDS Vendor (Adastec)
07	NFTA Buffalo ITS4US Project and City of Buffalo	Operations Agreement + Information Exchange and Action Agreement	This is an Operations Agreement between City of Buffalo and NFTA Project to operate and maintain the Traffic Signal Control Gateway (Miovision system) for the NFTA project. It also includes an Information Exchange and Action Agreement.	NFTA Project	City of Buffalo

Number	Agreement or Expectation	Agreement Type	Description	Source Stakeholder	Destination Stakeholder
08	ICF and Miovision Operations Agreement	Operations Agreement (contract) + Information Exchange and Action Agreement	This is an Integration and Operations contract between ICF and Miovision to integrate and operate the Traffic Signal Control Gateway (Miovision system) for the NFTA project. It also includes an Information Exchange and Action Agreement.	ICF	Traffic Signal Control Gateway Vendor (Miovision)
09	ICF and ETCH Development and Operations Agreement	Development and Operations Agreement (contract) + Information Exchange and Action Agreement	This is a development, integration, operations and maintenance contract between ICF and ETCH to integrate and operate the CTP system for the NFTA project. It also includes an Information Exchange and Action Agreement.	ICF	CTP Vendor (Etch)
10	ICF and Indoor Navigation Vendor Operations Agreement	Operations Agreement / Contract	This is an Operations Agreement and contract between ICF and the Indoor Navigation Vendor to deploy, operate and maintain the indoor navigation system and integration services for the NFTA project.	ICF	Indoor Navigation Vendor (CXApp)
11	NFTA (NFTA Stations) Facility Manager Operations Expectation	Operations Expectation	This is an Operations expectation between NFTA and NFTA Station Facility Manager to manage NFTA Project devices in MetroRail stations.	NFTA	NFTA Metro Rail Facilities
12	BNMC and ICF Operations Agreement	Development and Operations Agreement (contract) + Information Exchange and Action Agreement	This is a development, integration, operations and maintenance contract between BNMC and ICF to integrate and operate the PMD system for the NFTA project. It also includes an Information Exchange and Action Agreement.	BNMC	PMD System Administrator (ICF)
14	CoB – NFTA Project Information Provision Agreement for Work Zone Information	Information Provision Agreement	This is an Information Provision Agreement between City of Buffalo and the NFTA Project to coordinate publication of Work Zone data in the project area particularly sidewalk data for the Main and Best intersection.	CoB	NFTA
15	University at Buffalo and DMV SDS Permit	DMV AV Testing Permit	This is a Permit between New York State Division of Motor Vehicles and University at Buffalo to allow testing of the SDS in the project region on condition that the vehicle meets vehicle regulations.	UB	DMV

Number	Agreement or Expectation	Agreement Type	Description	Source Stakeholder	Destination Stakeholder
16	BNMC and BNMC Facility Information Exchange and Action Agreement	Information Exchange and Action Agreement	This is an Information Exchange and Action Agreement between BNMC and BNMC Facilities (VIA and Kaleida Health) to operate and/or integrate indoor navigation and TIH tools in their facilities.	BNMC	BNMC Facility
17	BNMC and Call Center Information Exchange and Action Agreement	Information Exchange and Action Agreement	This is an Information Exchange and Action Agreement between BNMC and Call Center to operate and/or integrate call center support for the NFTA Project.	NFTA Project	Call Center
18	NFTA Project and Travelers Information Exchange Expectation	Information Exchange Expectation	This is an Information Exchange Expectation between NFTA and Travelers.	NFTA Project	Travelers
19	Travelers and NFTA Project Information Exchange and Action Expectation	Information Exchange and Action Expectation	This is an Information Exchange and Action Agreement between Travelers and the NFTA Project.	Travelers	NFTA Project
20	NFTA Travelers Consent and recruitment agreement	Consent and Recruitment Agreement	This is a Consent and Recruitment Agreement between UB and Travelers that follows the Independent Review Board (IRB) protocols.	UB	Travelers

4.1.4 Enterprise Relationship Diagram

The Enterprise Architecture viewpoint diagram that illustrates the expectations and agreements between stakeholders are shown in **Figure 12**. Agreements are referenced by the numbers shown within the adjacent boxes and are consistent with the numbered agreements and expectations listed in **Table 8.**

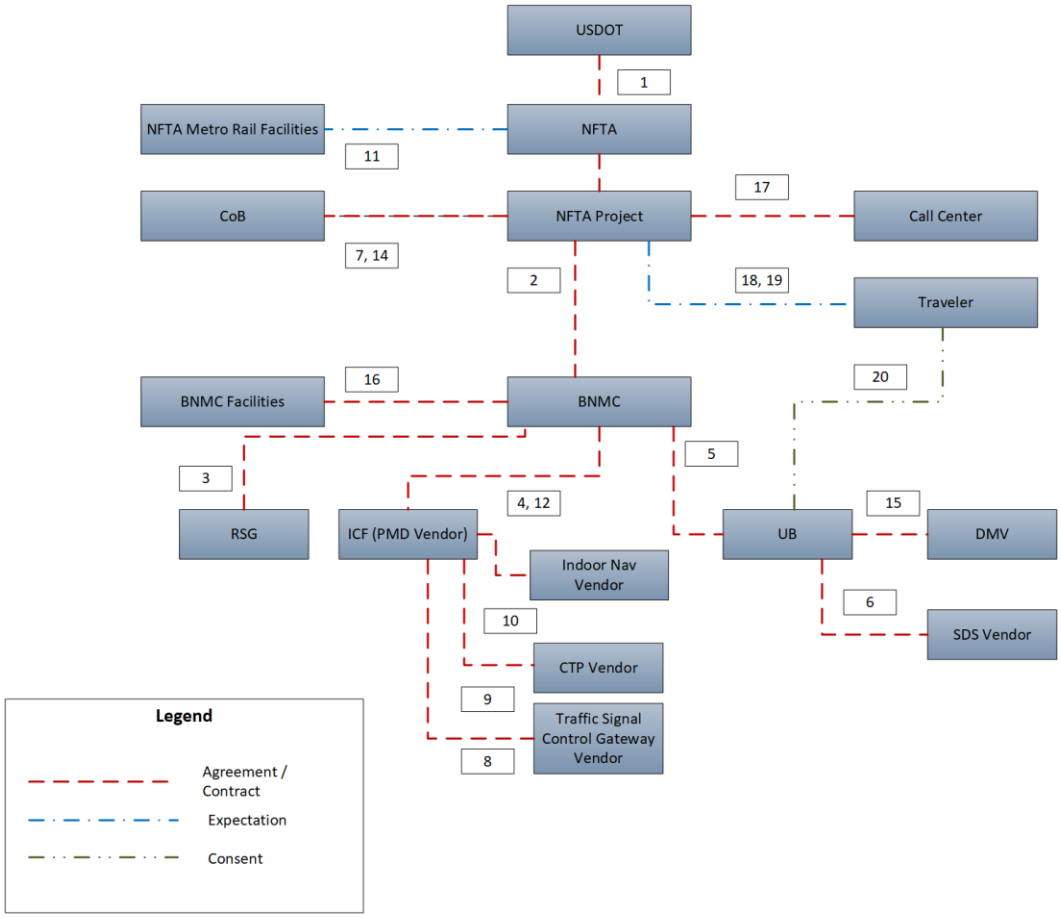

Figure 12. Enterprise Architecture – Agreements and Relationships
Source: Buffalo, NY ITS4US, 2024

4.2 Physical View

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

In accordance with the ARC-IT website, [ARC-IT v 9] the following objects are defined in the Physical Viewpoint.

1. **Physical Object (P-Object):** Person, place, or thing that participates in ITS. Physical Objects are defined in terms of the applications they support, the processing they include, and their interfaces with other physical objects. When instantiated, the physical object becomes an **Element**.

   The P-Objects are grouped into five classes: Center, Field, Support, Personal and Vehicle. Physical Objects are defined with scope such that they are under the control of a single enterprise object. Each object class is designated by a special color.

   i. **Center:** An element that provides application, management, administrative, and support functions from a fixed location not in proximity to the road network. The terms "back office" and "center" are used interchangeably. Center is traditionally a transportation-focused term, evoking management centers to support transportation needs, while back office generally refers to commercial applications. Center class objects are shown as teal/turquoise boxes.
   ii. **Field:** Infrastructure proximate to the transportation network which performs surveillance (e.g., traffic detectors, cameras), traffic control (e.g., signal controllers), information provision (e.g., Dynamic Message Signs (DMS)) and local transaction (e.g., tolling, parking) functions. Typically governed by transportation management functions running in centers. Field also includes connected vehicle roadside equipment and other non-DSRC wireless communications infrastructure that provides communications between mobile elements and fixed infrastructure. Field class objects are shown as orange boxes.
   iii. **Support:** A center that provides a non-transportation specific service. Typically, these are enabling functions, such as communications facilitation, security or management. Support class objects are shown as green boxes.
   iv. **Personal:** Equipment used by travelers to access transportation services pre-trip and enroute. This includes mobile/handheld as well as desktop equipment owned and operated by the traveler. Personal objects are shown as yellow boxes.
   v. **Vehicle:** Vehicles, including driver information and safety systems applicable to all vehicle types. Vehicles are shown as blue boxes.
2. **Functional Object:** The building blocks of the physical objects of the physical view. Functional objects group similar processes of a particular physical object together into an "implementable" package. The grouping also takes into account the need to accommodate various levels of functionality. Since functional objects are both the most detailed components of the Physical View and tied to specific service packages, they provide the common link between an interface-oriented architecture definition and deployment-oriented applications. Functional objects provide the functionality defined by P-Specs in the Functional View.
3. **Information Flow:** Information that is exchanged between physical objects in the physical view. Information flows and their associated communication requirements provide the highest-level definition of interfaces. Information flows are related to entity relationships in the Enterprise View and are more fully detailed in the Communications View. Information Flows are characterized by Flow Characteristics, which imply various communications protocol standards. They are always accompanied by a provision agreement relationship. Such relationships are formal if both participants are centers, support or field equipment. They are nearly always informal if between two mobile objects. If between mobile and fixed, the relationship may be formal if personalized or individually targeted information is exchanged.
4. **Terminator:** Physical object without defined functionality. Outside the ARC-IT system boundary.

5. **Service Package (Physical) Diagram:** A summary diagram illustrating all of the P-Objects, functional objects and Information Flows likely needed to support the Service Package.

The legend for all Physical View diagrams is presented in **Figure 13**.

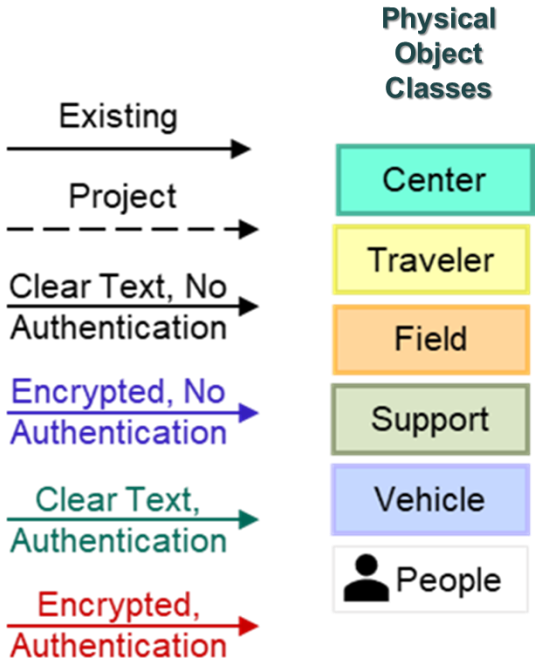

Figure 13. Legend for Physical View Diagrams
Source: Buffalo, NY ITS4US

4.2.1 Physical View for all Applications

The Physical View shows high level (or level 0) elements and interactions between all physical objects (elements). Each application is detailed in level 2 diagrams (**Section 4.2.2**) represented by service packages. The service package includes physical objects, functions, and information flows. The Level 0 Physical View is generated automatically by SET-IT and is shown in **Figure 14**.

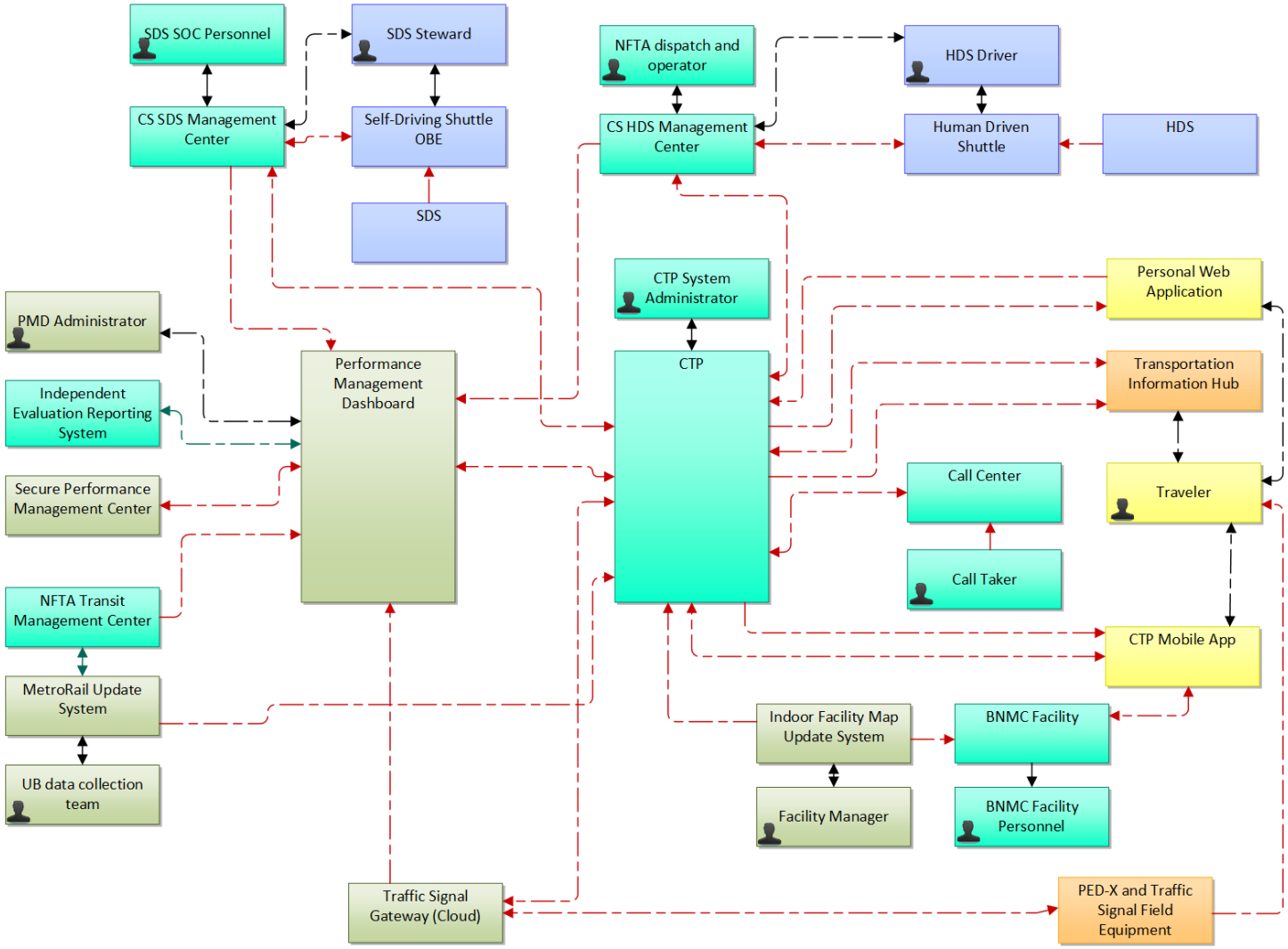

Figure 14. Physical Viewpoint Level 0 for NFTA ITS4US
Source: Buffalo, NY ITS4US, 2024

4.2.2 Service Package Diagram

Level 2 diagrams are represented by service packages. The ARC-IT 9.1 includes several service packages that reflect the framework for building the NFTA ITS4US system concept. The following service packages (and their diagrams) are listed below:

- DM02: Performance Management Dashboard (**Figure 15**)
- PT03: Dynamic SDS Operations (**Figure 16**)
- SU04: Facility Map Management (**Figure 17**)
- SU04: MetroRail Map Management (**Figure 18**)
- PT03: Dynamic HDS Operations (**Figure 19**)
- VS12: Pedestrian Signal Crossing (**Figure 20**)
- TI05: Travel Services Information and Reservations (**Figure 21**)
- TI04: Infrastructure-Provided Indoor Wayfinding (**Figure 22**)

A comprehensive list of the functions and information flows contained in these service packages are described in **Table 9Error! Reference source not found.** and **Table 11**, respectively.

4.2.2.1 DM02: Performance Management Dashboard

The PMD diagram (**Figure 15**) is an instantiation of the DM02 Performance Monitoring Service Package. In tailoring the ARC-IT DM02 service package, the Buffalo ITS4US project "…uses information collected from … operational data feeds from centers to support performance monitoring and other uses of historical data including transportation planning, condition monitoring, safety analyses, and research… Additional data are collected including… [planned data] and other operational decision [datasets] to provide context for measured transportation performance and additional safety and mobility-related measures. More complex performance measures may be derived from the collected data." (Source: ARC-IT v9)

The Dashboard collects summary information from subsystems and systems, as well as external systems such as NFTA fixed route on-time performance. No PII is stored in the PMD. The PMD applies quality checks (curation processes), on-line analysis and visualization services to users of the system. Authenticated personnel are provided access to summary CTP usage data by type and duration. The registration, operational and usage data are provided without any PII. In addition, a Secure Performance Management Center (SPMC) stores survey results from system participants. The SPMC shares summary data with the PMD for visualization and on-line analysis.

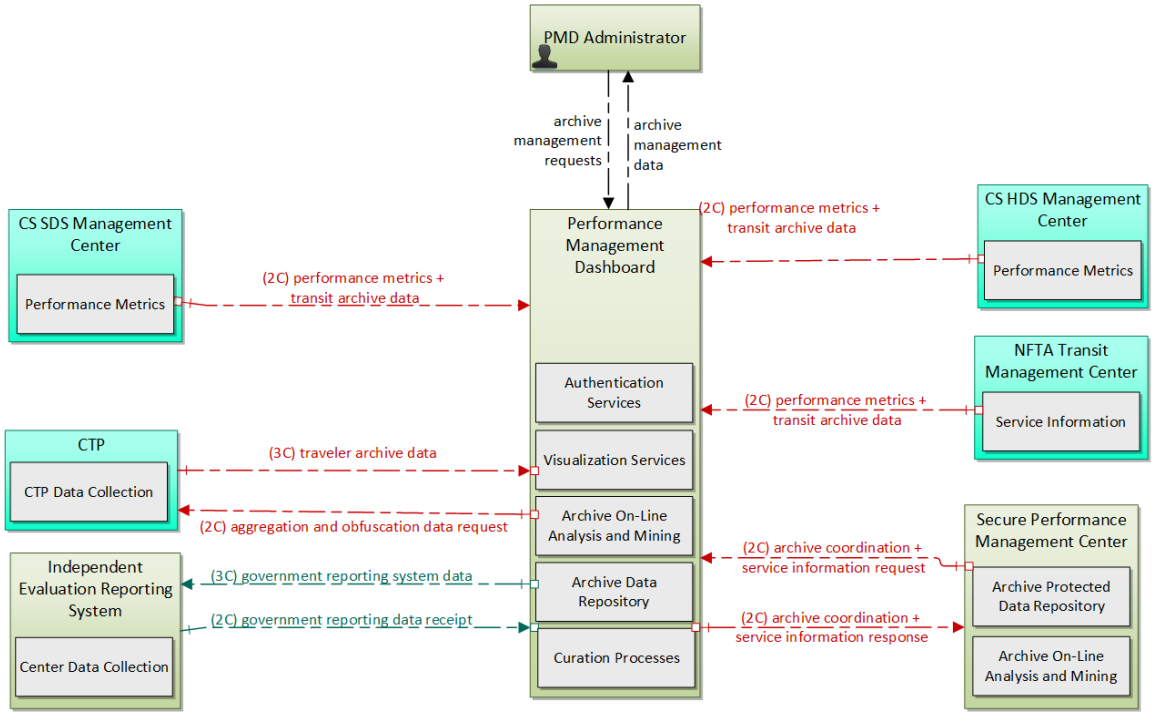

Figure 15. DM02: Performance Management Dashboard
Source: Buffalo, NY ITS4US, 2024

4.2.2.2 PT03: Dynamic SDS Operations

The Dynamic SDS Operations diagram (**Figure 16**) is an instantiation of the PT03: Dynamic Transit Operations service package. In tailoring the ARC-IT PT03 service package, the Buffalo ITS4US project "… allows travelers to request trips and obtain itineraries using a personal device such as a smart phone, tablet, [call center], or personal computer. The trips and itineraries cover [the SDS service provision]. This service package builds on existing technology systems such as computer-aided dispatch/ automated vehicle location (CAD/AVL) systems and automated scheduling software, providing a coordination function within and between transit providers that would dynamically schedule and dispatch or modify the route of an in-service vehicle by matching compatible trips together." (Source: ARC-IT v9)

The SDS Management Center depicts the SDS Shuttle Operation Center (SOC). The SOC manages (on-demand) flex service reservation requests from the CTP. The reservations drive Scheduling and Dispatch Operations of SDS vehicles. In addition, the SOC provides real time vehicle and schedule status information, including if the SDS is delayed or is operating in degraded mode. SOC Personnel manage planning, operations and maintenance of the SDS service, vehicles and SDS Stewards. They also manage traveler incidents and complaints through on-board services such as the Transit Vehicle Security (e.g., CCTV and emergency call). The SDS Steward is onboard the vehicle to facility operations of the SDS vehicle and passenger comfort. They are trained to manage incidents and events that occur onboard the vehicle including operating the vehicle. The SDS onboard operations service (referred to by ARC-IT as the Transit Vehicle On-Board Paratransit Operations) includes audio and visual, next stop and safety information.

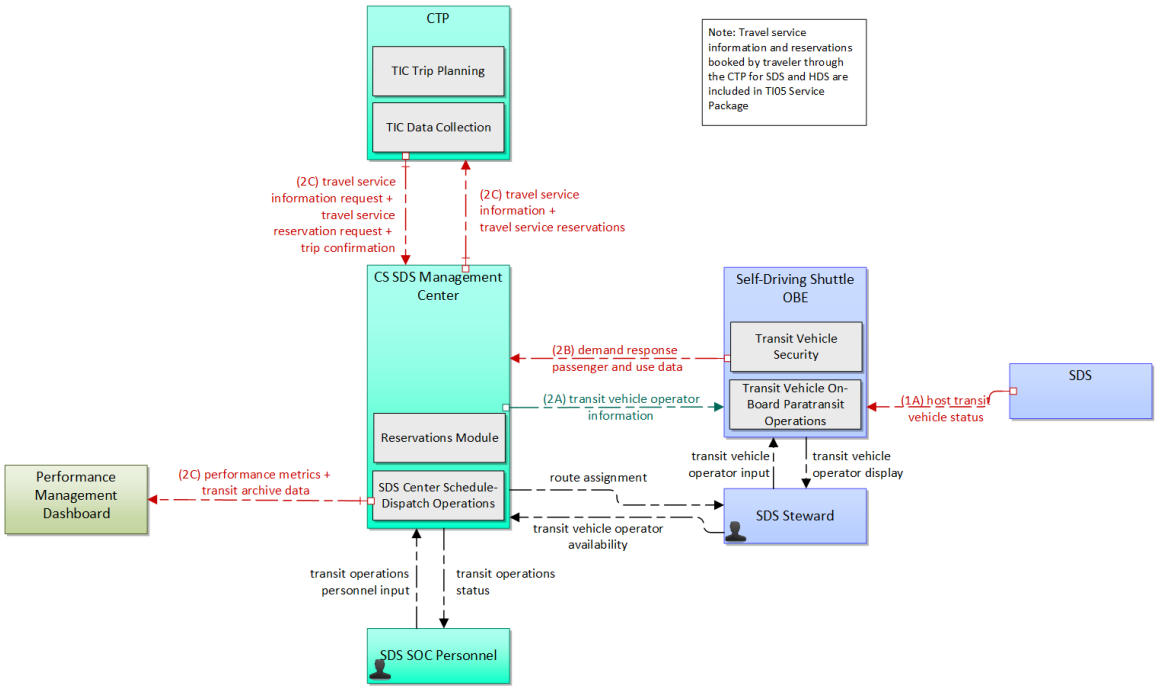

Figure 16. PT03: Dynamic SDS Operations
Source: Buffalo, NY ITS4US, 2024

4.2.2.3 SU04: Facility Map Management

The Facility Map Management diagram (**Figure 17**) is an instance of the SU04: Map Management service package. In tailoring the ARC-IT SU04: Map Management service package, the Buffalo ITS4US project "…defines interfaces that can be used download or update all types of map data [including indoor facility pathways] used to support… [wayfinding and navigation]. This map data will be accessed by centers, field, and vehicle physical objects…." (Source: ARC-IT v9)

The facility map management will be conducted as an external service in coordination between the Indoor Navigation Vendor and BNMC facility. An agreement with the facility owner will be executed to ensure that the CTP receives updated, current path information from the indoor facility. The format of the map update and status to the CTP is yet to be determined.

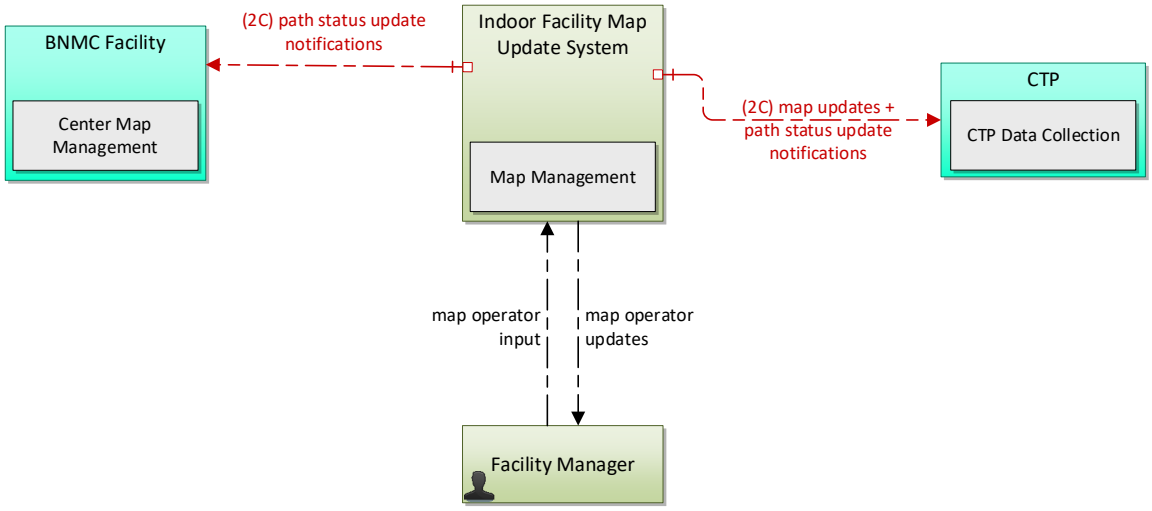

Figure 17. SU04: Facility Map Management
Source: Buffalo, NY ITS4US

4.2.2.4 SU04: MetroRail Map Management

The MetroRail Map Management diagram (**Figure 18**) is an instance of the SU04: Map Management service package. In tailoring the ARC-IT SU04: Map Management service package, the Buffalo ITS4US project "…defines interfaces that can be used download or update all types of map data [including metro rail station pathways] used to support… [wayfinding and navigation]. This map data will be accessed by centers, field, and vehicle physical objects…." (Source: ARC-IT v9)

The MetroRail facility map (pathway) update will be conducted as an external service in coordination between the NFTA facilities and UB students. An agreement between NFTA, UB and the Buffalo ITS4SU project will be executed to ensure that the CTP receives updated, current path information for the two MetroRail stations in the project area. The format of the map update and status to the CTP will use GTFS-Pathway specification.

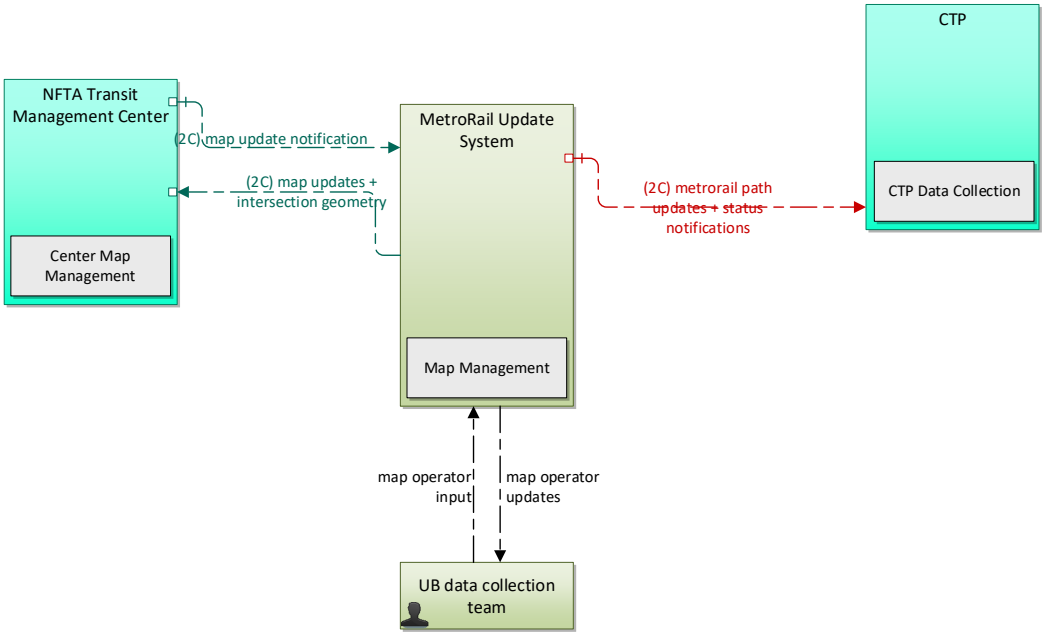

Figure 18. SU04: MetroRail Map Management
Source: Buffalo, NY ITS4US

4.2.2.5 PT03: Dynamic HDS Operations

The Dynamic HDS Operations diagram (**Figure 19**) is an instantiation of the PT03: Dynamic Transit Operations service package. In tailoring the ARC-IT PT03 service package, the Buffalo ITS4US project "… allows travelers to request trips and obtain itineraries using a personal device such as a smart phone, tablet, [call center], or personal computer. The trips and itineraries cover [the HDS service provision]. This service package builds on existing technology systems such as computer-aided dispatch/ automated vehicle location (CAD/AVL) systems and automated scheduling software, providing a coordination function within and between transit providers that would dynamically schedule and dispatch or modify the route of an in-service vehicle by matching compatible trips together." (Source: ARC-IT v9)

The Dynamic HDS Operations service package will use existing NFTA reservations, scheduling and operations software, vehicles, and operations and maintenance staff and facilities for the HDS operations. NFTA paratransit operations and dispatch staff will manage and oversee the operations including operator assignment, scheduling, and dispatch services to manage HDS on-board vehicle monitoring and communications between the dispatch and HDS driver, and other critical services. A on-demand service system (developed for New York State Department of Transportation) will be configured to manage on-demand reservation requests from the CTP including all real time HDS status information.

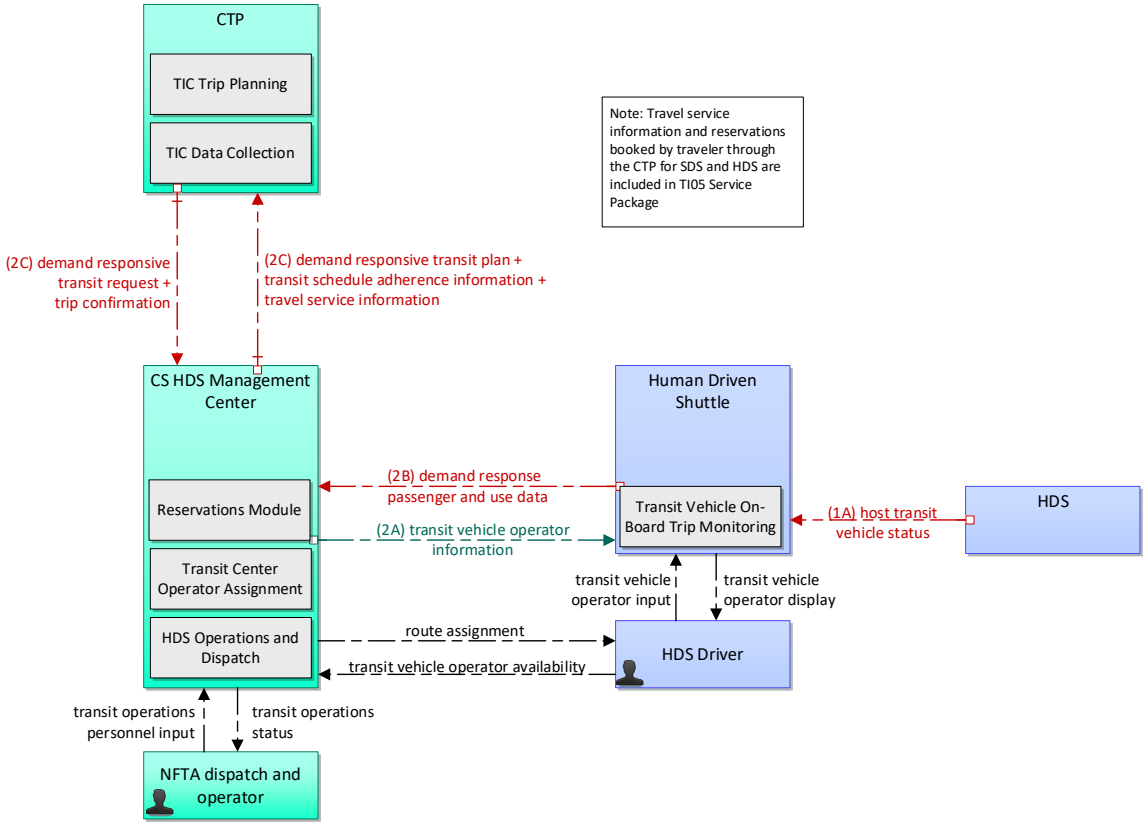

Figure 19. PT03: Dynamic HDS Operations
Source: Buffalo, NY ITS4US

4.2.2.6 VS12: Pedestrian Signal Crossing

The Pedestrian Signal Crossing diagram (**Figure 20**) is an instantiation of the VS12: Pedestrian Signal Crossing service package. In tailoring the ARC-IT VS12 service package, the Buffalo ITS4US project "… supports … systems used to interact with pedestrians…on pathways that intersect the main vehicle roadways. These systems … [integrate traffic and pedestrian] information from roadside or intersection detectors and new forms of data from wirelessly connected, non-motorized traveler-carried mobile devices to request right-of-way … when to cross and how to remain aligned with the crosswalk or pathway … This service package will enable a service call to be routed to the traffic controller... [via the Traffic Signal Gateway from the CTP which is triggered by a mobile device of a registered person, with a pre-registered travel planning account] … after confirming the direction and orientation of the roadway that the individual is intending to cross." (Source: ARC-IT v9)

The Pedestrian Signal Crossing (PED-X) operations uses existing Traffic Signal Control equipment including pedestrian signal equipment to actuate requests of travelers following their trip plan as they approach the planned intersection crossing. As the traveler approaches the intersection, the mobile app tracks their progress from their trip plan. When they are close to the crossing, the app will contact the CTP to indicate that the traveler is near the pedestrian crossing. The CTP will contact the Traffic Signal Gateway through a secure link and request actuation of the pedestrian signal request function. The Traffic Signal Gateway will manage the request and

forward it to the Traffic Signal controller. Through the Roadway Mixed Use Crossing Safety function, the actuation will be executed, and the PED-X will display and annunciate the appropriate message (e.g., walk / don't walk).

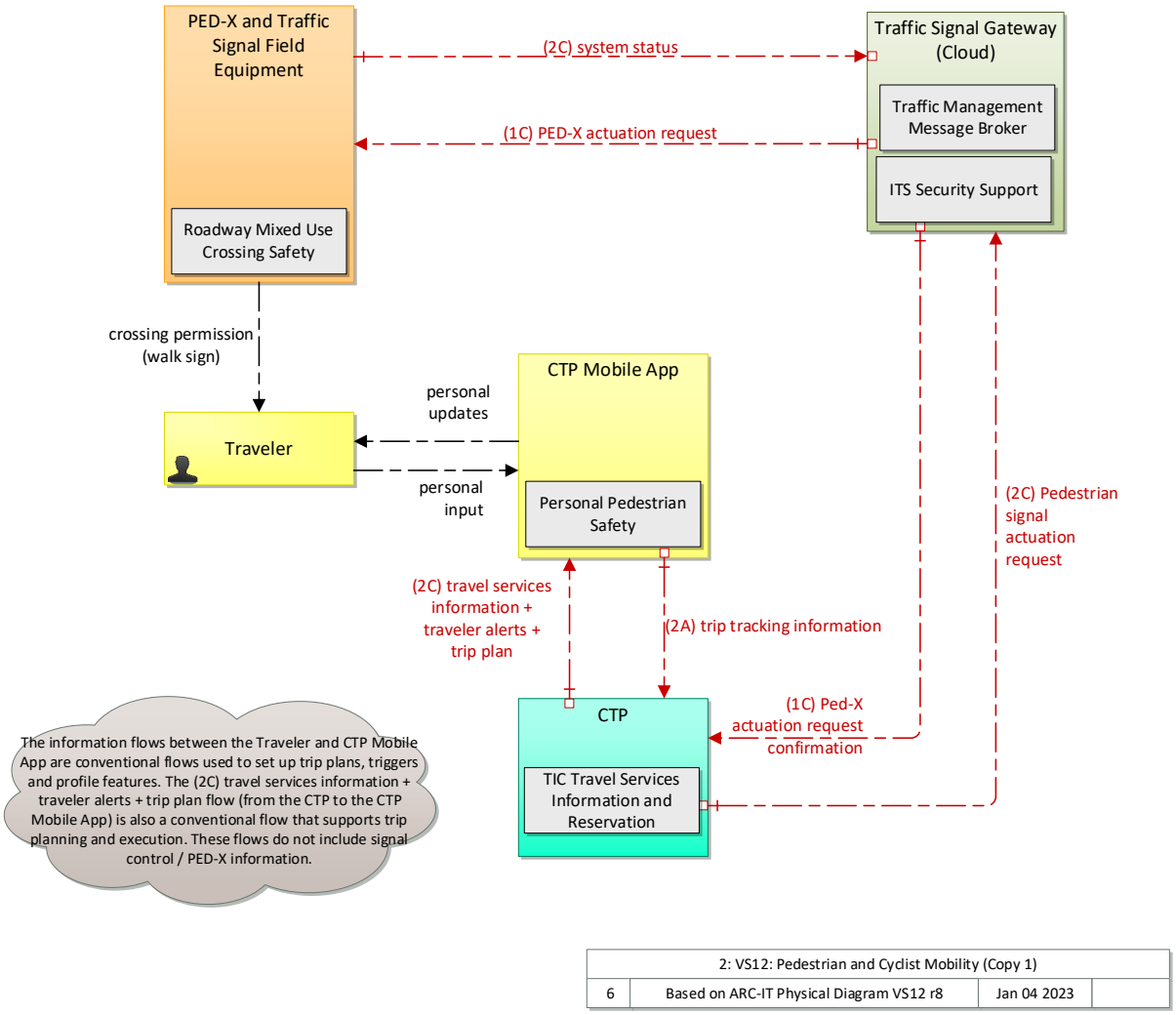

Figure 20. VS12: Pedestrian Mobility
Source: Buffalo, NY ITS4US

Note that the Information Flows between the **Traveler** and **CTP Mobile App** are conventional flows used to set up trip plans, triggers and profile features. The **(2C) travel services information + traveler alerts + trip plan flow** (from the **CTP** to the **CTP Mobile App**) is also a conventional flow that supports trip planning and execution. *These flows do not include signal control / PED-X information.*

4.2.2.7 TI05: Travel Services Information and Reservations

The Complete Trip Travel Services Information and Reservations diagram (**Figure 21**) is an instantiation of the TI05: Travel Services Information and Reservations service package. In tailoring the ARC-IT TI05 service package, the Buffalo ITS4US project "…provides travel service information and [community shuttle] reservation services to the traveler pre-trip and while enroute. This includes information for… [hands-free, turn-by-turn directions and interactive support for] the traveler." (Source: ARC-IT v9)

The Complete Trip Platform includes four information channels for travelers to access CTP services. These include their personal web application, CTP Mobile App, Transportation Information Hub (kiosk) and Call Center (through a Call Taker). The CTP provides personalized trip planning services through traveler registration and profile information (stored in the Traveler Information Center (TIC) Data Collection), trip planning and reservations to the CS service types (HDS and SDS), and wayfinding information to their mobile app. The CTP provides all personalized trip planning features through all the customer channels. The system provides real time status updates to their channel preferences.

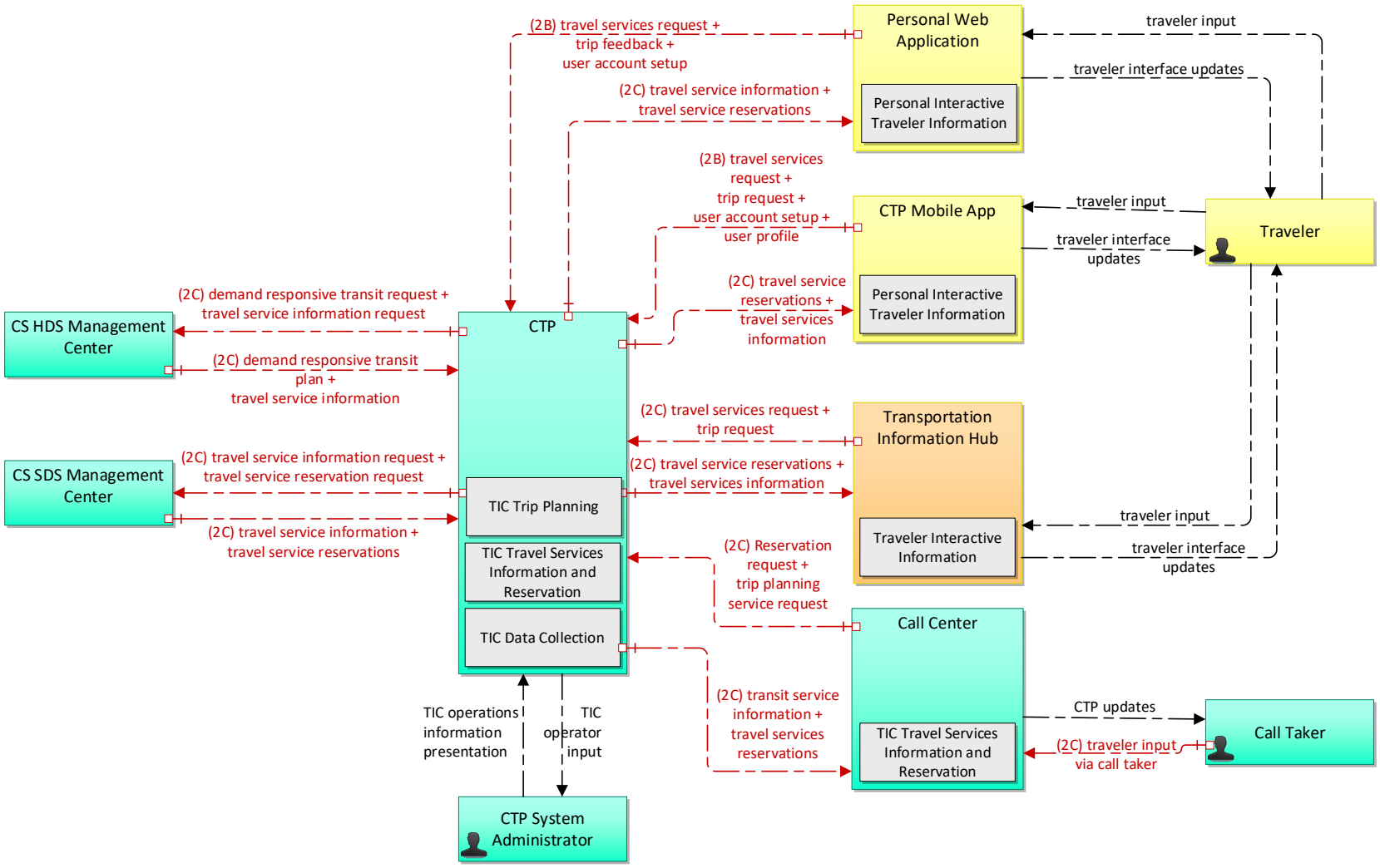

Figure 21. TI05: Travel Services Information and Reservations

Source: Buffalo, NY ITS4US

4.2.2.8 TI04: Infrastructure-Provided Indoor Wayfinding

The Infrastructure-Provided Indoor Navigation diagram (**Figure 22**) is an instantiation of the TI04: Infrastructure-Provided Trip Planning and Route Guidance service package. In tailoring the ARC-IT TI04 service package, the Buffalo ITS4US project "…offers the user trip planning and enroute guidance services [in facilities and indoor pathways]. After generating] a trip plan, including a multimodal route and associated service information, based on traveler preferences and constraints. Routes may be based on static information or reflect real time network conditions. … [The turn-by-turn route guidance that is provided by the CTP Mobile App which monitors sensors mounted as waypoints throughout the facility.]" (Source: ARC-IT v9)

The Indoor Navigation System is depicted in the TI04 service package. The service is enabled through waypoints (or beacons) installed throughout the BNMC facility that broadcast information about the beacon. The mobile app includes functions that detect the traveler's location (Personal Location Determination) and identify an efficient pathway from the facility entrance to their destination. Through the pathway navigation module, the traveler is guided through the facility using the beacon technology.

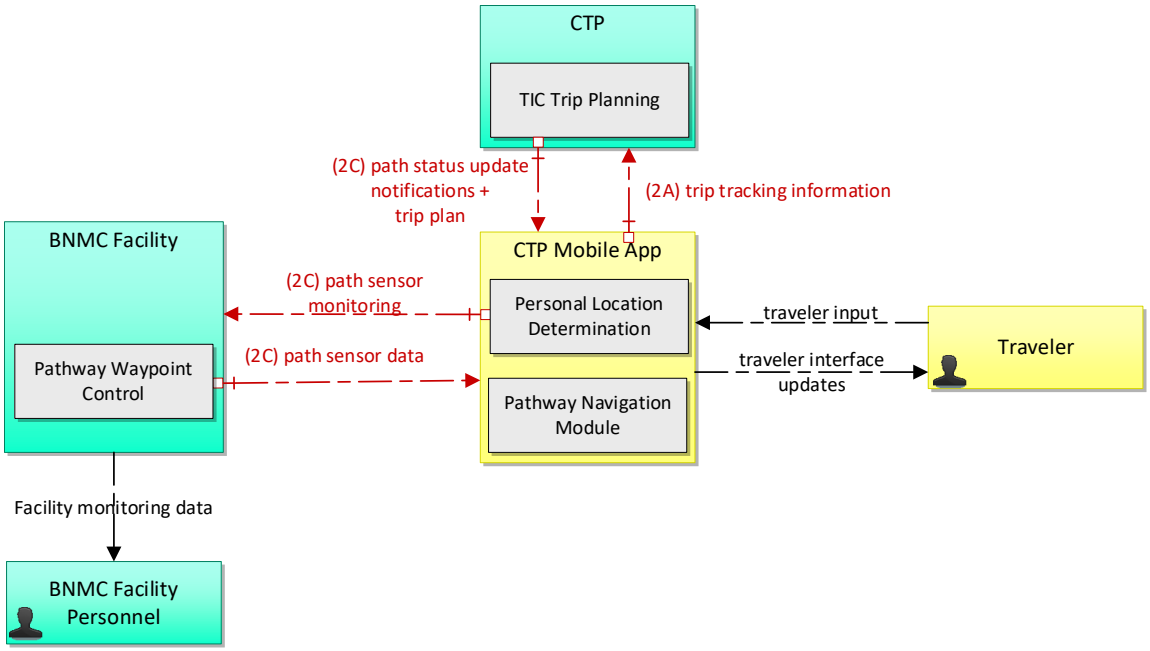

Figure 22. TI04: Infrastructure-Provided Indoor Wayfinding
Source: Buffalo, NY ITS4US

4.3 Functional View

The Functional View describes the functions and information flows performed by the elements in the system. These functions control and manage system behavior. The functions reflect the functions described in the context diagram although not all the functions are present in the Architecture View because they are internal to a physical object (e.g., center, field device, personal device), or aggregated into a composite function described in the ARC-IT 9.1. The Physical Object Layer 1 diagram shows the high-level functions and flows that reflect Buffalo

ITS4US subsystems. As a Layer 1 diagram, **Figure 23** describes the Complete Trip Platform subsystem by combining all the service packages with their respective functions and information flows of the subsystem. In addition to the Layer 1 diagram, this section includes a comprehensive set of functions listed in **Table 9**Error! Reference source not found.. Detailed information flows are included in the Communications View with their communications solution (see **Table 11**).

4.3.1 Trip Planning and Related Subsystems

The Layer 1 Trip Planning and Related System functional view, as shown in **Figure 23**, provides a comprehensive view of the CTP functions (Service Package PI05) and its interaction with the Community Shuttle subsystem (HDS and SDS) (PT03), indoor navigation (TI03) and pedestrian signal crossing (VS12) systems. This view shows how the trip plan supports traveler planning, navigation and wayfinding through channel services (personal web applications, call center, TIH, and CTP mobile app). The services are enabled through dynamic interactions between the CTP and CS reservations and status updates, interaction with indoor facility pathway waypoints, and with the traffic signal control gateway.

A comprehensive list of the functions and information are listed in **Table 9** and **Table 11**, respectively.

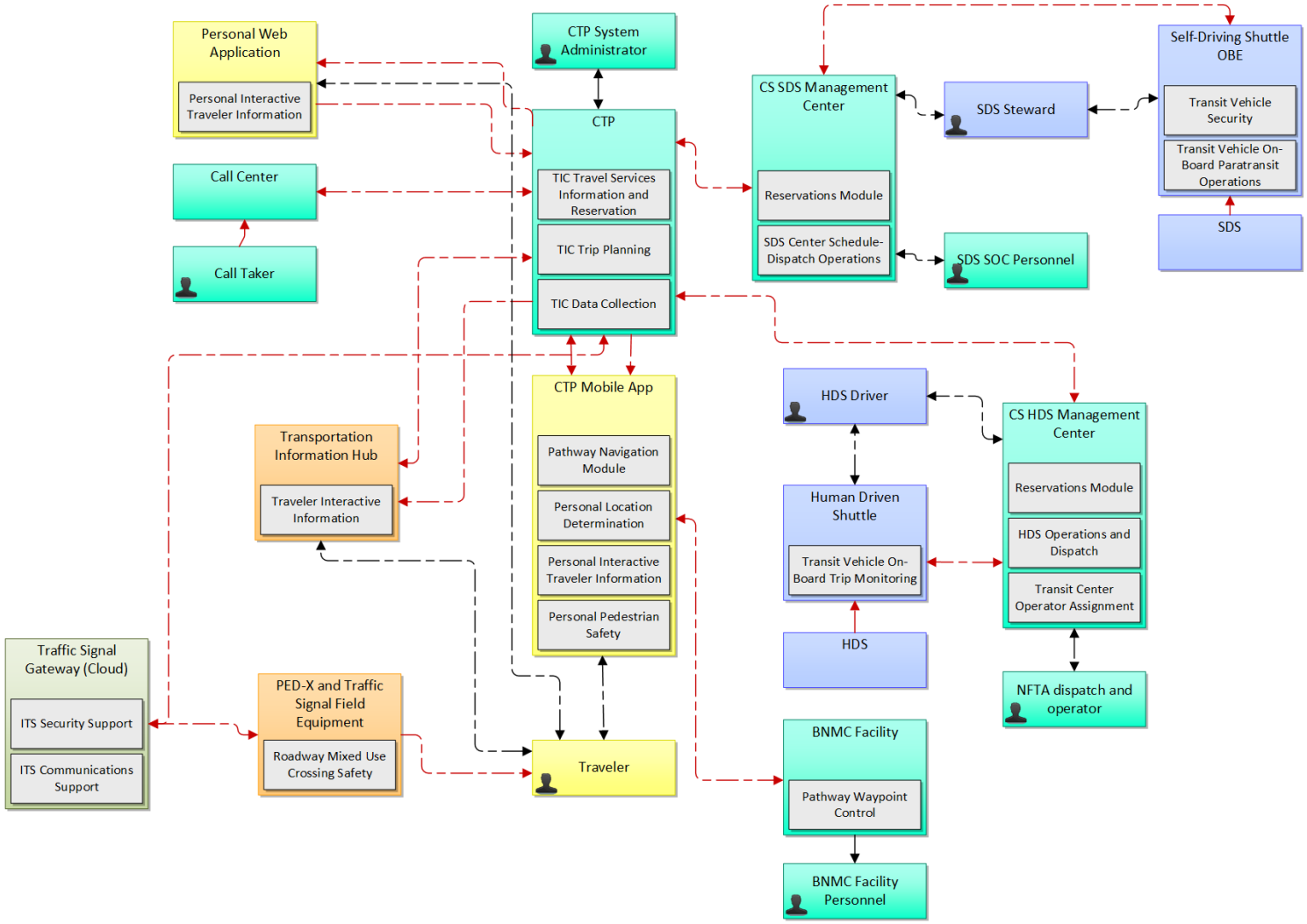

Figure 23.Trip Planning Functions (Layer 1 diagram)
Source: Buffalo, NY ITS4US, 2024

4.3.2 Functional Descriptions

The complete list of functions and their descriptions which are consistent with the physical architecture and service packages described in Section 4.2 are listed in **Table 9**.

Table 9. Functional Descriptions by Physical and Functional Objects

Function Object Name	Description	User Defined	Physical Object (Element)	Diagram(s)	(Subsystem/System) SOI Function
Archive Data Repository	Archive Data Repository' collects data and data catalogs from one or more data sources and stores the data in a focused repository that is suited to a particular set of ITS data users. It includes capabilities for performing quality checks on the incoming data, error notification, and archive to archive coordination. It includes the capability to define a data registry that allows registration of data identifiers or data definitions for interoperable use throughout a region. It supports a broad range of implementations, ranging from simple data marts that collect a focused set of data and serve a particular user community to large-scale data warehouses that collect, integrate, and summarize transportation data from multiple sources and serve a broad array of users within a region. Repositories may be established to support operations planning, performance monitoring and management, and policy and investment decisions.	No	PMD	DM02: Performance Management Dashboard (Copy 1)	(PMD) Data Tier and Data Lake

Function Object Name	Description	User Defined	Physical Object (Element)	Diagram(s)	(Subsystem/System) SOI Function
Archive On-Line Analysis and Mining	Archive On-Line Analysis and Mining' provides advanced data analysis, summarization, and mining features that facilitate discovery of information, patterns, and correlations in large data sets. Multidimensional analysis, selective summarization and expansion of data details, and many other advanced analysis services may be offered. Complex performance measures that are derived from multiple data sources may also be produced.	No	PMD, Secure Performance Management Center	DM02: Performance Management Dashboard (Copy 1)	(PMD) API Access, Generate performance metrics, Performance Measures
Archive Protected Data Repository	Archive Protected Data Repository provides secure storage for data that has Personally Identifiable Information (PII).	Yes	Secure Performance Management Center	DM02: Performance Management Dashboard (Copy 1)	(PMD) Performance Measures
Authentication Services	Authentication Services provides role based access to data including APIs and datasets.	Yes	PMD	DM02: Performance Management Dashboard (Copy 1)	(PMD) Authentication
Center Data Collection	Center Data Collection' collects and stores information that is created in the course of center operations. This data can be used directly by operations personnel or it can be made available to other data users and archives in the region. In coordination with the USDOT, the specific data will be identified at a later date.	No	Independent Evaluation Reporting System	DM02: Performance Management Dashboard (Copy 1)	(PMD) IE (independent evaluator)
Center Map Management	Center Map Management' provides the map functionality necessary to support path updates and use within a facility. It manages map data for the facility and provides path data to center applications such as trip planning apps.	No	BNMC Facility, NFTA Transit Management Center	SU04: Facility Map Management (Copy 1), SU04: MetroRail Map Management (Copy 2)	(Indoor Navigation System) BNMC Facility

Function Object Name	Description	User Defined	Physical Object (Element)	Diagram(s)	(Subsystem/System) SOI Function
CTP Data Collection	CTP Data Collection archives service and map data, user registration and profile data, trip plans including books, and operational data.	Yes	CTP	DM02: Performance Management Dashboard (Copy 1), SU04: Facility Map Management (Copy 1), SU04: MetroRail Map Management (Copy 2)	(CTP) CTP Database
Curation Processes	Curation Processes includes functions to ingest, quality checking, transform and disseminate information.	Yes	PMD	DM02: Performance Management Dashboard (Copy 1)	(PMD) Data Lake
HDS Operations and Dispatch	HDS Operations and Dispatch manages HDS operations and dispatch, tracks vehicles, and assigns drivers to vehicles and vehicles to trips.	Yes	CS HDS Management Center	PT03: Dynamic HDS Operations (Copy 2), Layer 1: Trip Planning Functions	(CS/HDS System) NFTA HDS Management Center
ITS Security Support	ITS Security Support' provides communications and system security functions to the Traffic Signal Gateway (MioVision), including privacy protection functions. It may include firewall, intrusion management, authentication, authorization, profile management, identity management, cryptographic key management. It may include a hardware security module and security management information base.	No	Traffic Signal Gateway (Cloud)	Layer 1: Trip Planning Functions, VS12: Pedestrian Mobility (Copy 1)	(PED-X System) Traffic Signal Gateway

Function Object Name	Description	User Defined	Physical Object (Element)	Diagram(s)	(Subsystem/System) SOI Function
Map Management	Map Management' provides the GIS functionality necessary to support pathway data creation and management. It provides an operator interface that supports management of the path data and rendering of the paths under operator control and interfaces to external data sources, including the CTP trip planner and indoor navigation system.	No	Indoor Facility Map Update System, MetroRail Update System	SU04: Facility Map Management (Copy 1), SU04: MetroRail Map Management (Copy 2)	(CTP), BNMC Facility and NFTA Facility
Pathway Navigation Module	Pathway Navigation Module provides indoor wayfinding and navigation services	Yes	CTP Mobile App	TI04: Infrastructure-Provided Indoor Wayfinding (Copy 1), Layer 1: Trip Planning Functions	(CTP Mobile App) Pathway Waypoint Control
Pathway Waypoint Control	Pathway Waypoint Control supports waypoint (location aiding sensor) technologies deployed in a facility to provide indoor navigation services.	Yes	BNMC Facility	TI04: Infrastructure-Provided Indoor Wayfinding (Copy 1), Layer 1: Trip Planning Functions	(Indoor Navigation System) BNMC Facility
Performance Metrics	Performance Metrics manages performance metrics of CS operations (HDS and SDS) including trips, on-time performance and other operational metrics collected by the management centers.	Yes	CS HDS Management Center, CS SDS Management Center	DM02: Performance Management Dashboard (Copy 1), Indoor Navigation and Data Collection	(CS/HDS System) NFTA HDS Management Center (CS/SDS System) SDS Shuttle Operations Center (SOC)

Function Object Name	Description	User Defined	Physical Object (Element)	Diagram(s)	(Subsystem/System) SOI Function
Personal Interactive Traveler Information	Personal Interactive Traveler Information' provides traffic information, road conditions, transit information, special event information, and other traveler information that is specifically tailored based on the traveler's request and/or previously submitted traveler profile information. It also supports interactive services that support enrollment, and account management for transportation services. The interactive traveler information capability is provided by personal devices including personal computers and personal portable devices such as smart phones.	No	CTP Mobile App, Personal Web Application	TI05: Travel Services Information and Reservation (Copy 1), Layer 1: Trip Planning Functions	(CTP Mobile App) Traveler Trip Planning (Complete Trip Platform) User Interface: Web
Personal Location Determination	Personal Location Determination' receives current location information and provides this information to other applications that use the location information. It interfaces with and encapsulates positioning technology such as a GPS receiver that is embedded in the user's device.	No	CTP Mobile App	TI04: Infrastructure-Provided Indoor Wayfinding (Copy 1), Layer 1: Trip Planning Functions	(CTP Mobile App) Traveler Trip Tracking
Personal Pedestrian Safety	Personal Pedestrian Safety' improves pedestrian and other non-motorized user safety by providing personal location information to the infrastructure that can be used to avoid collisions involving non-motorized travelers and activate pedestrian crossing. The information provided and the user interface delivery mechanism (visual, audible, or haptic) can also be tailored to the needs of the user that is carrying or wearing the device that hosts the application.	No	CTP Mobile App	Layer 1: Trip Planning Functions, VS12: Pedestrian Mobility (Copy 1)	(CTP Mobile App) Navigation

Function Object Name	Description	User Defined	Physical Object (Element)	Diagram(s)	(Subsystem/System) SOI Function
Reservations Module	Reservations Module manages the reservation/booking functionality in the CTP to respond to CS bookings and on-demand service.	Yes	CS HDS Management Center, CS SDS Management Center	PT03: Dynamic HDS Operations (Copy 2), PT03: Dynamic SDS Operations (Copy 1), Layer 1: Trip Planning Functions	(CS/HDS System) NFTA HDS Management Center (CS/SDS System) SDS Shuttle Operations Center (SOC)
Roadway Mixed Use Crossing Safety	Roadway Mixed Use Crossing Safety' is an advanced infrastructure application that detects pedestrians, cyclists, and other non-motorized users and provides active safety warnings to drivers when cross walks or other intersecting mixed use paths are occupied. This system will also be used to alert pedestrians about intersection crossing information.	No	PED-X and Traffic Signal Field Equipment	Layer 1: Trip Planning Functions, VS12: Pedestrian Mobility (Copy 1)	(PED-X System) Traffic Signal System (field equipment)
SDS Center Schedule-Dispatch Operations	The SDS Center Schedule-Dispatch operations manages vehicle scheduling, dispatch and pick-up/drop-off based on traveler bookings.	Yes	CS SDS Management Center	PT03: Dynamic SDS Operations (Copy 1), Layer 1: Trip Planning Functions	(CS/SDS System) SDS Shuttle Operations Center (SOC)
Service Information	Service Information provides GTFS datasets and other related service and on-time information about NFTA services.	Yes	NFTA Transit Management Center	DM02: Performance Management Dashboard (Copy 1)	(Complete Trip Platform) NFTA Mgmt Center

Function Object Name	Description	User Defined	Physical Object (Element)	Diagram(s)	(Subsystem/System) SOI Function
TIC Data Collection	TIC (traveler information center) Data Collection' collects transportation-related data from other centers, performs data quality checks on the collected data, and then consolidates, verifies, and refines the data and makes it available in a consistent format to applications that support operational data sharing between centers and deliver traveler information to end-users. A broad range of data is collected including traffic and road conditions, transit data, emergency information and advisories, special event information, traveler services, parking, and multimodal data. Note: Traveler Information Center (TIC) is an acronym referring to the Traveler Information Center used throughout ARC-IT.	No	CTP	PT03: Dynamic HDS Operations (Copy 2), PT03: Dynamic SDS Operations (Copy 1), TI05: Travel Services Information and Reservation (Copy 1), Layer 1: Trip Planning Functions	(Complete Trip Platform) CTP Database
TIC Travel Services Information and Reservation	TIC Travel Services Information' disseminates information about traveler services. Tailored traveler service information is provided on request that meets the constraints and preferences specified by the traveler. This application also supports reservations for traveler services.	No	CTP	TI05: Travel Services Information and Reservation (Copy 1), Layer 1: Trip Planning Functions, VS12: Pedestrian Mobility (Copy 1)	(Complete Trip Platform) Trip Booking

Function Object Name	Description	User Defined	Physical Object (Element)	Diagram(s)	(Subsystem/System) SOI Function
TIC Trip Planning	TIC Trip Planning' provides pre-trip and en route trip planning services for travelers. It receives origin, destination, constraints, and preferences and returns trip plan(s) that meet the supplied criteria. Trip plans may be based on current transit and community shuttle schedule information, and other real-time traveler information. Candidate trip plans are multimodal and may include vehicle, transit, and alternate mode segments (e.g., rail and walkways) based on traveler preferences. It also confirms the trip plan for the traveler and supports reservations for portions of the trip. The trip plan includes specific routing information and instructions for each segment of the trip along the route.	No	CTP	PT03: Dynamic HDS Operations (Copy 2), PT03: Dynamic SDS Operations (Copy 1), TI04: Infrastructure-Provided Indoor Wayfinding (Copy 1), TI05: Travel Services Information and Reservation (Copy 1), Layer 1: Trip Planning Functions	(Complete Trip Platform) Trip Planning
Traffic Management Message Broker	Traffic Management Message Broker provides means to send and receive messages to and from other ITS objects. It provides mechanisms for scheduling and prioritizing communications traffic. In particular (for this project), it provides functions to transform pedestrian actuation messages from CTP and relay the request using NTCIP messages to the Traffic Signal Field equipment (e.g., signal controller and PED-X equipment). In addition, the function includes management of regulatory information and policies, management of application processes, management of communication system configuration and update management, communications interfaces, protocol-specific techniques to ensure interoperability such as communications congestion management and interference management, local device states and communications information, fault management, service level and performance monitoring	Yes	Traffic Signal Gateway (Cloud)	Layer 1: Trip Planning Functions, VS12: Pedestrian Mobility (Copy 1)	(PED-X System) Traffic Signal Gateway

Function Object Name	Description	User Defined	Physical Object (Element)	Diagram(s)	(Subsystem/System) SOI Function
Transit Center Operator Assignment	Transit Center Operator Assignment' automates and supports the assignment of HDS vehicle operators to their assigned run.	No	CS HDS Management Center	PT03: Dynamic HDS Operations (Copy 2), Layer 1: Trip Planning Functions	(CS/HDS System) NFTA HDS Management Center
Transit Vehicle On-Board Paratransit Operations	SDS Vehicle On-board (Paratransit) Operations' forwards on-demand or flexible-route dispatch requests to the steward and forwards acknowledgements to the center. It coordinates and assists the steward in managing multi-stop runs associated with demand responsive transit services. It collects transit vehicle passenger data and makes it available to the center.	No	Self-Driving Shuttle OBE	PT03: Dynamic SDS Operations (Copy 1), Layer 1: Trip Planning Functions	(CS/SDS System) Self Driving Shuttle (SDS)
Transit Vehicle On-Board Trip Monitoring	Transit Vehicle On-Board Trip Monitoring' tracks vehicle location, monitors fuel usage, collects operational status (doors opened/closed, running times, etc.) and sends the collected, time stamped data to the HDS Management Center.	No	Human Driven Shuttle	PT03: Dynamic HDS Operations (Copy 2), Layer 1: Trip Planning Functions	(CS/HDS System) HDS Driver
Transit Vehicle Security	Transit Vehicle Security provides on-board security features which includes an emergency call button that connects passengers with the SDS SOC personnel in case of an event or emergency.	No	Self-Driving Shuttle OBE	PT03: Dynamic SDS Operations (Copy 1), Layer 1: Trip Planning Functions	(CS/SDS System) Self Driving Shuttle
Traveler Interactive Information	Traveler Interactive Information' provides traffic information, road conditions, transit information, special event information, and other traveler information that is specifically tailored based on the traveler's request and/or previously submitted traveler profile information. It also supports interactive services that support enrollment, and account management for transportation services. The interactive traveler information capability is provided by a public traveler interface, such as a kiosk.	No	Transportation Information Hub	TI05: Travel Services Information and Reservation (Copy 1), Layer 1: Trip Planning Functions	(Complete Trip Platform) Transportation Information Hub

Function Object Name	Description	User Defined	Physical Object (Element)	Diagram(s)	(Subsystem/System) SOI Function
Visualization Services	Visualization Services presents performance measures through various types of displays.	Yes	PMD	DM02: Performance Management Dashboard (Copy 1)	(PMD) Map Services

4.4 Communications View

The Communications Viewpoint describes and identifies the protocols necessary to implement the information flow between the physical objects shown in the Physical Viewpoint. Except for the Pedestrian Signal Crossing interface between the PED-X gateway and CoB Traffic Signal System that adopts a National Transportation Communications for Intelligent Transportation System Protocol (NTCIP) User Datagram Protocol (UDP) communications stack, all other information flows will use a commercial broadband or cellular communication service. **Table 10** lists the communications protocols associated with information flows that are identified in the Physical Architecture.

Table 10. Communications Protocol Stack

Communication Solution	Protocol / Standard
Guaranteed Secure Internet (ITS)	Bundle: Simple Network Management Protocol (SNMP) Management Information Base (MIB), Development needed, Internet Engineering Task Force (IETF) Request for Comments (RFC) 793 TCP, Internet Subnet Alternatives, Internet Protocol (IP) Alternatives, Secure Session Alternatives
Secure Internet (ITS)	Bundle: SNMP MIB, Development needed, Internet Subnet Alternatives, Internet Transport Alternatives, IP Alternatives, Secure Session Alternatives
Secure Wireless Internet (ITS)	Bundle: SNMP MIB, Development needed, Internet Transport Alternatives, IP Alternatives, Secure Session Alternatives, Wireless Internet Alternatives (NA)
GTFS real-time - Secure Internet (ITS)	Bundle: SNMP MIB, GTFS Realtime, IETF Request for Comment (RFC) 4180 Comma Separated Value (CSV) Files, IETF RFC 7230 Hypertext Transfer Protocol (HTTP), Internet Subnet Alternatives, Internet Transport Alternatives, IP Alternatives, International Organization for Standardization (ISO) 21320-1 ZIP, Secure Session Alternatives
GTFS static - Secure Internet (ITS)	Bundle: SNMP MIB, General Transit Feed Specification, IETF RFC 4180 CSV Files, IETF RFC 7230 HTTP, Internet Subnet Alternatives, Internet Transport Alternatives, IP Alternatives, ISO 21320-1 ZIP, Secure Session Alternatives
NTCIP Signal System Masters - TLS	Bundle: ISO 15784-2, Bundle: SNMP MIB, Field SubNet Alternatives, IETF RFC 6353 TLS for SNMP, Internet Transport Alternatives, IP Alternatives, NTCIP Global Objects, NTCIP Signal Controller Objects, NTCIP Signal System Master Objects

4.4.1 Information Flows and Communications Solutions

Communications between stakeholders or between Elements are listed in **Table 11**. These information flows are shown in the service packages diagrams (see **Section 4.2.2**). The table includes the following information:

Flow Name: identifies the information flow name as tagged in the Service Package

Flow Description: describes the information flow

User Defined: yes indicates that the information is unique to the Buffalo architecture; **no** indicates that the information is adapted from the ARC-IT reference

Communication Bundle: a reference to the Communication Bundle as described in **Table 10**

Source Element: physical object where the information flow is generated or forwarded

Destination Element: physical object where the information flow is destined

SOI Info Flow: cross reference to the system of interest information flow as described in **Table 5**. Note that the SOI Information Flows are assumed to be synchronous application programming interfaces (APIs) that include a request-response service. To that end, a single information flow may be equivalent to a request and response flow described in the ARC-IT views. In addition, specific information exchanges between personnel and systems are not covered in the SOI. Several information flows in the physical view are external to the system; they are depicted to ensure that information provision agreements are included in the enterprise view. These information flows are designated as n/a (not applicable).

Table 11. Information Flow Description and Communication Solution

Flow Name	Flow Description	User Defined	Communication Bundle	Source Element	Destination Element	SOI Info Flow
archive coordination	Catalog data, meta data, published data, and other information exchanged between archives to support data synchronization and satisfy user data requests.	no	Secure Internet (ITS)	Performance Management Dashboard	Secure Performance Management Center	I-14
archive coordination	Catalog data, meta data, published data, and other information exchanged between archives to support data synchronization and satisfy user data requests.	no	Secure Internet (ITS)	Secure Performance Management Center	Performance Management Dashboard	I-14
archive management data	Presentation of information to the administrator to support the management of an ITS archive including database reports on the condition and quality of the archived data, status of the import and collection process, reports that monitor archive usage, and any special requests that require direct action by the administrator (e.g., requests for access to new data sources).	no	none	Performance Management Dashboard	PMD Administrator	n/a
archive management requests	User input from the administrator including commands, requests, and queries that support data collection, administration, and management of an ITS data archive.	no	none	PMD Administrator	Performance Management Dashboard	n/a
crossing permission (walk signal)	Information provided to guide and warn pedestrians at crossings including crossing request acknowledgment, current crossing permission, crossing time remaining, and real-time warnings of safety threats.	no	none	PED-X and Traffic Signal Field Equipment	Traveler	n/a
CTP updates	Updates to traveler from Call Center module	yes	none	Call Center	Traveler	n/a
demand response passenger and use data	Data collected on board a demand response vehicle relating to the picking up and discharging of passengers.	no	Secure Wireless Internet (ITS)	Human Driven Shuttle	CS HDS Management Center	n/a (internal to legacy system)

Flow Name	Flow Description	User Defined	Communication Bundle	Source Element	Destination Element	SOI Info Flow
demand response passenger and use data	Data collected on board a demand response vehicle relating to the picking up and discharging of passengers.	no	Secure Wireless Internet (ITS)	Self-Driving Shuttle OBE	CS SDS Management Center	n/a (internal to turnkey system)
demand responsive transit plan	Plan regarding overall demand responsive transit schedules and deployment.	no	Secure Internet (ITS)	CS HDS Management Center	CTP	I-7
demand responsive transit plan	Plan regarding overall demand responsive transit schedules and deployment.	no	Secure Internet (ITS)	CS SDS Management Center	CTP	I-6
demand responsive transit request	Request for on-demand support.	no	Secure Internet (ITS)	CTP	CS HDS Management Center	I-7
demand responsive transit request	Request for on-demand support.	no	Secure Internet (ITS)	CTP	CS SDS Management Center	I-6
Facility monitoring data	Data about the sensors acquired during monitoring and preventive maintenance.	yes	Secure Internet (ITS)	BNMC Facility	BNMC Facility Personnel	n/a
government reporting data receipt	The acknowledgement of satisfactory receipt of information used as input to government data systems or a report identifying problems or issues with the data submittal.	no	Secure Internet (ITS)	Independent Evaluation Reporting System	Performance Management Dashboard	I-17 (I-15, I-16)
government reporting system data	Information provided by an ITS archive, formatted as appropriate, that can be used as input to government data reporting systems.	no	Secure Internet (ITS)	Performance Management Dashboard	Independent Evaluation Reporting System	I-17 (I-15, I-16)
host transit vehicle status	Information provided to the ITS on-board equipment from other systems on the Community Shuttle Vehicles.	no	Secure Wireless Internet (ITS)	HDS	Human Driven Shuttle	n/a
host transit vehicle status	Information provided to the ITS on-board equipment from other systems on the CS vehicles	no	Secure Wireless Internet (ITS)	SDS	Self-Driving Shuttle OBE	n/a
intersection geometry	The physical geometry of indoor pathway information.	no	Secure Internet (ITS)	MetroRail Update System	NFTA Transit Management Center	n/a (external)

Flow Name	Flow Description	User Defined	Communication Bundle	Source Element	Destination Element	SOI Info Flow
map operator input	The range of GIS operator inputs that support creation and update of navigable maps and management and distribution of the map data to end users.	no	Secure Internet (ITS)	Facility Manager	Indoor Facility Map Update System	n/a
map operator input	The range of GIS operator inputs that support creation and update of navigable maps and management and distribution of the map data to end users.	no	Secure Internet (ITS)	UB data collection team	MetroRail Update System	n/a
map operator updates	Interactive display of base map and information layers and associated information that supports map development, management, and dissemination.	no	Secure Internet (ITS)	Indoor Facility Map Update System	Facility Manager	n/a
map operator updates	Interactive display of base map and information layers and associated information that supports map development, management, and dissemination.	no	Secure Internet (ITS)	MetroRail Update System	UB data collection team	n/a
map update notification	Notification of maintenance, construction, and other activities that will result in medium to long term changes to road location and configuration that may impact navigable maps. This flow includes the timing of the changes and precise enumeration of the location and configuration changes.	no	Secure Internet (ITS)	NFTA Transit Management Center	MetroRail Update System	n/a
map updates	Map update that could include a new underlying static or real-time map or map layer(s) update. Map layers can include pedestrian routes in indoor facilities.	no	Secure Internet (ITS)	Indoor Facility Map Update System	CTP	I-4
map updates	Map update that could include a new underlying static or real-time map or map layer(s) update. Map layers can include pedestrian routes in indoor facilities.	no	Secure Internet (ITS)	MetroRail Update System	NFTA Transit Management Center	n/a
metrorail path updates + status notifications	GTFS Pathways data that support creation and update of navigable maps and management and distribution of the map data to end users	yes	Secure Internet (ITS)	MetroRail Update System	CTP	I-5
path sensor data	Data broadcast by sensor to identify waypoints along indoor facility.	yes	TBD	BNMC Facility	CTP Mobile App	I-9
path sensor monitoring	Waypoint (beacon) monitoring sensor communications deployed in facility to provide indoor navigation	yes	TBD	CTP Mobile App	BNMC Facility	I-9
path status update notifications	Pathway updates that include restrictions related to locations and pathways, conveyances	yes	Secure Wireless Internet (ITS)	CTP	CTP Mobile App	I-1

Flow Name	Flow Description	User Defined	Communication Bundle	Source Element	Destination Element	SOI Info Flow
path status update notifications	Pathway updates that include restrictions related to locations and pathways, conveyances	yes	Secure Internet (ITS)	Indoor Facility Map Update System	BNMC Facility	n/a
path status update notifications	Pathway updates that include restrictions related to locations and pathways, conveyances	yes	Secure Internet (ITS)	Indoor Facility Map Update System	CTP	I-4
Pedestrian signal actuation request	Request for pedestrian signal actuation	yes	Miovision API	CTP	Traffic Signal Gateway (Cloud)	I-8
PED-X actuation request	Request for pedestrian signal actuation to the signal system	yes	NTCIP 9014 v01.20 with NTCIP Signal System Masters - TLS	Traffic Signal Gateway (Cloud)	PED-X and Traffic Signal Field Equipment	I-22
Ped-X actuation request confirmation	Confirmation that request was received and acted on.	yes	Miovision API	Traffic Signal Gateway (Cloud)	CTP	I-8
performance metrics	Operational parameters per performance measurement provisions	yes	Secure Internet (ITS)	CS HDS Management Center	Performance Management Dashboard	I-13
performance metrics	Operational parameters per performance measurement provisions	yes	Secure Internet (ITS)	CS SDS Management Center	Performance Management Dashboard	I-14
performance metrics	Operational parameters per performance measurement provisions	yes	Secure Internet (ITS)	NFTA Transit Management Center	Performance Management Dashboard	I-18
personal input	User input to a personal device. This flow may request traveler information, request right of way, summon assistance, make a reservation, or request any other traveler service. This flow also establishes the settings that tailor each application to suit the user's needs.	no	none	Traveler	CTP Mobile App	n/a
personal updates	Personal information, alerts, and warnings provided to pedestrians, work crew members, and other individuals in a mixed use area. This includes visual, audio, and haptic outputs that may be customized to support individual needs.	no	none	CTP Mobile App	Traveler	n/a

Flow Name	Flow Description	User Defined	Communication Bundle	Source Element	Destination Element	SOI Info Flow
Reservation request	Reservation request for SDS and HDS on-demand pickup and dropoff service	yes	Secure Internet (ITS)	Call Center	CTP	I-2
route assignment	Route assignment information for Community Shuttle vehicle (operator/steward).	no	Secure Internet (ITS)	CS HDS Management Center	HDS Driver	n/a
route assignment	Route assignment information for Community Shuttle vehicle (operator/steward).	no	Secure Internet (ITS)	CS SDS Management Center	SDS Steward	n/a
service information request	Request to multimodal (possibly non-roadway) transit provider for general services information and specific trip information or reservation.	no	Secure Internet (ITS)	CTP	CS SDS Management Center	I-6
service information request	Request to multimodal (possibly non-roadway) transit provider for general services information and specific trip information or reservation.	no	Secure Internet (ITS)	Secure Performance Management Center	Performance Management Dashboard	I-14
service information response	Multimodal (possibly non-roadway) transit provider services information and trip reservation confirmations.	no	Secure Internet (ITS)	CS SDS Management Center	CTP	I-6
service information response	Multimodal (possibly non-roadway) transit provider services information and trip reservation confirmations.	no	Secure Internet (ITS)	Performance Management Dashboard	Secure Performance Management Center	I-14
system status	Monitoring of system device status including current mode, operational status, and configuration settings. It includes device housekeeping/heartbeat monitoring and includes network information, the status of installed applications, and the configuration of managed devices.	no	NTCIP 9014 v01.20 with NTCIP Signal System Masters - TLS	PED-X and Traffic Signal Field Equipment	Traffic Signal Gateway (Cloud)	I-22
TIC operations information presentation	Presentation of information to the TIC Operator including current operational status, parameters for broadcast information settings, route selection controls, and travel optimization algorithms.	no	Secure Internet (ITS)	CTP	CTP System Administrator	n/a
TIC operator input	User input from the TIC system operator including requests to monitor current system operation and inputs to affect system operation including tuning and performance enhancement parameters to traveler information algorithms.	no	Secure Internet (ITS)	CTP System Administrator	CTP	n/a

Flow Name	Flow Description	User Defined	Communication Bundle	Source Element	Destination Element	SOI Info Flow
transit and fare schedules	Transit service information including routes, schedules, and fare information. This also includes on-demand service information.	no	Secure Internet (ITS)	CS HDS Management Center	CTP	I-7
transit and fare schedules	Transit service information including routes, schedules, and fare information. This also includes on-demand service information.	no	Secure Internet (ITS)	CS SDS Management Center	CTP	I-6
transit archive data	Data used to describe and monitor transit demand, fares, operations, and system performance. Content may include a catalog of available information, the actual information to be archived, and associated meta data that describes the archived information.	no	Secure Internet (ITS)	CS HDS Management Center	Performance Management Dashboard	I-7
transit archive data	Data used to describe and monitor transit demand, fares, operations, and system performance. Content may include a catalog of available information, the actual information to be archived, and associated meta data that describes the archived information.	no	Secure Internet (ITS)	CS SDS Management Center	Performance Management Dashboard	I-6
transit archive data	Data used to describe and monitor transit demand, fares, operations, and system performance. Content may include a catalog of available information, the actual information to be archived, and associated meta data that describes the archived information.	no	Secure Internet (ITS)	NFTA Transit Management Center	Performance Management Dashboard	I-18
transit operations personnel input	User input from transit operations personnel including instructions governing service availability, schedules, emergency response plans, transit personnel assignments, transit maintenance requirements, and other inputs that establish general system operating requirements and procedures.	no	none	NFTA dispatch and operator	CS HDS Management Center	n/a (internal to legacy system)
transit operations personnel input	User input from transit operations personnel including instructions governing service availability, schedules, emergency response plans, transit personnel assignments, transit maintenance requirements, and other inputs that establish general system operating requirements and procedures.	no	none	SDS SOC Personnel	CS SDS Management Center	n/a

Flow Name	Flow Description	User Defined	Communication Bundle	Source Element	Destination Element	SOI Info Flow
transit operations status	Presentation of information to transit operations personnel including accumulated schedule and fare information, ridership and on-time performance information, emergency response plans, transit personnel information, maintenance records, and other information intended to support overall planning and management of a transit property.	no	none	CS HDS Management Center	NFTA dispatch and operator	n/a (internal to legacy system)
transit operations status	Presentation of information to transit operations personnel including accumulated schedule and fare information, ridership and on-time performance information, emergency response plans, transit personnel information, maintenance records, and other information intended to support overall planning and management of a transit property.	no	none	CS SDS Management Center	SDS SOC Personnel	n/a
transit schedule adherence information	Dynamic transit schedule adherence and transit vehicle location information.	no	Secure Internet (ITS)	CS HDS Management Center	CTP	I-7
transit schedule adherence information	Dynamic transit schedule adherence and transit vehicle location information.	no	Secure Internet (ITS)	CS SDS Management Center	CTP	I-6
transit service information	Transit service information including routes, schedules, and fare information as well as dynamic transit schedule adherence and transit vehicle location information.	no	Secure Internet (ITS)	CTP	Call Center	I-2
transit vehicle operator availability	Transit vehicle operator availability data that can be used to develop vehicle operator assignments and detailed operations schedules.	no	none	HDS Driver	CS HDS Management Center	n/a
transit vehicle operator availability	Transit vehicle operator availability data that can be used to develop vehicle operator assignments and detailed operations schedules.	no	none	SDS Steward	CS SDS Management Center	n/a

Flow Name	Flow Description	User Defined	Communication Bundle	Source Element	Destination Element	SOI Info Flow
transit vehicle operator display	Visual, audible, and tactile outputs to the transit vehicle operator including vehicle surveillance information, alarm information, vehicle system status, information from the operations center, and information indicating the status of all other on-board ITS services.	no	none	Human Driven Shuttle	HDS Driver	n/a
transit vehicle operator display	Visual, audible, and tactile outputs to the transit vehicle operator including vehicle surveillance information, alarm information, vehicle system status, information from the operations center, and information indicating the status of all other on-board ITS services.	no	none	Self-Driving Shuttle OBE	SDS Steward	n/a
transit vehicle operator information	Transit service instructions, wide area alerts, traffic information, road conditions, and other information for CS operators or stewards.	no	Secure Wireless Internet (ITS)	CS HDS Management Center	Human Driven Shuttle	n/a
transit vehicle operator information	Transit service instructions, wide area alerts, traffic information, road conditions, and other information for CS operators or stewards.	no	Secure Wireless Internet (ITS)	CS SDS Management Center	Self-Driving Shuttle OBE	n/a
Transit vehicle operator input	Transit vehicle operator inputs to on-board ITS equipment, including tactile and verbal inputs. Includes authentication information, on-board system control, emergency requests, and fare transaction data.	no	none	HDS Driver	Human Driven Shuttle	n/a
transit vehicle operator input	Transit vehicle operator inputs to on-board ITS equipment, including tactile and verbal inputs. Includes authentication information, on-board system control, emergency requests, and fare transaction data.	no	none	SDS Steward	Self-Driving Shuttle OBE	n/a
travel service information	Information supplied by a service provider that identifies the service provider and provides details of the service offering.	no	Secure Internet (ITS)	CS HDS Management Center	CTP	I-7
travel service information	Information supplied by a service provider that identifies the service provider and provides details of the service offering.	no	Secure Internet (ITS)	CS SDS Management Center	CTP	I-6
travel service information	Information supplied by a service provider that identifies the service provider and provides details of the service offering.	no	Secure Internet (ITS)	CTP	Personal Web Application	I-2

Flow Name	Flow Description	User Defined	Communication Bundle	Source Element	Destination Element	SOI Info Flow
travel service information request	Requests for travel service information. This flow supports initial registration of service providers and requests for additional traveler service information from registered providers.	no	Secure Internet (ITS)	CTP	CS HDS Management Center	I-7
travel service information request	Requests for travel service information. This flow supports initial registration of service providers and requests for additional traveler service information from registered providers.	no	Secure Internet (ITS)	CTP	CS SDS Management Center	I-6
travel service reservation request	Reservation request for traveler services.	no	Secure Internet (ITS)	CTP	CS HDS Management Center	I-7
travel service reservation request	Reservation request for traveler services.	no	Secure Internet (ITS)	CTP	CS SDS Management Center	I-6
travel service reservations	Reservation for traveler services from the HDS.	no	Secure Internet (ITS)	CS HDS Management Center	CTP	I-7
travel service reservations	Reservation for traveler services from the SDS.	no	Secure Internet (ITS)	CS SDS Management Center	CTP	I-6
travel service reservations	Forward reservation for traveler services from the CS (HDS or SDS).	yes	Secure Internet (ITS)	CTP	CTP Mobile App	I-1
travel service reservations	Forward reservation for traveler services from the CS (HDS or SDS).	yes	Secure Internet (ITS)	CTP	Personal Web Application	I-2
travel service reservations	Forward reservation for traveler services from the CS (HDS or SDS).	yes	Secure Internet (ITS)	CTP	Transportation Information Hub	I-2
travel services information	Travel service information and reservations for the traveler.	no	Secure Wireless Internet (ITS)	CTP	CTP Mobile App	I-1
travel services information	Travel service information and reservations for the traveler.	no	Secure Wireless Internet (ITS) or Secure Internet (ITS)	CTP	Transportation Information Hub	I-2
travel services request	Request for travel service information. The request identifies the type of service, the area of interest, optional reservation request information, parameters that are used to prioritize or filter the returned information, and sorting preferences.	no	Secure Wireless Internet (ITS)	CTP Mobile App	CTP	I-1

Flow Name	Flow Description	User Defined	Communication Bundle	Source Element	Destination Element	SOI Info Flow
travel services request	Request for travel service information. The request identifies the type of service, the area of interest, optional reservation request information, parameters that are used to prioritize or filter the returned information, and sorting preferences.	no	Secure Wireless Internet (ITS) or Secure Internet (ITS)	Personal Web Application	CTP	I-2
travel services request	Request for travel service information. The request identifies the type of service, the area of interest, optional reservation request information, parameters that are used to prioritize or filter the returned information, and sorting preferences.	no	Secure Wireless Internet (ITS) or Secure Internet (ITS)	Transportation Information Hub	CTP	I-2
travel services reservations	Forward reservation for traveler services from the CS (HDS or SDS).	yes	Secure Internet (ITS)	CTP	Call Center	I-2
traveler alerts	Traveler information alerts reporting congestion, incidents, transit service delays or interruptions, and other information that may impact the traveler. Relevant alerts are provided based on traveler-supplied profile information including trip characteristics and preferences.	no	Secure Wireless Internet (ITS)	CTP	CTP Mobile App	I-1
traveler archive data	Data associated with traveler information services including service requests, facility usage, rideshare, routing, and other traveler data.	no	Secure Internet (ITS)	CTP	Performance Management Dashboard	I-10
traveler input	User input from a traveler to summon assistance, request travel information, make a reservation, or request any other traveler service.	no	none	Traveler	CTP Mobile App	n/a
traveler input	User input from a traveler to summon assistance, request travel information, make a reservation, or request any other traveler service.	no	none	Traveler	Transportation Information Hub	n/a
traveler input via call taker	Input from traveler to generate or update trip plans	Yes	none	Call Taker	Call Center	n/a
traveler interface updates	Visual or audio information (e.g., routes, messages, guidance, emergency information) that is provided to the traveler.	no	none	CTP Mobile App	Traveler	n/a
traveler interface updates	Visual or audio information (e.g., routes, messages, guidance, emergency information) that is provided to the traveler.	no	none	Transportation Information Hub	Traveler	n/a

Flow Name	Flow Description	User Defined	Communication Bundle	Source Element	Destination Element	SOI Info Flow
trip confirmation	Acknowledgement by the traveler of acceptance of a trip plan with associated personal information required to confirm reservations. Conversely, this flow may also reject the proposed trip plan. Confirmations include the selected route and subsequent trip confirmation messages will be issued for route changes.	no	Secure Internet (ITS)	CTP	CS HDS Management Center	I-7
trip confirmation	Acknowledgement by the traveler of acceptance of a trip plan with associated personal information required to confirm reservations. Conversely, this flow may also reject the proposed trip plan. Confirmations include the selected route and subsequent trip confirmation messages will be issued for route changes.	no	Secure Internet (ITS)	CTP	CS SDS Management Center	I-6
trip confirmation	Acknowledgement by the traveler of acceptance of a trip plan with associated personal information required to confirm reservations. Conversely, this flow may also reject the proposed trip plan. Confirmations include the selected route and subsequent trip confirmation messages will be issued for route changes.	no	Secure Wireless Internet (ITS)	CTP Mobile App	CTP	I-1
trip feedback	Information provided at the conclusion of a trip that supports performance monitoring and system optimization. Information provided may include a record of the trip user provided feedback at the conclusion of the trip.	no	Secure Internet (ITS)	Personal Web Application	CTP	I-2
trip plan	A travel itinerary identifying a route and associated traveler information and instructions identifying recommended modes and transfer information, ride sharing options, and transit information. This flow also includes intermediate information that is provided as the trip plan is interactively created, including identification of alternatives, requests for additional information.	no	Secure Wireless Internet (ITS)	CTP	CTP Mobile App	I-1

Flow Name	Flow Description	User Defined	Communication Bundle	Source Element	Destination Element	SOI Info Flow
trip planning service request	Request for trip planning services that identifies the trip origin, destination(s), timing, preferences, and constraints. The request may also include the requestor's location or a request for transit and parking reservations and ridesharing options associated with the trip. The trip request also covers requests to revise a previously planned trip and interim updates that are provided as the trip is interactively planned.	yes	Secure Internet (ITS)	Call Center	CTP	I-2
trip request	Request for trip planning services that identifies the trip origin, destination(s), timing, preferences, and constraints. The request may also include the requestor's location or a request for transit and parking reservations and ridesharing options associated with the trip. The trip request also covers requests to revise a previously planned trip and interim updates that are provided as the trip is interactively planned.	no	Secure Wireless Internet (ITS)	CTP Mobile App	CTP	I-1
trip tracking information	information about current mobile app location and adherence to trip plan	yes	Secure Wireless Internet (ITS)	CTP Mobile App	CTP	I-1
user account setup	User account information and preferences for trip planning.	no	Secure Wireless Internet (ITS)	CTP Mobile App	CTP	I-1
user account setup	User account information and preferences for trip planning.	no	Secure Internet (ITS)	Personal Web Application	CTP	I-2
user profile	Information provided to register for a travel service and create a user account. The provided information includes personal identification, traveler preferences (e.g., maximum transfer wait time, maximum walking distance, mode preferences, special needs), device information, a user ID and password, and information to support payment transactions, if applicable.	no	Secure Wireless Internet (ITS)	CTP Mobile App	CTP	I-1

4.4.2 Information Flow Security

The Information Flows included in the Buffalo ITS4US Architecture were assessed to determine their security requirements. The information flows were assessed using the FIPS PUBS 199 Standards for Security Categorization of Federal Information and Information Systems and 200 Minimum Security Requirements for Federal Information and Information Systems, to assess the confidentiality, integrity, and availability (CIA assessment) of each data set. FIPS PUBS 199 defines confidentiality, integrity, and availability (CIA) as follows:

> **CONFIDENTIALITY** refers to "Preserving authorized restrictions on information access and disclosure, including means for protecting personal privacy and proprietary information." Note: ARC-IT defines confidentiality rating between people (personnel, traveler, etc.) and systems as not applicable.
>
> **INTEGRITY** refers to "Guarding against improper information modification or destruction, and includes ensuring information non-repudiation and authenticity." A loss of integrity is the unauthorized modification or destruction of information.
>
> **AVAILABILITY** refers to "Ensuring timely and reliable access to and use of information." A loss of availability is the disruption of access to or use of information or an information system.

FIPS PUBS 200 defines an approach for identifying the appropriate types of security controls (high-level requirements) for each security level in the three impact areas defined in FIPS PUBS 199. The document defines minimum requirements for Federal information and information processing systems. The first step is to identify the specific security and privacy controls of each type that the system will require. These are defined in NIST Special Publication 800-53 Rev. 4. Security and Privacy Controls for Federal Information Systems and Organizations.

As described in ARC-IT 9.1 a security level is a statement of its security requirements for its confidentiality, integrity, and availability. Because there are three security levels (low, moderate, or high) for each of the dimensions of confidentiality, integrity and availability, there are potentially 27 different device security classes. To simplify the process and to leverage the economies of scale, ARC-IT reduced the 27 classes into only five classes, based on the following two principles:

1. Every information flow is covered by a security class that matches or exceeds its security requirements
2. Every information flow is covered by a security class that exceeds its security requirements under no more than two headings

The five security classes are defined as in Table 12 below, which defines how the data security requirements levels in terms of confidentiality, integrity, and availability are related to the device security classes and their controls.

Table 12. Relationship between Data Security Requirements and Security Class Level.

Class	Confidentiality	Integrity	Availability
Class 1	Low	Moderate	Moderate
Class 2	Moderate	Moderate	Moderate
Class 3	Moderate	High	Moderate
Class 4	High	High	Moderate
Class 5	High	High	High

The defined definitions of the security classes can be found at: https://www.arc-it.net/html/security/deviceclasses.html.

Table 13 lists the Security Class rating for each information flow. The table includes:

- ID – refers to the information flow identifier [ID] (see **Table 11**)
- Flow Name – refers to the information flow name (see **Table 11**)
- Source Element -- refers to the source element name (see **Table 11**)
- Destination Element -- refers to the destination element name (see **Table 11**)
- Confidentiality – refers to the FIPS 199 rating as interpreted by the ARC-IT 9.1, Valid values include [Not applicable, Low, Moderate, High]
- Integrity – refers to the FIPS 199 rating as interpreted by the ARC-IT 9.1. Valid values include [Low, Moderate, High]
- Availability – refers to the FIPS 199 rating as interpreted by the ARC-IT 9.1, Valid values include [Low, Moderate, High]
- Security Class – refers to the ARC-IT 9.1 Security Class rating, Valid values include [Class 1, Class 2, Class 3]

Table 13. Security Characteristics of Information Flows

ID	Flow Name	User Defined	Source Element	Destination Element	Confidentiality	Integrity	Availability	Security Class
3	archive coordination	no	Performance Management Dashboard	Secure Performance Management Center	Moderate	High	High	Class 3
4	archive coordination	no	Secure Performance Management Center	Performance Management Dashboard	High	High	High	Class 5
5	archive management data	no	Performance Management Dashboard	PMD Administrator	Moderate	Moderate	Moderate	Class 2
6	archive management requests	no	PMD Administrator	Performance Management Dashboard	Moderate	Moderate	Moderate	Class 2
7	crossing permission (walk signal)	no	PED-X and Traffic Signal Field Equipment	Traveler	Moderate	Moderate	Moderate	Class 2
8	CTP updates	Yes	Call Center	Traveler	Not Applicable	Moderate	Moderate	Class 1
9	demand response passenger and use data	no	Human Driven Shuttle	CS HDS Management Center	External System	External System	External System	External System
10	demand response passenger and use data	no	Self-Driving Shuttle OBE	CS SDS Management Center	External System	External System	External System	External System
11	demand responsive transit plan	no	CS HDS Management Center	CTP	Moderate	Moderate	Moderate	Class 2
12	demand responsive transit plan	no	CS SDS Management Center	CTP	Moderate	Moderate	Moderate	Class 2
13	demand responsive transit request	no	CTP	CS HDS Management Center	Moderate	Moderate	Moderate	Class 2
14	demand responsive transit request	no	CTP	CS SDS Management Center	Moderate	Moderate	Moderate	Class 2
15	Facility monitoring data	yes	BNMC Facility	BNMC Facility Personnel	Not Applicable	Moderate	Moderate	Class 1
16	government reporting data receipt	no	Independent Evaluation Reporting System	Performance Management Dashboard	Low	High	Low	Class 3
17	government reporting system data	no	Performance Management Dashboard	Independent Evaluation Reporting System	Low	High	Low	Class 3
18	host transit vehicle status	no	HDS	Human Driven Shuttle	External System	External System	External System	External System

ID	Flow Name	User Defined	Source Element	Destination Element	Confidentiality	Integrity	Availability	Security Class
19	host transit vehicle status	no	SDS	Self-Driving Shuttle OBE	External System	External System	External System	External System
21	intersection geometry	no	MetroRail Update System	NFTA Transit Management Center	External System	External System	External System	External System
22	map operator input	no	Facility Manager	Indoor Facility Map Update System	Not Applicable	High	High	Class 1
23	map operator input	no	UB data collection team	MetroRail Update System	Not Applicable	High	High	Class 1
24	map operator updates	no	Indoor Facility Map Update System	Facility Manager	Not Applicable	Moderate	Moderate	Class 1
25	map operator updates	no	MetroRail Update System	UB data collection team	Not Applicable	Moderate	Moderate	Class 1
26	map update notification	no	NFTA Transit Management Center	MetroRail Update System	Low	Moderate	Moderate	Class 2
27	map updates	no	Indoor Facility Map Update System	CTP	Not Applicable	High	Moderate	Class 1
28	map updates	no	MetroRail Update System	NFTA Transit Management Center	Not Applicable	High	Moderate	Class 1
29	metrorail path updates + status notifications	yes	MetroRail Update System	CTP	Low	Moderate	Moderate	Class 1
30	path sensor data	yes	BNMC Facility	CTP Mobile App	Low	Moderate	Moderate	Class 1
31	path sensor monitoring	yes	CTP Mobile App	BNMC Facility	Low	Moderate	Moderate	Class 1
32	path status update notifications	yes	CTP	CTP Mobile App	Low	Moderate	Moderate	Class 1
33	path status update notifications	yes	Indoor Facility Map Update System	BNMC Facility	Low	Moderate	Moderate	Class 1
34	path status update notifications	yes	Indoor Facility Map Update System	CTP	Low	Moderate	Moderate	Class 1
35	Pedestrian signal actuation request	yes	CTP	Traffic Signal Gateway (Cloud)	High	Moderate	Moderate	Class 3
36	PED-X actuation request	yes	Traffic Signal Gateway (Cloud)	PED-X and Traffic Signal Field Equipment	High	Moderate	Moderate	Class 3
37	Ped-X actuation request confirmation	yes	Traffic Signal Gateway (Cloud)	CTP	Moderate	Moderate	Moderate	Class 3
39	performance metrics	yes	CS HDS Management Center	Performance Management Dashboard	Moderate	Moderate	Moderate	Class 2

ID	Flow Name	User Defined	Source Element	Destination Element	Confidentiality	Integrity	Availability	Security Class
40	performance metrics	yes	CS SDS Management Center	Performance Management Dashboard	Moderate	Moderate	Moderate	Class 2
41	performance metrics	yes	NFTA Transit Management Center	Performance Management Dashboard	Moderate	Moderate	Moderate	Class 2
42	personal input	no	Traveler	CTP Mobile App	Not Applicable	Moderate	Moderate	Class 1
43	personal updates	no	CTP Mobile App	Traveler	Not Applicable	Moderate	Moderate	Class 1
44	Reservation request	yes	Call Center	CTP	Not Applicable	Moderate	Moderate	Class 1
46	route assignment	no	CS HDS Management Center	HDS Driver	External System	External System	External System	External System
47	route assignment	no	CS SDS Management Center	SDS Steward	External System	External System	External System	External System
48	service information request	no	CTP	CS SDS Management Center	Moderate	Moderate	Moderate	Class 2
49	service information request	no	Secure Performance Management Center	Performance Management Dashboard	Moderate	Moderate	Moderate	Class 2
50	service information response	no	CS SDS Management Center	CTP	Moderate	Moderate	Moderate	Class 2
51	service information response	no	Performance Management Dashboard	Secure Performance Management Center	High	Moderate	Moderate	Class 3
52	system status	no	PED-X and Traffic Signal Field Equipment	Traffic Signal Gateway (Cloud)	High	Moderate	Moderate	Class 3
53	TIC operations information presentation	no	CTP	CTP System Administrator	Not Applicable	Moderate	Moderate	Class 1
54	TIC operator input	no	CTP System Administrator	CTP	Not Applicable	Moderate	Moderate	Class 1
57	transit and fare schedules	no	CS HDS Management Center	CTP	Low	Moderate	Moderate	Class 1
58	transit and fare schedules	no	CS SDS Management Center	CTP	Low	Moderate	Moderate	Class 1
59	transit archive data	no	CS HDS Management Center	Performance Management Dashboard	Moderate	Moderate	Low	Class 2
60	transit archive data	no	CS SDS Management Center	Performance Management Dashboard	Moderate	Moderate	Low	Class 2
61	transit archive data	no	NFTA Transit Management Center	Performance Management Dashboard	Moderate	Moderate	Low	Class 2

ID	Flow Name	User Defined	Source Element	Destination Element	Confidentiality	Integrity	Availability	Security Class
62	transit operations personnel input	no	NFTA dispatch and operator	CS HDS Management Center	External System	External System	External System	External System
63	transit operations personnel input	no	SDS SOC Personnel	CS SDS Management Center	External System	External System	External System	External System
64	transit operations status	no	CS HDS Management Center	NFTA dispatch and operator	External System	External System	External System	External System
65	transit operations status	no	CS SDS Management Center	SDS SOC Personnel	External System	External System	External System	External System
66	transit schedule adherence information	no	CS HDS Management Center	CTP	Low	Moderate	Moderate	Class 1
67	transit schedule adherence information	no	CS SDS Management Center	CTP	Low	Moderate	Moderate	Class 1
68	transit service information	no	CTP	Call Center	Low	Moderate	Moderate	Class 1
69	transit vehicle operator availability	no	HDS Driver	CS HDS Management Center	External System	External System	External System	External System
70	transit vehicle operator availability	no	SDS Steward	CS SDS Management Center	External System	External System	External System	External System
71	transit vehicle operator display	no	Human Driven Shuttle	HDS Driver	External System	External System	External System	External System
72	transit vehicle operator display	no	Self-Driving Shuttle OBE	SDS Steward	External System	External System	External System	External System
73	transit vehicle operator information	no	CS HDS Management Center	Human Driven Shuttle	External System	External System	External System	External System
74	transit vehicle operator information	no	CS SDS Management Center	Self-Driving Shuttle OBE	External System	External System	External System	External System
75	Transit vehicle operator input	no	HDS Driver	Human Driven Shuttle	External System	External System	External System	External System
76	transit vehicle operator input	no	SDS Steward	Self-Driving Shuttle OBE	External System	External System	External System	External System
77	travel service information	no	CS HDS Management Center	CTP	Low	Moderate	Low	Class 1
78	travel service information	no	CS SDS Management Center	CTP	Low	Moderate	Low	Class 1
79	travel service information	no	CTP	Personal Web Application	Low	Moderate	Low	Class 1
80	travel service information request	no	CTP	CS HDS Management Center	Moderate	Moderate	Moderate	Class 2

ID	Flow Name	User Defined	Source Element	Destination Element	Confidentiality	Integrity	Availability	Security Class
81	travel service information request	no	CTP	CS SDS Management Center	Moderate	Moderate	Moderate	Class 2
82	travel service reservation request	no	CTP	CS HDS Management Center	Moderate	Moderate	Moderate	Class 2
83	travel service reservation request	no	CTP	CS SDS Management Center	Moderate	Moderate	Moderate	Class 2
84	travel service reservations	no	CS HDS Management Center	CTP	Moderate	Moderate	Moderate	Class 2
85	travel service reservations	no	CS SDS Management Center	CTP	Moderate	Moderate	Moderate	Class 2
86	travel service reservations	yes	CTP	CTP Mobile App	Moderate	Moderate	Moderate	Class 2
87	travel service reservations	yes	CTP	Personal Web Application	Moderate	Moderate	Moderate	Class 2
88	travel service reservations	yes	CTP	Transportation Information Hub	Moderate	Moderate	Moderate	Class 2
89	travel services information	no	CTP	CTP Mobile App	Low	Moderate	Low	Class 1
90	travel services information	no	CTP	Transportation Information Hub	Low	Moderate	Low	Class 1
91	travel services request	no	CTP Mobile App	CTP	Moderate	Moderate	Moderate	Class 2
92	travel services request	no	Personal Web Application	CTP	Moderate	Moderate	Moderate	Class 2
93	travel services request	no	Transportation Information Hub	CTP	Moderate	Moderate	Moderate	Class 2
94	travel services reservations	yes	CTP	Call Center	Moderate	Moderate	Moderate	Class 2
95	traveler alerts	no	CTP	CTP Mobile App	Moderate	Moderate	Moderate	Class 2
96	traveler archive data	no	CTP	Performance Management Dashboard	Moderate	Moderate	Low	Class 2
97	traveler input	no	Traveler	CTP Mobile App	Not Applicable	Moderate	Moderate	Class 1
98	traveler input	no	Traveler	Transportation Information Hub	Not Applicable	Moderate	Moderate	Class 1
99	traveler input via call taker	yes	Call Taker	Call Center	External System	External System	External System	External System
100	traveler interface updates	no	CTP Mobile App	Traveler	Not Applicable	Moderate	Moderate	Class 1

ID	Flow Name	User Defined	Source Element	Destination Element	Confidentiality	Integrity	Availability	Security Class
101	traveler interface updates	no	Transportation Information Hub	Traveler	Not Applicable	Moderate	Moderate	Class 1
102	trip confirmation	no	CTP	CS HDS Management Center	Moderate	Moderate	Moderate	Class 2
103	trip confirmation	no	CTP	CS SDS Management Center	Moderate	Moderate	Moderate	Class 2
104	trip confirmation	no	CTP Mobile App	CTP	Moderate	Moderate	Moderate	Class 2
105	trip feedback	no	Personal Web Application	CTP	Moderate	Moderate	Moderate	Class 2
106	trip plan	no	CTP	CTP Mobile App	Moderate	Moderate	Moderate	Class 2
107	trip planning service request	yes	Call Center	CTP	Moderate	Moderate	Moderate	Class 2
108	trip request	no	CTP Mobile App	CTP	Moderate	Moderate	Moderate	Class 2
109	trip tracking information	yes	CTP Mobile App	CTP	High	High	Moderate	Class 3
110	user account setup	no	CTP Mobile App	CTP	High	High	Moderate	Class 3
112	user account setup	no	Personal Web Application	CTP	High	High	Moderate	Class 3
113	user profile	no	CTP Mobile App	CTP	High	Moderate	Low	Class 3

5 References

[1] [ARC-IT v9] "Architecture Reference for Cooperative and Intelligent Transportation," ARC-IT v9.0, Oct. 13, 2021. https://www.arc-it.net/index.html (accessed May 10, 2022).

[2] *[ConOps]* Gopalakrishna, D., et al. (2021). *Phase 1 Concept of Operations (ConOps) – Buffalo, NY ITS4US Deployment Project (FHWA-JPO-21-860)*. Federal Highway Administration.

[3] [DMP] Gopalakrishna, D., et al. (2021). *Phase 1 Data Management Plan (DMP) – Buffalo, NY ITS4US Deployment Project (FHWA-JPO-21-868)*. Federal Highway Administration.

[4] [SMP] Gopalakrishna, D., et al. (2021). *Phase 1 Safety Management Plan (SMP) – Buffalo, NY ITS4US Deployment Project (FHWA-JPO-21-873)*. Federal Highway Administration.

[5] [PMESP] 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] [SyRS] Gopalakrishna, D., et al. (2021). *Phase 1 System Requirements Specification (SyRS) – Buffalo, NY ITS4US Deployment Project (FHWA-JPO-21-883)*. Federal Highway Administration.

[7] [ISO SSE] ISO/IEC/IEEE 42010:2011 Systems and software engineering — Architecture description

[8] [FIPS 199] FIPS PUBS 199 Standards for Security Categorization of Federal Information and Information Systems

[9] [FIPS 200] FIPS 200 Minimum Security Requirements for Federal Information and Information Systems

[10] [SEMP] *Phase 1 System Engineering Management Plan (SEMP) – Buffalo, NY ITS4US Deployment Project (FHWA-JPO-21-918) Federal Highway Administration.*

[11] [NIST] *NIST Special Publication 800-53 Rev. 4. Security and Privacy Controls for Federal Information Systems and. Organizations.*

Appendix A. Acronyms

Table 14 summarizes the acronyms used in this document.

Table 14. List of Acronyms

Acronym	Description
ARC-ITS	ITS Architecture
AVL	Automated Vehicle Location
AWS	Amazon Web Services
BNMC	Buffalo Niagara Medical Campus
CAD	Computer-aided Dispatch
DMP	Data Management Plan
CoB	City of Buffalo
CS	Community Shuttle
CTP	Complete Trip Platform
ICD	Interface Control Document
GN	Guiding Needs
GTFS	General Transit Feed Specification
HDS	Human Driven Shuttle
HTTP	Hypertext Transfer Protocol
IETF	Internet Engineering Task Force
IP	Internet Protocol
ISO	International Organization for Standardization
MIB	Management Information Base

Acronym	Description
MSA	Metropolitan Statistical Area
NFTA	Niagara Frontier Transportation Authority
NITTEC	Niagara International Transportation Technology Consortium
NTCIP	National Transportation Communications for Intelligent Transportation System Protocol
OBE	Onboard Equipment
ODD	Operations Design Domain
OSI	Open Systems Interconnection
P-Object	Physical Object
PAL	Paratransit Access Line
PED-X	Pedestrian Crossing
PII	Personally Identifiable Information
PMD	Performance Management Dashboard
PROW	Public Right of Way
RFC	Request for Comments
ROW	Right of Way
SAD	System Architecture Document
SAV	Shared Autonomous Vehicles
SDS	Self-Driving Shuttle
SI	Smart Infrastructure
SNMP	Simple Network Management Protocol
SOC	Shuttle Operations Center
SOI	System of Interest
SyRS	Systems Requirements Specification

Acronym	Description
TIC	Transportation Information Center
TIH	Transportation Information Hub
TMC	Traffic Management Center
TMDD	Traffic Management Data Dictionary
UB	University at Buffalo
UI	User Interface
USDOT	United States Department of Transportation
VIA	Visually Impaired Advancement (name of facility/organization on the BNMC campus)
WZ	Work Zone

Appendix B. Standards Plan

The standards plan is included in the Phase 2 Interface Control Document (submitted 2024 February 21).

Appendix C. System of Interest Change Log

The following section details the changes made to the different diagrams as the concept has evolved from Phase 1 to Phase 2.

System of Interest Changes from Phase 1

Table 15 lists the edits made to the high level context diagram of the System of Interest (SOI), as it evolved from Phase 1 (see **Figure 24** and **Figure 25**) to Phase 2 (see **Figure 3**).

Table 15. Changes to the High Level Context Diagram

Diagram Element	Description of change (from ConOps)	Rationale	Date
Element color scheme	• Changed Smart Infrastructure (SI) to light blue • Changed CTP to dark blue • Changed PMD to dark grey • Changed External Systems to light grey • Changed Community Shuttle Subsystem to green • Changed traveler to clear. • Added icons to elements where appropriate • Removed named data flows and simplified where connections exist.	Easier to distinguish the different subsystems. These colors are now used in the detailed SOI diagrams to designate subsystem elements.	Phase 2 (10/24/2022)
Smart Infrastructure	Changed smart signs to indoor navigation	Refined the name of this component to indoor navigation in subsequent documents to better reflect the purpose and functionality.	Phase 2 (10/24/2022)

Diagram Element	Description of change (from ConOps)	Rationale	Date
Smart Infrastructure	Change intersections to Ped-X	Refined the name of this component to Ped-X is subsequent documents to better reflect the purpose and functionality.	Phase 2 (10/24/2022)
Smart Infrastructure	Added bullets for the locations where the Indoor Navigation and the Ped-X will be deployed	Clarified locations in the context diagrams	Phase 2 (10/24/2022)
External Systems	Grouped all external data sources/destinations into a grey box. Changed name of some external data sources and removed others (e.g., fare system/payment system) Specifically: • Removed performance tracking data • Removed emergency management exchange (will occur via 911) • NFTA service information now covers all NFTA data including NFTA Transit service • CoB Workzone replace PROW & NITTEC Traffic Information • Path data (NFTA Stations, Sidewalk, Facilities) replaces some PROW datasets and NFTA Elevator and Escalator Status	When reviewed with stakeholders during deployment planning, the types of data changed, and the sources of the information flows changed. (note: more detailed information on external sources and datasets are described in the detailed SOI subsystem diagrams) Some information flows were deemed not relevant given the changing concept, requirements, subconsultants on the project. NITTEC does not have data for the BNMC region. So the data feed was removed because it doesn't serve the end-user. A different system other than the PAL (Direct) System was used to provide Human-Driven Shuttle services, so PAL System was removed.	Phase 2 (10/24/2022) Removed PAL System and NITTEC (2/12/2024)
Complete Trip	Simplified the internal boxes to show two major components of the system.	Simplified the CTP Subsystem into the two major components.	Phase 2 (10/24/2022)

Diagram Element	Description of change (from ConOps)	Rationale	Date
CS	Changed the view from a single vehicle and SOC to two systems – for the HDS and SDS. Removed the human actors from the simplified view (i.e., operator/steward, shuttle driver, soc personnel).	A decision was made halfway through Phase 1 that the HDS and SDS will work independently under two separate business models. The systems will be independent of each other as well. The model now shows the independent systems that will be deployed under the CS subsystem.	Phase 2 (10/24/2022)
PMD	Added the public PMD component to the PMD.	The major function of the PMD will be to support public access to the system performance.	Phase 2 (10/24/2022)

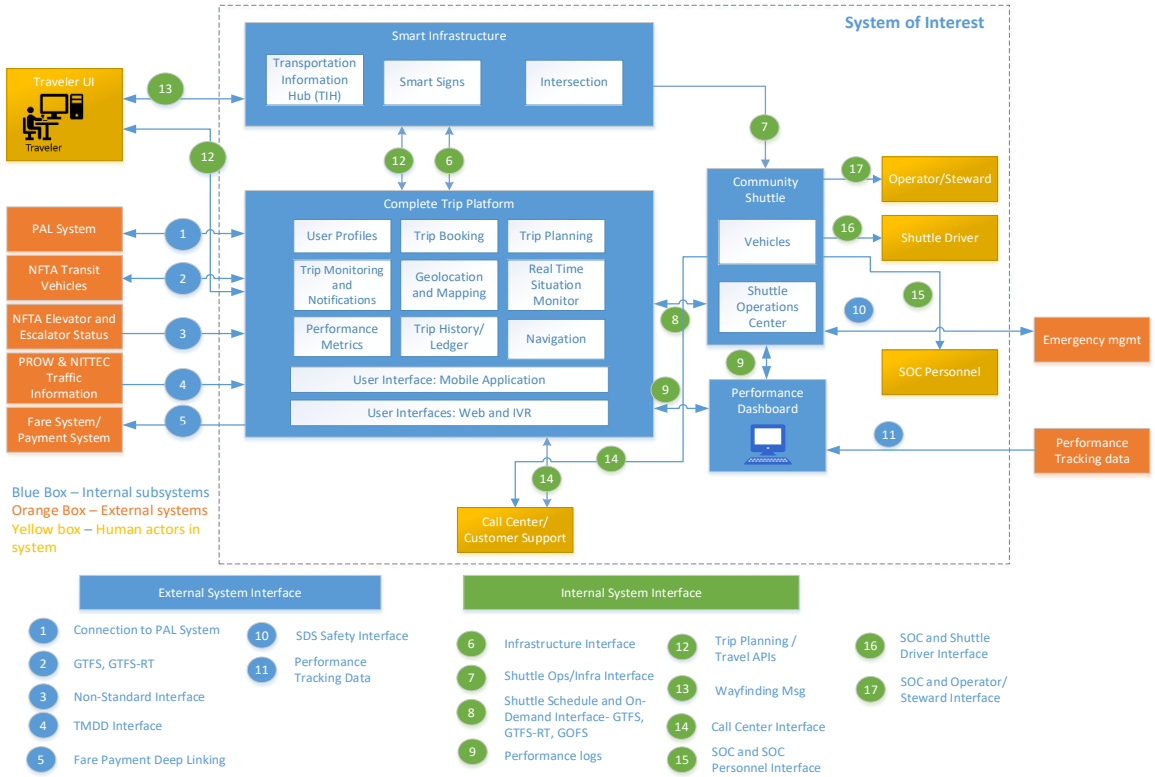

Figure 24. Phase 1 Context Diagram provided in the ConOps.
Source: Buffalo, NY ITS4US – ConOps [2]

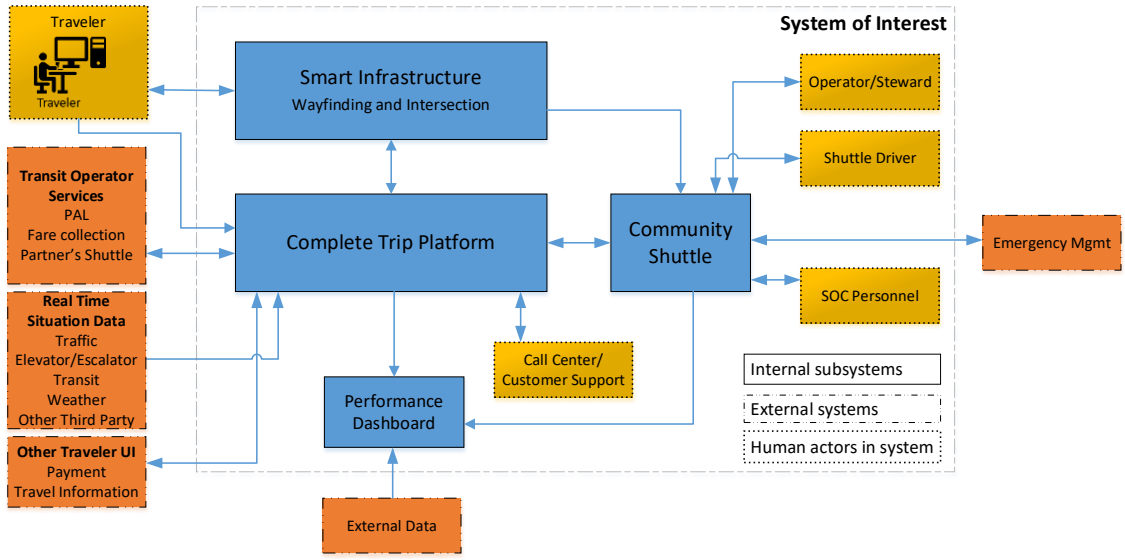

Figure 25. Phase 1 High Level Diagram of the SOI provided in the System Engineering Management Plan.
Source: Buffalo, NY ITS4US – SEMP [10]

Community Shuttle SDS Changes from Phase 1

Table 16 lists the changes made to the Community Shuttle context diagram from the Phase 1 ConOps (see **Figure 26**) to Phase 2 architecture (see **Figure 6** and **Figure 7**)

Table 16. Changes to the Community Shuttle Context Diagram.

Diagram Element	Description of change	Rationale	Date
Color	Changed color of subsystem to green Changed tag and colors of internal and external flows to overall color scheme and numbering scheme.	Changed colors to be consistent with simple context diagram	10/27/2022
HDS / SDS functions	Separated HDS and SDS systems	Separated hds and sds systems because although their systems overlap, they are two independent vendors, locations and systems that will implement functions differently.	10/27/2022
HDS and SDS functional details	Removed functions from SOI. Kept high level components: center, vehicle and personnel in each	Removed most details from context diagram because both HDS and SDS will be deployed as turn-key systems or by existing vendors without change or software development.	10/27/2022
Vehicle / personnel flows between SOC and vehicle	Removed information flow between human personnel and SOC and between vehicle OBE and SOC	Removed information flow between human personnel and SOC and between vehicle OBE and SOC because that data is part of the turn-key systems and will not be collected as part of the evaluation.	10/27/2022
Emergency Mgmt	Removed	Removed Emergency Mgmt from diagram (SDS) because emergencies will be treated through normal channels (per discussion with EMS stakeholders)	10/27/2022
PROW & NITTEC Traffic Info	Removed PROW from external source Removed NITTEC Traffic Info because NITTEC does not cover the project area.	Remove PROW from external source because that is a role of the SDS vendor which is part of the turn-key program.	10/27/2022 (NITTEC, 2/12/2024)

Diagram Element	Description of change	Rationale	Date
Call center flow	Call center flow is now depicted as a voice call between the SOC personnel and Call Center	This process was deemed as more direct during discussion with SDS vendors.	10/27/2022
NFTA HDS Mgmt Center	The SOC for the HDS is now called the NFTA HDS Mgmt Center	The NFTA will take the lead on the functions associated with reservations, operations, dispatch and summary trip reporting. In addition, it will use all its current systems and SOPs to provide operations services.	10/27/2022
HDS	HDS functions are not included	HDS OBE will depend on the existing fleet features currently deployed in NFTA paratransit vehicles.	10/27/2022

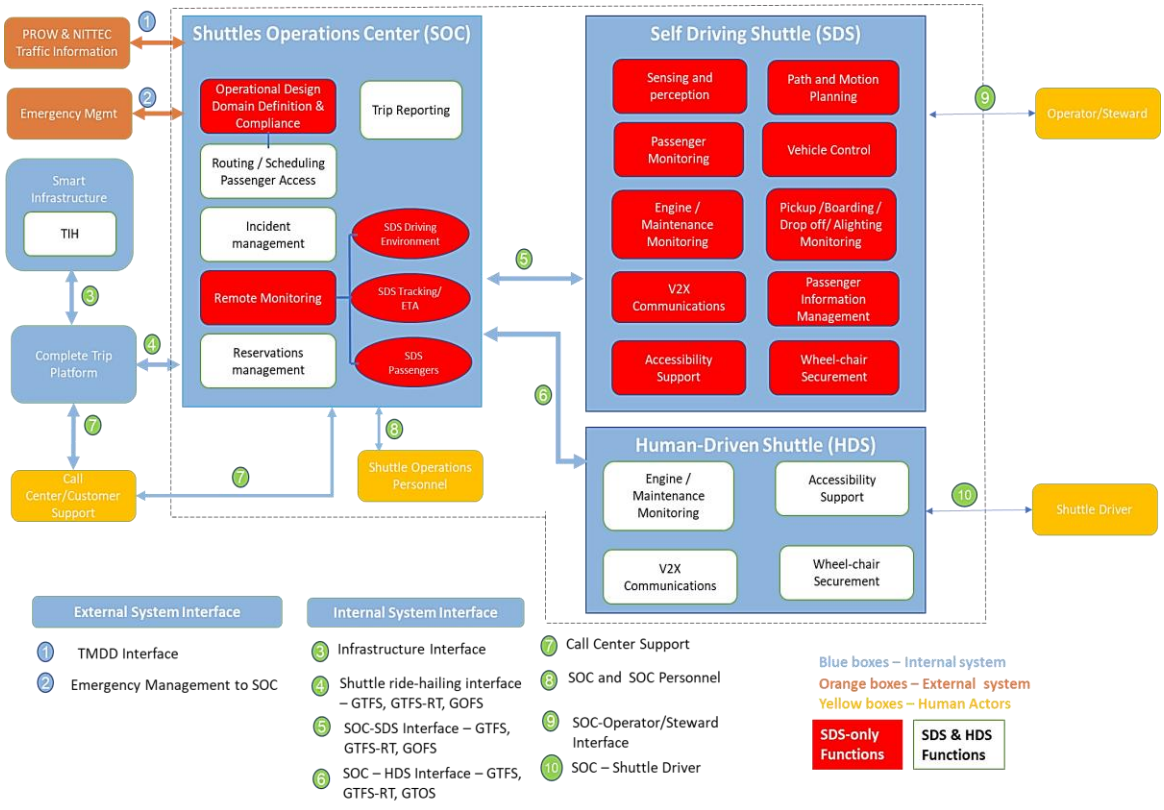

Figure 26. Phase 1 Community Shuttle Context Diagram
Source: Buffalo, NY ITS4US – ConOps [2]

Complete Trip Platform Changes from Phase 1

Table 17 lists the changes made from the Phase 1 ConOps (see **Figure 24**) to Phase 2 architecture (see **Figure 4**).

Table 17. Changes to the Complete Trip Platform Context Diagram

Diagram Element	Description of change	Rationale	Date
Colors	Changed color scheme to match High Level Context Diagram. Changed inputs from data sources to reflect new legend including external system interfaces designated by orange flows and internal system interfaces by green. Sources are colored using similar colors to match their source. Sources of information sources are all designated as ovals (called boxes in the legend).	Shows consistency throughout all SOI diagrams	10/27/2022
Information flow (interface) tags	Changed interface tags from number to prefix of “I-“.	Needed to differentiate differences between the DMP datasets and information flows.	10/27/2022
Added internal boxes	Added CTP Database	Added this to show database storage in the Phase 1 DMP document	10/27/2022
Added internal boxes	Added Data Broker	Added to show where data is ingested and exchanged to/from smart infrastructure systems (not TIH)	10/27/2022
Added CTP mobile app	Added CTP Mobile App and functions that will reside in mobile app	Added the mobile app because needed to show how the app can work when data is not applied to mobile app for turn by turn directions (ID Need); and the interconnection with the indoor navigation	10/27/2022

Performance Measurement Dashboard Changes from Phase 1

Table 18 list the changes between the PMD concept diagram presented in Phase 1 (see **Figure 27**) and the updated diagram presented in the Phase 2 architecture (see **Figure 11**).

Table 18. Changes to the Performance Measurement Dashboard Context Diagram

Diagram Element	Description of change	Rationale	Date
Colors	Change PMD color from blue to grey.	Distinguish PMD from CTP.	10/27/2022
External Data sets	Changed from dataset types (database, flat files, APIs) to specific datasets.	Became more precise in the data to be delivered.	10/27/2022
Data Tier	Added Pedestrian Crossing and removed Survey data.	Survey data will come from the Performance Measures (a secure data store). Survey data has PII and the PMD will not store PII. This was cancelled on 2/12/2024	10/27/2022
Data Tier	Added Survey data input directly to the PMD. Removed Pedestrian Crossing metrics input directly to PMD.	The PMD will acquire the Survey data directly from the Survey instrument and remove the PII when transferring it to the PMD. The PED-X operational data will be submitted through the CTP operational data.	2/12/2024
Processing Tier	Removed authentication services	Authentication services will be provided by existing UB Information Technology server services; it will not offered through the processing tier	2/12/2024
Processing Tier	Added post-processing datasets	Added a function to post-process the datasets including aggregation services and analytics.	2/12/2024
Presentation (Access) Tier	Updated Map Services to PMD	Map service is a subset of the public measurement dashboard. The PMD includes graphics and charts. It also includes the data portal to access tabular, data catalog, and metadata.	2/12/2024

Diagram Element	Description of change	Rationale	Date
Data lake flows to Dashboard	Removed information flow from data lake (direct/API) to Dashboard.	Removed information flows from the data lake to the dashboard because these are internal to the PMD.	10/27/2022
Tagged data flows	Tagged and enumerated specific data flows.	Became more precise in the information flows/interfaces to support PMD.	10/27/2022

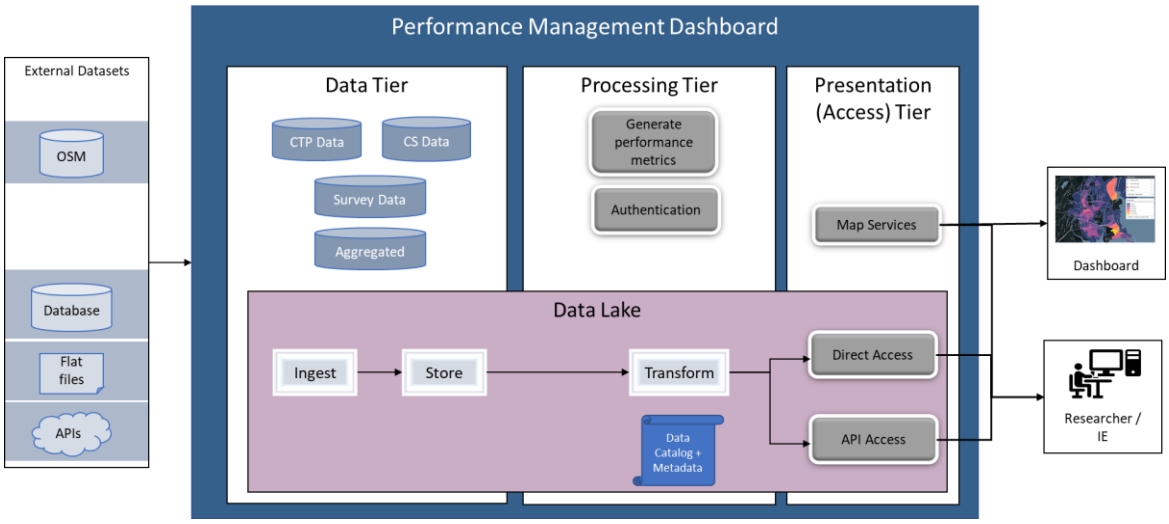

Figure 27. Performance Measurement Dashboard Context Diagram from the Phase 1 SEMP
Source: Buffalo, NY ITS4US – SEMP [10]

Smart Infrastructure Changes from Phase 1

There were no context diagrams developed for Smart Infrastructure elements in Phase 1 since these were depicted as terminators in the CTP SOI. As such, **Table 19** list the characteristics of the PED-X (**Figure 9**) and Indoor Navigation (**Figure 10**) component.

Table 19. Changes to the Smart Infrastructure Context Diagram

Diagram Element	Description of change	Rationale	Date
Diagrams Instances	Created SOI diagrams for two major applications (indoor navigation and PED-X)	More details were identified that represent internal and external (legacy) systems	10/27/2022

Diagram Element	Description of change	Rationale	Date
Colors	Added color for smart infrastructure components	Distinguish SI components	10/27/2022
External Data sets	Changed from dataset types (database, flat files, APIs) to specific datasets	Became more precise in the data to be delivered.	10/27/2022
Tagged data flows	Tagged and enumerated specific data flows	Became more precise in the information flows/interfaces to support PMD.	10/27/2022

Appendix D. SAD Change Log

The following section details the changes made from Version 1 (January 2023) to the current version.

Summary of high level changes from Version 1.0 to 1.1 includes:

- Updated vendor for HDS reservations, scheduling and dispatch software was changed from PAL to the open source code from NYSDOT Rural App.
- Removed NITTEC, NITTEC SOC and information flows because NITTEC doesn't collect traffic information in the project area.
- Updated PMD functions and information flows based on design.

Table 20: SAD Change Log

Section / Table/ Figure	Description of change	Rationale	Revision (from-to)
Table 3	Removed Touch Model from list	Touch model was equipment that was to be leveraged, but there is no interface to integrate with the All Access subsystems	1.0 to 1.1
Table 4	Removed NITTEC as a stakeholder name	NITTEC doesn't collect data in the project region.	1.0 to 1.1
Section 2.3	Changed Concerns to No concerns	The concerns addressed procurements and on-boarding of vendors. At the time of this writing all vendors were selected and integration is in progress	1.0 to 1.1
Figure 3	Removed NITTEC as an external system	NITTEC was removed as a stakeholder	1.0 to 1.1

Section / Table/ Figure	Description of change	Rationale	Revision (from-to)
Table 5	I-3 added on-demand and flex service reservations I-10 added PED-X reporting to PMD I-11 removed PED-X reporting to PMD I-14 changed performance measures to Survey Data Feeds I-15 changed map services to web services (PMD) I-17 Changed API data to queries I-18 Changed title to External Data and updated types of data that will be ingested I-19 Removed NITTEC traffic Info	Updated table to reflect architecture figures	1.0 to 1.1
Section 3.2	Removed reference to NFTA PAL Direct software	Design will implement a different software product (the NYSDOT Rural App).	1.0 to 1.1
Section 3.2.1	Removed sentence NITTEC from narrative	NITTEC removed as a stakeholder	1.0 to 1.1
Figure 6	Removed NITTEC TOC and flow I-19	NITTEC removed as a stakeholder	1.0 to 1.1
Section 3.2.2	Changed NFTA PAL to NYSDOT Rural App	Design will implement a different software product (the NYSDOT Rural App).	1.0 to 1.1
Figure 10	Removed information flow from PED-X to PMD	Information will come from CTP now.	1.0 to 1.1
Section 3.4 / Figure 11	Updated section to match SDD	Design refined the description of the functions including updated Figure 11 to correspond with description.	1.0 to 1.1
Table 6	Removed NITTEC TOC from resource list	NITTEC removed as a stakeholder	1.0 to 1.1
Table 7	Removed NITTEC TOC from Enterprise Objects	NITTEC removed as a stakeholder	1.0 to 1.1
Table 8	Changed several rows: (06) Added Adastec as SDS vendor (10) Added CXApp as INS vendor (13) removed NITTEC as stakeholder	Updated table to reflect architecture figures and on-boarded vendors	1.0 to 1.1
Figure 12	Removed NITTEC (13) agreement from EA agreements	NITTEC removed as a stakeholder	1.0 to 1.1
Figure 14	Removed NITTEC from figure	NITTEC removed as a stakeholder	1.0 to 1.1
Section 4.2.2.1	Edited paragraph and removed aggregation and obfuscation process	CTP will send detailed trace data and PMD will remove PII from data (moved function from CTP to PMD)	1.0 to 1.1
Figure 15	Removed PED-X data flow to PMD	Data will now flow from CTP.	1.0 to 1.1

Section / Table/ Figure	Description of change	Rationale	Revision (from-to)
Section 4,2,2,2	Removed sentence describing the NITTEC information flow	NITTEC doesn't collect data for the project region so there is no information to transfer.	1.0 to 1.1
Figure 16	Removed NITTEC	NITTEC removed as a stakeholder	1.0 to 1.1
Section 4.2.2.5	Changed PAL software to on-demand service	Change description to better reflect design / solution	1.0 to 1.1
Figure 23	Removed NITTEC	NITTEC removed as a stakeholder	1.0 to 1.1
Table 9	Cleaned up object and SOI subsystem names and removed function: Aggregation and Obfuscation Services	Services are conducted in the PMD through analytic processes.	1.0 to 1.1
Table 10	Removed TMDD	TMDD represented NITTEC information flow.	1.0 to 1.1
Table 11	Removed the following information flows: (CTP) aggregation and obfuscation (NITTEC) incident info (PED-X) performance metrics (NITTEC) road network conditions (NITTEC) traffic image metadata and traffic images	Changes were made to reflect architecture changes	1.0 to 1.1
Table 13	Remove the following IDs (corresponding to the information flows in Table 11): 1, 2, 20, 38, 45, 55, 56	Changes were made to reflect architecture changes	1.0 to 1.1
Appendix B	Updated References	Additional documents were issued since last update	1.0 to 1.1
Appendix C	Changed title to SOI Change Log Updated Table	SOI Change log better reflects content. Several updates were made including removing PAL and NITTEC from the SOI	1.0 to 1.1
Appendix D	Added this appendix to the document	This appendix reflects the detailed changes made to Rev 1.1	1.0 to 1.1

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