SMART COLUMBUS

System Architecture and Standards Plan

for the Smart Columbus Demonstration Program

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Produced by City of Columbus

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Abstract

This document presents the System Architecture and Standards Plan (SASP) for the Smart Columbus demonstration program. The Smart Columbus vision strives to empower residents to live their best lives through responsive, innovative, and safe mobility solutions with a supporting mission to demonstrate how Intelligent Transportation Systems (ITS) and equitable access to transportation have positive impacts on every day challenges faced by cities. The Smart Columbus Program includes the implementation of several inter-related complex systems as part of its projects to achieve its goal.

This SASP documents the architecture for each of the projects associated with the Smart City demonstration program and associated standards (whether ITS or other related standards) that will be referenced and applied to each project. The U.S. Department of Transportation's (USDOT) Systems Engineering Tool for Intelligent Transportation (SET-IT) tool was used to develop each project's detailed project architecture diagrams. This tool provides graphical depictions of physical, enterprise, and communication views that are tied to an underlying database of information, as well as to information from the National ITS Architecture, whose framework and resources are offered via the USDOT's Architecture Reference for Cooperative and Intelligent Transportation (ARC-IT) 9.0.[1] This tool includes various references including architecture content, examples, tools, and terminologies. SET-IT is an example of one of the tools provided via the ARC-IT 8.3.

The intended audience for this document is the developers and architects employed by the vendors of the Smart Columbus projects who will use the document as a reference to ensure interoperable solutions. While any system stakeholder may find valuable information within this document, the target audience for this document is a more technical one that includes developers and architects who will be involved in the design, build, and implementation of the system, and need guidelines to prepare and document their architectural decisions. In addition, the audience for this document may include administrators and managers who organize the evolution of their systems, as well as auditors or reviewers who must validate architecture information to assess or evaluate a proposed system. A basic understanding of Systems Engineering for ITS[2] will be useful when reviewing this document.

[1] https://local.iteris.com/arc-it/index.html

[2] https://ops.fhwa.dot.gov/publications/seitsguide/index.htm

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Executive Summary

The U.S. Department of Transportation (USDOT) pledged $40 million to Columbus, Ohio, as the winner of the Smart City Challenge. With this funding, Smart Columbus will demonstrate how advanced technologies can be integrated into other operational areas within the city. By utilizing advancements in Intelligent Transportation Systems (ITS), Connected Vehicles (CVs), and Autonomous Vehicles to meet these challenges, Smart Columbus will integrate data from various sectors and sources to simultaneously power these technologies while leveraging the new information they provide.

The Smart Columbus vision strives to empower residents to live their best lives through responsive, innovative, and safe mobility solutions with a supporting mission to demonstrate how ITS and equitable access to transportation have positive impacts on every day challenges faced by cities. The Smart Columbus demonstration program achieves the goal by implementing several interrelated, complex systems as part of its projects which are grouped into three overarching themes: Enabling Technologies, Enhanced Human Services, and Emerging Technologies.

A guiding light of the Smart Columbus Program has been the application of the systems engineering approach, which provides a structured, user-driven process for system development. All projects have completed concept and requirements development, with some projects completing the interface definition process and others pivoting to an agile development methodology. Specific information about the Smart Columbus Program systems engineering process are contained in the Systems Engineering Management Plan.[3]

As the Smart Columbus projects moved from concept to design, the team focused on applying the National ITS Architecture and its tool, Systems Engineering Tool for Intelligent Transportation (SET-IT) as shown in **Figure 1** to define the architecture for each of the projects. The USDOT's Architecture Reference for Cooperative and Intelligent Transportation (ARC-IT) 9.0 guidance[4] recommends the application of the SET-IT tool at this stage.

The System Architecture and Standards Plan (SASP) document has been updated to reflect the as-built project changes to better allow readers to see the actual project that has been implemented while also sharing changes that took place from the concept phase to the as-built phase of the project. Major changes that were included in the intial release of the SASP but are not included in the current version are described in **Section 1.7**. Additionally, each diagram and table in **Chapter 2**, is revised to so that all the design and system changes are captured as per the as-builts of the project.

[3] https://d2rfd3nxvhnf29.cloudfront.net/2019-08/Smart%20Columbus%20Systems%20Engineering%20Management%20Plan_0.pdf

[4] https://local.iteris.com/arc-it/html/archuse/projdev.html

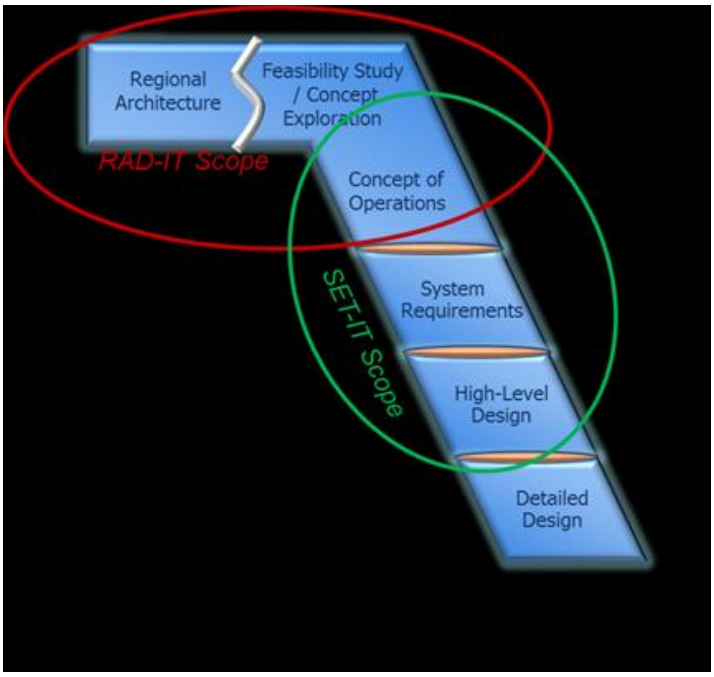


Figure 1: Moving from Concept to Design

Source: U.S. Department of Transportation

The purpose of this document, the SASP, is to document the System Architecture for the projects associated with the Smart City Challenge demonstration program and associated standards that it will use. This plan presents the following views for each of the projects within **Chapter 2**:

- **Physical View:** Physical Objects (systems and devices) and their Functional Objects as well as the high-level interfaces between those Physical Objects.
- **Enterprise View:** Relationships among organizations required to support the overall System Architecture.
- **Communications View:** Communications protocols between Physical Objects.
- **Functional View:** Abstract functional elements (processes) that satisfy the system requirements.

This SASP also identifies information exchange needs between systems that are supported by standards, documenting the applicable standards that will be used to ensure interoperability. Where new standards are needed, these are identified for each project in this SASP (see **Chapter 3**).

Chapter 1. Introduction

1.1. PROJECT DESCRIPTIONS

The Smart Columbus Program projects are grouped into three overarching themes: Enabling Technologies, Enhanced Human Services, and Emerging Technologies. The program also includes Smart Columbus Operating System – the backbone and heart of all Smart Columbus projects. **Figure 2** shows the Smart Columbus Program with projects and the Smart Columbus Operating System.

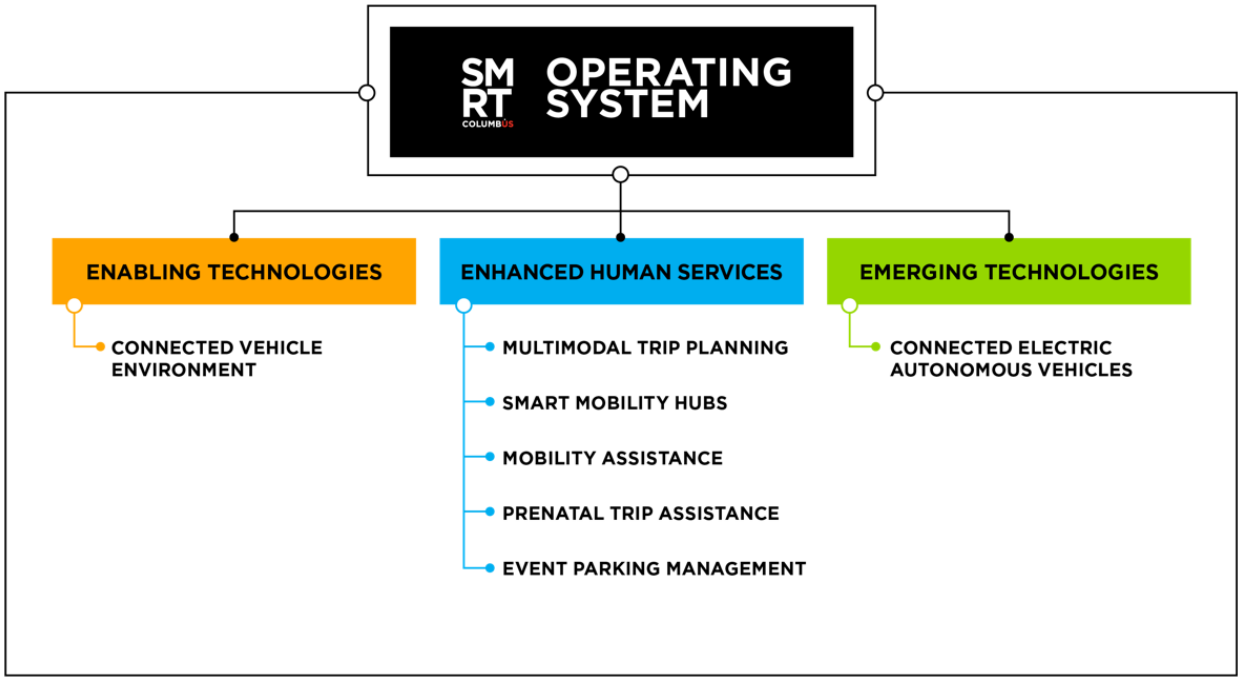


Figure 2: Smart Columbus Projects

Source: City of Columbus

1.1.1. Smart Columbus Operating System

The Smart Columbus Operating System is envisioned as a web-based, dynamic, governed data delivery platform built on a federated architecture that is at the heart of the Smart Columbus system. It will ingest, process, and disseminate data while providing access to data services from multiple sources and tenants (including the planned Smart Columbus technologies, traditional transportation data, and data from other community partners, such as food pantries and medical services). The Operating System will embody open-data, best-of-breed technologies including open-source and commercial off-the-shelf concepts that enable better decision-making and problem solving for all users. It will support a replicable, extensible, sustainable data delivery platform. The Smart Columbus Operating System will be the source for performance metrics for program monitoring and evaluation; serve the needs of public agencies, researchers and entrepreneurs; and assist health and human services organizations and other agencies in providing more effective services to their clients. The Smart Columbus Operating System will be scalable and demonstrate the potential for serving city and private sector needs beyond the life of the Smart City Challenge Award period.

1.1.2. Enabling Technologies

These technologies leverage today's foundation in new and innovative ways to greatly enhance the safety and mobility of the transportation infrastructure. These advanced technologies empower deployments that increase our capabilities because of rich data streams and infrastructure designed to handle on-demand responses. The Connected Vehicle Environment (CVE) is an enabling technology that will improve safety by leveraging cutting edge technology to advance the sustainable movement of people and goods.

1.1.3. Enhanced Human Services

These services encompass meeting human needs through the application of technology that focuses on prevention as well as remediation of problems, and maintain a commitment to improving the overall quality of life of users of the technology-based solutions. Opportunities will be created because of the Enhanced Human Services projects that improve access to jobs, healthcare, and events. These projects include Multimodal Trip Planning Application (MMTPA), Smart Mobility Hubs (SMH), Mobility Assistance for People with Cognitive Disabilities (MAPCD), Prenatal Trip Assistance (PTA), and Event Parking Management (EPM).

1.1.4. Emerging Technologies

New technologies that are currently developing, or will be developed over the next five to ten years, will substantially alter business and social environments. By focusing on the key Emerging Technologies surrounding Connected Electric Autonomous Vehicles (CEAVs), the City of Columbus will be able to exhibit potential solutions to address and mitigate future transportation and data-collection challenges.

1.1.5. System of Systems

With this understanding of the projects, it is also important to understand that the Smart Columbus Program has many interrelated systems that work together to provide a System of Systems. Information from the various projects are shared with the Smart Columbus Operating System. Both real-time and archived data are maintained in the Smart Columbus Operating System for use by other Smart Columbus projects and future applications. The System of Systems provides Smart Applications (Apps), smart vehicles, and infrastructure to travelers in the Columbus area. The Smart Columbus Operating System enables the System of Systems to share data with many other internal and external systems, providing the framework for the services provided.

The smart infrastructure element contains hardware-related items in the projects such as the roadside units (RSUs) in the CVE and the SMH. Smart vehicles include the installed onboard units (OBUs) and include various vehicle types. Apps include the software-oriented solutions that will deliver other Smart Columbus project capabilities such as the MMTPA and PTA.

The Smart Columbus Operating System is the repository for all performance data from the smart infrastructure and smart vehicles, as well as the microservices platform that allows direct integration of the Apps.

Finally, the projects depend on various external services, such as Security Credential Management System (SCMS) and Global Navigation Satellite System (GNSS).

Figure 3 shows the relationship of the System of Systems to external travelers and systems.

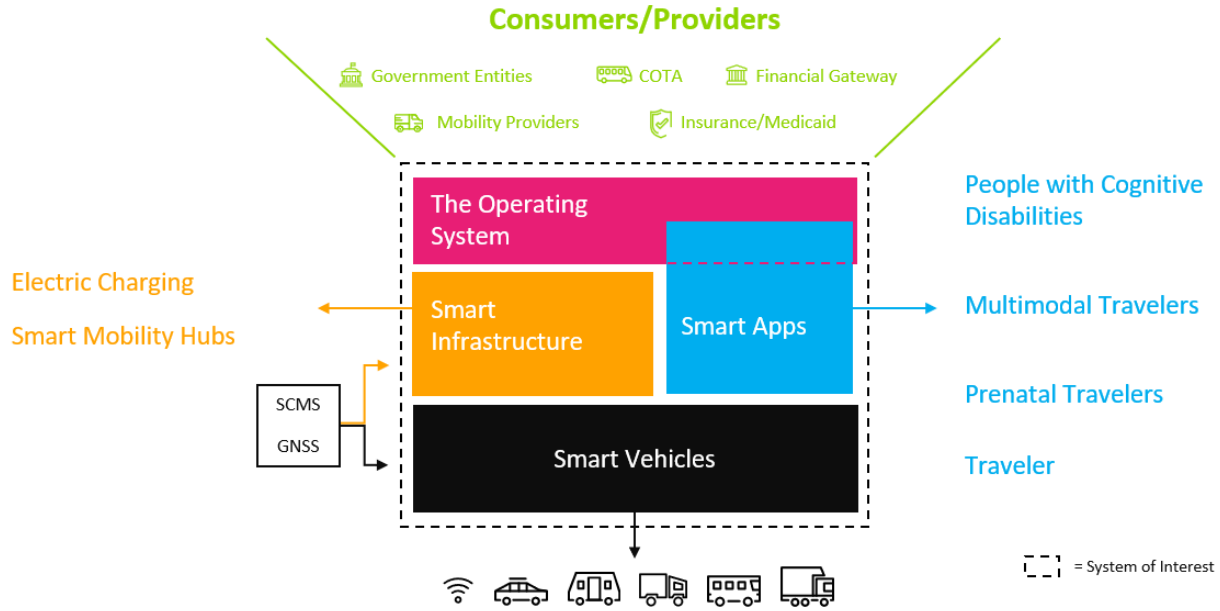


Figure 3: Smart Columbus System of Systems

Source: City of Columbus

1.2. INTRODUCTION TO SYSTEM ARCHITECTURE

International Organization of Standardization (ISO)/International Electrotechnical Commission (IEC) 42010:2007, *Systems and Software Engineering – Recommended Practice for Architecture Description of Software-Intensive Systems*, defines System Architecture as "fundamental concepts or properties of a system in its environment embodied in its elements, relationships, and in the principles of its design and evolution." Typically, System Architecture development follows the System Requirements/Interface Control definition phase of the project development. However, some of the projects followed the agile approach. The system engineering approach for each project can be found in **Table 1**. Refer to the Smart Columbus Systems Engineering Management Plan[5] (SEMP) for additional details on project development for Smart Columbus projects. The System Architecture is used as a basis or foundation to guide project design and development.

The ARC-IT is a mature architecture that provides a common framework for the ITS community to plan, define, and integrate ITS and Connected Vehicles (CVs). It includes a set of interconnected components that are organized into the following four "Views" (see Figure 4):

- Physical View defines the Physical Objects (the systems and devices) that provide ITS functionality. Information Flows define the flow of information between Physical Objects. Functional Objects organize the functionality that is required to support ITS within each Physical Object.

[5] https://d2rfd3nxvhnf29.cloudfront.net/2019-08/Smart%20Columbus%20Systems%20Engineering%20Management%20Plan_0.pdf

- Enterprise View considers ITS from an organizational perspective. It identifies stakeholder organizations or Enterprise Objects – the people and organizations that facilitate, own, develop, operate, maintain and use ITS. It defines stakeholder roles and the expectations and agreements among stakeholders.
- Communications View defines how Physical Objects communicate. It defines communications standards and profiles that are combined into communications solutions to specify how information can be reliably and securely shared among Physical Objects.
- Functional View looks at ITS from a functional perspective. Functional Requirements that support ITS User Needs are defined. Processes and data flows provide a structured presentation of functions and interactions that support the requirements.
- Security is paramount in 21st century ITS and ARC-IT, which addresses security concerns holistically, spanning all four Views.
- Finally, Service Packages comprise a service-oriented entry point that makes it easy to view a vertical slice of ARC-IT spanning all four Views for a particular ITS service (e.g., Infrastructure-Provided Trip Planning and Route Guidance).

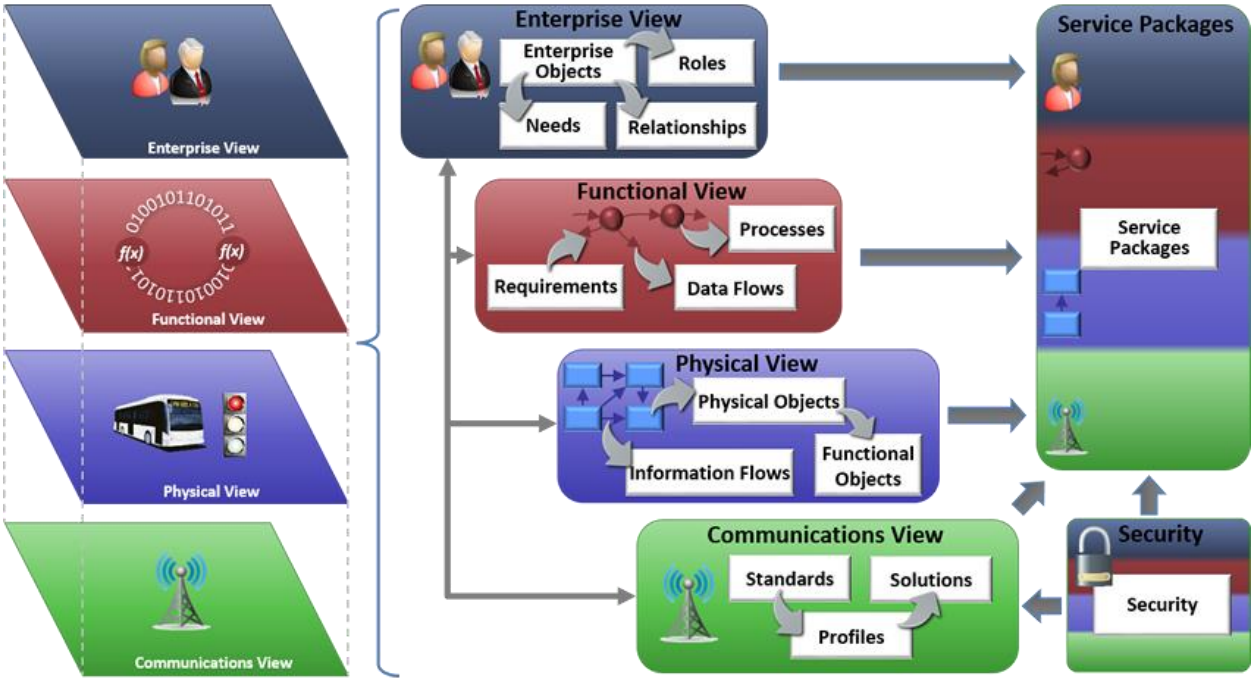


Figure 4: ARC-IT System Architecture Views

Source: USDOT Architecture Reference for Cooperative and Intelligent Transportation

1.3. INTRODUCTION TO STANDARDS

Architecture standards define how systems, products, and components interconnect, exchange information, and interact to deliver services within a transportation network. Standards establish communication rules for how systems can perform, how they can connect, and how they can exchange data to interoperate. It is important to note that these standards are not design standards; they do not specify specific products or designs to use. Instead, the standards give transportation agencies confidence that components from different manufacturers will work together, without removing the incentive for designers and manufacturers to compete to provide products that are more efficient or offer more features.

The ARC-IT and the associated SET-IT software tool provide a single comprehensive software toolset to support development of interoperable architectures, including complete ITS infrastructure and CV capabilities, along with interface information needed for standards selection. This SASP uses the ARC-IT, SET-IT, and published and developing ITS standards to demonstrate interoperable ITS capabilities that are nationally extensible. Though the USDOT developed the ARC-IT and SET-IT specifically with ITS in mind, the framework and the software are flexible enough to accommodate other systems within the Smart Columbus Program.

1.4. PURPOSE

This SASP has the following three purposes:

- Define the System Architectures including Physical, Enterprise, Functional and Communication views for projects associated with the Smart Columbus Program.
- Identify the associated standards that each project likely will use.
- Document the lessons learned during this SASP development.

A well-defined, well-developed architecture provides a tool for making a strong initial start in doing the systems engineering for a project. It builds upon the project's concept of operations, which outlines each project's stakeholders, their roles and responsibilities, User Needs, and will help the teams move into the design process for each project, guiding interface definition, Request for Proposals development, and system design.

This document is intended to serve as a resource to developers and architects employed by the vendors of the Smart Columbus projects who will use the document as a reference to ensure interoperable solutions.

1.5. METHODOLOGY

The Smart Columbus project team follows a system engineering approach for all the projects as documented in the program level SEMP. Following the process, depending on individual projects, Concept of Operations (ConOps), Trade Study, Operational Concept, Systems Requirements, System Design, and Interface Control Documents have been developed for the individual projects, where applicable. Please note that the development methodology for each project varied (some followed a traditional V-Model, while others shifted into Agile development or evaluated the technology landscape through a trade study and Requests for Information). Specific project documentation can be found on the Smart Columbus website under "Projects"[6]. In addition, the SEMP also provides a list of documentation that accompanies each engineering approach, whether Agile or V-Model. The system engineering methodology for each project can be found below in **Table 1**.

Table 1: System Engineering Methodology

Project	V-Model	Agile
Smart Columbus Operating System		X
Connected Vehicle Environment	X	
Multimodal Trip Planning Application		X
Mobility Assistance for People with Cognitive Disabilities		X

[6] https://smart.columbus.gov/projects/

Project	V-Model	Agile
Prenatal Trip Assistance		X
Smart Mobility Hubs	X	
Event Parking Management	X*	
Connected Electric Autonomous Vehicles		X

** Note: EPM originally used the V-Model and switched to Agile during design.*

Source: City of Columbus

It should also be noted that a program-level Data Privacy Plan and the Data Management Plan have also been developed. **Section 1.7** describes the relationship of this SASP to the Data Privacy Plan and Data Management Plan.

Developing this SASP document is the next step in the system engineering process. The Smart Columbus team developed this SASP for the projects following the USDOT's ARC-IT and its associated SET-IT tool.

1.6. REPORT ORGANIZATION

The remainder of this SASP is organized into the following sections:

- **Chapter 2. System Architecture** defines the System Architectures for all Smart Columbus projects.
- **Chapter 3. Intelligent Transportation Systems Standards Plan** identifies the applicable standards for all Smart Columbus projects.

1.7. PROJECT CHANGES

Listed below are the major changes that were changed between the initial SASP and the current updated SASP.

1.7.1. Smart Columbus Operating System

- Moved Information Flows between the Personal Wireless Devices (PWD) and Smart Columbus Operating System to between the EPM Central System (EPMCS) and Smart Columbus Operating System
- Removed Loading Zone Availability from the Parking Zone Availability application
- Updated Communications View to ARC-IT V9 format

1.7.2. Connected Vehicle Environment

- Updated Communications View to ARC-IT V9 format

1.7.3. Multimodal Trip Planning Application

- Interface with CPS has been removed
- Functionality that has been salvaged from CPS related to account management has been moved to MMTPA
- Mobility Provider Payment Equipment has been moved to the MMTPA project from the CPS project.
- Trip Metrics function has been added to MMTPA

- Central Ohio Transit Agency (COTA) has been removed and is now considered one of the mobility providers
- Updated Communications View to ARC-IT V9 format

1.7.4. Common Payment System

- Project has been removed

1.7.5. Mobility Assistance for People with Cognitive Disabilities

- Updated Communications View to ARC-IT V9 format

1.7.6. Prenatal Trip Assistance

- Updated Communications View to ARC-IT V9 format

1.7.7. Smart Mobilty Hubs

- Removed payment device and ability for users without smartphones to use the MMTPA functionality
- Updated Communications View to ARC-IT V9 format

1.7.8. Event Parking Management

- Interface with CPS has been removed and replaced with Financial Centers
- CPS related functionality of the PWD has been removed
- Removed Loading Zone Availability from the Smart Columbus Operating System
- Updated Communications View to ARC-IT V9 format

1.7.9. Connected Electric Autonomous Vehicle

- Updated Communications View to ARC-IT V9 format

1.8. OTHER RELATED DOCUMENTS

This SASP is related to several other program-level and project-level documents developed for the Smart Columbus Program. The sections below identify these relationships. The documents that were developed for each of the projects can be found in **Table 2**.

1.8.1. Systems Engineering Management Plan

The SEMP outlines the engineering approach followed by each of the projects. It includes the relevant documentation that accompanies each project path. It is referenced earlier in this SASP and is a core document containing descriptions of engineering deliverables, how the program is managed, and how the different engineering methodologies (whether Agile or V-Model) are utilized by the individual projects.

1.8.2. Concept of Operations/Trade Study/Operational Concept

Smart Columbus projects follow different Project Advancement Steps as the Smart Columbus SEMP defines. Depending on the project, one the following documents identifies the stakeholders and roles, User Needs, and a high-level system component: ConOps, Trade Study or Operational Concept. This SASP uses

all of these documents as a collective foundation to develop the Architecture Views including Physical and Enterprise Views.

1.8.3. System Requirements/ Interface Control Document

The System Requirements or Interface Control Document defines requirements including functional and interface requirements, or it defines the respective interface and data flows among components establishing traceability to User Needs. This SASP uses these requirements and/or interfaces/data flows as a collective foundation on which to develop the Physical (Information Flows), Communications, and Functional Views.

1.8.4. Data Privacy Plan

The Smart Columbus Data Privacy Plan provides an overarching framework for the ways in which Smart Columbus will protect the security of personal information that it collects and uses, and the privacy of the individuals to whom this information pertains. This SASP will maintain privacy and security by incorporating them in different Architecture Views. This SASP will ensure consistency with the Data Privacy Plan when presenting different Architecture Views.

1.8.5. Data Management Plan

The Smart Columbus Data Management Plan provides operational information for the use of data within the Operating System platform to ensure optimal program functionality in addition to properly securing, backing up, maintaining, and sharing the data. This SASP will ensure consistency with the Data Management Plan when presenting different Architecture Views.

Related documents developed for the Smart Columbus program can be found in **Table 2**. Note that items that are still in development or that cannot be made publicly available are identified in *italics*.

Table 2: Related Documents

Smart Columbus Project	Documentation/ Process
Operating System*	Data Privacy Plan Data Management Plan De-Identification Policy *Data Curation Process* *Privacy Impact Assessment* Operations & Maintenance Plan

Smart Columbus Project	Documentation/ Process
Connected Vehicle Environment	Concept of Operations System Requirements Specifications Interface Control Document System Design Document OBU and RSU Integration Request for Proposals *Institutional Review Board (IRB) materials (research protocol, informed consent document, recruiting and training materials)* *Operations and Maintenance Plan* Test Plan *Test Results Report*
Multimodal Trip Planning Application	Concept of Operations MMTPA Request for Proposals *Operations and Maintenance Plan* *Training materials* *Test Plan* *Test Results Report*
Mobility Assistance for People with Cognitive Disabilities	Trade Study Interface Control Document Test Plan and Report Operations and Maintenance Plan *IRB materials (research protocol, informed consent, training plan – for caregivers and participants)*
Prenatal Trip Assistance	Concept of Operations Request for Proposals *IRB materials (research protocol, informed consent document, training materials)* Participant User Guide Test Plan and Report Operations and Maintenance Plan
Smart Mobility Hubs	Concept of Operations System Requirements Specifications Interface Control Document System Design Document Request for Proposal Test Plan Test Results Report Operations and Maintenance Plan

Smart Columbus Project	Documentation/ Process
Event Parking Management	Concept of Operations System Requirements Specifications Test Plan *Test Results Report* Operations and Maintenance Plan
Connected Electric Autonomous Vehicles	CEAV Operational Concept Request for Information Request for Proposal *EasyMile User Guide* *Standard Operating Procedures* Test Plan *Test Results Report*

** These documents apply to the Smart Columbus Operating System and any vendor that provides information to the Smart Columbus Operating System. The above referenced Smart Columbus documents are available from the digital document library Smart Columbus Program website at: https://smart.columbus.gov/projects/.*

Source: City of Columbus

Chapter 2. System Architecture

2.1. INTRODUCTION

The Smart Columbus Program includes several projects with multiple, interrelated, and complex systems. Project-level System Architecture helps to conceptualize and view these systems from different perspectives, including Physical View, Functional View, Enterprise View, and Communications View. System Architecture often relies on a framework–for example, a reference model–to organize various elements of a system into complementary and consistent predefined "Views," encompassing the entire scope of the System Architecture. USDOT has developed the ARC-IT, an architecture framework for planning, defining, and integrating ITS that also provides material to facilitate System Architecture development.

The following section explains the following essential terms and concepts needed to understand, navigate, and use ARC-IT:

- Views
- ITS Services/Service Packages
- Physical View
  - Physical Objects
  - Information Flows
  - Functional Objects
- Enterprise View
- Communications View
- Functional View

2.1.1. Views

ARC-IT is organized around four "views," each of which provides a different perspective of the System Architecture. This approach to developing a System Architecture is based on ISO/IEC/Institute of Electrical and Electronics Engineers (IEEE) 42010:2011, a standard for "Systems and software engineering — Architecture description," and it includes steps to define data and messages and also the full environment in which stakeholder concerns are satisfied.

Figure 4 identifies the four views that describe ARC-IT: Physical, Enterprise, Communication, and Functional.

2.1.2. Intelligent Transportation System Services/Service Packages

A set of ITS Services, meaning transportation services, that can be provided through the use of ITS – defines the scope of ARC-IT. ARC-IT V8 and V9 cover a broader range of services than the original set of 33 user services defined in earlier versions, and it incorporates all applications of the Connected Vehicle Reference Implementation Architecture (CVRIA) as well as additional, internationally defined ITS Services, creating a larger set of transportation services that ITS can provide.

ARC-IT uses the term “Service Packages” to describe portions of each of the four views that the Architecture needs to implement a service. Details of how Service Packages are represented in each of the four views are given in the sections below.

Service Packages are not intended to be tied to specific technologies but depend on the current technology and product market to actually be implemented. As transportation needs evolve, technology advances, and new devices are developed, Service Packages may change, and new Service Packages may be defined.

For this SASP, individual project Architectures were developed for each of the Smart Columbus projects with Service Packages as the foundation. For each project, based on the User Needs, standard Service Package(s) defined in the ARC-IT were selected and customized using SET-IT software tool. A list of standard Service Packages can be downloaded from the link below:

https://local.iteris.com/arc-it/html/servicepackages/servicepackages-areaspsort.html

For example, for the SMH project, the Infrastructure-Provided Trip Planning and Route Guidance Service Package was selected and customized based on the SMH project User Needs identified in the SMH ConOps.

2.1.3. Physical View

The Physical View describes the transportation systems and information exchanges that support ITS Services. In this view, the Architecture is depicted as a set of Physical Objects that interact and exchange information to support the Architecture. Since the Physical View is concerned with constructs in the real world, it tends to be the most approachable view from which to start.

The following three components comprise the Physical View:

- Physical Objects
- Information Flows
- Functional Objects

2.1.3.1. PHYSICAL OBJECTS

Physical Objects that provide ITS functionality are referred to as subsystems, whereas those that do not provide ITS functionality are called terminators. Both types of Physical Objects exchange information to provide ITS services. Physical Objects in ARC-IT belong to one of five “classes”:

- Centers, such as a Traffic Management Center
- Field Equipment, such as a Traffic Signal Controller
- Vehicles, such as Transit Vehicles
- Traveler Devices, such as personal devices (smartphones)
- Support Systems, which includes systems that provide non-operational use of ITS data (e.g. Archive Data Systems), and systems that provide support to a variety of services (e.g. Map Update System)

Appendix A includes a table with the definition for each of the five classes.

Physical elements represent these Physical Objects. For example, the “EPM Central System” element of the EPM project represents the Center Subsystem for the EPM project.

2.1.3.2. INFORMATION FLOW

Information Flows depict the exchange of information that occurs between Physical Objects (Subsystems and Terminators).

2.1.3.3. FUNCTIONAL OBJECTS

Functional Objects break up the subsystems into deployment-sized pieces, and define more specifically the functionality and interfaces that are required to support a particular Service Package.

The information exchanges in the Physical View (see **Figure 5**) are identified by Triples that include the source and destination Physical Objects and the Information Flow that is exchanged.

The Physical View is related to the other Architecture Views. Each Functional Object is linked to the Functional View, which describes more precisely the functions that are performed and the details of the data that is exchanged by the object. Physical Objects and Functional Objects are also depicted as Resources in the Enterprise View, which describes the organizations that are involved and the roles they play in installing, operating, maintaining, and certifying all of the components of the Architecture.

In addition, the Physical View includes a notional hierarchy. Considering the Architecture from its most abstract (highest) level, the Physical View describes interactions (called P-Interconnects) between support, center, field, traveler and vehicle systems as shown in **Figure 5**. **Appendix A** includes a table with the definition for each of the P-Interconnects.

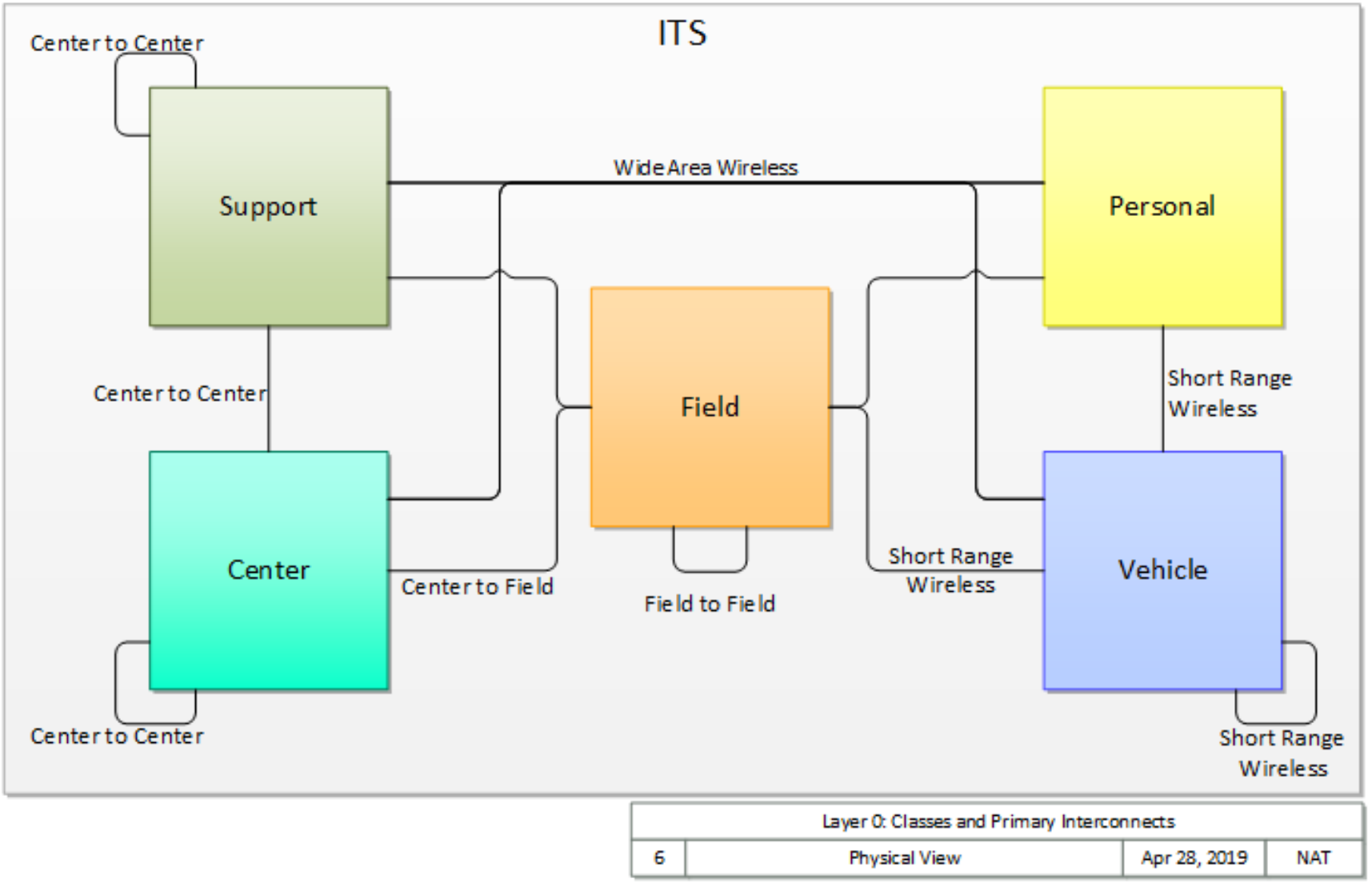


Figure 5: Physical View – Connections Among Systems

Source: USDOT Architecture Reference for Cooperative and Intelligent Transportation

Per ARC-IT guidance for the Service Packages, a Physical Architecture View Diagram and description tables for Elements, Functional Objects and Information Flows comprise the Physical Architecture View. These items provide the following information:

- **Physical Architecture View Diagram:** Shows the Elements along with their allocated Functional Objects and types of interconnects that enable the Information Flows among the Elements. The Smart Columbus team used the SET-IT tool to develop the Physical View. Selected Service Packages customized in the SET-IT tool represent the Elements and Information Flows that the ConOps' context diagram and User Needs defined.

  The Smart Columbus team used the SET-IT tool to define customized Functional Objects within each Element for cases in which the standard Functional Objects didn't meet the project needs. Note that modifications (from the ConOps context diagram) to the Elements, Element Names and interconnects among Elements in the Physical View reflect project progress.

- **Physical View Elements Table:** Describes Elements the Physical Architecture View Diagram identifies, including the Elements' classes and descriptions.

- **Physical View Functional Objects Table:** Describes Functional Objects the Physical Architecture View Diagram identifies. The Smart Columbus SASP uses the following three types of Functional Objects:

  - **Standard Functional Objects:** Standard Functional Objects, as the ARC-IT defines them, without changes.
  - **Personalized Functional Objects:** Standard Functional Objects, as the ARC-IT defines them, with minor changes that personalize them for the projects.
  - **Customized Functional Objects:** Functional Objects specifically developed for the projects.

- **Physical View Information Flows Table:** Describes the Information Flows that the Physical View Diagram identifies. The Smart Columbus SASP uses the following three types of Information Flows:

  - **Standard Information Flows:** Standard Information Flows, as the ARC-IT defines them, without changes. Standard Information Flows are all lower case and no additional detail is provided in the table.
  - **Personalized Information Flows:** Standard Information Flows, as the ARC-IT defines them, with minor changes that personalize them for the projects. Personalized flows are also in lower case, although the changes are described in the table that follows the physical diagram. The change is introduced with text that begins "For this project…" followed by the description of the flow.
  - **Customized Information Flows:** Information Flows developed specifically for the projects. Information Flow names with Title Cases identify Customized Information Flows on the physical architecture diagram, and described in more detail in the table that follows.

For the projects that use only a single Service Package, the Smart Columbus SASP provides only a Layer 2 diagram, as defined in the SET-IT tool, because these simpler projects convey the intent of the Physical Architecture. For the projects that use more than a single Service Package, Layer 0 and Layer 2 diagrams, as defined in the SET-IT tool, convey the intent of the Physical Architecture. Projects using multiple service packages include the Smart Columbus Operating System, CVE, SMH and CEAV, and thus these projects include multiple Physical View diagrams and associated tables for Physical View elements, Information Flows and Functional Objects for each of the Physical View diagrams. Projects using a single service package are: MMTPA, PTA, MAPCD and EPM. These projects contain a single Physical View and set of tables.

For example, the EPM project uses customized Services Packages to develop the Physical View, which includes the following elements:

- EPMCS
- Financial Center
- City Parking Meter System (CPMS)
- Gated Parking Facility System (GFAC)
- Parking Operator
- Parking Operator PM360 Application
- PWD
- Smart Columbus Operating System
- Ungated Parking Facility (UFAC)
- Parking Availability Sensor System
- Travelers

The EPMCS identifies the following Functional Objects, many of which were custom-created for the project:

- Notifications and Alerts
- Traveler Profile
- Parking Coordination
- Payment Coordination
- Discounted Parking Options
- Administration
- Account Management
- Transportation Information Center (TIC) Data Collection
- EPM API

In addition, this SASP identifies Information Flows between EPMCS and the Parking Operator PM360 Application for parking parking area management information and parking area information (both standard).

2.1.3.4. PHYSICAL VIEW LEGEND

Figure 6 serves as the Legend for the Physical View drawings. The Physical View Legend will apply for all Physical Views in this document since it does not vary by project. The individual diagrams for each project do not contain this legend to allow for the diagram to be sized as large as possible for readability.

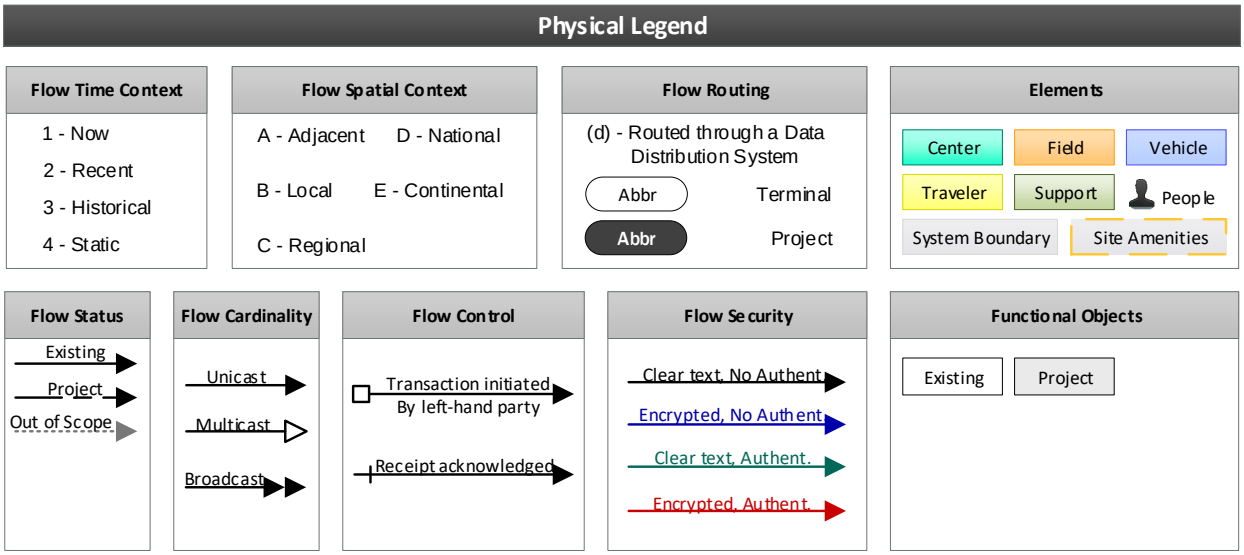


Figure 6: Physical View Legend

Source: City of Columbus

Per ARC-IT guidance for the Physical View, the diagrams consist of the following components:

- **Elements:** Physical Objects are shown as colored rectangles. They represent the operational centers, field equipment, vehicle onboard equipment, personal devices, and support systems in the ITS environment. They are color coded to identify their class. Since they correspond closely with the physical transportation system, the interfaces between Physical Objects tend to be prime candidates for standardization.
- **Functional Objects:** Functional Objects are shown as smaller rectangles that are contained within a physical object. Clear rectangles represent existing objects, while grey rectangles indicate objects created for a Smart Columbus project. Functional Objects define the functionality that is required for each Physical Object to support one or more Services Package. The Functional Objects serve as service-oriented containers for the functionality defined in the Functional View. Not all Physical Objects include Functional Objects since functionality that is peripheral to a particular service may not be shown on the Service Package diagram. Physical Objects that are peripheral to ITS (e.g., a Financial Center or Weather Service Center) may not include Functional Objects in any of the Services Packages. The interfaces to these Physical Objects are important to ITS, but ITS will not add functionality to these broader systems.
- **Flow Time Context:** Flow Time Context is represented as a number to the left of the flow name. This indicates the time sensitivity of the data contained within the information flow. The values are “Now”, “Recent”, “Historical”, or “Static” for data that never or rarely changes.
- **Flow Spatial Context:** Flow Spatial Context is represented by a letter to the left of the flow name. This indicates the spatial relevance of the data contained within the information flow. The values are “Adjacent”, “Local”, “Regional”, “National”, or “Continental”.
- **Flow Status:** The Flow Status indicates whether the information flow is part of the project or existing (1). Information Flows that are outside the scope of the project are shown as grey, dotted lines.
- **Flow Cardinality:** Flow Cardinality shows whether a flow is unicast (sent to one destination), multicast (flow is sent to multiple addresses), or broadcast (sent to anyone with the right equipment). It is represented by the arrowhead–single/closed, single/open, or double/closed.

- **Flow Control:** A crossing line at the flow source indicates whether an information flow is acknowledged. Flows that are part of a transaction initiated by one side or the other are shown with a white box on the site that initiates the transaction.
- **Flow Security:** Flow Security is used to indicate what mechanisms should be in place in order for the information to get to its destination securely and in support of the overall security and privacy requirements for the system and its users. Black indicates 'clear,' or no security specified. Blue indicates it should be encrypted, but the sender does not have to be authenticated as the source of the message. Green indicates the information can be sent without encryption, but the sender should be authenticated. Red indicates flows that require both encryption of the information and authentication of the source. These characteristics are based on a FIPS-199 analysis that evaluates confidentiality, integrity, and availability requirements for each triple.

2.1.4. Enterprise View

The Enterprise View addresses the relationships between organizations and users, and the roles those entities play in the delivery and consumption of ITS services. Relationships between entities are dependent on the roles those entities take in the delivery of user services.

The building blocks of ARC-IT's Enterprise View are Enterprise Objects that interact to exchange information, manage, and operate systems beyond the scope of one organization. The Enterprise View focuses on the relationships between those Enterprise Objects, but also defines how Enterprise Objects interact with Physical Objects, which appear in the Enterprise View as Resources.

The relationships between Enterprise Objects are organized as various types of Coordination: an expectation and/or agreement or contract intended to achieve the common purposes necessary to implement and deliver an ITS service. The relationship between an Enterprise Object and a Resource is a Role: facilitates, owns, operates, develops, installs, maintains, etc. Stakeholders take the position of Enterprise Objects when they participate in ITS.

Appendix A includes tables with descriptions of the Types of Agreements, Types of Expectations, and Types of Roles from ARC-IT.

For the Smart Columbus SASP, the Enterprise Architecture View includes the Enterprise Architecture View diagram and a List of Agreements table that includes the status of each agreement and the vendor (if any involved). It also includes a list of roles and responsibilities for the project. The SET-IT tool was used to generate an Enterprise View diagram from the Physical View. This diagram was then customized using the SET-IT tool for the project needs.

For example, Enterprise View for the EPM project identifies the following:

The stakeholders play the following roles:

- OS Vendor develops, operates, and maintains Smart Columbus Operating System;
- City of Columbus owns Smart Columbus Operating System;
- City of Columbus owns and operates CPMS;
- City of Columbus facilitates EPMCS;
- EPM Vendor owns, develops, operates, and maintains EPMCS and Parking Operator PM360 Application;
- Parking Operator uses the Parking Operator Application;
- Parking Facility Operator owns and operates UFAC and GFAC;
- Travelers owns and operates PWD;

- Parking Availability Sensor Vendor owns, operates, maintains, and develops the Parking Availability Sensors;
- Financial Institution owns and operates the Financial Center;

The following Expectations exist:

- Between Traveler and EPM Vendor
- Between City of Columbus and EPM Vendor
- Between Parking Facility Operator and EPM Vendor

The following Agreements exist:

- Between EPM Vendor and Traveler
- Between City of Columbus and EPM Vendor
- Between EPM Vendor and Parking Facility Operator
- Between Parking Facility Operator and Parking Operator

2.1.4.1. ENTERPRISE VIEW LEGEND

Figure 7 serves as the Legend for the Enterprise View drawings since it does not vary by project. The Enterprise View Legend will apply for all Enterprise Views in this document. The individual diagrams for each project do not contain this legend to allow for the diagram to be sized as large as possible for readability.

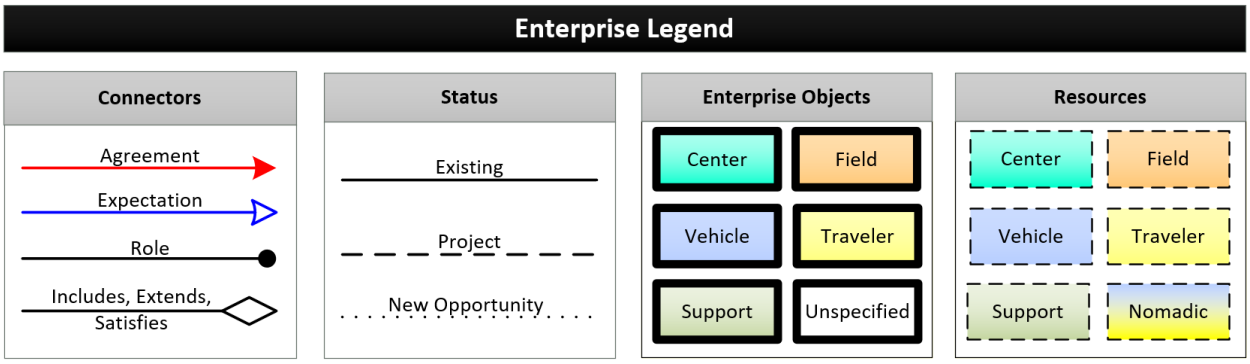


Figure 7: Enterprise View Legend

Source: City of Columbus

Per ARC-IT guidance for the Enterprise View, the diagrams consist of the following components:

- **Enterprise Objects:** 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 (e.g., a Device Developer is a component of Auto Manufacturer but also participates in Standards Body).
- **Resources:** Assets that can support the achievement of Enterprise Objects. These may be physical or virtual elements and may be of limited availability. All Physical Objects are resources, but other resources may include policies and documents.

- **Connectors:**
  - **Relationship:** Formal or informal coordination between Enterprise Objects, such as agreements, contracts, funding, and expectations.
  - **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.
- **Status:** The Status of a Relationship is given by the line type connecting the Enterprise Objects. A solid line indicates an existing relationship. A dashed line indicates a relationship created through the relevant project. A dotted line indicates a new opportunity.

2.1.5. Communications View

The Communications View describes the protocols necessary to provide interoperability between Physical Objects in the Physical View. Each Triple from the Physical View has been mapped to a set of standards or published specifications that can be used to build an interoperable implementation. These standards are typically considered in hierarchical fashion, from those that include the data element, message and dialog definitions at the top, to those providing access facilities, networking, transport and physical data exchange at the bottom. Owing to the necessary hierarchical nature of the relationships between most standards, these protocols are organized in a series of layers. Also considered are those standards providing device management and security, which are typically modeled across all communications-centric layers.

The ARC-IT Communications Model includes dozens of communications profiles that support all links defined in the Physical View. These links are described using the communication profiles that define the protocols to be used at each network layer.

The layers of the ARC-IT V9 Communications Model are described below:

- **ITS Application Entity:** ITS Application Entity standards specify the structure, meaning, and exchange patterns of information between two end points. Referred to as 'ITS Application Specifications' in some contexts.
- **Facilities Layer:** Facilities Layer Protocols define the rules and procedures for exchanging data, for representing the bits and bytes of information content to be transferred (e.g. encoding), and provide mechanisms for opening, closing and managing a dialogue between ITS Applications. Sessions may be asynchronous as in paired requests and responses (information exchanges), asynchronous as in an unsolicited publication of information, and may require acknowledgement of receipt or not.
- **TransNet Layer:** TransNet layer protocols define the rules and procedures for exchanging application data between endpoints as well as the routing, message disassembly/re-assembly and network management functions.
- **Access Layer:** Access Layer protocols define the rules and procedures for exchanging data between two adjacent devices over some communications media, as well as the signaling protocols that are typically developed for specific communications media.

The **Management Plane** uses standards that define the rules and procedures for controlling elements at all layers.

In addition, the **Security Plane** identifies standards that specify policies and methods for system-to-system authentication and encryption of data across one or more layers of the communications stack. Security solutions terminate inside the physical device that uses the Information Flows in question. This means for example, that if a given flow specifies TLS in the security plane, that TLS is terminated inside the device receiving/sending data to satisfy the flow.

For the Smart Columbus SASP, Communications View is presented in the form of the layered Communications Model from ARC-IT, along with a Communications View Table for both the World Wide

Web (WWW) Browser/ JavaScript Object Notation (JSON)/Wide Area Wireless (WAW) (WAW-WWWBrowser-JSON) and Human Interfaces. These tables include the Communications Profile and the flows between the Elements that use the Communications profile. Any applicable ITS Standards for the Information Flows between the source and destination are identified in **Chapter 3**.

For the EPM project example, communications between all elements and EPMCS will use WAW-WWWBrowser-JSON.

2.1.6. Functional View

The Functional View addresses the analysis of abstract functional elements and their logical interactions. Here ARC-IT is depicted as a set of Processes organized hierarchically. These Processes (activities and functions) trace to a set of Requirements derived from source documents. The data flows that move between Processes and the data stores where data may reside for longer periods are all defined in a Data Dictionary.

The behavior of a Function (also known as Process) is the set of actions performed by this Element to achieve an objective. A Process performs actions to achieve an application objective, or to support actions of another Process. This may involve data collection, data transformation, data generation, or data processing in performing those actions. The Functional View defines Processes to control and manage system behavior, such as monitoring, and other active control elements that are part of describing the functional behavior of the system. It also describes data processing functions, data stores, and the logical flows of information among these elements.

The Functional View is modeled using a Structure Analysis methodology. This uses the National ITS Architecture's Logical Architecture as the starting point that was based on the work of Hatley/Pirbhai and included Yourdon-Demarco Data Flow Diagrams to illustrate the flow of data between functional elements. For expedience in ARC-IT, the diagrams are not included and just the collections of processes and their data flows are shown. The reader should use the Physical View diagrams for graphical representations of system behavior.

For the Smart Columbus SASP, a table identifying the Functional Objects (identified as part of the Physical View) and the associated high-level Processes for each of these Functional Objects are presented in a table since ARC-IT does not have the ability to generate the Functional View diagrams.

For the EPM Project, the following high-level Processes are Parking Coordination Functional Objects:

- Provide Interface for Current City Parking Management System
- Provide Interface for the Smart Columbus Operating System
- Provide Interface for the Parking Facilities/Operators
- Provide Parking Availability Information
- Process Parking Requests
- Confirm Parking Requests
- Update Parking Availability Information

2.1.7. Smart Columbus Projects' Systems Architecture Layout

The following sections identify the four views for each of the Smart Columbus projects along with elements tables as described below. Please note, the various diagrams and tables within each project's architectures are not referenced or introduced individually in these subsections because the order does not vary and is consistent as described within the **Section 2.1**, and as outlined below:

- Physical Architecture View:
  - Layer 0 Physical Diagram (for projects with multiple service packages)
  - Layer 2 Physical Diagram(s) (for all projects; some projects have multiple Layer 2 diagrams depending on how many service packages are represented)
  - For each Layer 2 Physical Diagram:
    - Physical View Elements Table
    - Physical View Information Flow Table
    - Physical View Functional Object Table
- Enterprise Architecture View:
  - Enterprise Diagram
  - Table of Agreements
  - Description of Roles and Responsibilities
- Communications Architecture:
  - Communications Models
  - Table of Information Flows
- Functional Architecture:
  - Table of Physical Objects, Functional Objects and Processes

2.2. PROJECT 1: SMART COLUMBUS OPERATING SYSTEM

2.2.1. Introduction

The Smart Columbus Operating System is at the heart of the Smart Columbus Program, and serves as the conduit that connects, collects, and transforms data from all Smart Columbus projects, field sensors, devices, and data from independent sources. The Smart Columbus Operating System is a cloud-based digital information technology environment with on-demand services, infrastructure to achieve real-time scalability, and integrations. The Smart Columbus Operating System enables information technology to operate like a service with transparency, reduced wait times, and almost no service downtime. The Smart Columbus Operating System is a state-of-the-art back office for Smart Columbus deployments.

2.2.2. System of Interest

The Smart Columbus Operating System can be classified into three Service Packages:

- **ITS Data Warehouse:** This Service Package focuses on the data management aspect of the Smart Columbus Operating System. This includes ingesting, processing, transforming, and storing data.
- **Performance Monitoring:** This Service Package focuses on depicting the Functional Objects that work together to deliver performance monitoring to Smart Columbus Operating System stakeholders and users. This includes discovering, exploring, analyzing, and visualizing the archived data.
- **Applications:** This Service Package contains a collection of several transportation applications deployed independently, managed by the Technology Center, and leveraging the microservice architecture and the Information Flows that connect them and other important internal systems.

A comprehensive Layer 0 architecture that includes all of the Smart Columbus Operating System Service Packages is presented first, then each Service Package will be introduced as its own Layer 2 diagram.

2.2.3. Comprehensive View of the Smart Columbus Operating System

Each of the Service Packages mentioned in the preceding sections work together to deliver a comprehensive set of capabilities that offer significant improvement over current technologies, and enables new capabilities for CVs and other Smart Columbus projects. The following Layer 0 diagram shows all Service Package components and their interconnections.

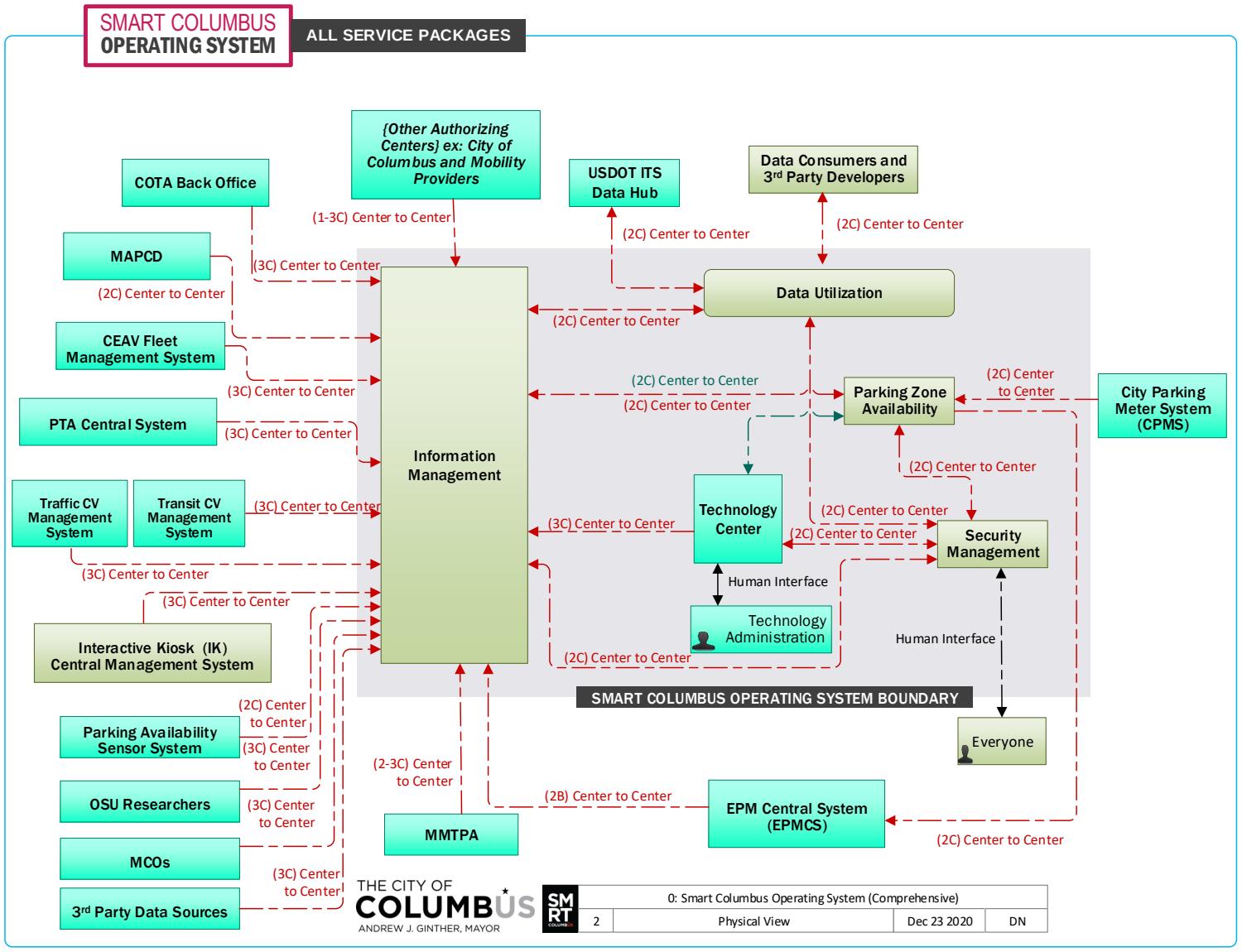


Figure 8: Smart Columbus Operating System Physical Architecture View (Layer 0)

Source: City of Columbus

For clarity, the Smart Columbus Operating System has been decomposed into three main Service Packages, which are described in further detail in the subsequent sections.

2.2.3.1. ITS DATA WAREHOUSE

The ITS Data Warehouse is made up two primary components: (1) a wide variety of data sources, which are represented as centers in green, and (2) an Information Management support system. Data collected through each of the Smart Columbus projects are described in more detail within its respective project section.

The ITS Data Warehouse is capable of streaming data in near real-time as well as collecting data in batches, and supports a wide array of formats—all managed by the feed manager. When data are received, they go through a validation and normalization process. Then they run through scheduling algorithms, a key factor for achieving high performance in processing big data. All data are cataloged by the metadata management function, where the metadata has a dedicated repository. Once processed, the data are sent to the data repository—a big data storage area. **Figure 9** shows the archive data coordination that takes place between the data repository and the Data Utilization support system, which is a component of the Performance Monitoring Service Package. The Data Utilization component will be described in greater detail in **Section 2.2.3.2**.

All components in the ITS Data Warehouse and their relationships are secured and governed by the Security Management (OS-SM) support system. Since all components in the Smart Columbus Operating System are governed by the OS-SM security functions and practices, this component is shown in its short-hand form for diagram simplification. A terminal, represented by the icon, indicates the component is managed by the OS-SM from a security posture.

The Smart Columbus Operating System's ITS Data Warehouse has the following physical architecture.

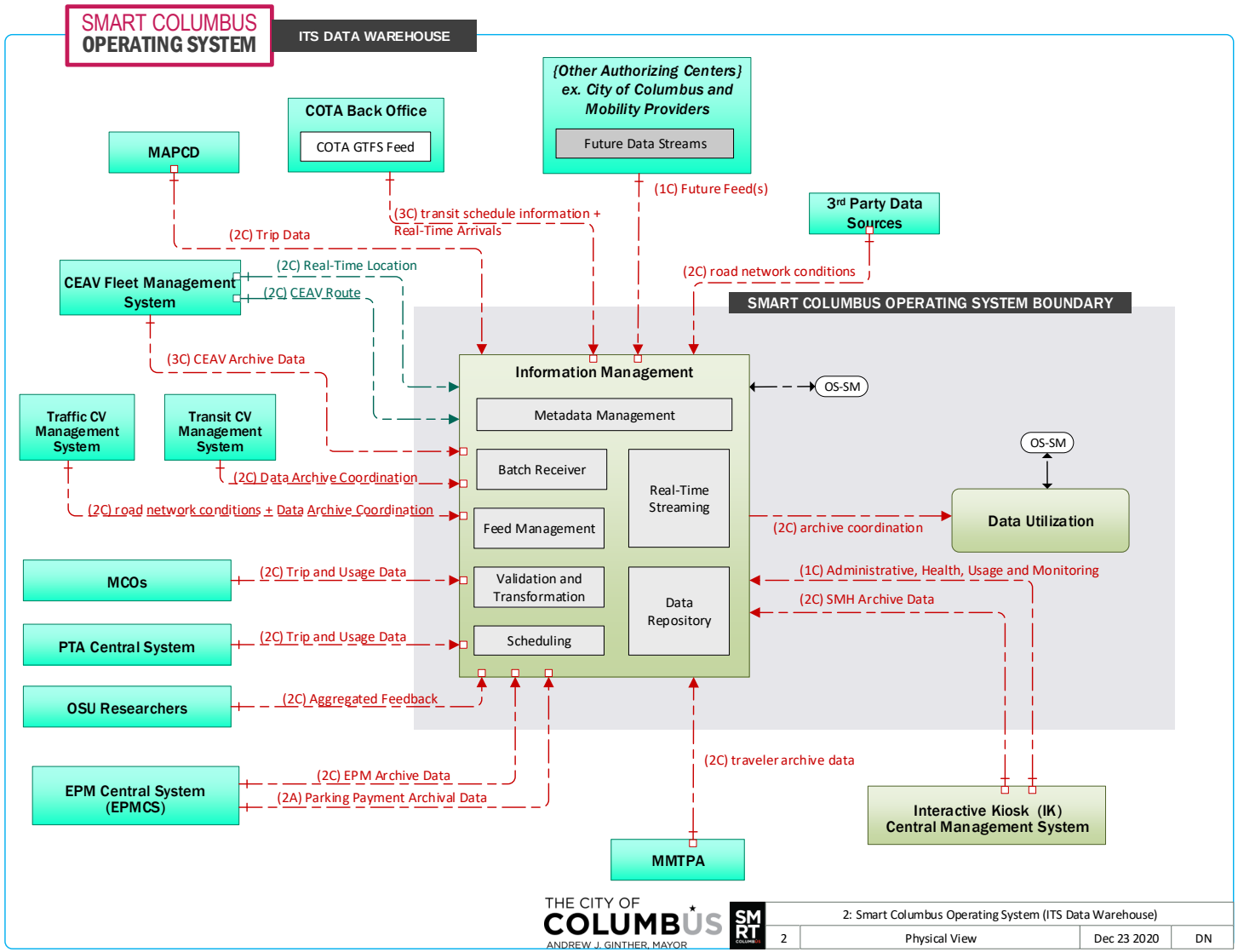


Figure 9: Smart Columbus Operating System ITS Data Warehouse Physical Architecture View (Layer 2)

Source: City of Columbus

Table 3: Smart Columbus Operating System ITS Data Warehouse Physical View Elements

Name	Class	Description
3rd Party Data Sources	Center	The 3rd Party Data Sources provide additional data. For example, traffic and parking information providers and Experience Columbus.
CEAV Fleet Management Center	Center	The CEAV Fleet Management System represents the system that manages CEAV, including providing guidance/suggestion for onboard operator and/or vehicle system to make decisions locally to maintain schedule and/or even headways.
COTA Back Office	Center	The COTA Back Office manages transit vehicle fleets and coordinates with other modes and transportation services. It provides operations, maintenance, customer information, planning, and management functions for the transit property. It spans distinct central dispatch and garage management systems, and supports the spectrum of fixed route, flexible route, paratransit services, and bus rapid transit (BRT) service. The Physical Object's interfaces support communication between transit departments and with other operating entities, such as emergency response services and traffic management systems.
Data Utilization	Support	The Smart Columbus Operating System provides a web-based interface which allows users, from hobbyists to experienced data scientists, to explore the data, and gain insights from it.
EPM Central System (EPMCS)	Center	The EPM Central System (EPMCS) is a system to search, find, schedule, and reserve parking. It maintains the traveler profile, coordinates parking payment, sends reminders/notifications, provides discounted parking options, and calculates the probability of finding a parking meter space in the City.
Interactive Kiosk (IK) Central Management System	Support	The Interactive Kiosk (IK) Central Management System is the central intelligence software for all kiosks installed in the field. It supports, configures, collects, archives, manages, and distributes data generated from kiosk sources for use in SMH project administration, policy evaluation, safety, planning, performance monitoring, program assessment, and operations.
Information Management	Support	This component covers the ingestion and organization of the information stored in the Smart Columbus Operating System. The ingestion process is initiated by the Data Curator using a web interface to define and manage the data feeds.

Name	Class	Description
MAPCD	Center	The MAPCD is a mobile based application (available on both Android and iOS) to allow for personal choice and user preferences. It displays real-time bus location information and alerts to complete trips using COTA's fixed-route bus system. Travelers are alerted to any changes in scheduled service that might impact their ability to complete a trip. The application guides the user by voice commands and step-by-step visual instructions to complete a trip. Travelers will be able to speak to a Caregiver for assistance in case of emergency to feel safe and secure while en route. The application notifies a Caregiver of a traveler's progress en route via SMS or email messages to be assured that the traveler is safely progressing towards a destination. A Caregiver can view a traveler's progress in real-time on a map to be assured that the traveler is safely en route and progressing toward a destination. Caregivers can easily and effectively create routes and tailor end-user experience to suit the individual needs of a traveler. The MAPCD also has several backend services that support the mobile-based application. These include the SMART Route Library, which stores previously created routes, and SMART Travel Manager, which can be used to view current or previously taken trips. Additionally, other backend components handle the processing of real-time alerts for the mobile application and trip data feeds for the Smart Columbus Operating System.
Managed Care Organizations (MCOs)	Center	The MCOs represent those who provide Non-Emergency Medical Transportation (NEMT) services for MCO members who are not involved in the pilot and for those PTA participants who are in the unexposed group. For the pilot program, MCOs will contract with the PTA system technology vendor to provide the PTA services described. The Ohio State University (OSU) Researchers will work with the MCOs to verify eligibility of benefits with pilot participants. MCOs will receive the exposed group NEMT trip data from the PTA system for verification of services and payment.
MMTPA	Center	The MMTPA is an app available to travelers on both iOS and Android devices as well as a web-based platform. MMTPA accesses mobility provider service options from multiple Mobility Providers via APIs. The project will allow travelers to create multimodal trips and pay each mobility provider. Multimodal trip options include walking, fixed-route bus service, ride-hailing, bike-sharing, paratransit, and scooter services.
OSU Researchers	Center	OSU Researchers represent the team who will screen the prenatal traveler information provided by StepOne to see if she is qualified to be part of the pilot program. If the woman meets the qualifications and completes the baseline questionnaire, she will be admitted to the pilot. She will be randomized into the exposed or unexposed group. The OSU Researchers will also evaluate the performance of the PTA project.

Name	Class	Description
Other Authorizing Centers	Center	Other Authorizing Centers represent scalability of the Smart Columbus Operating System and the additional entities that provide (or may provide in the future) data. Currently, these include the City of Columbus and Mobility Providers: ○ City of Columbus: Government body representing the interest of the residents within the political jurisdiction of the City of Columbus. Comprised of multiple data generating and consuming departments, for example the Department of Public Utilities, and the Department of Technology. ○ Mobility Providers: Data providers who collect and share data pertinent for enabling mobility within the area of interest—for example bikeshare companies operating within the City of Columbus.
PTA Central System	Center	The PTA Central System is a web- and smart phone-based software application that will be used to facilitate NEMT trips for expectant women enrolled in Medicaid within Franklin County. OSU Researchers will identify potential participants and verify Medicaid enrollment with the appropriate MCO and place the women into an exposed and unexposed group. For the exposed group, these trips will connect the pregnant women with on-demand transportation necessary to attend prenatal and post-partum care appointments, as well as all other medical appointments. The exposed group will also receive trips to the grocery store and free standing pharmacy trips. The system will also provide vehicle driver and location information to boost the data available, assisting government entities, MCOs, and NEMT Mobility Providers in making better informed decisions. The PTA system will ingest the NEMT reservation request through a web portal, smartphone application, or call center input process. Should any issues arise with the smartphone application or the web portal, the prenatal traveler will be able to contact the call center for service. The PTA system will act in place of an MCO's current Transportation Broker, and transfer approved reservation requests to the appropriate NEMT Mobility Providers. In return, the PTA system will receive information about the assigned driver, their vehicle and general trip data. The PTA system will send a confirmation of the transportation reservation and multiple notifications to the prenatal traveler to remind her of the upcoming transportation reservation. The methods of notification will be text or phone call. Trip optimization will be provided by the technology vendor/transportation broker to ensure the most efficient route is taken for the prenatal traveler.
Traffic CV Management System	Center	The Traffic CV Management System monitors and controls the CVE and road network. It communicates with ITS Roadway Equipment and CV Roadside Equipment (RSE) to monitor and manage traffic flow, and monitor the condition of the roadway, surrounding environmental conditions, and field equipment status.

Name	Class	Description
Transit CV Management System	Center	The Transit CV Management System represents COTA's CV back office. This center receives application output data and Basic Safety Messages captured by transit vehicle OBEs and CEAV OBEs. The Transit CV Management System is responsible for generating vehicle interaction data that could result in issuing notifications or warnings to transit vehicle operators. Finally, the vehicle interaction data is archived in the Smart Columbus Operating System.

Source: City of Columbus

Table 4: Smart Columbus Operating System ITS Data Warehouse Information Flows

Name	Description
Administrative, Health, Usage and Monitoring	Information flow for administrative, health, usage, and monitoring.
Aggregated Feedback	De-identified general feedback from the users in the study.
archive coordination	Catalog data, meta data, published data, and other information exchanged between archives to support data synchronization and to satisfy user data requests.
CEAV Archive Data	At the minimum, CEAV archive data will include time in service, miles traveled, ridership, high-accuracy positioning, speed, battery usage, and number and reasons for disengagements and hard braking.
CEAV Route	Include CEAV Route information.
Data Archive Coordination	The data archive coordination represents the various strategies established between City of Columbus Traffic Connected Vehicle Management System (TCVMS) and the Smart Columbus Operating System to collect and curate data, and measure the performance of Vehicle-to-Vehicle (V2V) safety and Vehicle-to-Infrastructure (V2I) safety and mobility applications reported by the RSE. This may include traffic operational data, a record of intersection safety issues identified, alerts, and warnings issued. This TCVMS process will help produce fundamental measures of operations such as, but not limited to, roadway speed, queue/incident detection, travel time/intersection delay, and/or CV volume. This process includes receiving and archiving status information, event messages, and raw or filtered traffic situation data (safety and priority request messages) from equipment on the roadside based on appropriate data assets, processing and filtering.
EPM Archive Data	Includes EPM archive data.
Future Feed(s)	Batch or streaming data feeds.
Parking Payment Archival Data	Data used to analyze and monitor trends in parking demand, pricing, and operational actions. Content may include a catalog of available information, the actual information to be archived, and associated meta data that describes the archived information.
Real-Time Arrivals	COTA real-time data streamed via General Transit Feed Specification (GTFS) feed.
Real-Time Location	Includes the real-time location information of the CEAV.

Name	Description
road network conditions	Current and forecasted traffic information, road and weather conditions, and other road network status. Either raw data, processed data, or some combination of both may be provided by this flow. Information on diversions and alternate routes, closures, and special traffic restrictions (lane/shoulder use, weight restrictions, width restrictions requirements) in effect is included.
SMH Archive Data	Includes SMH archive data.
schedule information	Current and projected transit schedule information used to initialize the transit vehicle with a vehicle assignment, monitor schedule performance, and develop corrective actions on-board.
traveler archive data	Data associated with traveler information services including service requests, facility usage, rideshare, routing, and traveler payment transaction data. Content may include a catalog of available information, the actual information to be archived, and associated meta data that describes the archived information.
Trip and Usage Data	The Trip and Usage Data consists of, at a minimum, the following: origin, destination, whether trip was scheduled in advance or on demand, trip start time, trip end time, type of trip, and vehicle identification. Trip and Usage Data will also include whether or not the user was a PTA participant or control group for the OSU study. All Trip and Usage Data that flows to the Smart Columbus Operating System will be de-identified.
Trip Data	Includes data on starting a particular route, completing a route, canceling a route before completion, pausing a route, resuming a route, loss of Global Positioning System (GPS) connection, reacquisition of GPS connection, leaving the travel corridor for the route, reentering the travel corridor for the route, requests for assistance by the traveler, downloading a route with mode of travel used, and caregiver updates and communications.

Source: City of Columbus

Table 5: Smart Columbus Operating System ITS Data Warehouse Functional Objects

Physical Object	Functional Object	Description
Smart Columbus Operating System Project Functions		
Information Management	Batch Receiver	The Smart Columbus Operating System ingests information from a variety of static data sources, typically through a Representational State Transfer (REST) endpoint. The data can have different structure such as tabular, hierarchical, or unstructured. Data can range in size from a few kilobytes to gigabytes.
	Data Repository	The Smart Columbus Operating System has a data repository that is capable of establishing, tracking, and controlling datasets.
	Feed Management	The Smart Columbus Operating System can manage the ingestion of data feeds that are established by the ingestion process.

Physical Object	Functional Object	Description
	Metadata Management	The Smart Columbus Operating System is capable of establishing, tracking, and controlling the use of Technical, Business, and Operational Metadata in a dedicated metadata repository.
	Real-Time Streaming	The Smart Columbus Operating System ingests from a variety of streaming data sources, typically through a REST endpoint. The data can have different structure such as flat/tabular, hierarchical, or unstructured.
	Scheduling	The Smart Columbus Operating System is capable of establishing, tracking, and controlling the ingestion schedule of a data feed.
	Validation and Transformation	Data ingested into the Smart Columbus Operating System may be transformed to ensure quality, consistency, and searchability.
Existing/Planned Functions (External to the Smart Columbus Operating System)		
COTA Back Office	COTA GTFS Feed	COTA provides their schedule and real-time arrival data for 3rd parties to use via the GTFS format.
Other Authorizing Centers	Future Data Streams	The Smart Columbus Operating System is built to ingest live, streaming data from a variety of sources, typically through a REST endpoint. The data can have different structure such as flat/tabular, hierarchical, or unstructured.

Source: City of Columbus

2.2.3.2. PERFORMANCE MONITORING

The Smart Columbus Operating System Performance Monitoring is made up two primary components: (1) a large number of data consumers, and (2) the Data Utilization component. Access to all data are provisioned and managed through APIs issued by the Data Utilization component via a secure URL address (i.e., https). Consumers (distinctly identified as general data consumers and 3rd party developers, and USDOT Research Data Exchange center) are given data access through an API, and have the option of extracting and feeding that data directly to an existing reporting system, developing a new reporting mechanism, or using the Visualization function offered by the Smart Columbus Operating System (Jupyter Hub).

Similar to the ITS Data Warehouse, all components and connections to the Smart Columbus Operating System Performance Monitoring, and the relationships between components, are secured and governed by the OS-SM support system. To simplify the diagram, the OS-SM component is shown in its short-hand icon, indicating the component connects to the OS-SM to validate identities and memberships, and authenticate, and authorize data consumers.

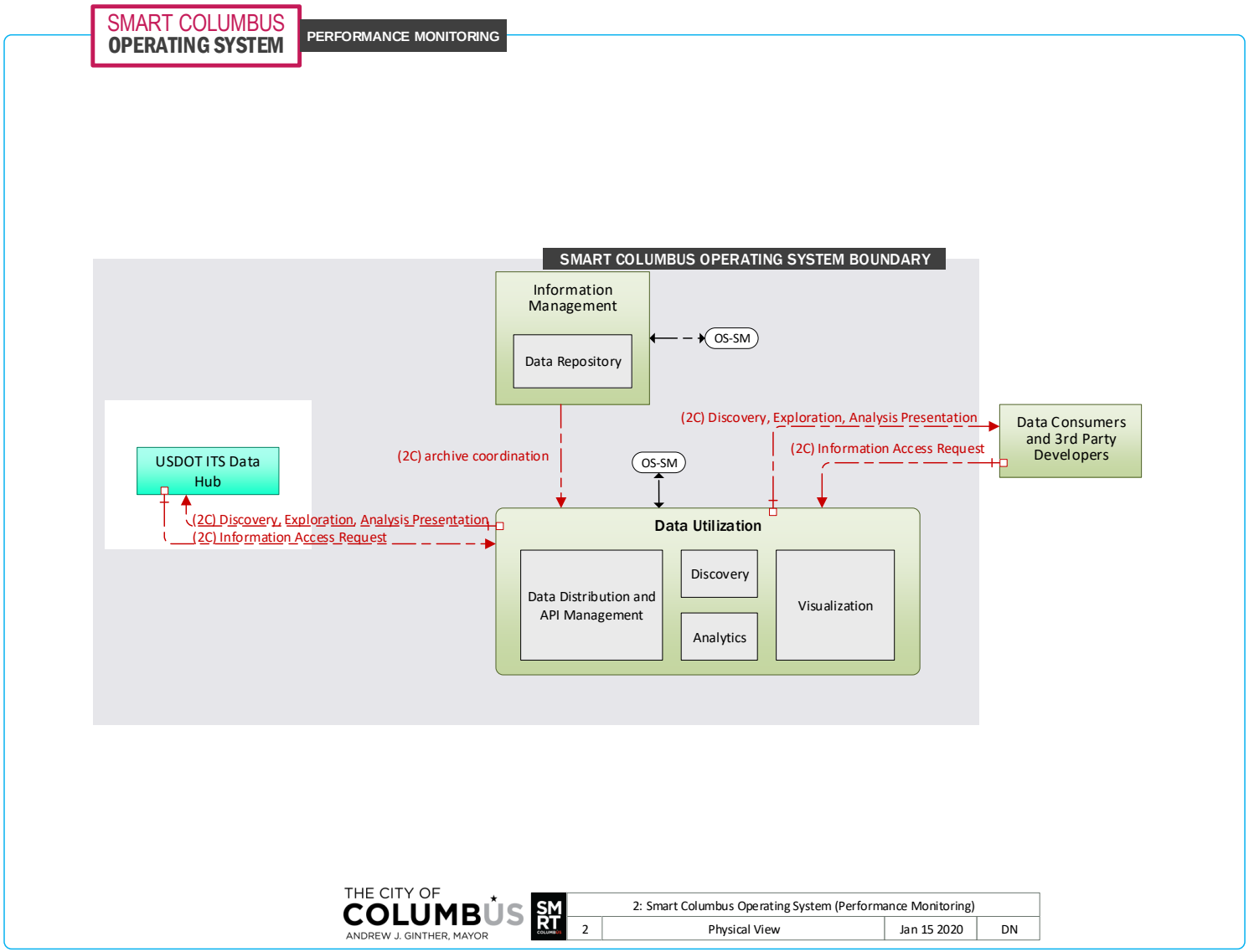


Figure 10: Smart Columbus Operating System Performance Monitoring (Layer 2)

Source: City of Columbus

Table 6: Smart Columbus Operating System Performance Monitoring Physical Elements

Name	Class	Description
Data Consumers and 3rd Party Developers	Support	Data Consumers generally describes all members of the Smart Columbus Program that will consume, access, or interact with the Smart Columbus Operating System data in any way, including City of Columbus, Ohio Department of Transportation, USDOT, Department of Public Service, Department of Technology, mobility providers, NEMT, trucking companies, and the general public. 3rd Party Developers represent the external personnel leveraging the data in the Smart Columbus Operating System. These developers use the data for exploration, discovery, and other initiatives.
Data Utilization	Support	The Smart Columbus Operating System provides a web-based interface which allows users, from hobbyists to experienced data scientists, to explore the data and gain insights from it.
Information Management	Support	This component covers the ingestion and organization of information stored in the Smart Columbus Operating System. The ingestion process is initiated by the Data Curator using a web interface to define and manage the data feeds.
USDOT ITS Data Hub	Center	The USDOT Innovative Technology Administration and the Federal Highway Administration developed the ITS Data Hub, a transportation data sharing system that promotes sharing of archived and real-time data from multiple sources and multiple modes to support the needs of ITS researchers and developers.

Source: City of Columbus

Table 7: Smart Columbus Operating System Performance Monitoring Information Flows

Name	Description
archive coordination	Catalog data, metadata, published data, and other information exchanged between archives to support data synchronization and satisfy user data requests.
Discovery, Exploration, Analysis Presentation	The delivery of queried data in the form of a user interface for Smart Columbus Operating System users to explore data sets. Data presented is dependent on the role and level of access permissions unique to each user.
Information Access Request	Request to access data set within the data utilization object.

Source: City of Columbus

Table 8: Smart Columbus Operating System Performance Monitoring Functional Objects

Physical Object	Functional Object	Description
Smart Columbus Operating System Project Functions		
Data Utilization	Analytics	The Smart Columbus Operating System will support analytics, which allow users to gain deeper insights into the data collected.
	Data Distribution and API Management	Access to all data and is provided and managed through APIs issued by the Data Utilization component via a secure URL address (i.e., https). Consumers (distinctly identified as general data consumers, 3rd party developers, and USDOT ITS Data Hub) are given data access through an API, and have the option of extracting and feeding the data to their own reporting system, developing a new reporting mechanism, or using the Visualization function offered by the Smart Columbus Operating System.
	Discovery	The Smart Columbus Operating System enables users to explore the data that is being collected. Information is shared about the different sources of data, types of data, data quality, etc.
	Visualization	The Smart Columbus Operating System provides users with tools to graphically visualize and understand the data.
Information Management	Data Repository	The Smart Columbus Operating System has a data repository that is capable of establishing, tracking, and controlling datasets.

Source: City of Columbus

2.2.3.3. APPLICATIONS

The applications within the Smart Columbus Operating System leverage the microservices architecture. Historically, software systems have been developed as a single, monolithic unit constructed from a blend of hand-built custom technologies. The more features are added, the more complicated the system becomes. This creates high-risk, high-maintenance dependencies and a software structure that resembles spaghetti code, making the software difficult and costly to manage over time. The architecture of the applications within the Smart Columbus Operating System breaks apart this model by designing a set of small, discrete, independent, standardized microservices that can be synchronously plugged-in for a cleaner, more efficient application build. Within this environment, the Smart Columbus Operating System is hosting one application using microservices managed by the Technology Center. More applications are anticipated to be added as the program evolves.

The Technology Center is the foundation that delivers the end-user experience, and administratively coordinates all components within the Smart Columbus Operating System. It is responsible for hosting, environment monitoring, alerting, and notifying, and allows technical administrators to view health, log, availability, capacity, and other technical metrics via dashboards and systemic reports.

Similar to the other Smart Columbus Operating System Service Packages, all components, relations between, and connections to/from the Smart Columbus Operating System applications environment are secured and governed by the OS-SM support system. To simplify the diagram, the OS-SM component is shown in its short-hand icon, indicating the component connects to the OS-SM to access the security functions shown within the OS-SM component.

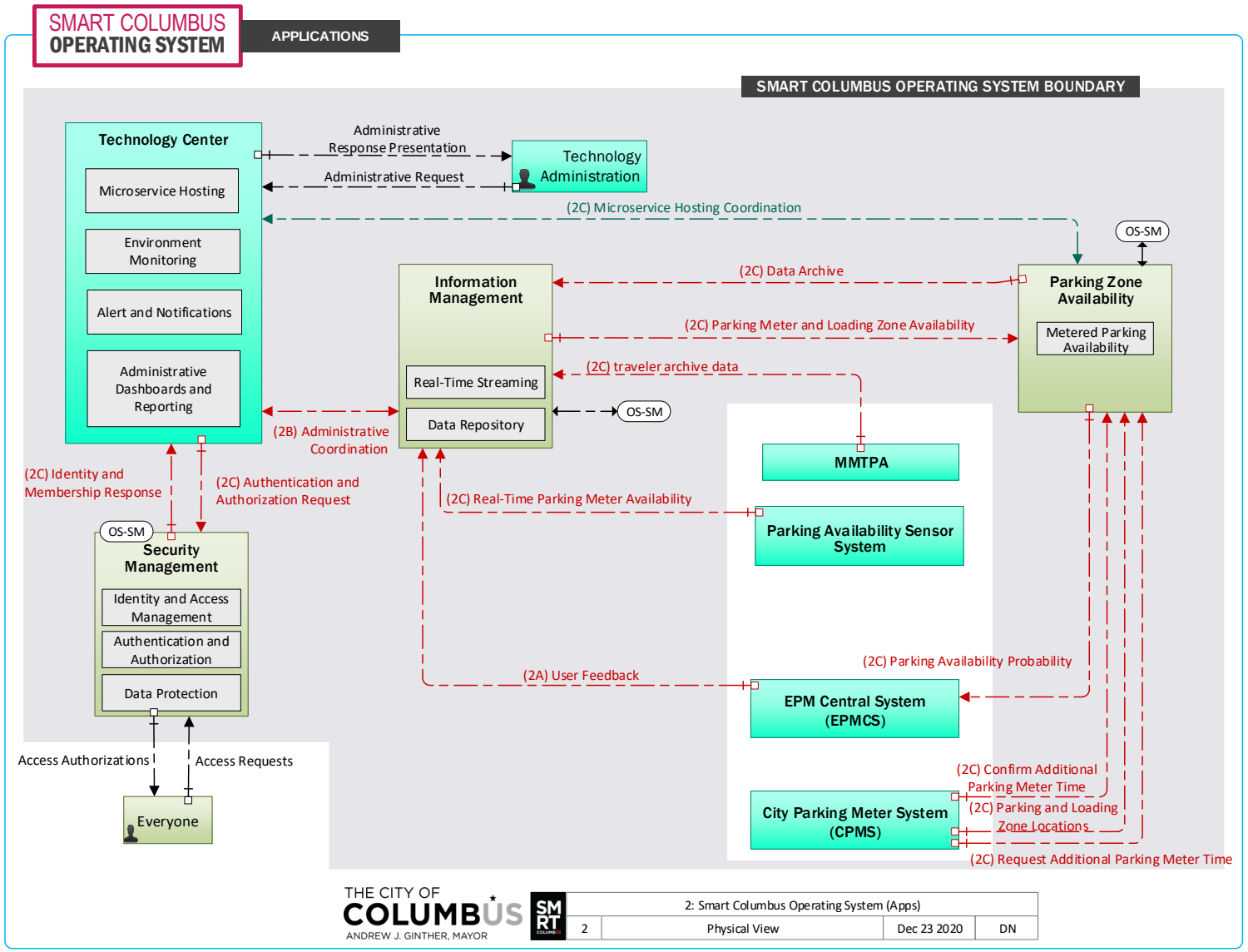


Figure 11: Smart Columbus Operating System Applications Physical Architecture View (Layer 2)

Source: City of Columbus

Table 9: Smart Columbus Operating System Applications Physical Elements

Name	Class	Description
City Parking Meter System (CPMS)	Center	The City Parking Meter System (CPMS) will send meter usage and general meter and loading zone information to the Smart Columbus Operating System. Loading zone information includes locations and hourly restrictions.
EPM Central System (EPMCS)	Center	The EPM Central System (EPMCS) is a system to search, find, schedule, and reserve parking. It maintains the traveler profile, coordinates parking payment, sends reminder/notifications, provides discounted parking options, and calculates the probability of finding parking meter space in the City.
Everyone	Support	Everyone describes any user who attempts to access the Smart Columbus Operating System.
Information Management	Support	This component covers the ingestion and organization of information stored in the Smart Columbus Operating System. The ingestion process is initiated by the Data Curator using a web interface to define and manage the data feeds.
MMTPA	Center	The MMTPA is an app available to travelers on both iOS and Android devices and a web-based platform. MMTPA collects, stores, and aggregates the data from multiple Mobility Providers via APIs. The project will allow travelers to create multimodal trips and pay once using an account-based system, which is linked to different payment media and modes of transportation. Multimodal trip options include walking, fixed-route bus service, ride-hailing, bike-sharing, paratransit, and scooter services.
Parking Availability Sensor System	Center	The Parking Availability Sensor System collects, processes, and distributes real-time parking sensor information. The system provides real-time information for parking space occupancy for several zones in the Short North area.
Parking Zone Availability	Support	A microservice that supports the EPM project by providing algorithmic determinations on parking availability for travelers.
Security Management	Support	Security Management describes the services that detect, protect, and respond to security issues, used by all major components of the Smart Columbus Operating System.
Technology Administration	Center	The Technology Administration includes staff who support the operation of the Smart Columbus Operating System.
Technology Center	Center	Technology Center supports the continuous, smooth operation of the Smart Columbus Operating System, including the administration of the data archive center, microservices, service monitor, administrative reporting, management of system alerts and notifications, etc. The Technology Administrator is a role that acts as the system administrator for this center.

Source: City of Columbus

Table 10: Smart Columbus Operating System Applications Information Flows

Name	Description
Access Authorizations	Identity management authorizations, typically in the form of tokens or user certificates.

Name	Description
Access Requests	Request to access a component of the Smart Columbus Operating System.
Administrative Coordination	Data associated with the technical administration of an information support system or center. This could include data elements such as system configuration (parameters, filters, thresholds, etc.), API definitions, data ingestion rules, system usage data, health monitoring heartbeats, device states, security monitoring and compliance, software event triggers, network interface statistics, data governance and policy, etc.
Administrative Request	Technology administrator makes requests to administer the Smart Columbus Operating System through the user interface.
Administrative Response Presentation	Technology center presents request results via the technology center user interface.
archive coordination	Catalog data, metadata, published data, and other information exchanged between archives to support data synchronization and satisfy user data requests.
Authentication and Authorization Request	Any request to connect to a part of the Smart Columbus Operating System containing user name and password credentials. The Smart Columbus Operating System will use this information to validate (authenticate) the user is permitted to access the requested resource, and looks up membership information to determine level of access the user is permitted for the given request.
Confirm Additional Parking Meter Time	Confirmation of the additional parking meter time.
Identity and Membership Response	Authorization and authentication responses in the form of a token with active directory membership (authorization) level permissions.
Microservice Hosting Coordination	The technology center provides microservice application independence to run each process as a service. These services communicate via a well-defined interface using lightweight APIs. Services are built for business capabilities, and each service performs a single function. Because they are independently run, each service is updated, deployed, and scaled to meet demand for specific functions of an application. The technology center is the enabler of these infrastructure hosting services.
Parking and Loading Zone Locations	The locations of parking space and loading zones.
Parking Availability Probability	The probability that parking spaces in a region will be available.
Parking Meter and Loading Zone Availability	Data elements for parking and loading zone availability as established by the EPM project.
Real-Time Parking Meter Availability	Real-time parking meter availability information based on field sensor data.
Request Additional Parking Meter Time	Renew parking meter to extend the expiry time.

Name	Description
traveler archive data	Data associated with traveler information services, including service requests, facility usage, rideshare, routing, and traveler payment transaction data. Content may include a catalog of available information, the actual information to be archived, and associated meta data that describes the archived information.
User Feedback	Feedback provided by the user after the use of the EPM application
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.

Source: City of Columbus

Table 11: Smart Columbus Operating System Applications Functional Objects

Physical Object	Functional Object	Description
Smart Columbus Operating System Project Functions		
Information Management	Data Repository	The Smart Columbus Operating System has a data repository that is capable of establishing, tracking, and controlling datasets.
	Real-Time Streaming	The Smart Columbus Operating System ingests information from a variety of streaming data sources, typically through a REST endpoint. The data can have different structures such as flat/tabular, hierarchical, or unstructured.
Parking Zone Availability	Metered Parking Availability	Provide metered parking availability to the EPM application.
Security Management	Authentication and Authorization	Set of components that ensure the proper controls are in place. The way this is performed is technology specific.
	Data Protection	Set of technologies and well-established security practices that ensure data are protected within the Smart Columbus Operating System and as it is being consumed by 3rd parties.
	Identity and Access Management	Provides an administrative interface to define users and their access rights to various Smart Columbus Operating System components.
Technology Center	Administrative Dashboards and Reporting	Reports and visualization tools are provided for measuring and monitoring the performance of all aspects of information technology administratively in the environment. This includes technology inventory, heartbeat, utilizations, capacities, queries and counts, etc. Information technology administrators leverage information to make strategic decisions for improving and/or sustaining a high-performance environment.

Physical Object	Functional Object	Description
	Alert and Notifications	Administrators receive alerts with information about the system's performance and any issues which may arise. Notifications are provided to end users who request them, with information about service interruptions, new system features, etc.
	Environment Monitoring	The health of the system is continuously monitored for a variety of reasons, including ensuring satisfactory performance and proactively responding to system outages.
	Microservice Hosting	The Smart Columbus Operating System provides a microservices environment that can be used by Smart Columbus Operating System developers and 3rd party developers to deploy their services.

Source: City of Columbus

2.2.4. Enterprise Architecture View

The following diagram shows the relationships between Smart Columbus stakeholders and the roles organizations play within the Smart Columbus Operating System.

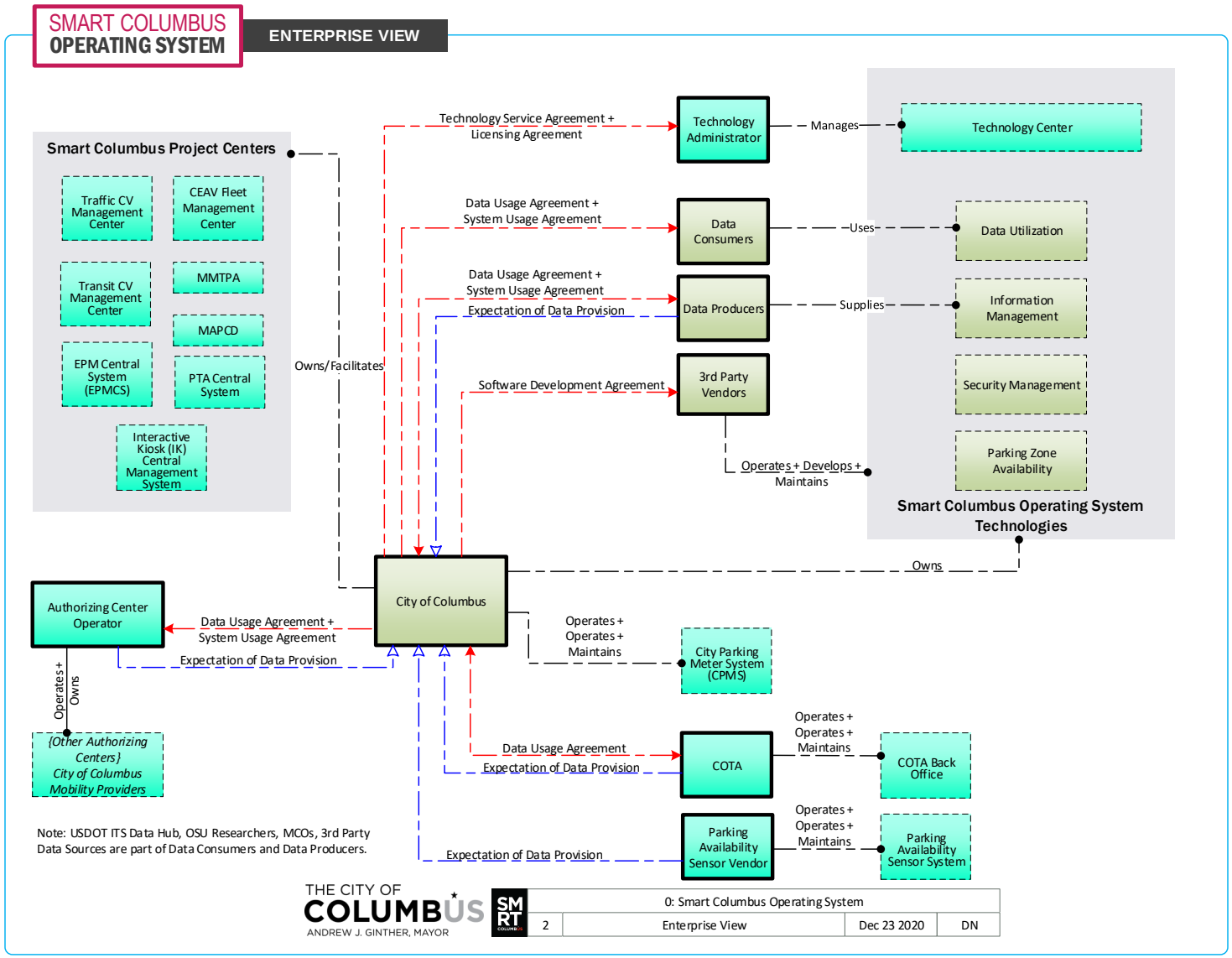


Figure 12: Smart Columbus Operating System Enterprise Architecture View

Source: City of Columbus

Table 12: Smart Columbus Operating System List of Agreements

Name	Description
Licensing Agreement	An agreement between the City and the Technology Administrator for providing technology service and open source licensing. The vendor currently uses Apache 2.0 Open Source License for code that is open sourced. Vendor: Accenture Status: Existing
Technology Service Agreement	An Agreement between the City and the cloud services/hosting provider (Amazon Web Services) for the Smart Columbus Operating System. Vendor: Amazon Web Services Status: Existing
System Usage Agreement	A terms of use agreement provided to data consumers when interacting with the Smart Columbus Operating System user interface. It provides the Smart Columbus Operating System privacy policy and terms of use. Status: Existing
Data Usage Agreement	An informal agreement between the City and Data Producers. Data producers submit requests to the Smart Columbus Operating System team to describe the data that will be provided, and agrees to the rules around how the data will be provided. This includes the agreements between the City and each project vendor to collect data from the project and place it on the Smart Columbus Operating System. Status: Existing
Software Development Agreement	An agreement for the vendor to develop software required to operate and maintain the Smart Columbus Operating System through the life of the USDOT grant. The agreement covers all three phases: development, operations, and maintenance through May 2021. Vendor: Accenture Status: Existing
Employment Agreement	An agreement between the City and Battelle for staff support to provide data curation expertise and services to support the Smart Columbus Operating System technologies. Vendor: Battelle Status: Existing

Source: City of Columbus

2.2.4.1. ROLES AND RESPONSIBILITIES

Development:

- City of Columbus/Smart Columbus Program Management Office (PMO) (product owner, owner)
  - Accenture (contract): development lead
  - HNTB: development support
  - Amazon Web Services (hosting provider): key leveraged partner
  - Smart Columbus Project Teams (interfaces – data):
    - MAPCD

        - PTA
        - CVE
        - MMTPA
        - CEAV
        - EPM
        - SMH (IK)
- Data Providers – require data sharing agreement, agreement to Data Management Plan/Data Privacy Plan and their associated policies

Installation:

- City of Columbus/Smart Columbus PMO (product owner, owner)
    - Accenture (contract): development lead
    - Amazon Web Services (hosting provider): key leveraged partner
    - Smart Columbus Project Teams (interfaces – data):
        - MAPCD
        - PTA
        - CVE
        - MMTPA
        - CEAV
        - EPM
        - SMH (IK)
- Data Providers – require data sharing agreement, agreement to Data Management Plan/Data Privacy Plan and their associated policies
- Data Consumers – require agreement to terms of use/account to download data

Operations:

- City of Columbus/Smart Columbus PMO (product owner, owner)
    - Accenture (contract): data curation, privacy and security management
    - Security
    - Privacy
    - Amazon Web Services (hosting provider): key leveraged partner
    - Smart Columbus Project Teams (interfaces – data):
        - MAPCD
        - PTA
        - CVE
        - MMTPA
        - CEAV
        - EPM

    - SMH (IK)
- Data Providers – require data sharing agreement, agreement to Data Management Plan/Data Privacy Plan and their associated policies:
- Data Consumers – require agreement to terms of use/account to download data

Maintenance:

- City of Columbus/Smart Columbus PMO (product owner, owner)
    - Accenture (contract): bug fixes, reporting, data curation
    - Amazon (hosting provider): key leveraged partner

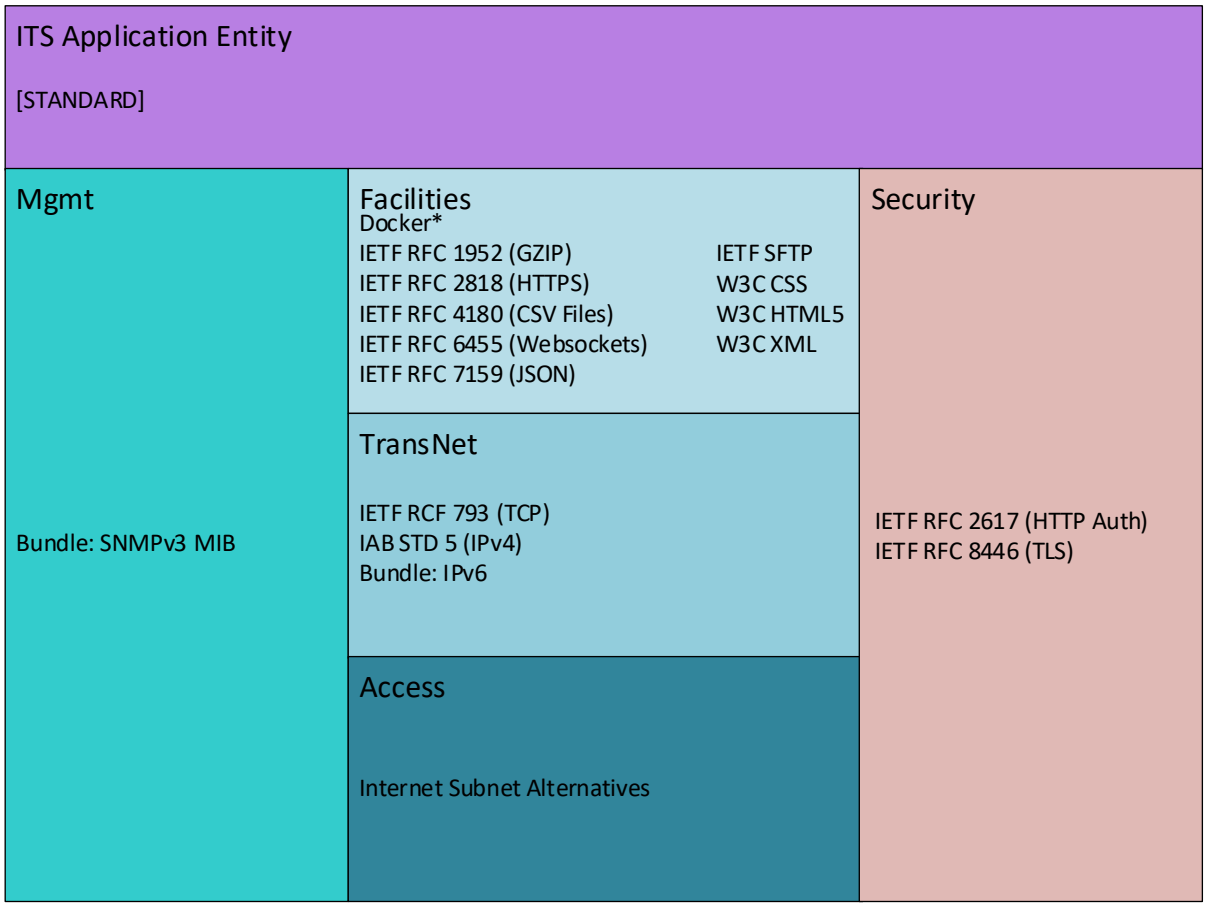
2.2.5. Communications Architecture View

The following sections describe the layered sets of communication protocols that are required to support communications among the Physical Objects that make up the Smart Columbus Operating System and participate in producing or consuming data.

Information Flows that are internal to the Smart Columbus Operating System are not identified in the Communications View.

2.2.5.1. COMMUNICATION PROFILES USED

2.2.5.1.1. World Wide Web Browser/JSON/Wide Area Wireless



** Non-standard protocol. (Please note the Websockets are used for output only)*

Figure 13: World Wide Web Browser/JSON/Wide Area Wireless

Source: City of Columbus

Table 13: World Wide Web Browser/JSON/Wide Area Wireless

Name	Source	Destination	Standard	Profile
Administrative, Health, Usage and Monitoring	Interactive Kiosk (IK) Central Management System	Information Management	(Unspecified)	WAW-WWWBrowser-JSON
Aggregated Feedback	OSU Researchers	Information Management	(Unspecified)	WAW-WWWBrowser-JSON
Authentication and Authorization Request	Technology Center	Security Management	(Unspecified)	WAW-WWWBrowser-JSON

Name	Source	Destination	Standard	Profile
CEAV Archive Data	CEAV Fleet Management System	Information Management	(Unspecified)	WAW-WWWBrowser-JSON
CEAV Route	CEAV Fleet Management System	Information Management	(Unspecified)	WAW-WWWBrowser-JSON
Confirm Additional Parking Meter Time	City Parking Meter System (CPMS)	Parking Zone Availability	(Unspecified)	WAW-WWWBrowser-JSON
Data Archive Coordination	Traffic CV Management System	Information Management	(Unspecified)	WAW-WWWBrowser-JSON
Data Archive Coordination	Transit CV Management System	Information Management	(Unspecified)	WAW-WWWBrowser-JSON
Discovery, Exploration, Analysis Presentation	Data Utilization	Data Consumers and 3rd Party Developers	(Unspecified)	WAW-WWWBrowser-JSON
Discovery, Exploration, Analysis Presentation	Data Utilization	USDOT ITS Data Hub	(Unspecified)	WAW-WWWBrowser-JSON
EPM Archive Data	EPM Central System (EPMCS)	Information Management	(Unspecified)	WAW-WWWBrowser-JSON
Identity and Membership Response	Security Management	Technology Center	(Unspecified)	WAW-WWWBrowser-JSON
Information Access Request	Data Consumers and 3rd Party Developers	Data Utilization	(Unspecified)	WAW-WWWBrowser-JSON
Information Access Request	USDOT ITS Data Hub	Data Utilization	(Unspecified)	WAW-WWWBrowser-JSON
Parking and Loading Zone Locations	City Parking Meter System (CPMS)	Parking Zone Availability	(Unspecified)	WAW-WWWBrowser-JSON
Parking Availability Probability	Parking Zone Availability	EPM Central System (EPMCS)	(Unspecified)	WAW-WWWBrowser-JSON
Parking Payment Archival Data	EPM Central System (EPMCS)	Information Management	(Unspecified)	WAW-WWWBrowser-JSON

Name	Source	Destination	Standard	Profile
Real-Time Arrivals	COTA Back Office	Information Management	GTFS-Real Time	WAW-WWWBrowser-JSON
Real-Time Location	CEAV Fleet Management System	Information Management	(Unspecified)	WAW-WWWBrowser-JSON
Real-Time Parking Meter Availability	Parking Availability Sensor System	Information Management	(Unspecified)	WAW-WWWBrowser-JSON
Request Additional Parking Meter Time	City Parking Meter System (CPMS)	Parking Zone Availability	(Unspecified)	WAW-WWWBrowser-JSON
road network conditions	3rd Party Data Sources	Information Management	(Unspecified)	WAW-WWWBrowser-JSON
road network conditions	Traffic CV Management System	Information Management	(Unspecified)	WAW-WWWBrowser-JSON
SMH Archive Data	Interactive Kiosk (IK) Central Management System	Information Management	(Unspecified)	WAW-WWWBrowser-JSON
transit schedule information	COTA Back Office	Information Management	GTFS	WAW-WWWBrowser-JSON
traveler archive data	MMTPA	Information Management	(Unspecified)	WAW-WWWBrowser-JSON
Trip Data	MAPCD	Information Management	(Unspecified)	WAW-WWWBrowser-JSON
Trip and Usage Data	PTA Central System	Information Management	(Unspecified)	WAW-WWWBrowser-JSON
Trip and Usage Data	MCOs	Information Management	(Unspecified)	WAW-WWWBrowser-JSON
User Feedback	EPM Central System (EPMCS)	Information Management	(Unspecified)	WAW-WWWBrowser-JSON

Source: City of Columbus

2.2.5.1.2. Human Interface

Table 14: Human Interface

Name	Source	Destination	Standard	Profile
Access Authorizations	Everyone	Security Management	(Unspecified)	Human Interface
Access Requests	Security Management	Everyone	(Unspecified)	Human Interface
Administrative Request	Technology Administration	Technology Center	(Unspecified)	Human Interface
Administrative Response Presentation	Technology Center	Technology Administration	(Unspecified)	Human Interface

Source: City of Columbus

2.2.6. Functional View

The following table provides a Functional View of the Smart Columbus Operating System. It identifies the owning Service Package, its Physical Object(s) and descriptions, as well as the functions and descriptions associated with each Physical Object.

Table 15: Smart Columbus Operating System Functional Architecture View

Physical Object	Functional Object	Description
Information Management	Batch Receiver	Receive and Parse Data Files
	Data Repository	Receive Data Process Data Store Data
	Feed Management	Manage Data Sources Provide Data Source Parameters
	Metadata Management	Provide Metadata for Data Sets and Data Sources Manage Metadata for Data Sets and Data Sources
	Real-Time Streaming	Receive Streaming Data
	Scheduling	Provide Schedule Data Manage Scheduled System Events
	Validation and Transformation	Receive Data Validate Data Process Data Provide Data
COTA Back Office	COTA GTFS Feed	Provide Data Feed
Other Authorizing Centers	Future Data Feeds	Provide Data Feed

Physical Object	Functional Object	Description
Data Utilization	Analytics	Query Data
	Data Distribution and API Management	Provide Interface for Data Consumers and 3rd Party Developers
	Discovery	Provide Interface for Data Consumers and 3rd Party Developers Filter Data Manage Data
	Visualization	Provide Interface for Data Consumers and 3rd Party Developers Create Visualizations Save Visualizations Share Visualizations
Parking Zone Availability	Metered Parking Availability	Receive Metered Parking Availability Information Calculate Metered Parking Availability Probability Provide Information to EPMCS
Security Management	Authentication and Authorization	Authenticate Users
	Data Protection	Verify User Authentication Provide Data to Users
	Identity Access and Management	Verify User Authentication Provide User Identity and Access Rights Manage User Access Rights
Technology Center	Administrative Dashboards and Reporting	Provide Interface for Administrators Manage System Events, Notification and Warnings
	Alerts and Notifications	Provide Alerts to Administrators Provide Alerts to Data Consumers and 3rd Party Developers Receive System Events, Notification and Warnings
	Environment Monitoring	Monitor Data Ingestion Monitor System Performance Provide System Events, Notification and Warnings
	Microservice Hosting	Provide Interface for 3rd Party Developers Provide Hosting for 3rd Party Developers Provide Ability to Upload Microservices Provide Ability to Manage Microservices

Source: City of Columbus

2.3. PROJECT 2: CONNECTED VEHICLE ENVIRONMENT

2.3.1. Introduction

The CVE project plays a role in accomplishing the goal of better connecting Columbus residents to safe, reliable transportation. To this end, a set of objectives were established in the Performance Measurement Plan based on CVE stakeholder needs:

- Improve reliability of transit vehicle schedule adherence
- Improve emergency response times
- Reduce truck wait (delay) time at signalized intersections
- Improve motorists' adherence to red lights
- Improve adherence to speed limits in school zones
- Improve traffic management capability

The CVE will meet these objectives by deploying CV technology in vehicles and on the roadside. The project will integrate smart traveler applications, automated vehicles, connected vehicles, and smart sensors into its transportation network by focusing on deploying CV infrastructure and CV applications. As outlined in the CVE ConOps, the project intends to deploy proven, mature CV technology into an operational environment. Therefore, only applications that have demonstrated sufficient levels of development and testing are considered for implementation. However, the CVE will be designed in such a way that new technologies can be integrated, once development and testing have matured, to being deployment-ready.

2.3.2. System of Interest

The CVE can be described as a combination of subsystems that work together: a system of RSE, a system of in-vehicle equipment, and a system of backhaul networks for agency data.

On the roadside, the fundamental functions of the RSE is to obtain several types of status information from roadside ITS devices, and broadcast this information to vehicles in the vicinity. Intersections identified for the deployment of roadside CV equipment presumably contain necessary physical cabinet and conduit space for the proposed CV equipment, and that the distance between the cabinet equipment and overhead RSU mounting locations conform to distance constraints for physical communication between locally networked devices. Necessary remedies will be addressed upon completion of detailed installation plans. The RSE refers to the hardware and software ecosystem at the edge, used to facilitate message transmission to/from nearby vehicles using Dedicated Short Range Communications (DSRC) or other alternative wireless communications technologies.

In vehicles, the fundamental functions of OBUs are to obtain various types of status information from the vehicle, and broadcast this information to other vehicles and infrastructure in the vicinity. The OBUs may utilize status information from the vehicle (this includes interfaces with other in-vehicle devices deployed as part of the Smart Columbus Program), other vehicles (i.e., remote OBUs), the roadside, and location and time data (obtained from a location and time source) such as GNSS to support safety and mobility applications. Similarly, the RSE exchanges information with the roadside ITS equipment, vehicles, and location and time data to support mobility applications. A vehicle's onboard equipment (OBE) will be comprised of DSRC radios, a Human Machine Interface (depending on their applications), and/or connect to vehicle data systems. Both the vehicle and RSE utilize an SCMS to establish a hierarchy chain of trust between actors in the CVE. Lastly, the CVE project will capture operational data from the roadside to the Smart Columbus Operating System for further analysis, decision support, and performance metrics.

Table 16 lists the planned CVE applications that will be deployed for this project.

Table 16: Connected Vehicle Environment Applications

		Light-Duty Vehicle + Operator	Emergency Vehicle + Operator	Heavy-Duty Vehicle + Operator	Transit Vehicle + Operator	Traffic Manager	Transit Manager	Network Manager
V2V Safety	Emergency Electronic Brake Light Warning	H/R①	R	R	R	-	-	-
	Forward Collision Warning	H/R①	R	R	R	-	-	-
	Intersection Movement Assist	H/R①	R	R	R	-	-	-
	Lane Change Warning / Blind Spot Warning	H/R①	R	R	R	-	-	-
V2I Mobility	Transit Signal Priority*	-	-	-	①	-	①	②
	Freight Signal Priority*	-	-	①	-	-	-	②
	Emergency Vehicle Preemption*	-	①	-	-	-	-	②
	Vehicle Data for Traffic Operations	R	R	R	R	①	-	②
	Transit Vehicle Interaction Event Recording	R	R	R	R	-	①	②
V2I Safety	Red Light Violation Warning	H ①	-	-	-	-	-	-
	Reduced Speed School Zone	H ①	-	-	-	-	-	-

H Host is the issuer of alerts/warnings based on processing Basic Safety Messages received.
R Remote broadcasts data received by the host.
① User classes that will primarily benefit from these applications.
② Network manager provides system support for stated applications.
* Priority/Preempt applications require back and forth communications between vehicles and equipment on the roadside. Therefore, host and remote vehicles are not designated.
- Null Value

Source: City of Columbus

2.3.3. Physical Architecture View

Maintaining the service-oriented perspective, the CVE project includes the following Service Packages (discussed in greater detail in sections to follow):

- **V2V Safety:** Focuses on the architecture between vehicles in a CVE to deliver safety critical functionality. The following applications in the CVE project will use this architecture:
  - Emergency electronic braking

  - Forward collision warning
  - Intersection movement assist
  - Lane change warning/blind spot warning
- **V2I Mobility:** Focuses on services that enhance mobility in the CVE and includes the following Service Packages:
  - Traffic Signal Priority and Preemption
  - Vehicle Data for Traffic Operations
  - Transit Vehicle Interaction Event Recording
- **V2I Safety:** Focuses on services that improve safety by enabling communications between CVs and connected infrastructure to deliver location-specific safety information. The following Service Packages are included:
  - Red Light Violation Warning
  - Reduced Speed School Zone
- **V2I Support:** Focuses on the services that support the maintenance and operations of the CVE infrastructure. The following Service Pakcages are included:
  - Connected Vehicle System Monitoring and Management
  - Vehicle Maintenance
  - Security and Credentials Managment

A comprehensive Layer 0 Architecture that includes all of the CVE Service Packages is presented first shown in **Figure 14**, then each Service Package will be introduced as a Layer 2 diagram in the order presented above, which provides additional Information Flows among objects.

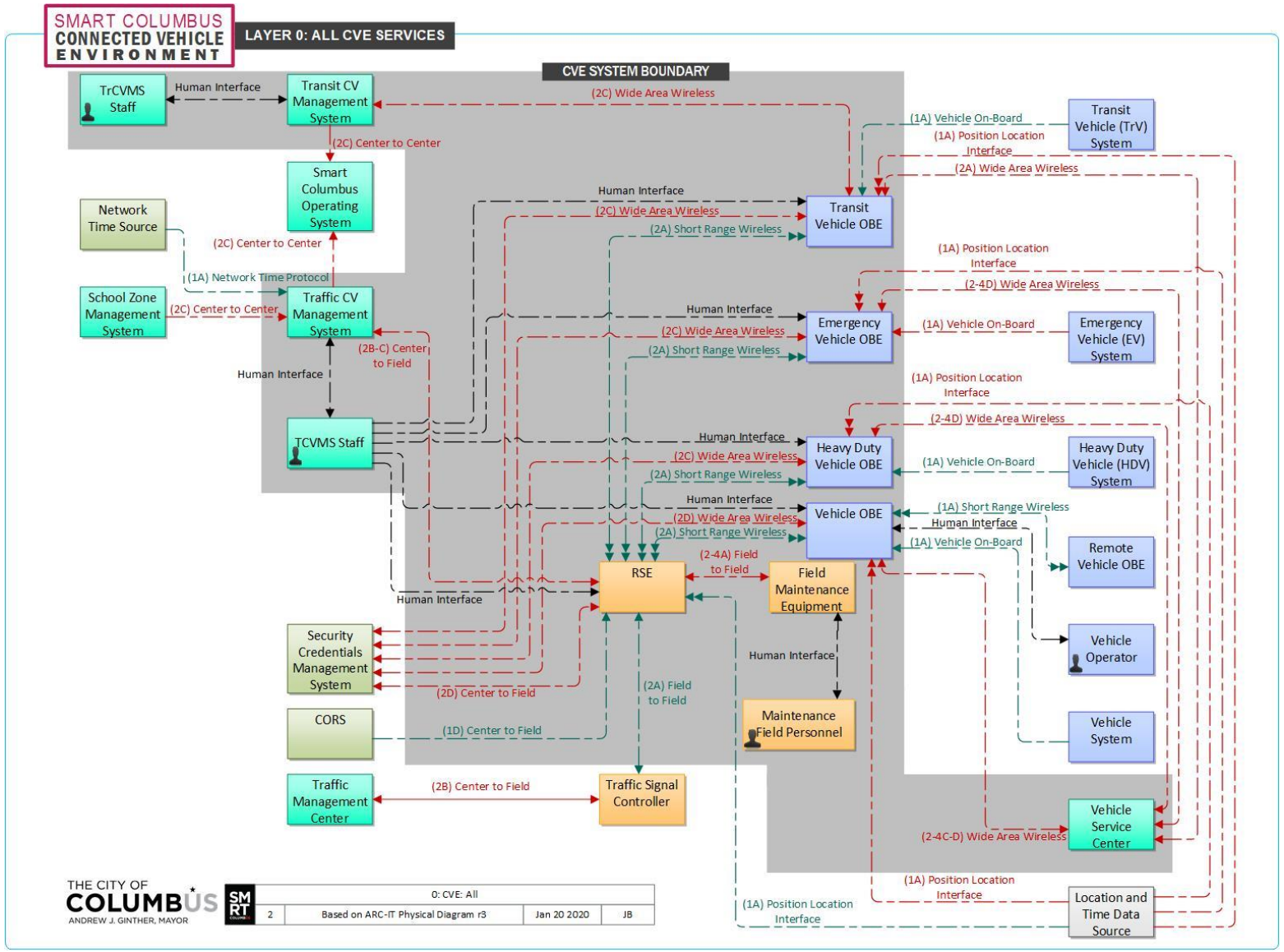


Figure 14: Connected Vehicle Environment Physical Architecture View (Layer 0)

Source: City of Columbus

2.3.4. Vehicle-to-Vehicle Safety

The ARC-IT and its predecessor, the CVRIA, are CVE project resources for V2V application deployments that have been researched in the context of the National ITS architecture. In addition, the Open Source Application Development Portal contains the necessary software for these applications, which are classified as deployment-ready. Where possible, the CVRIA and this portal will be used as-is or will have minimal modifications to address Smart Columbus stakeholder needs. The following applications will be deployed for this first phase of the CVE project. The descriptions below have been adapted from the VSC-A ConOps and the CVRIA.

2.3.4.1. EMERGENCY ELECTRONIC BRAKE LIGHT

The Emergency Electronic Brake Light[7] application enables a vehicle to broadcast a self-generated emergency braking event to surrounding vehicles. Any receiving vehicle determines the relevance of the event and, if appropriate, provides a warning to the vehicle operator to avoid a crash. This application is particularly useful when receiving-vehicle operator line of sight is obstructed by other vehicles or bad weather conditions such as fog or heavy rain. The Emergency Electronic Brake Light app provides an output to drivers to improve awareness of emergency braking events in an attempt to reduce rear-end crashes between multiple vehicles at intersection and non-intersection locations.

2.3.4.2. FORWARD COLLISION WARNING

The Forward Collision Warning[8] app warns the vehicle operator of an impending rear-end collision with another vehicle ahead in traffic in the same lane and direction of travel. The app uses data received from other vehicles to determine if a forward collision is imminent. The Forward Collision Warning app advises vehicle operators to take specific action to avoid or mitigate rear-end vehicle collisions in the forward path of travel to attempt to reduce rear-end crashes among multiple vehicles at intersection and non-intersection locations.

2.3.4.3. INTERSECTION MOVEMENT ASSIST

The Intersection Movement Assist[9] app warns the vehicle operator when it is not safe to enter an intersection due to a high probability of collision with other vehicles at stop sign-controlled and uncontrolled intersections. This application can provide collision warning information to the driver, who may perform actions to reduce the likelihood of crashes at the intersections. The Intersection Movement Assist app provides an output to drivers to improve awareness of approaching vehicles on conflicting approaches in an attempt to reduce crashes between multiple vehicles at intersections. This app may also assist in addressing angle crashes between vehicles at non-intersection locations where vehicles are turning across traffic at driveway locations.

2.3.4.4. LANE CHANGE WARNING/BLIND SPOT WARNING

The Lane Chance Warning/Blind Spot Warning[10] app warns the vehicle operator during a lane change attempt if the blind-spot zone into which the vehicle intends to switch is, or will soon be, occupied by another vehicle traveling in the same direction. Moreover, the application provides advisory information that informs the vehicle operator that another vehicle in an adjacent lane is positioned in a blind-spot zone of the vehicle

[7] *CVRIA – Emergency Electronic Brake Light:* http://local.iteris.com/cvria/html/applications/app23.html#tab-3

[8] *CVRIA – Forward Collision Warning:* http://local.iteris.com/cvria/html/applications/app31.html#tab-3

[9] *CVRIA – Intersection Movement Assist:* http://local.iteris.com/cvria/html/applications/app36.html#tab-3

[10] *CVRIA – Lane Change Warning/Blind Spot Warning:* http://local.iteris.com/cvria/html/applications/app7.html#tab-3

when the vehicle's turn signal is turned on. This output raises driver awareness in an attempt to reduce issues associated with sideswipe crashes among multiple vehicles at non-intersection locations.

2.3.4.5. V2V SAFETY PHYSICAL ARCHITECTURE

Figure 15 represents the implementation architecture for all V2V safety applications described, which J2735/J2945 also defines.

The V2V Service Package shows how basic safety messages are exchanged with surrounding CVs (i.e., remote vehicle OBE) to support and enhance safety warning, and control automation features for the Emergency Electronic Brake Light, Forward Collision Warning, Intersection Movement Assist, and Lane Change Warning/Blind Spot Warning applications defined in Society of Automotive Engineers (SAE) J2945/1. GNSS data will be used to provide position, speed, and heading for all CVs and the USDOT will provide the SCMS prototype used by the CVE. See corresponding USDOT specification documents for details.

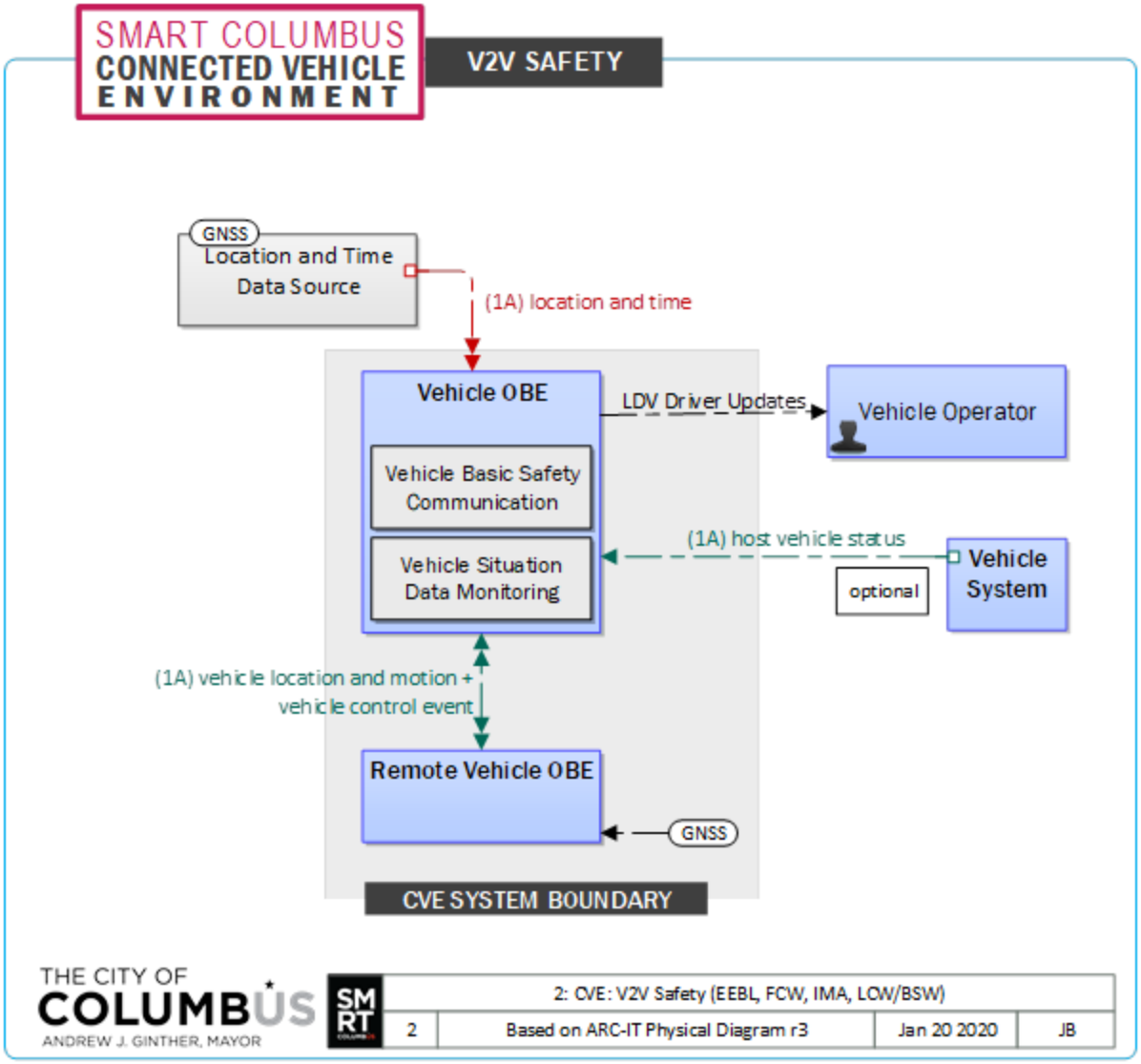


Figure 15: Connected Vehicle Environment Vehicle-to-Vehicle Safety Architecture

Source: City of Columbus

The following tables describe in greater detail the Physical Elements, Information Flows, and Functional Objects seen on the diagram above, associated with V2V safety applications.

Table 17: Vehicle-to-Vehicle Safety Physical Elements

Name	Class	Description
Location and Time Data Source	ITS	The Location and Time Data Source is a GNSS that provides accurate position information for vehicle-based mobile devices. GNSS data are used to provide position, speed, and heading for vehicles. While a GPS Receiver is the most common implementation, this Physical Object represents the technology that provides a position fix in three dimensions and time with sufficient accuracy.
Remote Vehicle OBE	Vehicle	The Remote Vehicle OBE represents other CVs that are communicating with the host vehicle. This includes all connected motorized vehicles that support V2V communications. The remote vehicle broadcasts data that is received by the host vehicle. For instance, in an emergency braking situation, the leading vehicle is the remote vehicle, and makes its emergency braking status known to other vehicles. A following vehicle, a host vehicle, would receive the status from the remote vehicle to display a warning to the host-vehicle operator. In CVRIA, this object provides a source and destination for information transfers between connected vehicles. The host vehicle OBE, represented by the Vehicle OBE Physical Object, sends information to, and receives information from Remote Vehicle OBE to model all connected vehicle V2V communications in CVRIA.
Vehicle System	Vehicle	The Vehicle System represents the interface to the vehicle system (e.g., hardwire connection to cable harness, CAN, LIN, Ethernet/IP, FlexRay, and MOST) that may enable communication between the Vehicle OBE and other vehicle systems to support CV applications. The vehicle system statuses and/or sensor outputs available on the databus will vary based on the equipment installed on the vehicle and availability on databus. System statuses and sensor outputs may include select vehicle systems and sensors such as GPS derived location and timing information. In CVRIA, this Physical Object is used to represent the onboard interactions between the Vehicle OBE and the other systems included in a host vehicle. Note that the vehicle databus interface is optional, and is not standardized across all vehicle classes. Also, some Vehicle OBE implementations may not have access to the vehicle databus.
Vehicle OBE	Vehicle	The Vehicle OBE provides the vehicle-based sensory, processing, storage, and communications functions that support efficient, safe, and convenient travel. The Vehicle OBE includes general capabilities that apply to passenger cars, trucks, and motorcycles. Many of these capabilities apply to all vehicle types including light-duty vehicles (LDVs), heavy-duty vehicles (HDVs), emergency vehicles, and transit vehicles. From this perspective, the Vehicle OBE includes the common interfaces and functions that apply to all motorized vehicles. The radio(s) supporting V2V and V2I communications are a key component of the Vehicle OBE. Both one-way and two-way communications options support a spectrum of information services from basic broadcast to advanced personalized information services. This Physical Object supports all six levels of driving automation as defined in SAE J3016.

Name	Class	Description
Vehicle Operator	Vehicle	The Vehicle Operator represents the person that operates a vehicle on the roadway. Included are operators of private, transit, commercial, and emergency vehicles where the interactions are not particular to the type of vehicle (e.g., interactions supporting vehicle safety applications) unless the Information Flow states otherwise. For instance, driver updates between the vehicle OBE and operator are valid for the LDV class and operators only. In the V2V safety Service Package above, the operator originates driver requests, and receives information that reflects the interactions which might be useful to all drivers, regardless of vehicle classification.

Source: City of Columbus

Table 18: Vehicle-to-Vehicle Safety Information Flows

Name	Description
host vehicle status [optional]	Information provided to the ITS OBE from other systems on the vehicle platform. This includes the current status of the powertrain, steering, and braking systems, as well as the status of other safety and convenience systems. In implementations where GPS is not integrated into the Vehicle OBE, the host vehicle is also the source for data describing the vehicle's location in three dimensions (latitude, longitude, elevation) and accurate time that can be used for time synchronization across the ITS environment.
LDV Driver Updates	Information provided to the LDV driver including visual displays, audible information and warnings, and haptic feedback. The updates inform the driver about current conditions, potential hazards, and the current status of vehicle OBE.
location and time	The current geographic location in three dimensions (latitude, longitude, elevation) and the current time.
vehicle control event	Notification that the vehicle has performed an emergency action that could impact the safety of surrounding vehicles. This includes hard braking and activation of traction/stability control systems, or other actions that warrant immediate notification of surrounding vehicles. The Information Flow conveys the vehicle's position, heading, speed, acceleration, transmission, steering wheel angle, braking status, size information, and trajectory.
vehicle location and motion	Data describing the vehicle's position, heading, speed, acceleration, transmission, steering wheel angle, braking status, size information, and trajectory.

Source: City of Columbus

Table 19: Vehicle-to-Vehicle Safety Functional Objects

Physical Object	Functional Object	Description
Connected Vehicle Environment Project Functions		
Vehicle OBE	Vehicle Basic Safety Communication	Vehicle Basic Safety Communication exchanges current vehicle location and motion information with other vehicles in the vicinity, uses that information to calculate vehicle paths, and warns the driver when the potential for an impending collision is detected. If available, map data are used to filter and interpret the relative location and motion of vehicles in the vicinity. If available, information from onboard sensors (e.g., radars and image processing) are also used in combination with the V2V communications to detect non-equipped vehicles and corroborate CV data. Vehicle location and motion broadcasts are also received by the infrastructure, and used by the infrastructure to support a wide range of roadside safety and mobility applications for current and future implementations.
	Vehicle Situation Data Monitoring	Vehicle Situation Data Monitoring is the highest-level representation of the functionality required to collect traffic and environmental situation data by monitoring and storing the experience of the vehicle as it travels through the road network. For transit OBE, collected data are aggregated into snapshots that are reported when communications are available and with flow control based on parameters provided by the infrastructure. Note that this Functional Object supports collection of data for areas remote from RSEs or other communications infrastructure for future enhancements. For this project, environmental situation data is not applicable.

Source: City of Columbus

2.3.5. Vehicle-to-Infrastructure Mobility

2.3.5.1. CONNECTED VEHICLE ENVIRONMENT TRAFFIC SIGNAL PRIORITY AND PREEMPTION

V2I CV applications provide improved mobility, accommodating transit and freight signal priority, preemption for emergency vehicles, and pedestrian movements—while maximizing overall arterial network performance. The CVE will leverage Kapsch's Connected Vehicle Control Center to deploy Traffic Signal Priority and Preemption for emergency vehicle operators, HDV operators, and transit vehicle operators. Traffic Signal Priority and Preemption operates in collaboration with, or independently of, surrounding intersections. Also, vehicles approaching from either the 'main street' and/or the 'side street' have the ability to communicate with RSE at intersections to acquire priority/preemption status. The RSE can be configured to limit which approaches can receive priority/preemption based on traffic management policy.

Signal preemption is provided for emergency vehicle operators. It provides a high level of priority for emergency first responders, and interrupts the current intersection state to provide service to a specified phase. Signal priority is provided for HDV operators and transit vehicle operators, and is considered a lower level of priority compared with the needs of emergency vehicle operators. Signal priority is characterized by providing either an early green or an extended green for a specified phase.

When a priority request is received, it may not be granted if there are conflicting priority requests, or does not comply with the criteria in the Priority Authorization List. A signal status message is returned from the

RSE to the vehicle to indicate whether the priority request was granted. This allows the application to provide feedback, if deemed necessary, to the emergency vehicle, HDV, or transit vehicle operator indicating whether the signal priority has been granted. This application can contribute to improved operating performance of the emergency vehicles, HDVs, and transit vehicles by reducing the time spent stopped at a red light. This application intends to address emergency vehicle delay, transit delay, and freight delay.

Figure 16 illustrates the Layer 2 architecture for Traffic Signal Priority and Preemption.

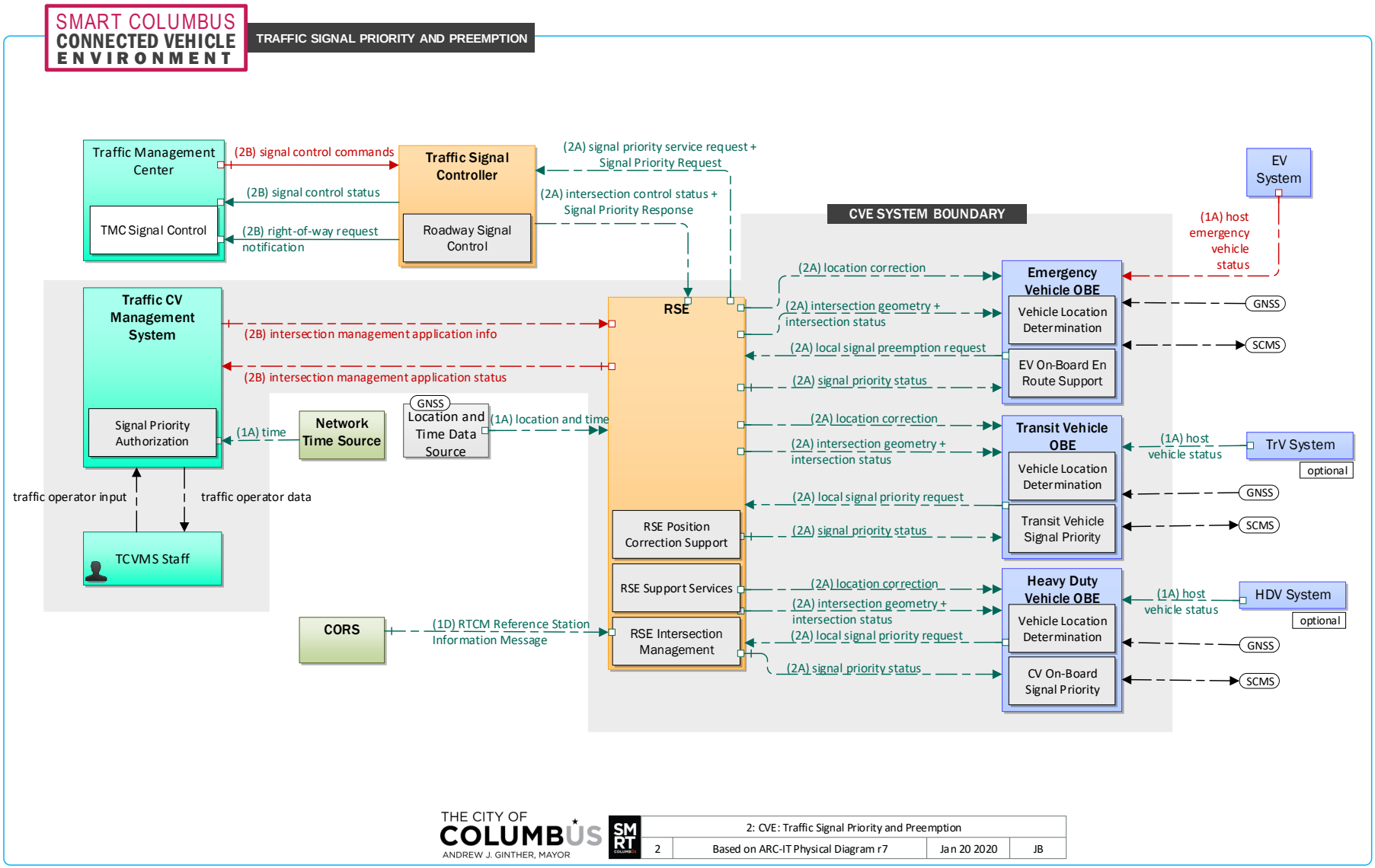


Figure 16: Connected Vehicle Environment Traffic Signal Priority and Preemption

Source: City of Columbus

The following tables describes the Physical Elements, Information Flows, and Functional Objects seen on the diagram above, associated with the Traffic Signal Priority and Preemption applications.

Table 20: Connected Vehicle Environment Traffic Signal Priority and Preemption Elements

Name	Class	Description
CORS	Support	The CORS represents the external source of land-based position corrections that augment satellite-provided (e.g., GNSS) positioning data. The City of Columbus will utilize the ODOT CORS network to perform the role of the reference stations.
Emergency Vehicle OBE	Vehicle	The Emergency Vehicle OBE resides in an emergency vehicle and provides the processing, storage, and communications functions that support public safety-related CV applications. It represents a range of vehicles, including those operated by police, fire, and emergency medical services within the scope of the project. It includes two-way communications to support coordinated response to emergencies. The emergency vehicle OBE supports the general vehicle safety and driver information capabilities that apply to all vehicles and supplements these general capabilities with capabilities that are specific to emergency vehicles.
EV System	Vehicle	The EV Databus represents the interface to the emergency vehicle databus (e.g., hardwire connection to cable harness, CAN, LIN, Ethernet/IP, FlexRay, and MOST) that may enable communication between the vehicle OBE and other vehicle systems to support CV applications.
Heavy Duty Vehicle OBE	Vehicle	The Heavy Duty Vehicle OBE resides in a commercial freight vehicle owned and operated by local freight companies. The HDV OBE provides the sensory, processing, storage, and communications functions necessary to support safe and efficient commercial vehicle operations. It provides two-way communications between the commercial vehicle drivers, their fleet managers, attached freight equipment, and roadside officials. The HDV OBE supports vehicle safety and driver information capabilities that apply to all vehicles, including heavy duty freight vehicles and supplements these general ITS capabilities with capabilities that are specific to commercial freight.
HDV System	Vehicle	The HDV System represents the interface to the commercial freight vehicle databus (e.g., hardwire connection to cable harness, CAN, LIN, Ethernet/IP, FlexRay, and MOST) that may enable communication between the HDV OBE and other vehicle systems to support CV applications.
Location and Time Data Source	ITS	The Location and Time Data Source is a GNSS that provides accurate position information for vehicle-based mobile devices. GNSS data are used to provide position, speed, and heading for vehicles. While a GPS Receiver is the most common implementation, this Physical Object represents the technology that provides a position fix in three dimensions and time with sufficient accuracy.
Network Time Source	Support	The Network Time Source represents the external time source the CV service monitor uses as the basis for time.

Name	Class	Description
RSE	Field	The RSE represents the CV roadside devices that are used to send messages to, and receive messages from, nearby vehicles using DSRC or other alternative wireless communications technologies. Communications with adjacent ITS field equipment and the back office TCVMS that monitors and controls the RSE are also supported. The RSU portion operates from a fixed position on vertical strain poles, mast arms, or spanwire on which signal heads are installed for permanent deployment. The RSE includes a processor, data storage, and communications capabilities that support secure communications with passing vehicles, other field equipment, and centers.
TCVMS Staff	Center	The TCVMS Staff represents the operational personnel responsible for traffic management, maintenance operations, and administrative activities of the TCVMS. These different roles represent a variety of individuals in the transportation industry.
Traffic CV Management System	Center	The Traffic CV Management System monitors and controls the CVE and road network. It communicates with ITS Roadway Equipment and CV RSE to monitor and manage traffic flow, and monitor the condition of the roadway, surrounding environmental conditions, and field equipment status.
Traffic Management Center	Center	The Traffic Management Center monitors and controls traffic and the road network. It represents centers that manage a broad range of transportation facilities including freeway systems, rural and suburban highway systems, and urban and suburban traffic control systems. It manages traffic and transportation resources to support allied agencies in responding to, and recovering from, incidents ranging from minor traffic incidents through major disasters.
Traffic Signal Controller	Field	City of Columbus signaling device positioned at a road intersection, pedestrian crossing, or other location that indicates which driver, rider, or walker is assigned the right-of-way at a given moment, using a universal color code (and a precise sequence for those that are color-blind). The City of Columbus owns and operates many local traffic signals.
Transit Vehicle OBE	Vehicle	The Transit Vehicle OBE represents COTA's fixed-route transit bus, paratransit, and CEAVs. It provides the sensory, processing, storage, and communications functions necessary to support safe and efficient movement of passengers. It also collects ridership levels, and could support electronic fare collection in future programs. In the context of CVE, it supports a traffic signal prioritization function that communicates with the roadside Physical Object to improve on-schedule performance. Automated vehicle location enhances the information available to the transit operator enabling more efficient operations. Onboard sensors support transit vehicle maintenance. The Physical Object supports onboard security and safety monitoring. This monitoring includes transit user or vehicle operator activated alarms (silent or audible). The Transit Vehicle OBE supports the general vehicle safety and driver information capabilities that apply to all vehicles (light-duty, heavy-duty, emergency, etc.), and supplements these general capabilities with capabilities that are specific to transit vehicles. In addition, the Vehicle OBE contains Wi-Fi, and connects to the transit vehicle's data collection system. When the transit vehicle arrives at the garage, the Vehicle OBE will off-load the collected data to the TrCVMS over Wi-Fi.

Name	Class	Description
TrV System	Vehicle	The TrV System represents the interface to the transit vehicle databus (e.g., hardwire connection to cable harness, CAN, LIN, Ethernet/IP, FlexRay, and MOST) that may enable communication between the Vehicle OBE and other vehicle systems to support connected vehicle applications.

Source: City of Columbus

Table 21: Connected Vehicle Environment Traffic Signal Priority and Preemption Information Flows

Name	Description
host emergency vehicle status	Information provided to the ITS OBE from other systems on the Emergency Vehicle Platform.
host vehicle status [optional]	Information provided to the ITS OBE from other systems on the vehicle platform. This includes the current status of the powertrain, steering, and braking systems, and status of other safety and convenience systems. In implementations where GPS is not integrated into the Vehicle OBE, the host vehicle is also the source for data describing the vehicle's location in three dimensions (latitude, longitude, elevation) and accurate time that can be used for time synchronization across the ITS environment.
intersection control status	Status data provided by the traffic signal controller including phase information, alarm status, and priority/preempt status. For this project, priority/preempt status will not be sent to the RSE with the signal phasing and timing.
intersection geometry	The physical geometry of an intersection covers the location and width of each approaching lane, egress lane, and valid paths between approaches and egresses. This flow also defines the location of stop lines, cross walks, specific traffic law restrictions for the intersection (e.g., turning movement restrictions), and other elements that support calculation of a safe and legal vehicle path through the intersection.
intersection management application info	Intersection and device configuration data, including intersection geometry, and warning parameters and thresholds. This flow also supports remote control of the application, so the application can be taken offline, reset, or restarted.
intersection management application status	Infrastructure application status reported by the RSE. This includes current operational state and status of the RSE and a log of operations.
intersection status	Current signal phase and timing information for all lanes at a signalized intersection. This flow identifies active lanes and lanes that are being stopped, and specifies the length of time that the current state will persist for each lane. It also identifies signal priority and preemption status and pedestrian crossing status information where applicable.
local signal preemption request	Direct control signal or message to a signalized intersection that results in preemption of the current control plan, and grants right-of-way to the requesting vehicle.

Name	Description
local signal priority request	Request from a vehicle to a signalized intersection for priority at that intersection. This flow also allows the vehicle to cancel a priority request (for example, when the vehicle clears the intersection).
location correction	Information provided to improve positional accuracy. These corrections allow a mobile GPS receiver, such as a GPS system in a CV, to achieve a greater absolute positional accuracy, compensating for errors that exist in satellite positioning.
right-of-way request notification	Notice that a request has occurred for signal prioritization, signal preemption, pedestrian call, multi-modal crossing activation, or other source for right-of-way.
RTMC Reference Station Information Message	ODOT CORS provides RTMC data for GPS reference station coordinates, delta and differential corrections, and other information messages.
signal control commands	Control of traffic signal controllers or field masters, including clock synchronization.
signal control status	Operational and status data of traffic signal control equipment, including operating condition and current indications.
Signal Priority Request	A request for the signal priority/preemption status.
Signal Priority Response	The signal priority/preemption status.
signal priority service request	A service request for vehicle priority issued to a traffic signal controller resulting in green extension or other accommodation for the priority vehicle, within the current signal timing plan. The request includes the priority level, the desired time and duration of service, and the intended travel path through the intersection. This flow also allows the RSE to cancel a previously issued request for priority.
signal priority status	In response to a request for signal priority, this flow indicates the status of the priority or preemption request.
time	Current time expressed in Universal Time Coordinated format from the time server.

Source: City of Columbus

Table 22: Connected Vehicle Environment Traffic Signal Priority and Preemption Functional Objects

Physical Object	Functional Object	Description
Connected Vehicle Environment Project Functions		
Emergency Vehicle OBE	EV On-Board En Route Support	EV On-Board En Route Support provides communications functions to responding emergency vehicles that reduce response times, and improve safety of responding public safety personnel and the general public. It supports traffic signal preemption via short range communication directly with signal control equipment, and sends alert messages to surrounding vehicles.

Physical Object	Functional Object	Description
	Vehicle Location Determination	Vehicle Location Determination receives the current location of the vehicle, and provides this information to vehicle applications that use the location information to provide ITS services.
Heavy Duty Vehicle OBE	CV On-Board Signal Priority	CV On-Board Signal Priority provides the capability for commercial vehicles to determine eligibility for priority, and to request signal priority at signalized intersections, ramps, and interchanges through short range communication with traffic control equipment at the roadside.
	Vehicle Location Determination	Vehicle Location Determination receives the current location of the vehicle, and provides this information to vehicle applications that use the location information to provide ITS services.
RSE	RSE Intersection Management	RSE Intersection Management uses short range communications to support connected vehicle applications that manage signalized intersections. It communicates with approaching vehicles and ITS infrastructure (e.g., the traffic signal controller) to enhance traffic signal operations. Coordination with the ITS infrastructure also supports conflict monitoring to ensure the RSE output and traffic signal control output are consistent and degrade in a fail safe manner.
	RSE Position Correction Support	RSE Position Correction Support broadcasts differential positioning data to enable precise locations to be determined by passing vehicles, supporting CV applications that require highly accurate positioning. The differential positioning data may be calculated directly by a precisely located RSE that is operating as a reference station, or received from an external reference station and relayed to passing vehicles.
	RSE Support Services	RSE Support Services provide foundational functions that support data collection, management, location reference, timing, and data distribution. It coordinates with support subsystems to maintain necessary registrations with respect to location and scope. It maintains precise location and time information to support other services.
Traffic CV Management System	Signal Priority Authorization	TCMVS Staff will have the ability to authorize intersections to support the signal priority application.
Traffic Management Center	TMC Signal Control	TMC Signal Control provides the capability for traffic managers to monitor and manage the traffic flow at signalized intersections. This capability includes analyzing and reducing the collected data from traffic surveillance equipment, and developing and implementing control plans for signalized intersections. Control plans may be developed and implemented that coordinate signals at many intersections under the domain of a single Traffic Management Center, and are responsive to traffic conditions adapting to support incidents, preemption and priority requests, pedestrian crossing calls, etc.

Physical Object	Functional Object	Description
Traffic Signal Controller	Roadway Signal Control	Roadway Signal Control includes the field elements that monitor and control signalized intersections. It includes the traffic signal controllers, detectors, conflict monitors, signal heads, and other ancillary equipment that supports traffic signal control. It also includes field masters and equipment that supports communications with a central monitoring and/or control system, as applicable. The communications link supports upload and download of signal timings and other parameters and reporting of current intersection status. It represents the field equipment used in all levels of traffic signal control from basic actuated systems that operate on fixed-timing plans through adaptive systems. It also supports all signalized intersection configurations, including those that accommodate pedestrians. In advanced, future implementations, environmental data may be monitored and used to support dilemma zone processing and other aspects of signal control that are sensitive to local environmental conditions.
Transit Vehicle OBE	Transit Vehicle Signal Priority	Transit Vehicle Signal Priority provides the capability for transit vehicles to determine eligibility for priority, and request signal priority at signalized intersections, ramps, and interchanges through short range communication with traffic control equipment at the roadside.
	Vehicle Location Determination	Vehicle Location Determination receives the current location of the vehicle, and provides this information to vehicle applications that use the location information to provide ITS services.

Source: City of Columbus

2.3.5.2. VEHICLE DATA FOR TRAFFIC OPERATIONS

The Vehicle Data for Traffic Operations application captures telemetry (location, speed, trajectory) data obtained from vehicles and traffic signal data (such as signal state and signal priority requests) from connected RSE, and sends it to the TCVMS for subsequent archiving in the Smart Columbus Operating System. The TCVMS is responsible for capturing data so that it can be made available to the Smart Columbus Operating System. This processing and filtering transform raw messages received by the TCVMS into useful operational information to be used for traffic management purposes so that operational data may be archived on the Smart Columbus Operating System. The Smart Columbus Operating System makes this data available to CVE stakeholders to support traffic operations, including incident detection and the implementation of localized operational strategies. As a result of the Vehicle Data for Traffic Operations, it is expected the TCVMS will leverage the curated data to produce fundamental measures of operations such as roadway speed, queue/incident detection, travel time/intersection delay, and/or CV volume. **Figure 17** illustrates the Layer 2 architecture for the Vehicle Data for Traffic Operations application.

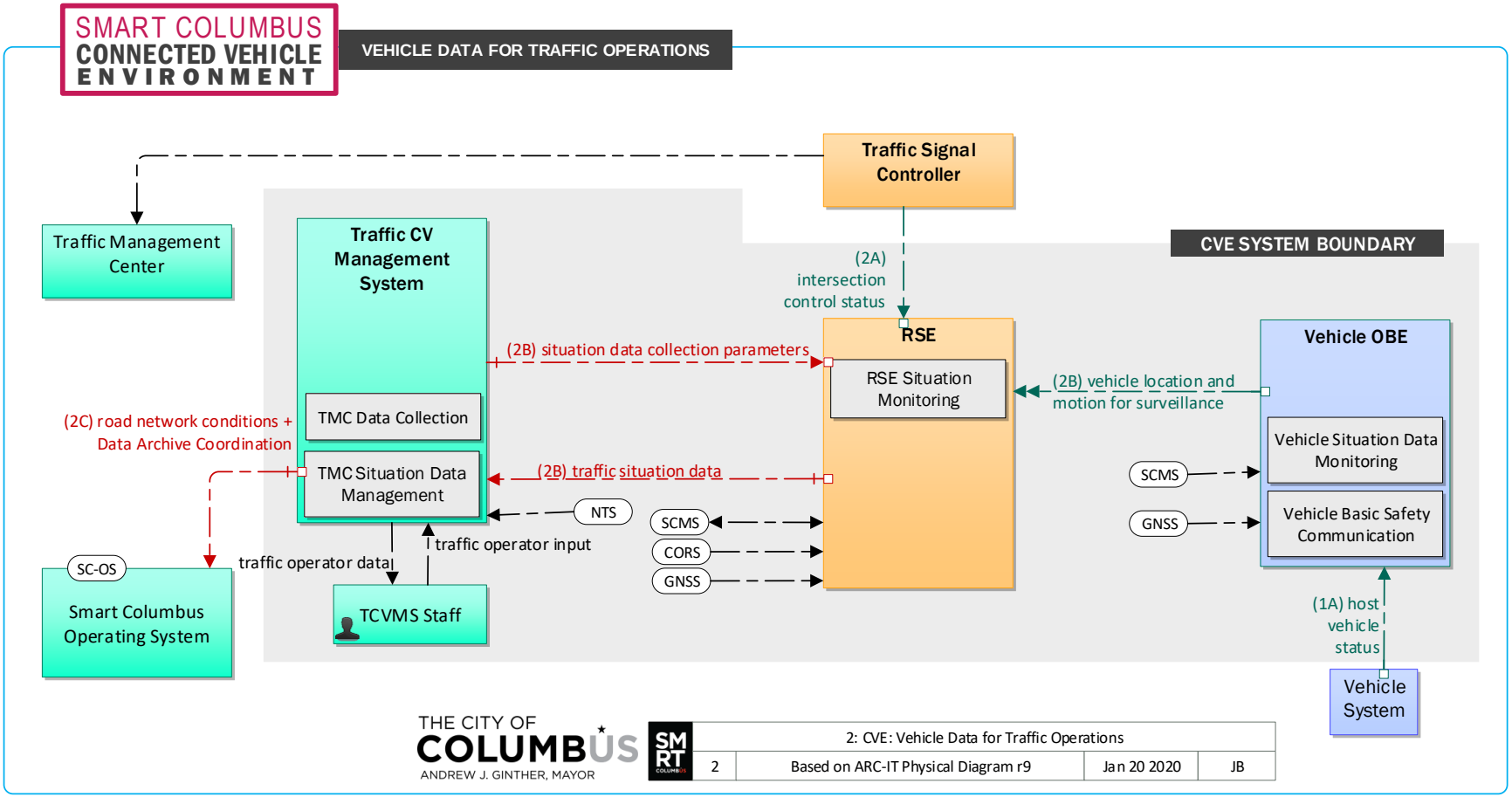


Figure 17: Connected Vehicle Environment Vehicle Data for Traffic Operations (Layer 2)

Source: City of Columbus

The following tables describe the Physical Elements, Information Flows, and Functional Objects seen on the diagram above, associated with the Vehicle Data for Traffic Operations application.

Table 23: Connected Vehicle Environment Vehicle Data for Traffic Operations Elements

Name	Class	Description
RSE	Field	The RSE represents the CV roadside devices that are used to send messages to, and receive messages from, nearby vehicles using DSRC or other alternative wireless communications technologies. Communications with adjacent ITS field equipment and the back office TCVMS that monitors and controls the RSE are also supported. The RSU portion operates from a fixed position on vertical strain poles, mast arms, or spanwire on which signal heads are installed for permanent deployment. The RSE includes a processor, data storage, and communications capabilities that support secure communications with passing vehicles, other field equipment, and centers.
Smart Columbus Operating System	Center	The Smart Columbus Operating System covers the ingestion and organization of information stored in the Smart Columbus Operating System. The ingestion process is initiated by the Data Curator using a web interface to define and manage the data feeds.
TCVMS Staff	Center	The TCVMS Staff represents the operational personnel responsible for traffic management, maintenance operations, and administrative activities of the TCVMS. These different roles represent a variety of individuals in the transportation industry.
Traffic CV Management System	Center	The Traffic CV Management System monitors and controls the CVE and road network. It communicates with ITS Roadway Equipment and CV RSE to monitor and manage traffic flow, and monitor the condition of the roadway, surrounding environmental conditions, and field equipment status.
Traffic Management Center	Center	The Traffic Management Center monitors and controls traffic and the road network. It represents centers that manage a broad range of transportation facilities including freeway systems, rural and suburban highway systems, and urban and suburban traffic control systems. It communicates with ITS RSE to monitor and manage traffic flow and monitor the condition of the roadway, surrounding environmental conditions, and field equipment status. It manages traffic and transportation resources to support allied agencies in responding to, and recovering from, incidents ranging from minor traffic incidents through major disasters.
Traffic Signal Controller	Field	City of Columbus signaling device positioned at a road intersection, pedestrian crossing, or other location that indicates which driver, rider, or walker is assigned the right-of-way at a given moment, using a universal color code (and a precise sequence for those that are color-blind). The City of Columbus owns and operates many local traffic signals.

Name	Class	Description
Vehicle OBE	Vehicle	The Vehicle OBE provides the vehicle-based sensory, processing, storage, and communications functions that support efficient, safe, and convenient travel. The Vehicle OBE includes general capabilities that apply to passenger cars, trucks, and motorcycles. Many of these capabilities apply to all vehicle types including LDVs, HDVs, emergency vehicles, and transit vehicles. From this perspective, the Vehicle OBE includes the common interfaces and functions that apply to all motorized vehicles. The radio(s) supporting V2V and V2I communications are a key component of the Vehicle OBE. Both one-way and two-way communications options support a spectrum of information services from basic broadcast to advanced personalized information services. This Physical Object supports all six levels of driving automation as defined in SAE J3016.
Vehicle System	Vehicle	The Vehicle System represents the interface to the vehicle system (e.g., hardwire connection to cable harness, CAN, LIN, Ethernet/IP, FlexRay, and MOST) that may enable communication between the Vehicle OBE and other vehicle systems to support CV applications. The vehicle system statuses and/or sensor outputs available on the databus will vary based on the equipment installed on the vehicle and availability on databus. System statuses and sensor outputs may include select vehicle systems and sensors such as GPS derived location and timing information. In CVRIA, this Physical Object is used to represent the onboard interactions between the Vehicle OBE and the other systems included in a host vehicle. Note that the vehicle databus interface is optional and is not standardized across all vehicle classes. Also, some Vehicle OBE implementations may not have access to the vehicle databus.

Source: City of Columbus

Table 24: Connected Vehicle Environment Vehicle Data for Traffic Operations Information Flows

Name	Description
Data Archive Coordination	The data archive coordination represents the various strategies established between City of Columbus TCVMS and the Smart Columbus Operating System to collect, curate data, and measure the performance of V2V safety, V2I safety, and mobility applications reported by the RSE. This may include traffic operational data, a record of intersection safety issues identified, alerts, and warnings issued. This TCVMS process will help produce fundamental measures of operations such as roadway speed, queue/incident detection, travel time/intersection delay, and/or CV volume. This process includes receiving and archiving status information, event messages, and raw or filtered traffic situation data (safety and priority request messages) from equipment on the roadside based on appropriate data assets, processing and filtering.
host vehicle status [optional]	Information provided to the ITS OBE from other systems on the vehicle platform. This includes the current status of the powertrain, steering, and braking systems, and status of other safety and convenience systems. In implementations where GPS is not integrated into the Vehicle OBE, the host vehicle is also the source for data describing the vehicle's location in three dimensions (latitude, longitude, elevation) and accurate time that can be used for time synchronization across the ITS environment.

Name	Description
intersection control status	Status data provided by the traffic signal controller including phase information, alarm status, and priority/preempt status. For this project, priority/preempt status will not be sent to the RSE.
road network conditions	Current and forecasted traffic information, road and weather conditions, and other road network status. Either raw data, processed data, or some combination of both may be provided by this flow. Information on diversions and alternate routes, closures, and special traffic restrictions (lane/shoulder use, weight restrictions, width restrictions, high occupancy vehicle (HOV) requirements) in effect is included. For this project, HOV requirements are not applicable.
situation data collection parameters	The situation data collection parameters are used to control the flow of situation data from the RSE. This flow identifies the type of data/snapshots that are requested from passing vehicles and reporting parameters, such as snapshot frequency, filtering criteria (data thresholds for reporting), and reporting interval that control the type and volume of data reported to the back office center.
traffic operator data	Presentation of traffic operations data to the operator including traffic conditions, current operating status of field equipment, maintenance activity status, incident status, video images, security alerts, emergency response plan updates and other information. This data keeps the operator apprised of current road network status, provides feedback to the operator as traffic control actions are implemented, provides transportation security inputs, supports review of historical data, and preparation for future traffic operations activities.
traffic operator input	User input from traffic operations personnel, including requests for information, configuration changes, commands to adjust current traffic control strategies (e.g., adjust signal timing plans, change DMS messages), and other traffic operations data entry.
traffic situation data	Current, aggregate traffic data collected from CVs that can be used to supplement or replace information collected by roadside traffic detectors. It includes raw and/or processed reported vehicle speeds, counts, and other derived measures. Raw and/or filtered vehicle control events may also be included to support incident detection. For this project, data will not be aggregated by the RSE. All of the raw data will be passed to the TCVMS.
vehicle location and motion for surveillance	Data describing the vehicle's position, heading, speed, acceleration, transmission, steering wheel angle, braking status, size information, and trajectory. This flow represents monitoring of basic safety data (vehicle location and motion) broadcast by passing connected vehicles for use in vehicle detection and traffic monitoring applications.

Source: City of Columbus

Table 25: Connected Vehicle Environment Vehicle Data for Traffic Operations Functional Objects

Physical Object	Functional Object	Description
Connected Vehicle Environment Project Functions		
RSE	RSE Situation Monitoring	RSE Situation Monitoring is a general Functional Object that supports collection of traffic data from passing vehicles. The data are collected and forwarded to the back office. In addition, this object collects current status information from local field devices, including intersection status, sensor data, and signage data—providing complete, configurable monitoring of the situation for the local transportation system in the vicinity of the RSE.
Traffic CV Management System	TMC Data Collection	TMC Data Collection collects and stores information that is created in the course of traffic operations performed by the Traffic Management Center. This data can be used directly by operations personnel, or it can be made available to other data users and archives in the region.
	TMC Situation Data Management	TMC Situation Data Management collects, assimilates, and disseminates vehicle probe data collected from roadside short range communications equipment and centers controlling transit vehicles, toll collection points, and route-guided vehicles. It estimates traffic and road conditions based on the aggregated probe data, and disseminates this information to other centers.
Vehicle OBE	Vehicle Basic Safety Communication	Vehicle Basic Safety Communication exchanges current vehicle location and motion information with other vehicles in the vicinity, uses that information to calculate vehicle paths, and warns the driver when the potential for an impending collision is detected. If available, map data are used to filter and interpret the relative location and motion of vehicles in the vicinity. If available, information from onboard sensors (e.g., radars and image processing) are also used in combination with the V2V communications to detect non-equipped vehicles and corroborate CV data. Vehicle location and motion broadcasts are also received by the infrastructure, and used by the infrastructure to support a wide range of roadside safety and mobility applications for current and future implementations.
	Vehicle Situation Data Monitoring	Vehicle Situation Data Monitoring is the highest-level representation of the functionality required to collect traffic and environmental situation data by monitoring and storing the experience of the vehicle as it travels through the road network. For transit OBEs, collected data are aggregated into snapshots that are reported when communications are available and with flow control based on parameters provided by the infrastructure. Note that this Functional Object supports collection of data for areas remote from RSEs or other communications infrastructure for future enhancements. For this project, environmental situation data is not applicable.

Source: City of Columbus

2.3.5.3. TRANSIT VEHICLE INTERACTION EVENT RECORDING

The Transit Vehicle Interaction Event Recording app enables COTA Management Staff to capture output (not issued to the Transit Vehicle Operator) from applications to assess the potential interactions and benefits that transit vehicle operators may receive if COTA decides to implement a user interface on its transit vehicles. The application on the transit vehicle passively captures its own telematics data, Basic Safety Messages from other vehicles and Signal Phase and Timing, MAP, and TIM messages from the RSE in communications range.

The transit vehicle OBE will log these messages for a period of time before and after a warning or alert is issued from CV applications. The period of time over which this data are recorded is expected to be configurable for each alert or warning. These periods will consist of a several seconds (e.g., 10-20) prior to and a few seconds (e.g., 30-40) after the activation of the alert or warning. **Figure 18** shows the architecture for the Transit Vehicle Interaction Event Recording app.

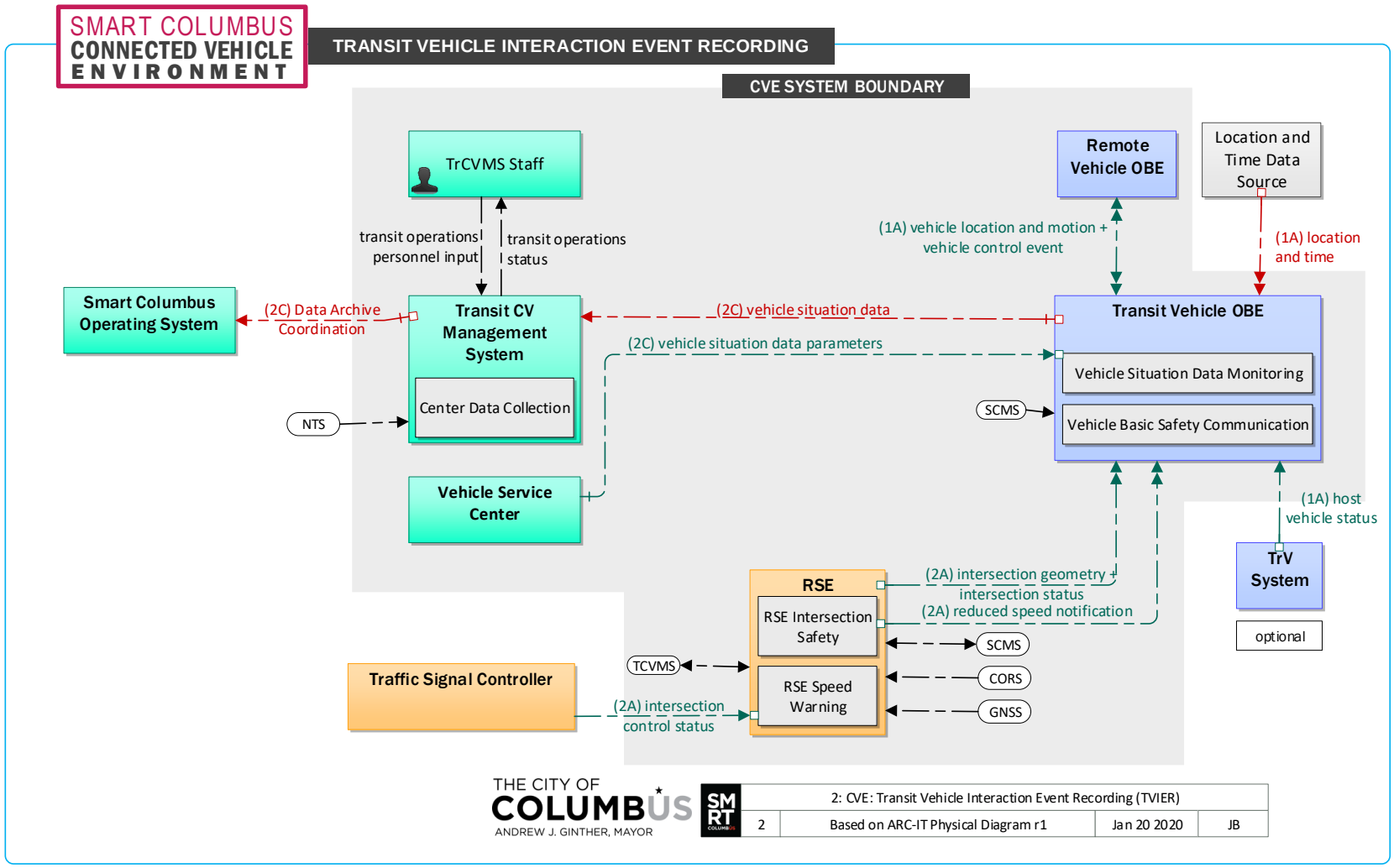


Figure 18: Connected Vehicle Environment Transit Vehicle Interaction Event Recording (Layer 2)

Source: City of Columbus

The following tables describe the Physical Elements, Information Flows and Functional Objects seen on the diagram above, associated with the Transit Vehicle Interaction Event Recording application.

Table 26: Connected Vehicle Environment Transit Vehicle Interaction Event Recording Elements

Name	Class	Description
Location and Time Data Source	Vehicle	The Location and Time Data Source is a GNSS that provides accurate position information for vehicle-based mobile devices. GNSS data are used to provide position, speed, and heading for vehicles. While a GPS Receiver is the most common implementation, this Physical Object represents the technology that provides a position fix in three dimensions and time with sufficient accuracy.
Remote Vehicle OBE	Vehicle	The Remote Vehicle OBE represents other CVs that are communicating with the host vehicle. This includes all connected motorized vehicles that support V2V communications. The remote vehicle broadcasts data that is received by the host vehicle. For instance, in an emergency braking situation, the leading vehicle is the remote vehicle, and makes its emergency braking status known to other vehicles. A following vehicle, a host vehicle, would receive the status from the remote vehicle to display a warning to the host-vehicle operator. In CVRIA, this object provides a source and destination for information transfers between connected vehicles. The host vehicle OBE, represented by the Vehicle OBE Physical Object, sends information to, and receives information from Remote Vehicle OBE to model all connected vehicle V2V communications in CVRIA.
RSE	Field	The RSE represents the CV roadside devices that are used to send messages to, and receive messages from, nearby vehicles using DSRC or other alternative wireless communications technologies. Communications with adjacent ITS field equipment and the back office TCVMS that monitors and controls the RSE are also supported. The RSU portion operates from a fixed position on vertical strain poles, mast arms, or spanwire on which signal heads are installed for permanent deployment. The RSE includes a processor, data storage, and communications capabilities that support secure communications with passing vehicles, other field equipment, and centers. For this process, RSEs are only transmitting messages.
Smart Columbus Operating System	Center	The Smart Columbus Operating System covers the ingestion and organization of information stored in the Smart Columbus Operating System. The ingestion process is initiated by the Data Curator using a web interface to define and manage the data feeds.
Traffic Signal Controller	Field	City of Columbus signaling device positioned at a road intersection, pedestrian crossing, or other location that indicates which driver, rider, or walker is assigned the right-of-way at a given moment, using a universal color code (and a precise sequence for those that are color-blind). The City of Columbus owns and operates many local traffic signals.

Name	Class	Description
Transit CV Management System	Center	The Transit CV Management System represents COTA's CV back office. This center receives application output data and Basic Safety Messages captured by transit vehicle OBEs and CEAV OBEs. The TrCVMS is responsible for generating vehicle interaction data that could result in issuing notifications or warnings to transit vehicle operators. Finally, the vehicle interaction data are archived in the Smart Columbus Operating System.
Transit Vehicle OBE	Vehicle	The Transit Vehicle OBE represents COTA's fixed-route transit bus, paratransit, and CEAVs. It provides the sensory, processing, storage, and communications functions necessary to support safe and efficient movement of passengers. It also collects ridership levels, and could support electronic fare collection in future programs. In the context of CVE, it supports a traffic signal prioritization function that communicates with the roadside Physical Object to improve on-schedule performance. Automated vehicle location enhances the information available to the transit operator enabling more efficient operations. Onboard sensors support transit vehicle maintenance. The Physical Object supports onboard security and safety monitoring. This monitoring includes transit user or vehicle operator activated alarms (silent or audible). The Transit Vehicle OBE supports the general vehicle safety and driver information capabilities that apply to all vehicles (light-duty, heavy-duty, emergency, etc.), and supplements these general capabilities with capabilities that are specific to transit vehicles. In addition, the Vehicle OBE contains Wi-Fi, and connects to the transit vehicle's data collection system. When the transit vehicle arrives at the garage, the Vehicle OBE will off-load the collected data to the TrCVMS over Wi-Fi.
TrCVMS Staff	Center	TrCVMS staff represents the operational personnel responsible for fleet management, maintenance operations, and scheduling activities of the transit system. These different roles represent a variety of individuals in the transit industry. This staff actively monitors, controls, and modifies the transit fleet routes and schedules on a day-to-day basis (dynamic scheduling). The modifications will take account of abnormal situations such as vehicle breakdown, vehicle delay, detours around work zones or incidents (detour management, connection protection, and service restoration), and other causes of route or schedule deviations. Transit operations personnel are also responsible for demand responsive transit operation and for managing emergency situations within the transit network such as silent alarms on board transit vehicles, or the remote disabling of the vehicle. In addition, the TrCVMS staff may be responsible for assigning vehicle operators to routes, checking vehicle operators in and out, and managing transit stop issues. This object also represents the personnel in the transit garage that are responsible for maintenance of the transit fleets, including monitoring vehicle status, matching vehicles with operators, and maintenance checking of transit vehicles. Finally, it represents the people responsible for the planning, development, and management of transit routes and schedules.
TrV System	Vehicle	The TrV System represents the interface to the transit vehicle databus (e.g., hardwire connection to cable harness, CAN, LIN, Ethernet/IP, FlexRay, and MOST) that may enable communication between the Vehicle OBE and other vehicle systems to support connected vehicle applications.

Name	Class	Description
Vehicle Service Center	Vehicle	Vehicle Service Center represents centers that collect vehicle diagnostic information from vehicles, and provide service options for drivers of these vehicles. The Physical Object also includes centers operated by vehicle manufacturers that can coordinate with CVs to obtain vehicle operating data, and provide software or data updates to CVs that they have manufactured.

Source: City of Columbus

Table 27: Connected Vehicle Environment Transit Vehicle Interaction Event Recording Information Flows

Name	Description
Data Archive Coordination	The data archive coordination represents the various strategies established between City of Columbus TCVMS and the Smart Columbus Operating System to collect, curate data, and measure the performance of V2V safety, V2I safety, and mobility applications reported by the RSE. This may include traffic operational data, a record of intersection safety issues identified, alerts, and warnings issued. This TCVMS process will help produce fundamental measures of operations such as, but not limited to roadway speed, queue/incident detection, travel time/intersection delay, and/or CV volume and includes receiving and archiving status information, event messages, and raw or filtered traffic situation data (safety and priority request messages) from equipment on the roadside based on appropriate data assets, processing and filtering.
host vehicle status [optional]	Information provided to the ITS OBE from other systems on the vehicle platform. This includes the current status of the powertrain, steering, and braking systems, and status of other safety and convenience systems. In implementations where GPS is not integrated into the Vehicle OBE, the host vehicle is also the source for data describing the vehicle's location in three dimensions (latitude, longitude, elevation) and accurate time that can be used for time synchronization across the ITS environment.
intersection control status	Status data provided by the traffic signal controller including phase information, alarm status, and priority/preempt status. For this project, priority/preempt status will not be sent to the RSE.
intersection geometry	The physical geometry of an intersection covering the location and width of each approaching lane, egress lane, and valid paths between approaches and egresses. This flow also defines the location of stop lines, crosswalks, specific traffic law restrictions for the intersection (e.g., turning movement restrictions), and other elements that support calculation of a safe and legal vehicle path through the intersection.
intersection status	Current Signal Phase and Timing information for all lanes at a signalized intersection. This flow identifies active lanes and lanes that are being stopped, and specifies the length of time that the current state will persist for each lane. It also identifies signal priority/preemption status and pedestrian crossing status information where applicable.
location and time	The current geographic location in three dimensions (latitude, longitude, elevation) and the current time.

Name	Description
reduced speed notification	Reduced speed zone information provided to passing vehicles. This flow provides the reduced speed limit, the location and extent of the reduced speed zone, and associated warning information.
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.
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.
vehicle control event	Notification that the vehicle has performed an emergency action that could impact the safety of surrounding vehicles. This includes hard braking and activation of traction/stability control systems or other actions that warrant immediate notification of surrounding vehicles. The Information Flow conveys the vehicle's position, heading, speed, acceleration, transmission, steering wheel angle, braking status, size information, and trajectory.
vehicle location and motion	Data describing the vehicle's position, heading, speed, acceleration, transmission, steering wheel angle, braking status, size information, and trajectory.
vehicle situation data	This flow represents vehicle snapshots that may be provided by the vehicle to support traffic and environmental conditions monitoring. Snapshots are collected by the vehicle for specific events (e.g., when a sensor exceeds a threshold) or periodically, and reported based on control parameters when communications are available. Traffic-related data includes snapshots of measured speed, heading, and events—including starts and stops, speed changes, and other vehicle control events. Environmental data may include measured air temperature, exterior light status, wiper status, sun sensor status, rain sensor status, traction control status, anti-lock brake status, and other collected vehicle system status and sensor information. The collected data are reported along with the location, heading, and time that the data was collected. For this project, environmental data will not be collected.
vehicle situation data parameters	A request for vehicle situation data that includes parameters used to control the data that is reported and the flow of data reported by the vehicle. This flow identifies the type of data/snapshots that are requested and reporting parameters such as snapshot frequency, filtering criteria (data thresholds for reporting), and reporting interval.

Source: City of Columbus

Table 28: Connected Vehicle Environment Transit Vehicle Interaction Event Recording Functional Objects

Physical Object	Functional Object	Description
Connected Vehicle Environment Project Functions		
RSE	RSE Intersection Safety	RSE Intersection Safety uses short range communications to support CV applications that improve intersection safety. It communicates with approaching vehicles and ITS infrastructure to alert and warn drivers of potential stop sign, red light, and non-motorized user crossing conflicts or violations.
	RSE Speed Warning	RSE Speed Warning notifies CVs that are approaching a reduced speed zone, providing: (1) the zone's current posted speed limit; (2) any roadway configuration changes associated with the reduced speed zone (e.g., lane closures, lane shifts) if applicable; and (3) associated warning information (i.e., the reason for the reduced speed warning). Configuration parameters that define the applicable speed limit(s), geographic location and extent of the reduced speed zone, and roadway configuration information are received from a center or provided through a local interface. The characteristics of individual vehicles may also be monitored and used to warn vehicles with specific limitations that reduce safe operating speeds, (e.g., rollover risk for tall vehicles). This Functional Object works in conjunction with the Roadway Speed Monitoring and Warning Functional Object, which uses traditional ITS field equipment to warn non-equipped vehicles.
Transit CV Management System	Center Data Collection	The 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.
Vehicle OBE	Vehicle Basic Safety Communication	Vehicle Basic Safety Communication exchanges current vehicle location and motion information with other vehicles in the vicinity, uses that information to calculate vehicle paths, and warns the driver when the potential for an impending collision is detected. If available, map data are used to filter and interpret the relative location and motion of vehicles in the vicinity. If available, information from onboard sensors (e.g., radars and image processing) are also used in combination with the V2V communications to detect non-equipped vehicles and corroborate CV data. Vehicle location and motion broadcasts are also received by the infrastructure, and used by the infrastructure to support a wide range of roadside safety and mobility applications for current and future implementations.

Physical Object	Functional Object	Description
	Vehicle Situation Data Monitoring	Vehicle Situation Data Monitoring is the highest-level representation of the functionality required to collect traffic and environmental situation data by monitoring and storing the experience of the vehicle as it travels through the road network. For transit OBEs, collected data are aggregated into snapshots that are reported when communication is available and with flow control based on parameters provided by the infrastructure. Note that this Functional Object supports collection of data for areas remote from RSEs or other communications infrastructure for future enhancements. For this project, environmental situation data is not applicable.

Source: City of Columbus

2.3.6. Vehicle-to-Infrastructure Safety

2.3.6.1. RED LIGHT VIOLATION WARNING

The Red Light Violation Warning is designed to improve roadway safety by reducing red-light running and collisions at signalized intersections. The application enables a CV approaching a signalized intersection to receive information about the signal timing and geometry of the intersection. The application in the vehicle uses its speed and acceleration profile, along with the signal timing and geometry information, to determine if that vehicle will enter the intersection in violation of a traffic signal. If the violation seems likely to occur, a warning can be provided to the vehicle operator. This application provides an output to drivers to improve awareness when approaching a signal that will turn red before arriving at the intersection in an attempt to reduce crashes between multiple vehicles at intersections. **Figure 19** illustrates the Layer 2 architecture for the Red Light Violation Warning application.

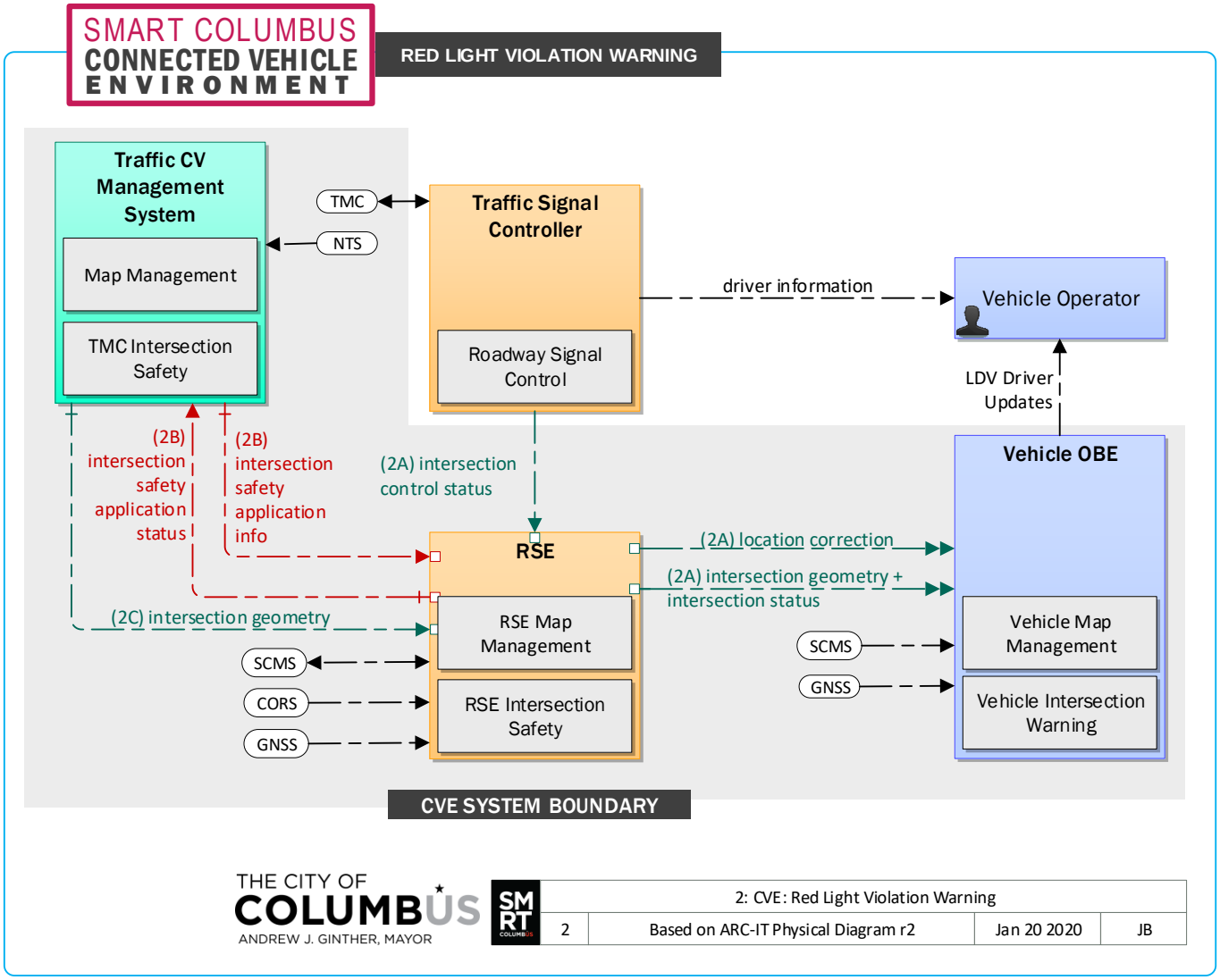


Figure 19: Connected Vehicle Environment Red Light Violation Warning (Layer 2)

Source: City of Columbus

The following tables describe the Physical Elements, Information Flows, and Functional Objects seen on the diagram above, associated with the Red Light Violation Warning application.

Table 29: Connected Vehicle Environment Red Light Violation Warning Elements

Name	Class	Description
RSE	Field	The RSE represents the CV roadside devices that are used to send messages to, and receive messages from, nearby vehicles using DSRC or other alternative wireless communications technologies. Communications with adjacent ITS field equipment and the back office TCVMS that monitors and controls the RSE are also supported. The RSU portion operates from a fixed position on vertical strain poles, mast arms, or spanwire on which signal heads are installed for permanent deployment. The RSE includes a processor, data storage, and communications capabilities that support secure communications with passing vehicles, other field equipment, and centers.
Traffic CV Management System	Center	The Traffic CV Management System monitors and controls the CVE and road network. It communicates with ITS Roadway Equipment and CV RSE to monitor and manage traffic flow, and monitor the condition of the roadway, surrounding environmental conditions, and field equipment status.
Traffic Signal Controller	Field	City of Columbus signaling device positioned at a road intersection, pedestrian crossing, or other location that indicates which driver, rider, or walker is assigned the right-of-way at a given moment, using a universal color code (and a precise sequence for those that are color-blind). The City of Columbus owns and operates many local traffic signals.
Vehicle OBE	Vehicle	The Vehicle OBE provides the vehicle-based sensory, processing, storage, and communications functions that support efficient, safe, and convenient travel. The Vehicle OBE includes general capabilities that apply to passenger cars, trucks, and motorcycles. Many of these capabilities apply to all vehicle types including LDVs, HDVs, emergency vehicles, and transit vehicles. From this perspective, the Vehicle OBE includes the common interfaces and functions that apply to all motorized vehicles. The radio(s) supporting V2V and V2I communications are a key component of the Vehicle OBE. Both one-way and two-way communications options support a spectrum of information services from basic broadcast to advanced personalized information services. This Physical Object supports all six levels of driving automation as defined in SAE J3016.
Vehicle Operator	Vehicle	The Vehicle Operator represents the person that operates a vehicle on the roadway. Included are operators of private, transit, commercial, and emergency vehicles where the interactions are not particular to the type of vehicle (e.g., interactions supporting vehicle safety applications) unless the Information Flow states otherwise. For instance, driver updates between the vehicle OBE and operator are valid for the LDV class and operators only. In the V2V safety Service Package above, the operator originates driver requests, and receives information that reflects the interactions which might be useful to all drivers—regardless of vehicle classification.

Source: City of Columbus

Table 30: Connected Vehicle Environment Red Light Violation Warning Information Flows

Name	Description
driver information	Regulatory, warning, and guidance information provided to the driver while en route to support safe and efficient vehicle operation.
intersection control status	Status data provided by the traffic signal controller including phase information, alarm status, and priority/preemption status. For this project, priority/preemption status will not be sent to the RSE.
intersection geometry	The physical geometry of an intersection covering the location and width of each approaching lane, egress lane, and valid paths between approaches and egresses. This flow also defines the location of stop lines, crosswalks, specific traffic law restrictions for the intersection (e.g., turning movement restrictions), and other elements that support calculation of a safe and legal vehicle path through the intersection.
intersection safety application info	Intersection and device configuration data, including intersection geometry, warning parameters, and thresholds. This flow also supports remote control of the application, so the application can be taken offline, reset, or restarted.
intersection safety application status	Infrastructure safety application status reported by the RSE. This includes current operational state and status of the RSE and a record of intersection safety issues identified, alerts, and warnings issued.
intersection status	Current Signal Phase and Timing information for all lanes at a signalized intersection. This flow identifies active lanes and lanes that are being stopped, and specifies the length of time that the current state will persist for each lane. It also identifies signal priority/preemption status and pedestrian crossing status information where applicable.
LDV Driver Updates	Information provided to the LDV driver including visual displays, audible information and warnings, and haptic feedback. The updates inform the driver about current conditions, potential hazards, and the current status of vehicle OBE.
location correction	Information provided to improve positional accuracy. These corrections allow a mobile GPS receiver, such as a GPS system in a CV, to achieve a greater absolute positional accuracy, compensating for errors that exist in satellite positioning.

Source: City of Columbus

Table 31: Connected Vehicle Environment Red Light Violation Warning Functional Objects

Physical Object	Functional Object	Description
Connected Vehicle Environment Project Functions		
RSE	RSE Intersection Safety	RSE Intersection Safety uses short range communications to support CV applications that improve intersection safety. It communicates with approaching vehicles and ITS infrastructure to alert and warn drivers of potential stop sign, red light, and non-motorized user crossing conflicts or violations.
	RSE Map Management	RSE Map Management provides the map functionality necessary to support map data information to passing vehicles. It collects current map and geometry data, and provides current map and geometry data to CVs.
Traffic CV Management System	Map Management	Map Management provides the GIS functionality necessary to support map data creation and management. It provides an operator interface supporting management of the map data and rendering the maps under operator control. It also interfaces to external data sources, including the CVE.
	TMC Intersection Safety	TMC Intersection Safety controls and monitors RSE that support stop sign, red light, and mixed-use crossing violations. It configures the RSE for the current intersection geometry and traffic signal control equipment at the intersection. Information that is currently being communicated to passing vehicles and the operational status of the field equipment is monitored by this application. The operational status of the field equipment is reported to operations personnel.
Traffic Signal Controller	Roadway Signal Control	Roadway Signal Control includes the field elements that monitor and control signalized intersections. It includes the traffic signal controllers, detectors, conflict monitors, signal heads, and other ancillary equipment that supports traffic signal control. It also includes field masters, and equipment that supports communications with a central monitoring and/or control system, as applicable. The communications link supports upload and download of signal timings and other parameters as well as reporting current intersection status. It represents the field equipment used in all levels of traffic signal control, from basic actuated systems that operate on fixed timing plans through adaptive systems. It also supports all signalized intersection configurations, including those that accommodate pedestrians. In advanced, future implementations, environmental data may be monitored and used to support dilemma zone processing and other aspects of signal control that are sensitive to local environmental conditions.

Physical Object	Functional Object	Description
Vehicle OBE	Vehicle Intersection Warning	Vehicle Intersection Warning uses V2V and V2I communications to monitor other CVs at intersections and support the safe movement of the vehicle through the intersection. Driver warnings are provided, and the application may also optionally take control of the vehicle to avoid collisions. The application will also notify the infrastructure and other vehicles if it detects an unsafe infringement on the intersection.
	Vehicle Map Management	Vehicle Map Management supports map updates, and makes current map and geometry data available to other applications. It manages map data on board and provides map data to end-user applications that provide location-based services.

Source: City of Columbus

2.3.6.2. REDUCED SPEED SCHOOL ZONE

The Reduced Speed School Zone[11] application delivers the posted speed limit (generally 20 mph) in school zones to CVs. The Reduced Speed School Zone application inside the CV uses the school zone location and speed limit, vehicle location, and the speed of the vehicle to evaluate and determine whether to alert or warn the vehicle operator. The application will provide an alert to passenger vehicle operators when braking is required to reduce speed to the posted speed limit. Transit and emergency vehicle operators will not get an alert. This output increases driver awareness to active school zones and the school zone speed limit in an attempt to reduce speed when in school zones.

Note that the placement of the RSE in the intersection may affect DSRC coverage. To address potential communication barriers between vehicle OBE and RSE, the RSE will be positioned close to the center of the intersection such that attenuation is minimized. This would allow an OBE to communicate with an RSE when approaching along the main corridor, as well as from cross-streets. **Figure 20** illustrates the Layer 2 Architecture for the Reduced Speed School Zone application.

[11] *CVRIA – Reduced Speed Zone Warning/Lane Closure.* http://local.iteris.com/cvria/html/applications/app60.html#tab-3

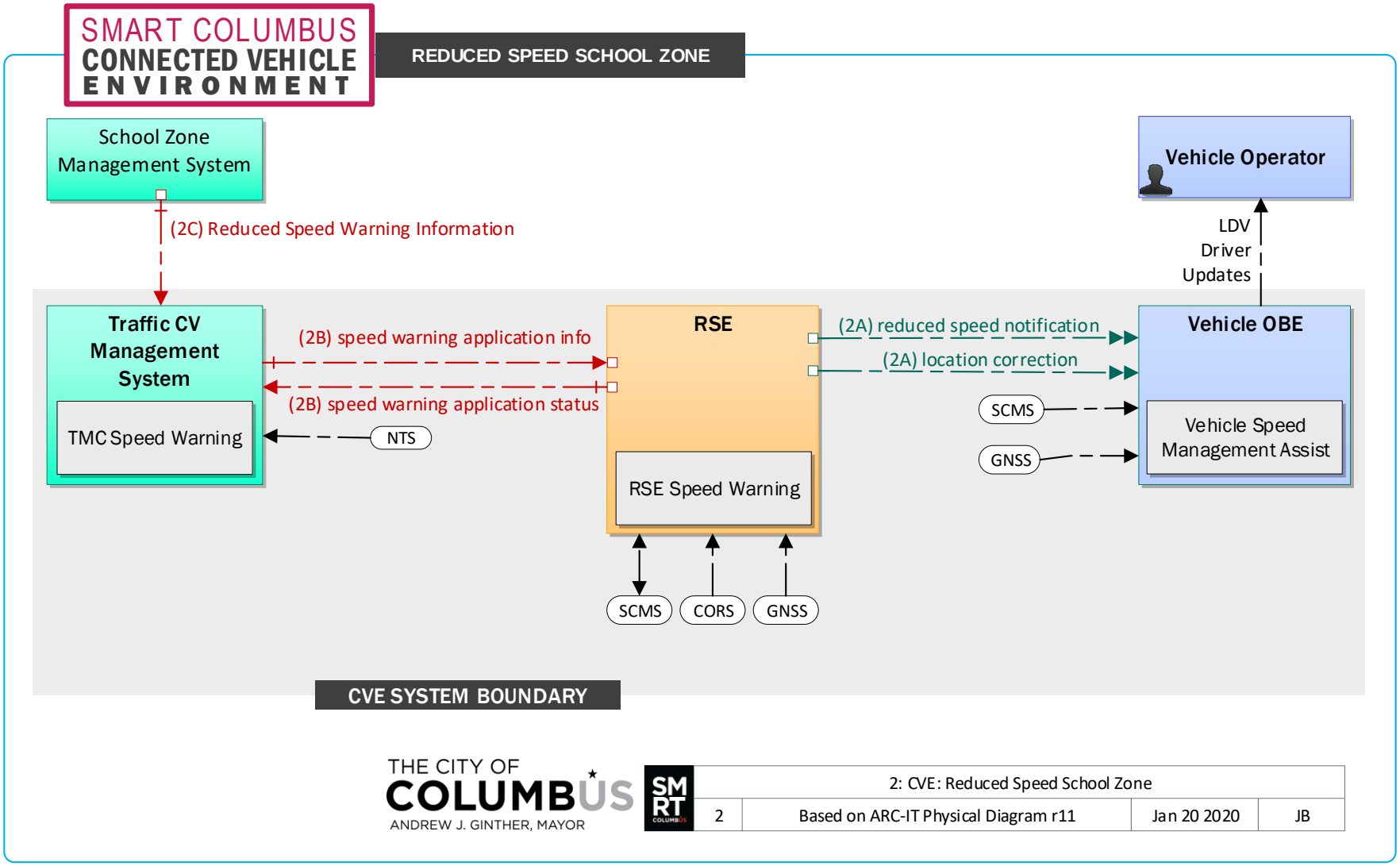


Figure 20: Connected Vehicle Environment Reduced Speed School Zone (Layer 2)

Source: City of Columbus

The following tables describe the Physical Elements, Information Flows, and Functional Objects seen on the diagram above, associated with the Reduced Speed School Zone application.

Table 32: Connected Vehicle Environment Reduced Speed School Zone Elements

Name	Class	Description
RSE	Field	The RSE represents the CV roadside devices that are used to send messages to, and receive messages from, nearby vehicles using DSRC or other alternative wireless communications technologies. Communications with adjacent ITS field equipment and the back office TCVMS that monitors and controls the RSE are also supported. The RSU portion operates from a fixed position on vertical strain poles, mast arms, or spanwire on which signal heads are installed for permanent deployment. The RSE includes a processor, data storage, and communications capabilities that support secure communications with passing vehicles, other field equipment, and centers.
School Zone Management System	Center	The School Zone Management System manages and controls school zone signals in the City of Columbus.
Traffic CV Management System	Center	The Traffic CV Management System monitors and controls the CVE and road network. It communicates with ITS Roadway Equipment and CV RSE to monitor and manage traffic flow, and monitor the condition of the roadway, surrounding environmental conditions, and field equipment status.
Vehicle OBE	Vehicle	The Vehicle OBE provides the vehicle-based sensory, processing, storage, and communications functions that support efficient, safe, and convenient travel. The Vehicle OBE includes general capabilities that apply to passenger cars, trucks, and motorcycles. Many of these capabilities apply to all vehicle types including LDVs, HDVs, emergency vehicles, and transit vehicles. From this perspective, the Vehicle OBE includes the common interfaces and functions that apply to all motorized vehicles. The radio(s) supporting V2V and V2I communications are a key component of the Vehicle OBE. Both one-way and two-way communications options support a spectrum of information services from basic broadcast to advanced personalized information services. This Physical Object supports all six levels of driving automation as defined in SAE J3016.
Vehicle Operator	Vehicle	The Vehicle Operator represents the person that operates a vehicle on the roadway. Included are operators of private, transit, commercial, and emergency vehicles where the interactions are not particular to the type of vehicle (e.g., interactions supporting vehicle safety applications) unless the Information Flow states otherwise. For instance, driver updates between the Vehicle OBE and operator are valid for the LDV class and operators only. In the V2V safety Service Package above, the operator originates driver requests and receives information that reflects the interactions which might be useful to all drivers, regardless of vehicle classification.

Source: City of Columbus

Table 33: Connected Vehicle Environment Reduced Speed School Zone Information Flows

Name	Description
LDV Driver Updates	Information provided to the LDV driver including visual displays, audible information and warnings, and haptic feedback. The updates inform the driver about current conditions, potential hazards, and the current status of vehicle OBE.
location correction	Information provided to improve positional accuracy. These corrections allow a mobile GPS receiver, such as a GPS system in a CV, to achieve a greater absolute positional accuracy, compensating for errors that exist in satellite positioning.
reduced speed notification	Reduced speed zone information provided to passing vehicles. This flow provides the reduced speed limit, the location and extent of the reduced speed zone, and associated warning information.
Reduced Speed Warning Information	Indications of the timing of when school zone warning lights will be active during the current day. This provides information to set up the timing for the messages published to vehicles.
speed warning application info	Roadway configuration data, current speed limits including time of day, week, or season speed limits as necessary, and warning parameters and thresholds. This flow also supports remote control of the application so the application can be taken offline, reset, or restarted.
speed warning application status	Speed warning application status reported by the RSE. This includes current operational state and status of the RSE and a record of measured vehicle speeds and notifications, alerts, and warnings issued.

Source: City of Columbus

Table 34: Connected Vehicle Environment Reduced Speed School Zone Functional Objects

Physical Object	Functional Object	Description
Connected Vehicle Environment Project Functions		
RSE	RSE Speed Warning	RSE Speed Warning notifies CVs that are approaching a reduced speed zone, providing: (1) the zone's current posted speed limit; (2) any roadway configuration changes associated with the reduced speed zone (e.g., lane closures, lane shifts) if applicable; and (3) associated warning information (i.e., the reason for the reduced speed warning). Configuration parameters that define the applicable speed limit(s), geographic location and extent of the reduced speed zone, and roadway configuration information are received from a center or provided through a local interface. The characteristics of individual vehicles may also be monitored and used to warn vehicles with specific limitations that reduce safe operating speeds (e.g., rollover risk for tall vehicles). This Functional Object works in conjunction with the Roadway Speed Monitoring and Warning Functional Object, which uses traditional ITS field equipment to warn non-equipped vehicles.

Physical Object	Functional Object	Description
Traffic CV Management System	TMC Speed Warning	TMC Speed Warning supports remote control and monitoring of reduced speed zone warning RSE. It provides the location and extent of the reduced speed zone, the posted speed limit(s) with information about the applicability of the speed limit(s) (e.g., time of day, day of week, seasonality, relevant vehicle types), and information about associated road configuration changes—including lane merges and shifts. It monitors field equipment operation, and reports current status to the operator.
Vehicle OBE	Vehicle Speed Management Assist	Vehicle Speed Management Assist assists the driver in operating the vehicle within the current speed limit. It monitors current vehicle speed, and communicates with the infrastructure to receive current speed limits and associated road configuration change notifications. Driver warnings are issued when unsafe or excessive speeds are detected based on the provided speed limits and current conditions.

Source: City of Columbus

2.3.7. Vehicle-to-Infrastructure Support

2.3.7.1. CONNECTED VEHICLE SYSTEM MONITORING AND MANAGEMENT

CV System Monitoring and Management allows traffic management personnel to perform the following functions for the locations of the installed RSE:

- Monitor the status of all devices involved in CV applications at a location. This may include RSE, traffic controllers, and computing devices used in CV application processing.
- Manage the configurations of the devices used in CV application processing. This may include store and repeat messages, available Wireless Access in a Vehicle Environment (WAVE) Service Advertisement services, channel configuration, and WAVE Route Advertisement parameters.
- Monitor the data being transmitted and received from a CV enabled location in real time. This allows users to quickly observe any immediately apparent issues with CV equipment before testing them physically in the field.

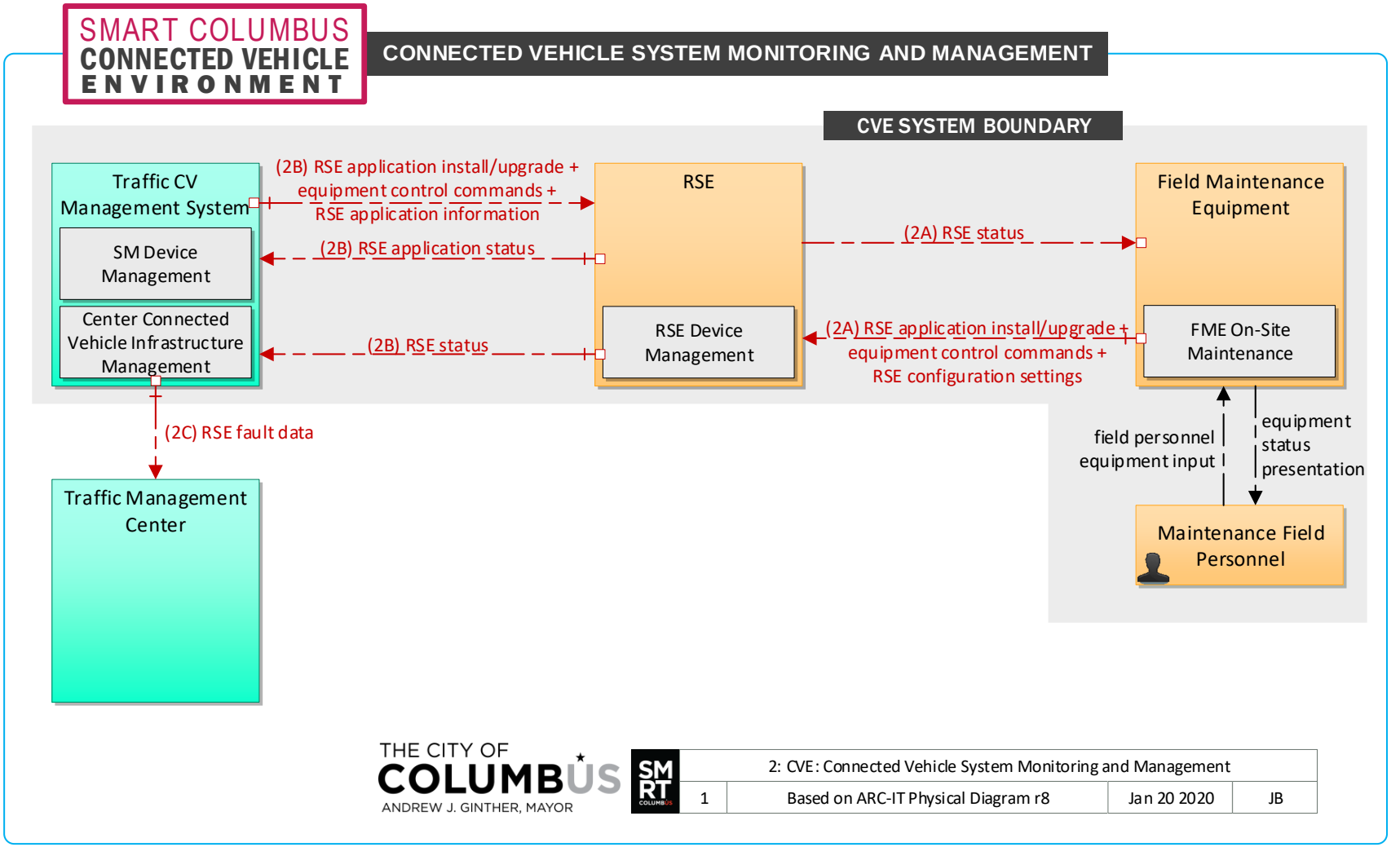


Figure 21: Connected Vehicle Environment System Monitoring and Management (Layer 2)

Source: City of Columbus

The following tables describe the Physical Elements, Information Flows, and Functional Objects seen on the diagram above, associated with the Connected Vehicle System Monitoring and Management application.

Table 35: Connected Vehicle Environment Connected Vehicle System Monitoring and Management Elements

Name	Class	Description
Field Maintenance Equipment	Field	Field Maintenance Equipment represents the portable equipment used by field personnel to locally troubleshoot, initialize, reprogram, and test infrastructure equipment. It may include a laptop, specialized diagnostics tools, or any other general purpose or specialized equipment that is interfaced locally to infrastructure equipment to support maintenance and repair.
Maintenance Field Personnel	Field	Represents the people that perform maintenance and construction field activities, including vehicle and equipment operators, field supervisory personnel, field crews, and work zone safety personnel. Information flowing from the Maintenance and Construction Field Personnel will include those system inputs specific to maintenance and construction operations, such as information regarding work zone status, or the status of maintenance actions. The field personnel are also monitored within the work zone to enhance work zone safety. Information provided to Maintenance and Construction Field Personnel includes dispatch requests, maintenance and construction actions to be performed, and work zone safety warnings.
RSE	Field	The RSE represents the CV roadside devices that are used to send messages to, and receive messages from, nearby vehicles using DSRC or other alternative wireless communications technologies. Communications with adjacent ITS field equipment and the back office TCVMS that monitors and controls the RSE are also supported. The RSU portion operates from a fixed position on vertical strain poles, mast arms, or spanwire on which signal heads are installed for permanent deployment. The RSE includes a processor, data storage, and communications capabilities that support secure communications with passing vehicles, other field equipment, and centers.
Traffic CV Management System	Center	The Traffic CV Management System monitors and controls the CVE and road network. It communicates with ITS Roadway Equipment and CV RSE to monitor and manage traffic flow, and monitor the condition of the roadway, surrounding environmental conditions, and field equipment status.

Name	Class	Description
Traffic Management Center	Center	The Traffic Management Center monitors and controls traffic and the road network. It represents centers that manage a broad range of transportation facilities including freeway systems, rural and suburban highway systems, and urban and suburban traffic control systems. It communicates with ITS RSE to monitor and manage traffic flow and monitor the condition of the roadway, surrounding environmental conditions, and field equipment status. It manages traffic and transportation resources to support allied agencies in responding to, and recovering from, incidents ranging from minor traffic incidents through major disasters.

Source: City of Columbus

Table 36: Connected Vehicle Environment Connected Vehicle System Monitoring and Management Information Flows

Name	Description
equipment control commands	System-level control commands issued to the RSE, such as reset and remote diagnostics.
equipment status presentation	Presentation of operational status of field equipment (sensors, signals, signs, controllers, etc.) to field personnel.
field personnel equipment input	User input from field personnel that supports querying, controlling, and configuring field equipment.
RSE application information	RSE application configuration data and parameters that are used to control applications and configure the application for a specific local use. This flow also supports remote control of the application so the application can be taken offline, reset, or restarted.
RSE application install/upgrade	This flow supports remote installation and update of software applications residing in the RSE. It supports transmission of the secure software installation files, including executable application code and associated support files.
RSE application status	Monitoring of RSE application status including current mode, operational status, and configuration settings. It includes the status of installed applications and the application-specific data provided by the RSE.
RSE configuration settings	Control settings and parameters that are used to configure roadside equipment.
RSE fault data	RSE fault information that can be used to identify RSEs that require initialization, reconfiguration, repair or replacement. This flow identifies the device, the nature of the fault, and associated error codes and diagnostic data.

Name	Description
RSE status	Monitoring of RSE 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, the configuration of managed devices, cybersecurity, and physical security status of the RSE.

Source: City of Columbus

Table 37: Connected Vehicle Environment Connected Vehicle System Monitoring and Management Functional Objects

Physical Object	Functional Object	Description
Connected Vehicle Environment Project Functions		
Field Maintenance Equipment	FME On-Site Maintenance	FME On-Site Maintenance provides field personnel with diagnostic information from field equipment, and provides the capability for field personnel to locally control and configure this equipment to support on-site installation, repair, and maintenance.
RSE	RSE Device Management	RSE Device Management provides executive control and monitoring of the RSE hardware and installed software applications. It monitors the operational status of the hardware and other attached field devices, and detects and reports fault conditions. A back office interface supports application installation, upgrade, and configuration as well as remote control of the operating mode and hardware configuration settings and initiation of remote diagnostics. A local interface is provided to field personnel for local monitoring and diagnostics, supporting field maintenance, repair, and replacement.
Traffic CV Management System	Center Connected Vehicle Infrastructure Management	Center Connected Vehicle Infrastructure Management is the back office application that supports monitoring and maintenance of the CV infrastructure (RSEs, support systems, and associated communications links). It monitors the performance and configuration of the infrastructure portion of the CVE. This includes tracking and management of the infrastructure configuration as well as detection, isolation, and correction of infrastructure service problems. The application also includes monitoring of performance of the infrastructure equipment, including RSEs and communications links.
	SM Device Management	SM Device Management provides the functions necessary to manage devices, including network management, operational status monitoring, and application performance monitoring.

Source: City of Columbus

2.3.7.2. VEHICLE MAINTENANCE

This Service Package identifies the interfaces and functionality that support vehicle maintenance, including maintenance of ITS equipment onboard the vehicle. An interface with a Vehicle Service Center supports vehicle monitoring to support timely, effective maintenance. It also supports software configuration management and updates as part of maintenance of the software-based onboard systems. While this Service Package covers only maintenance of the Vehicle OBE, it is defined at the highest level of abstraction so that any center that is contemplating advanced maintenance concepts for its fleet vehicles can use this Service Package.

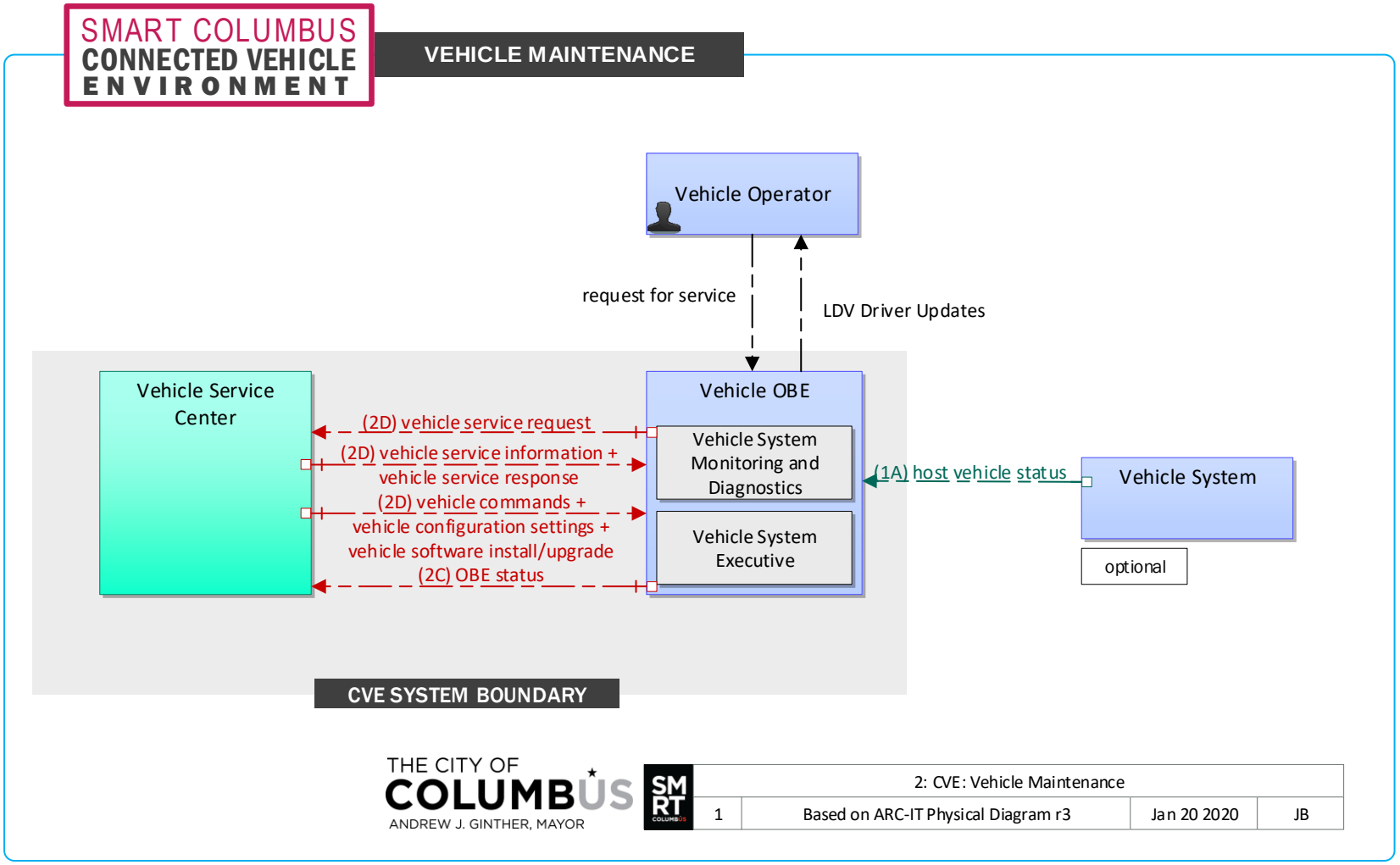


Figure 22: Connected Vehicle Environment Vehicle Maintenance (Layer 2)

Source: City of Columbus

The following tables describe the Physical Elements, Information Flows, and Functional Objects seen on the diagram above, associated with the Vehicle Maintenance application.

Table 38: Connected Vehicle Environment Vehicle Maintenance Elements

Name	Class	Description
Vehicle OBE	Vehicle	The Vehicle OBE provides the vehicle-based sensory, processing, storage, and communications functions that support efficient, safe, and convenient travel. The Vehicle OBE includes general capabilities that apply to passenger cars, trucks, and motorcycles. Many of these capabilities apply to all vehicle types including LDVs, HDVs, emergency vehicles, and transit vehicles. From this perspective, the Vehicle OBE includes the common interfaces and functions that apply to all motorized vehicles. The radio(s) supporting V2V and V2I communications are a key component of the Vehicle OBE. Both one-way and two-way communications options support a spectrum of information services from basic broadcast to advanced personalized information services. This Physical Object supports all six levels of driving automation as defined in SAE J3016.
Vehicle Operator	Vehicle	The Vehicle Operator represents the person that operates a vehicle on the roadway. Included are operators of private, transit, commercial, and emergency vehicles where the interactions are not particular to the type of vehicle (e.g., interactions supporting vehicle safety applications) unless the Information Flow states otherwise. For instance, driver updates between the vehicle OBE and operator are valid for the LDV class and operators only. In the V2V safety Service Package above, the operator originates driver requests and receives information that reflects the interactions which might be useful to all drivers, regardless of vehicle classification.
Vehicle Service Center	Vehicle	Vehicle Service Center represents centers that collect vehicle diagnostic information from vehicles, and provides service options for drivers of these vehicles. The Physical Object also includes centers operated by vehicle manufacturers that can coordinate with CVs to obtain vehicle operating data and provide software or data updates to CVs that they have manufactured.

Name	Class	Description
Vehicle System	Vehicle	The Vehicle System represents the interface to the vehicle system (e.g., hardwire connection to cable harness, CAN, LIN, Ethernet/IP, FlexRay, and MOST) that may enable communication between the Vehicle OBE and other vehicle systems to support CV applications. The vehicle system statuses and/or sensor outputs available on the databus will vary based on the equipment installed on the vehicle and availability on databus. System statuses and sensor outputs may include select vehicle systems and sensors, such as GPS derived location and timing information. In CVRIA, this Physical Object is used to represent the onboard interactions between the Vehicle OBE and the other systems included in a host vehicle. Note that the vehicle databus interface is optional, and is not standardized across all vehicle classes. Also, some Vehicle OBE implementations may not have access to the vehicle databus.

Source: City of Columbus

Table 39: Connected Vehicle Environment Vehicle Maintenance Information Flows

Name	Description
host vehicle status [optional]	Information provided to the ITS OBE from other systems on the vehicle platform. This includes the current status of the powertrain, steering, and braking systems, and status of other safety and convenience systems. In implementations where GPS is not integrated into the Vehicle OBE, the host vehicle is also the source for data describing the vehicle's location in three dimensions (latitude, longitude, elevation) and accurate time that can be used for time synchronization across the ITS environment.
LDV Driver Updates	Information provided to the LDV driver including visual displays, audible information and warnings, and haptic feedback. The updates inform the driver about current conditions, potential hazards, and the current status of vehicle OBE.
OBE status	Monitoring of OBE 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.
request for service	Driver inputs that summon an emergency response, request a financial transaction, or initiate other services.
vehicle commands	System-level control commands issued to vehicle equipment such as reset and remote diagnostics.
vehicle configuration settings	Control settings and parameters that are used to configure vehicle equipment.

Name	Description
vehicle service information	Vehicle problem diagnosis information and available vehicle service options, along with information about how to make a service reservation.
vehicle service request	Request for a service reservation from a CV.
vehicle service response	Response to a request for service reservation.
vehicle software install/upgrade	This flow supports installation and update of software residing in vehicle OBE. It supports download of the software installation files, including executable code and associated support files.

Source: City of Columbus

Table 40: Connected Vehicle Environment Vehicle Maintenance Functional Objects

Physical Object	Functional Object	Description
Connected Vehicle Environment Project Functions		
Vehicle OBE	Vehicle System Executive	Vehicle System Executive provides the Operating System kernel and executive functions that manage the software configuration and operation, and support computer resource management, security, and software installation and upgrade.
	Vehicle System Monitoring and Diagnostics	Vehicle System Monitoring and Diagnostics includes onboard sensors and integrated self-test software that monitors the condition of each of the vehicle systems and diagnostics used to support vehicle maintenance. The status of the vehicle and ancillary equipment and diagnostic information is provided to the driver and service center.

Source: City of Columbus

2.3.7.3. SECURITY AND CREDENTIALS MANAGEMENT

This Service Package is used to ensure trusted communications between mobile devices and other mobile devices or roadside devices, and protect data they handle from unauthorized access. This Service Package grants trust credentials to qualified mobile devices and infrastructure devices in the CVE so that those devices may be considered trusted by other devices that receive trust credentials from the Security and Credentials Management Service Package. This Service Package allows credentials to be requested and revoked, and secures the exchange of trust credentials between parties, preventing another party from intercepting and using those credentials illegitimately. This Service Package provides security to the transmissions between CV, ensuring authenticity and integrity of the transmissions. Additional security features include privacy protection, authorization and privilege class definition, as well as non-repudiation of origin. The end entities in this Service Package include vehicle, personal device, field device, center system etc. For this project, the Security and Credential Management support element is the equivalent of the Cooperative ITS Credential Management System (CCMS) support element described in ARC-IT.

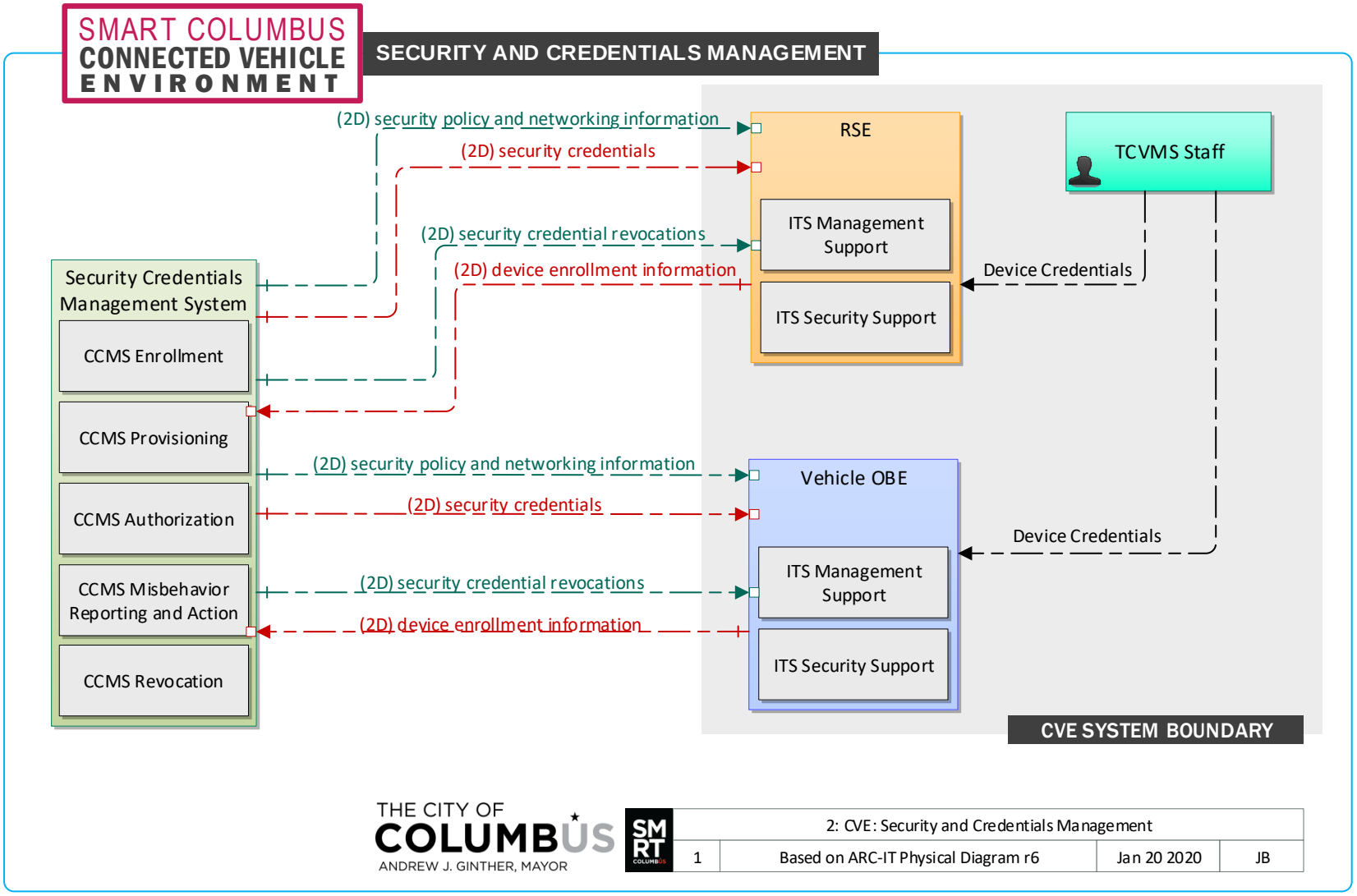


Figure 23: Connected Vehicle Environment Security and Credentials Management (Layer 2)

Source: City of Columbus

The following tables describe the Physical Elements, Information Flows, and Functional Objects seen on the diagram above, associated with the Security and Credentials Management application.

Table 41: Connected Vehicle Environment Security and Credentials Management Elements

Name	Class	Description
RSE	Field	The RSE represents the CV roadside devices that are used to send messages to, and receive messages from, nearby vehicles using DSRC or other alternative wireless communications technologies. Communications with adjacent ITS field equipment and the back office TCVMS that monitors and controls the RSE are also supported. The RSU portion operates from a fixed position on vertical strain poles, mast arms, or spanwire on which signal heads are installed for permanent deployment. The RSE includes a processor, data storage, and communications capabilities that support secure communications with passing vehicles, other field equipment, and centers.
Security and Credential Management System	Support	The Security and Credential Management System represents the security infrastructure that issues and manages the security certificates which form the basis of trust for V2V and V2I communication. CV devices enroll into the SCMS, obtain a variety of security certificates from certificate authorities, and attach those certificates to their messages as part of a digital signature. The certificates prove the device is a trusted actor in the system, while also maintaining privacy. Misbehavior detection and reporting allow the system to identify bad actors, and revoke message privileges, when necessary.
TCVMS Staff	Center	The TCVMS Staff represents the operational personnel responsible for traffic management, maintenance operations, and administrative activities of the TCVMS. These different roles represent a variety of individuals in the transportation industry.
Vehicle OBE	Vehicle	The Vehicle OBE provides the vehicle-based sensory, processing, storage, and communications functions that support efficient, safe, and convenient travel. The Vehicle OBE includes general capabilities that apply to passenger cars, trucks, and motorcycles. Many of these capabilities apply to all vehicle types including LDVs, HDVs, emergency vehicles, and transit vehicles. From this perspective, the Vehicle OBE includes the common interfaces and functions that apply to all motorized vehicles. The radio(s) supporting V2V and V2I communications are a key component of the Vehicle OBE. Both one-way and two-way communications options support a spectrum of information services from basic broadcast to advanced personalized information services. This Physical Object supports all six levels of driving automation as defined in SAE J3016.

Source: City of Columbus

Table 42: Connected Vehicle Environment Security and Credentials Management Information Flows

Name	Description
Device Credentials	Long-term security credentials such as 'enrollment certificates' that demonstrate the trust-worthiness of the source device or application. Certificates will be loaded onto devices manually by project staff.
device enrollment information	Information provided by an end-entity to support enrollment and authorization for the CVE. This includes device identification, requested permissions and restrictions, and security credentials used to establish the current level of trust and eligibility for enrollment and authorization.
security credential revocations	Certificate Revocation List; lists the certificates whose trust has been revoked by the CCMS.
security credentials	The material used by an end-entity (vehicle, personal device, field device, center system etc.) to ensure privacy, integrity and authentic ability of its data transmissions. This includes certificates with associated public and private verifying/signing and decrypting/encrypting keys.
security policy and networking information	Security policy information describing the CCMS enrollment, authorization, misbehavior, and revocation policies, and communications information related to CCMS components; including contact information and public credentials of those components.

Source: City of Columbus

Table 43: Connected Vehicle Environment Security and Credentials Management Functional Objects

Physical Object	Functional Object	Description
Connected Vehicle Environment Project Functions		
RSE	ITS Management Support	ITS Management Support provides management of the ITS Object. This 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 service advertisements, communications congestion management and interference management, local device states and communications information, billing management, fault management, service level, and performance monitoring.
	ITS Security Support	ITS Security Support provides communications and system security functions to the ITS Object, including privacy protection functions. It may include firewall, intrusion management, authentication, authorization, profile management, identity management, cryptographic key management. It may include a hardware security module and security management information base.

Physical Object	Functional Object	Description
Security and Credential Management System	CCMS Provisioning	CCMS Provisioning components provide the end-entity with material that allows it to enter the 'Unenrolled' state. This consists of root certificates and the crypto material that allows it to communicate securely with the Enrollment components. This function ensures the requesting entity meets requirements for provisioning, and provides the certificates and relevant policy information to entities that meet the requirements.
	CCMS Authorization	CCMS Authorization components provide authorization credentials (e.g., pseudonym certificates) to end entities. The end entity applies for and obtains authorization credentials, enabling the end entity to enter the “Operational” state. This function requires an interactive dialog, minimally including a Certificate Request from the end-entity desiring certificates. This request will be checked for validity, with the embedded enrollment certificate checked against an internal blacklist. If all checks are passed, this function will distribute a bundle of linked pseudonym certificates suitable for use by the requesting end-entity, with the characteristics and usage rules of those certificates dependent on the operational policies of the CCMS. It also provides the secure provisioning of a given object’s Decryption Key in response to an authorized request from that object. The retrieved Decryption Key will be used by the receiving object to decrypt the “next valid” batch within the set of previously retrieved Security Credential batches.
	CCMS Enrollment	CCMS Enrollment components provide enrollment credentials to end entities. The end entity applies for and obtains enrollment credentials that can be used to communicate with other CCMS components, entering the "Unauthorized" state. CCMS Enrollment components also participate in de-registration processes through interaction with CCMS Revocation components.
	CCMS Misbehavior Reporting and Action	CCMS Misbehavior Reporting and Action components process misbehavior reports from end-entities. Misbehavior reports are analyzed and investigated if warranted. Investigated misbehavior reports are correlated with end entities, and systemic issues are identified. If revocation is warranted, this component provides information to Authorization or Revocation components to initiate revocation and/or blacklisting, as appropriate.
	CCMS Revocation	CCMS Revocation components generate the internal blacklist and Certificate Revocation List and distribute them to other CCMS components and end entities. Once placed on the Certificate Revocation List, an end entity is in the Unauthorized state. Once placed on the blacklist, an end entity is in the Unenrolled state.

Physical Object	Functional Object	Description
Vehicle OBE	ITS Management Support	ITS Management Support provides management of the ITS Object. This 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 service advertisements, communications congestion management and interference management, local device states and communications information, billing management, fault management, service level, and performance monitoring.
	ITS Security Support	ITS Security Support provides communications and system security functions to the ITS Object, including privacy protection functions. It may include firewall, intrusion management, authentication, authorization, profile management, identity management, and cryptographic key management. It may include a hardware security module and security management information base.

Source: City of Columbus

2.3.8. Enterprise Architecture

Figure 24 shows the relationships between CVE project stakeholders, the roles various organizations play within the project context, and the agreements among stakeholders. **Table 44** provides the list of agreements with brief descriptions.

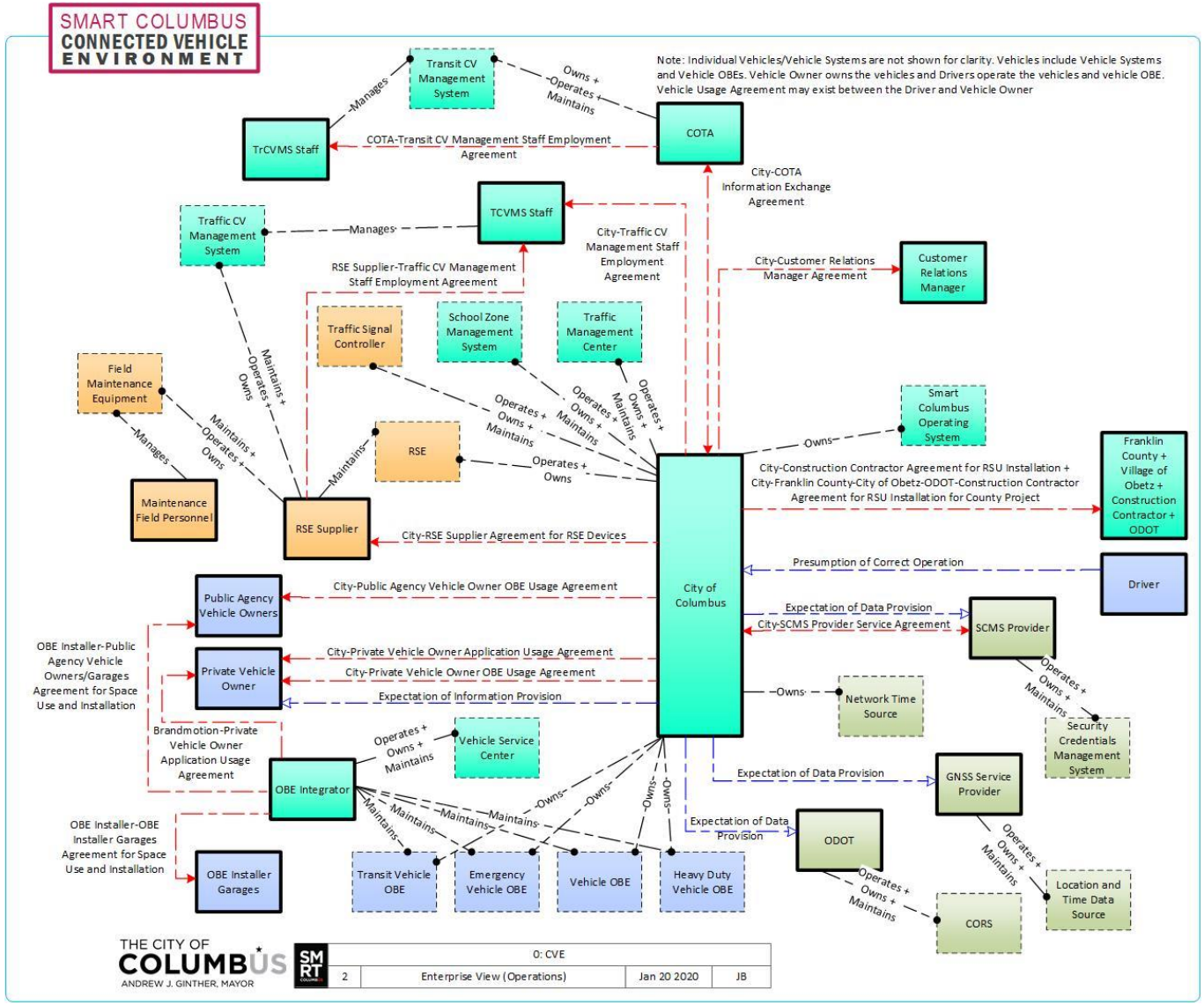


Figure 24: Connected Vehicle Environment Enterprise Architecture

Source: City of Columbus

Table 44: Connected Vehicle Environment Agreements

Name	Description
City-TCVMS Staff Employment Agreement	An agreement between the City and TCVMS Staff, whereupon the staff agrees to provide labor to the City, which in turn compensates the employee. Stipulates level of compensation, working conditions, necessary equipment and training and expectations of employee performance. The RSE Supplier will have the responsibility of supplying TCVMS Staff at the beginning of operations, and the responsibility will later the transferred to the City. Status: Existing
RSE Supplier-TCVMS Staff Employment Agreement	An agreement between the RSE Supplier and TCVMS Staff, whereupon the staff agrees to provide labor to the RSE Supplier, which in turn compensates the employee. Stipulates level of compensation, working conditions, necessary equipment and training and expectations of employee performance. The RSE Supplier will have the responsibility of supplying TCVMS Staff at the beginning of operations, and the responsibility will later the transferred to the City. Status: Existing
COTA-Transit CV Management System Staff Employment Agreement	An agreement between COTA and Transit CV Management System Staff, whereupon the staff agrees to provide labor to COTA, which in turn compensates the employee. Stipulates level of compensation, working conditions, necessary equipment and training and expectations of employee performance. Status: Existing
Brandmotion-Private Vehicle Owner Vehicle OBE Usage Agreement	An agreement between Brandmotion and the Private Vehicle Owner where Vehicle Owner agrees to allow installation of OBE equipment, to operate & to maintain OBE for this project. This will occur through the Notice and Consent process for individual vehicle owners. Brandmotion will be responsible for liability of installation and operation of the vehicle components. Brandmotion will also facilitate the collection of the notice and consent with the individual. Status: Existing
City-Private Vehicle Owner Application Usage Agreement	An agreement between the City and the Vehicle Owner for using CV applications. Stipulates the terms and conditions of service usage. Status: Existing
City-Private Vehicle Owner OBE Usage Agreement	An agreement between the City and the Vehicle Owner for usage of the OBE. Status:Existing
City-SCMS Provider Service Agreement	An agreement between the City and the SCMS Provider where SCMS Provider agrees to provide SCMS services. This is a unidirectional agreement. City directed the integrators to secure the SCMS needs (DriveOhio is paying for this). DriveOhio has the contract with SCMS and has issued City the authority to purchase SCMS services (digital certificates) and then City gives them to the integrators. Status: Existing

Name	Description
City-COTA Information Exchange Agreement	This is an Information Exchange Agreement between City of Columbus and COTA. Status: Existing
City-Public Agency Vehicle Owner OBE Usage Agreement	An agreement between the City and the Public Agency Vehicle Owner to allow for the installation of OBE devices/applications and the use and collection of information from those devices. Public Vehicle Owners – Franklin County, COTA and ODW (private company) Status: Existing
City-Construction Contractor Agreement for RSE Installation	An agreement between the City and Gudenkauf for RSE installation. Vendor: Gudenkauf Status: Existing
City-Franklin County-Village of Obetz-ODOT-Construction Contractor Agreement for RSE Installation for County Project	An agreement between the City, Franklin County, the Village of Obetz, ODOT and a construction contractor for RSE installation in the County project – Alum Creek. Vendor: Gudenkauf Status: Existing
City-RSE Supplier Agreement for RSE Devices	An agreement between the City and the RSE supplier for the RSE hardware devices and the accompanying software. Vendor: Kapsch Status: Existing
OBE Installer-OBE Installer Garages Agreement for Space Use and Installation	An agreement between the OBE Installer and the OBE Installer Garages to allow OBE Installer to use space and for OBE Installer Garages to conduct installations. Also includes training garage staff, as some mechanics will be contracted as on-site installers. OBE Installer – Brandmotion (Sub to OBE Integrator, Siemens) OBE Installer Garages – Two Brothers Automotive, Sound Chamber Audio, Procat Towing Status: Existing and Planned
OBE Installer-Public Vehicle Owners/Garages Agreement for Space Use and Installation	An agreement between the OBE Installer and the Public Vehicle Owners to allow OBE Integrator to use space to conduct installations on their vehicles. OBE Installer – Siemens/Brandmotion Public Vehicle Owners – Franklin County, COTA and ODW Status: Existing and Planned
City-Customer Relations Manager Agreement	An agreement between the City and the Customer Relations Manager to perform customer relations duties with the private project participants when they are recruited and during the installation process. Customer Relations Manager: Brandmotion Status: Existing
Construction Permits	The County will need a permit to install a node cabinet from the state. City permits will use existing permits.

Source: City of Columbus

2.3.8.1. ROLES AND RESPONSIBILITIES

Development:

- City of Columbus/Smart Columbus PMO (City) with support from:
  - HNTB/WSP – contract
  - RSE Integrator – Kapsch team (Danlaw, Econolite, PathMaster) - contract
  - OBE Integrator – Siemens team Brandmotion, WMC - contract
  - Smart Columbus Operating System team (Accenture) – contract
  - City of Columbus Public Service – Traffic Management Center operations (TCVMS staff and system), network time source
  - City of Columbus Department of Technology – IPv6 network set up
- ODOT:
  - CORS provider
  - SCMS (through statewide contract with ISS/Green Hills)
  - Channel allocation guidance

Installation:

- City of Columbus/Smart Columbus PMO (City):
  - HNTB: installation plans
  - RSE Integrator (Kapsch team (Danlaw, Econolite, PathMaster))
  - OBE integrator (Siemens team (Brandmotion, WMC))
  - Electrical contractor (Gudenkauf)
- Franklin County Engineer's office:
  - Coordination of Alum Creek intersection RSE installation (Gudenkauf); availability of vehicles and installation location for select OBE
- Other OBE Installation Locations:
  - City of Columbus:
    - Department of Public Service (police, fire, emergency, fleet) – availability of vehicles and installation locations
    - Department of Public safety (City fleet) – availability of vehicles and installation location
  - COTA – availability of vehicles and installation location
  - ODW Logistics (HDV) – availability of vehicles and installation location
  - OSE – private installs
  - Private (LDV) – availability of installation location and support staff. Contractual agreements will be developed between the OBE Installer and the installation location (2 Brothers Automotive).
    - 2 Brothers Automotive
    - Sound chamber
    - Procat

        - Columbus State Community College

Testing:

- City of Columbus/Smart Columbus PMO, with support from:
    - HNTB/WSP
    - RSE Integrator (Kapsch team (Danlaw, Econolite, PathMaster))
    - OBE Integrator (Siemens team (Brandmotion, WMC))
    - OS team (Accenture)

Operations:

- City of Columbus/Smart Columbus PMO: owner providing system administration and management, Operate TCVMS, traffic signal controller, school zone signal, network time source
    - Kapsch Team (Danlaw, Econolite, PathMaster): data collection, RSE health/system monitoring
    - Siemens Team (Brandmotion, WMC): OBE troubleshooting
    - Smart Columbus Operating System: data storage
    - HNTB/WSP: performance measurement
    - Other City of Columbus departments:
        - Department of Public Service:
            - Fleet: operate vehicles
            - Traffic management: traffic controller, school zone signal, network time source
        - Department of Technology: IPv6 network administrator
        - Department of Public Safety: Police, fire, emergency, fleet – operate vehicles
- COTA:
    - Operate buses
    - Data offload and transfer for TVIER application (transit CV management system)
- ODOT:
    - CORS administrator
    - SCMS administrator
- ODW Logistics: operate HDV
- Franklin County Engineers Office: operate vehicles
- GNSS provides satellite location and time data source for OBEs

Maintenance:

- City of Columbus/Smart Columbus PMO: owner
    - RSE Integrator (Kapsch team (Danlaw, Econolite, PathMaster))
    - OBE integrator (Siemens team (Brandmotion, WMC)) – private LDV
    - Electrical contractor (Gudenkauf)
    - HNTB/WSP: operations and maintenance plan

  - Department of Technology — network
  - Department of Public Service – police, fire, emergency vehicles
  - Department of Public Safety: controllers, school zone signal, traffic management – TCVMS, fleet LDV, network time source
  - Smart Columbus Operating System Team (Accenture) – Smart Columbus Operating System administration
- ODOT:
  - CORS administrator
  - SCMS administrator
- COTA:
  - Transit CV management system
  - Transit Vehicles

2.3.9. Communications Architecture View

2.3.9.1. COMMUNICATION PROFILES USED

The following sections describe the layered sets of communications protocols that are required to support communications among the elements that make up the CVE project.

2.3.9.1.1. CCMS

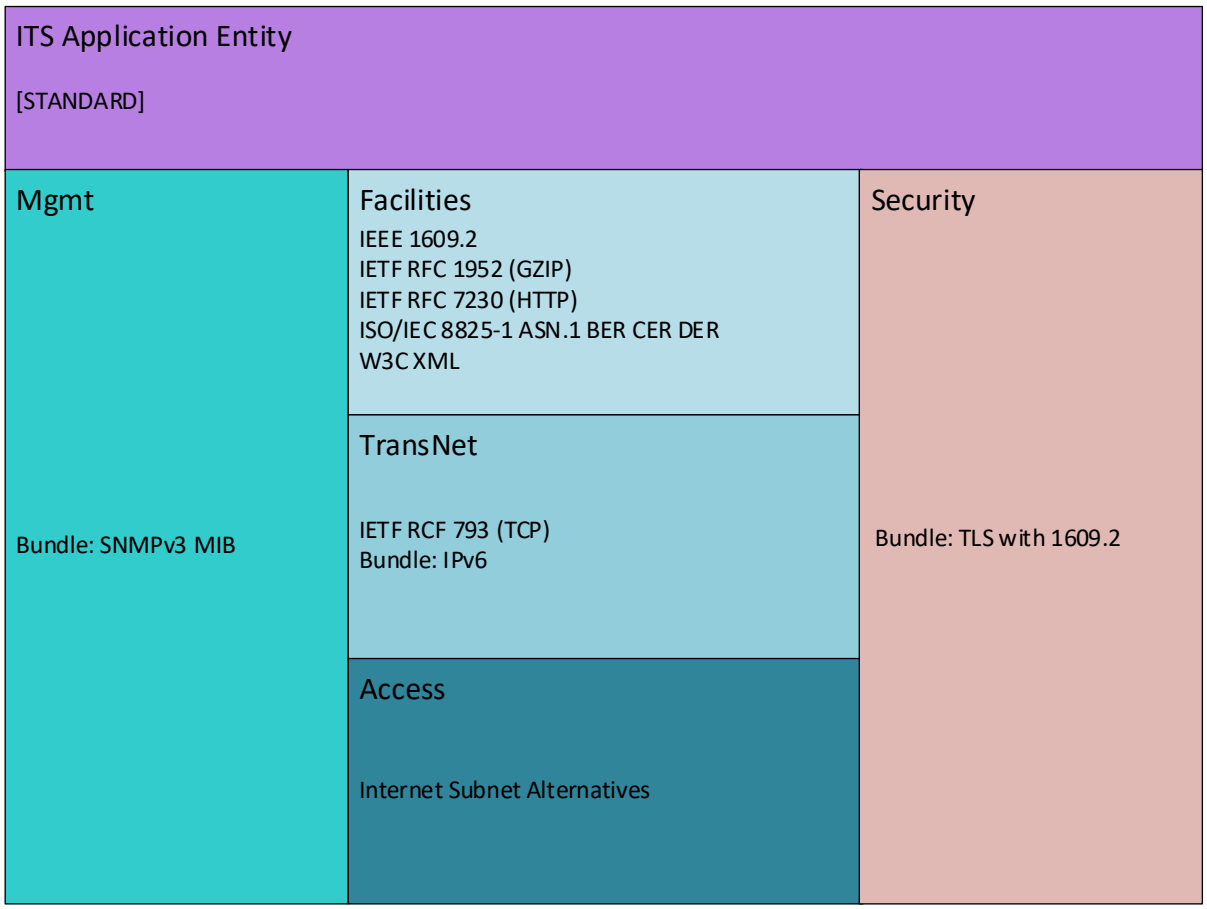


Figure 25: CCMS

Source: City of Columbus

Table 45: CCMS

Name	Source	Destination	Standard	Profile
device enrollment information	RSE	Security and Credential Management System	IEEE 1609.2/CAMP SCMS	CCMS
device enrollment information	Vehicle OBE	Security and Credential Management System	CAMP SCMS	CCMS
security credential revocations	Security and Credential Management System	RSE	IEEE 1609.2/CAMP SCMS	CCMS
security credential revocations	Security and Credential Management System	Vehicle OBE	CAMP SCMS	CCMS

Name	Source	Destination	Standard	Profile
security credentials	Security and Credential Management System	RSE	IEEE 1609.2/CAMP SCMS	CCMS
security credentials	Security and Credential Management System	Vehicle OBE	CAMP SCMS	CCMS
security policy and networking information	Security and Credential Management System	RSE	IEEE 1609.2/CAMP SCMS	CCMS
security policy and networking information	Security and Credential Management System	Vehicle OBE	CAMP SCMS	CCMS

Source: City of Columbus

2.3.9.1.2. DSRC-WSMP

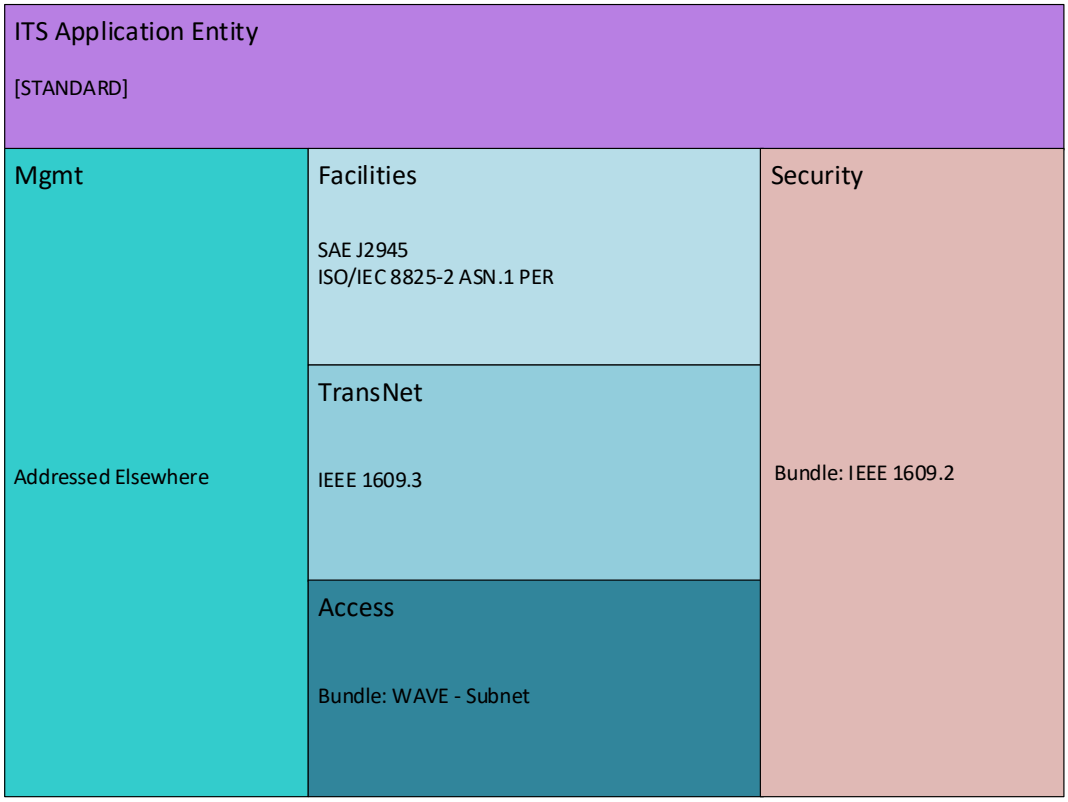


Figure 26: DSRC-WSMP

Source: City of Columbus

Table 46: DSRC-WSMP

Name	Source	Destination	Standard	Profile
intersection geometry	RSE	Emergency Vehicle OBE	ISO 19091	DSRC-WSMP
intersection geometry	RSE	Emergency Vehicle OBE	SAE J2735	DSRC-WSMP
intersection geometry	RSE	Heavy Duty Vehicle OBE	ISO 19091	DSRC-WSMP
intersection geometry	RSE	Heavy Duty Vehicle OBE	SAE J2735	DSRC-WSMP
intersection geometry	RSE	Transit Vehicle OBE	ISO 19091	DSRC-WSMP
intersection geometry	RSE	Transit Vehicle OBE	SAE J2735	DSRC-WSMP
intersection geometry	RSE	Vehicle OBE	ISO 19091	DSRC-WSMP
intersection geometry	RSE	Vehicle OBE	SAE J2735	DSRC-WSMP
intersection status	RSE	Emergency Vehicle OBE	ISO 19091	DSRC-WSMP
intersection status	RSE	Emergency Vehicle OBE	SAE J2735	DSRC-WSMP
intersection status	RSE	Heavy Duty Vehicle OBE	ISO 19091	DSRC-WSMP
intersection status	RSE	Heavy Duty Vehicle OBE	SAE J2735	DSRC-WSMP
intersection status	RSE	Transit Vehicle OBE	ISO 19091	DSRC-WSMP
intersection status	RSE	Transit Vehicle OBE	SAE J2735	DSRC-WSMP
intersection status	RSE	Vehicle OBE	ISO 19091	DSRC-WSMP
intersection status	RSE	Vehicle OBE	SAE J2735	DSRC-WSMP
local signal preemption request	Emergency Vehicle OBE	RSE	ISO 19091	DSRC-WSMP
local signal preemption request	Emergency Vehicle OBE	RSE	SAE J2735	DSRC-WSMP
local signal priority request	Heavy Duty Vehicle OBE	RSE	ISO 19091	DSRC-WSMP
local signal priority request	Heavy Duty Vehicle OBE	RSE	SAE J2735	DSRC-WSMP

Name	Source	Destination	Standard	Profile
local signal priority request	Transit Vehicle OBE	RSE	ISO 19091	DSRC-WSMP
local signal priority request	Transit Vehicle OBE	RSE	SAE J2735	DSRC-WSMP
reduced speed notification	RSE	Transit Vehicle OBE	SAE J2735	DSRC-WSMP
reduced speed notification	RSE	Vehicle OBE	SAE J2735	DSRC-WSMP
signal priority status	RSE	Emergency Vehicle OBE	ISO 19091	DSRC-WSMP
signal priority status	RSE	Emergency Vehicle OBE	SAE J2735	DSRC-WSMP
signal priority status	RSE	Heavy Duty Vehicle OBE	ISO 19091	DSRC-WSMP
signal priority status	RSE	Heavy Duty Vehicle OBE	SAE J2735	DSRC-WSMP
signal priority status	RSE	Transit Vehicle OBE	ISO 19091	DSRC-WSMP
signal priority status	RSE	Transit Vehicle OBE	SAE J2735	DSRC-WSMP
vehicle control event	Remote Vehicle OBE	Transit Vehicle OBE	SAE J2735	DSRC-WSMP
vehicle control event	Remote Vehicle OBE	Transit Vehicle OBE	SAE J2945/1	DSRC-WSMP
vehicle control event	Remote Vehicle OBE	Vehicle OBE	SAE J2735	DSRC-WSMP
vehicle control event	Remote Vehicle OBE	Vehicle OBE	SAE J2945/1	DSRC-WSMP
vehicle control event	Transit Vehicle OBE	Remote Vehicle OBE	SAE J2735	DSRC-WSMP
vehicle control event	Transit Vehicle OBE	Remote Vehicle OBE	SAE J2945/1	DSRC-WSMP
vehicle control event	Vehicle OBE	Remote Vehicle OBE	SAE J2735	DSRC-WSMP
vehicle control event	Vehicle OBE	Remote Vehicle OBE	SAE J2945/1	DSRC-WSMP
vehicle location and motion	Remote Vehicle OBE	Transit Vehicle OBE	SAE J2735	DSRC-WSMP
vehicle location and motion	Remote Vehicle OBE	Transit Vehicle OBE	SAE J2945/1	DSRC-WSMP
vehicle location and motion	Remote Vehicle OBE	Vehicle OBE	SAE J2735	DSRC-WSMP

Name	Source	Destination	Standard	Profile
vehicle location and motion	Remote Vehicle OBE	Vehicle OBE	SAE J2945/1	DSRC-WSMP
vehicle location and motion	Transit Vehicle OBE	Remote Vehicle OBE	SAE J2735	DSRC-WSMP
vehicle location and motion	Transit Vehicle OBE	Remote Vehicle OBE	SAE J2945/1	DSRC-WSMP
vehicle location and motion	Vehicle OBE	Remote Vehicle OBE	SAE J2735	DSRC-WSMP
vehicle location and motion	Vehicle OBE	Remote Vehicle OBE	SAE J2945/1	DSRC-WSMP
vehicle location and motion for surveillance	Vehicle OBE	RSE	SAE J2735	DSRC-WSMP
vehicle location and motion for surveillance	Vehicle OBE	RSE	SAE J2945/1	DSRC-WSMP

Source: City of Columbus

2.3.9.1.3. NTCIP-SNMPv1

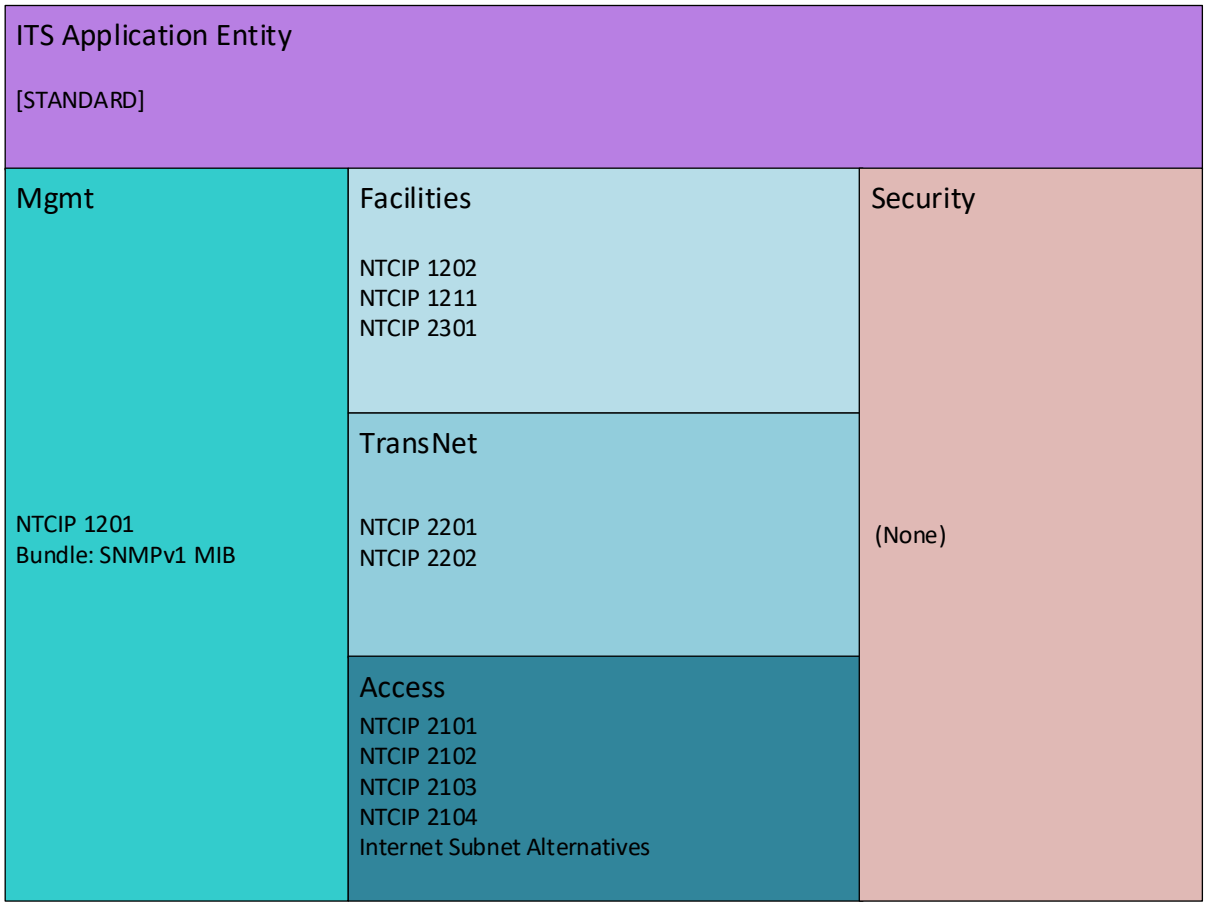


Figure 27: NTCIP-SNMPv1

Source: City of Columbus

Table 47: NTCIP-SNMPv1

Name	Source	Destination	Standard	Profile
right-of-way request notification *	Traffic Signal Controller	Traffic Management Center	-	NTCIP-SNMPv1
signal control status *	Traffic Signal Controller	Traffic Management Center	-	NTCIP-SNMPv1

** Existing Information Flow*

Source: City of Columbus

2.3.9.1.4. NTCIP-SNMPv1 Secure

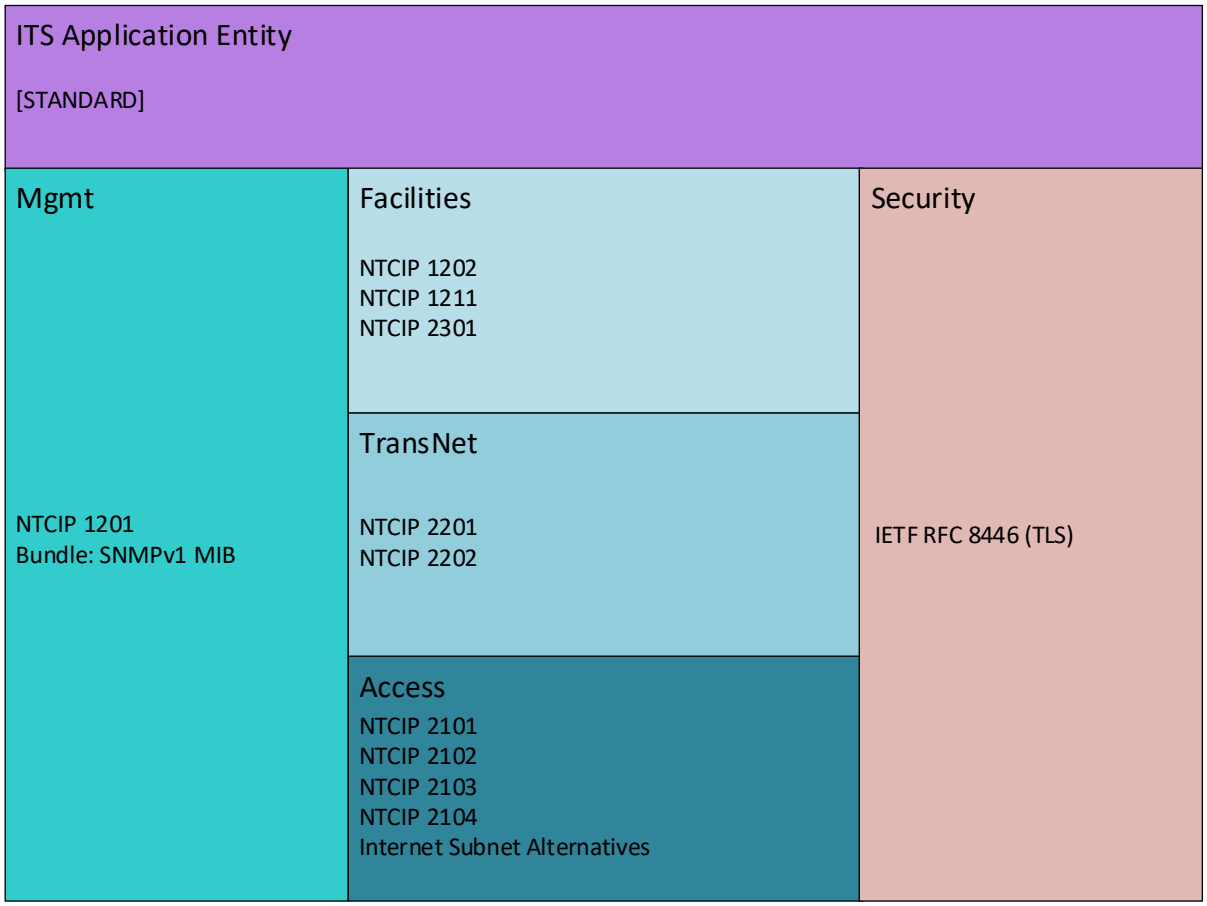


Figure 28: NTCIP-SNMPv1 Secure

Source: City of Columbus

Table 48: NTCIP-SNMPv1 Secure

Name	Source	Destination	Standard	Profile
signal control commands *	Traffic Management Center	Traffic Signal Controller	-	NTCIP-SNMPv1 Secure

** Existing Information Flow*

Source: City of Columbus

2.3.9.1.5. NTCIP-SNMPv3

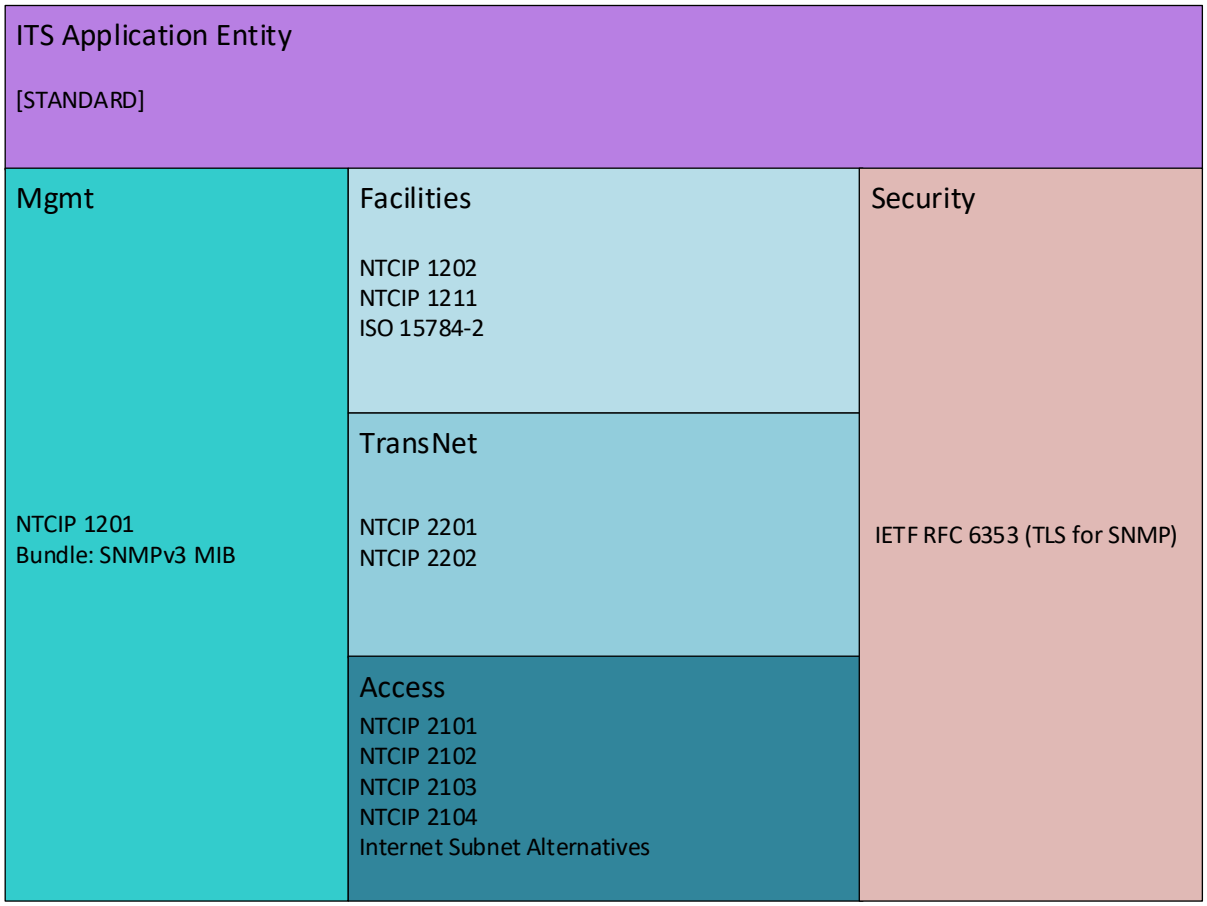


Figure 29: NTCIP-SNMPv3

Source: City of Columbus

Table 49: NTCIP-SNMPv3

Name	Source	Destination	Standard	Profile
location correction	RSE	Vehicle OBE	RSU 4.1	NTCIP-SNMPv3

Source: City of Columbus

2.3.9.1.6. Position-Location-Interface

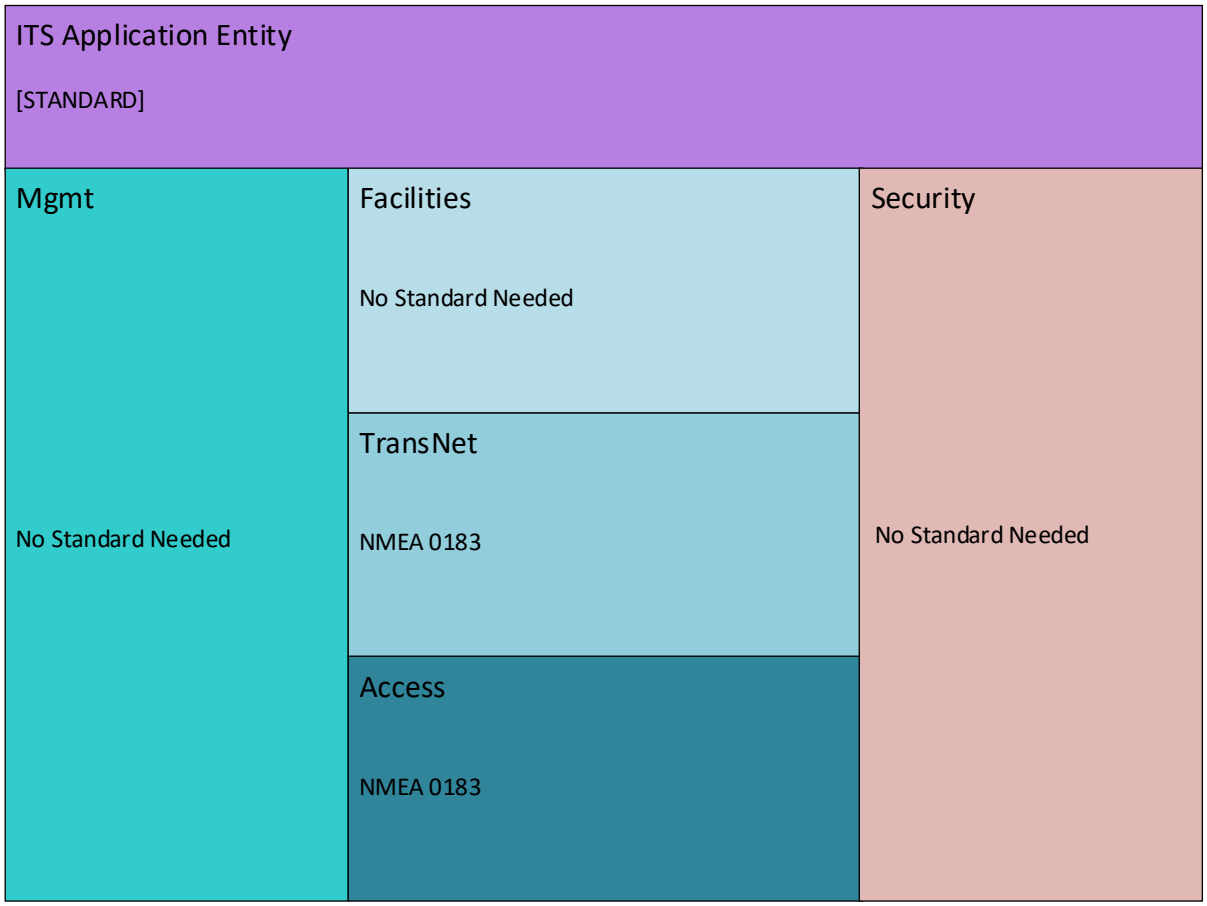


Figure 30: Position-Location-Interface

Source: City of Columbus

Table 50: Position-Location-Interface

Name	Source	Destination	Standard	Profile
location and time	Location and Time Data Source	RSE	NMEA 0183	Position-Location-Interface
location and time	Location and Time Data Source	Transit Vehicle OBE	NMEA 0183	Position-Location-Interface
location and time	Location and Time Data Source	Vehicle OBE	NMEA 0183	Position-Location-Interface

Source: City of Columbus

2.3.9.1.7. RSE-C2F

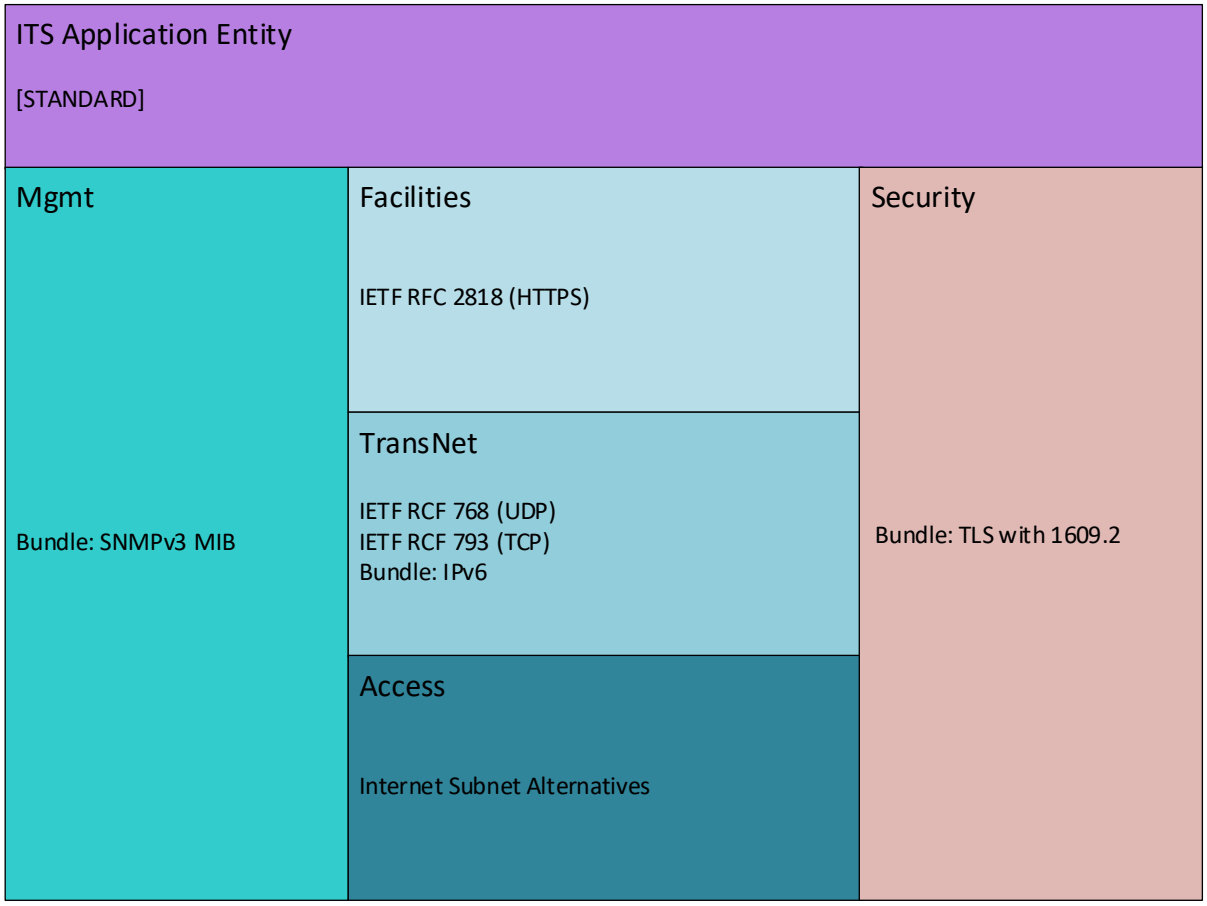


Figure 31: RSE-C2F

Source: City of Columbus

Table 51: RSE-C2F

Name	Source	Destination	Standard	Profile
RTCM Reference Station Information Message	CORS	RSE	Networked Transport of Radio Technical Commission for Maritime Services via Internet Protocol	RSE-C2F
traffic situation data	RSE	Traffic CV Management System	(Unspecified)	RSE-C2F

Source: City of Columbus

2.3.9.1.8. RSE-C2F-SNMP

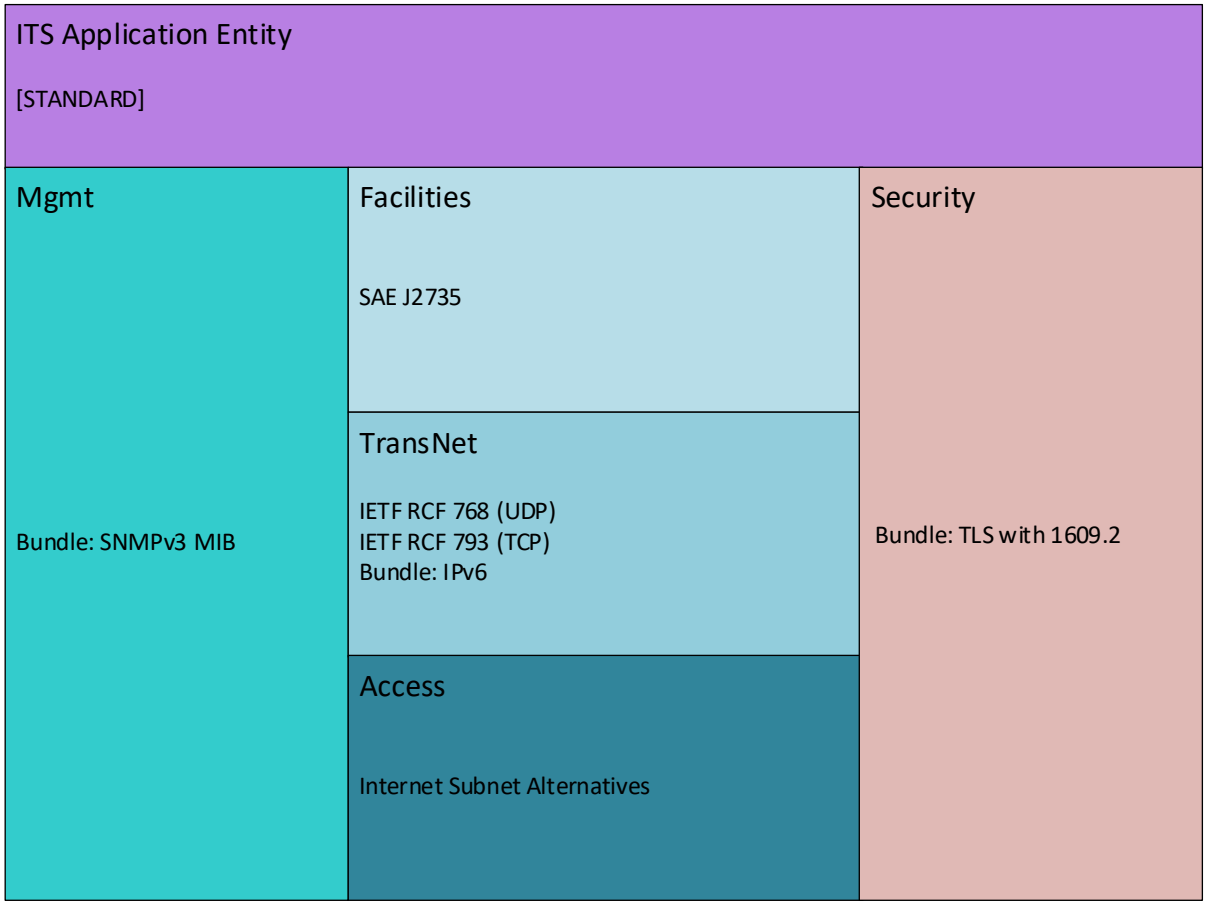


Figure 32: RSE-C2F-SNMP

Source: City of Columbus

Table 52: RSE-C2F-SNMP

Name	Source	Destination	Standard	Profile
equipment control commands	TVCMS	RSE	RSU 4.1 SNMP	RSE-C2F-SNMP
intersection geometry	Traffic CV Management System	RSE	SAE J2735	RSE-C2F-SNMP
intersection management application info	Traffic CV Management System	RSE	RSU 4.1 SNMP	RSE-C2F-SNMP
intersection management application status	RSE	Traffic CV Management System	(Unspecified)	RSE-C2F-SNMP
intersection safety application info	Traffic CV Management System	RSE	RSU 4.1 SNMP	RSE-C2F-SNMP

Name	Source	Destination	Standard	Profile
intersection safety application status	RSE	Traffic CV Management System	(Unspecified)	RSE-C2F-SNMP
RSE application information	Traffic CV Management System	RSE	RSU 4.1 SNMP	RSE-C2F-SNMP
RSE application install/upgrade	Traffic CV Management System	RSE	(Unspecified)	RSE-C2F-SNMP
RSE application status	RSE	Traffic CV Management System	(Unspecified)	RSE-C2F-SNMP
RSE status	RSE	Traffic CV Management System	(Unspecified)	RSE-C2F-SNMP
situation data collection parameters	Traffic CV Management System	RSE	RSU 4.1 SNMP	RSE-C2F-SNMP
speed warning application info	Traffic CV Management System	RSE	RSU 4.1 SNMP	RSE-C2F-SNMP
speed warning application status	RSE	Traffic CV Management System	(Unspecified)	RSE-C2F-SNMP

Source: City of Columbus

2.3.9.1.9. RSE-F2F

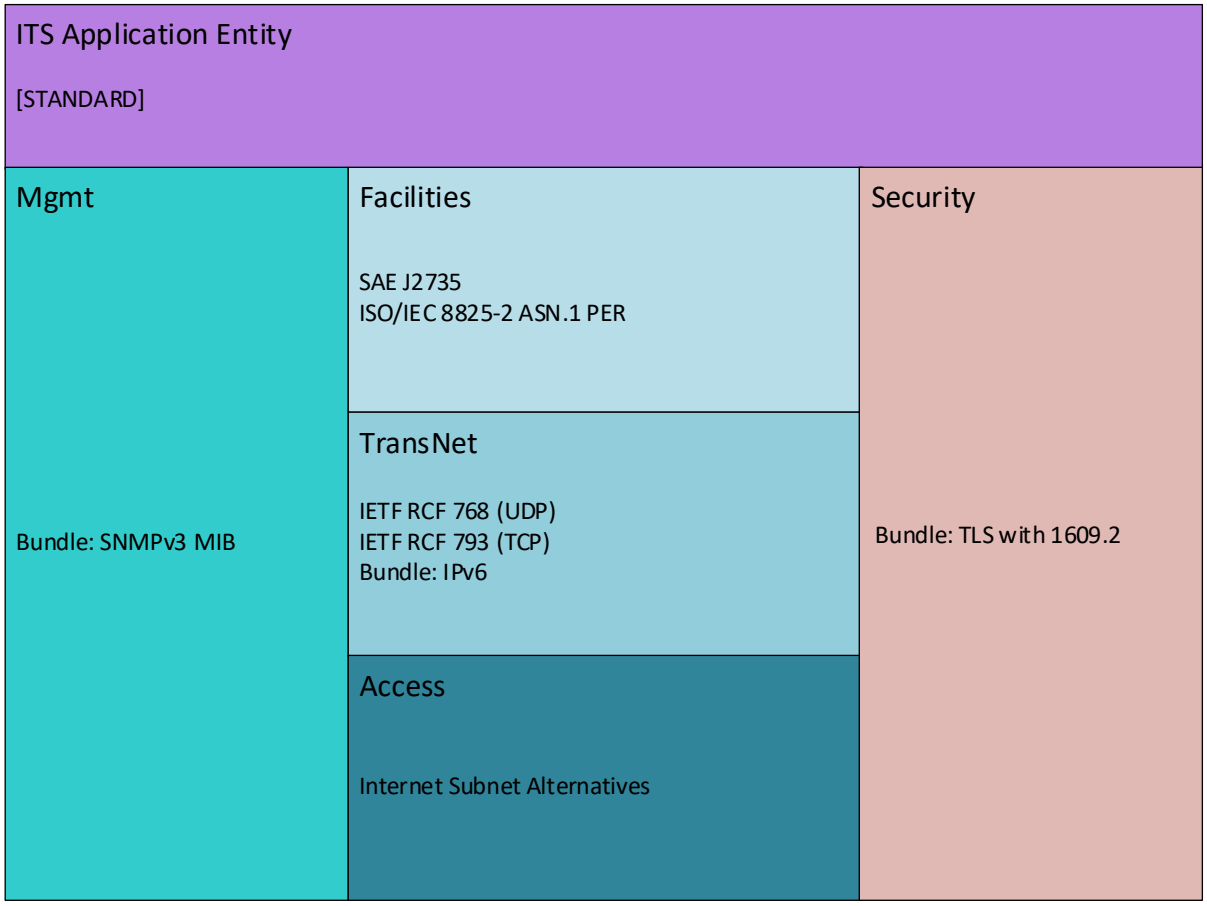


Figure 33: RSE-F2F

Source: City of Columbus

Table 53: RSE-F2F

Name	Source	Destination	Standard	Profile
equipment control commands	Field Maintenance Equipment	RSE	RSU 4.1 SNMP	RSE-F2F
intersection control status	Traffic Signal Controller	RSE	NTCIP 1202-ASC	RSE-F2F
RSE application install/upgrade	Field Maintenance Equipment	RSE	(Unspecified)	RSE-F2F
RSE configuration settings	Field Maintenance Equipment	RSE	(Unspecified)	RSE-F2F
RSE status	RSE	Field Maintenance Equipment	RSU 4.1 SNMP	RSE-F2F
Signal Priority Request	RSE	Traffic Signal Controller	(Unspecified)	RSE-F2F

Name	Source	Destination	Standard	Profile
Signal Priority Response	Traffic Signal Controller	RSE	(Unspecified)	RSE-F2F
signal priority service request	RSE	Traffic Signal Controller	NTCIP 1202-ASC	RSE-F2F

Source: City of Columbus

2.3.9.1.10. Time

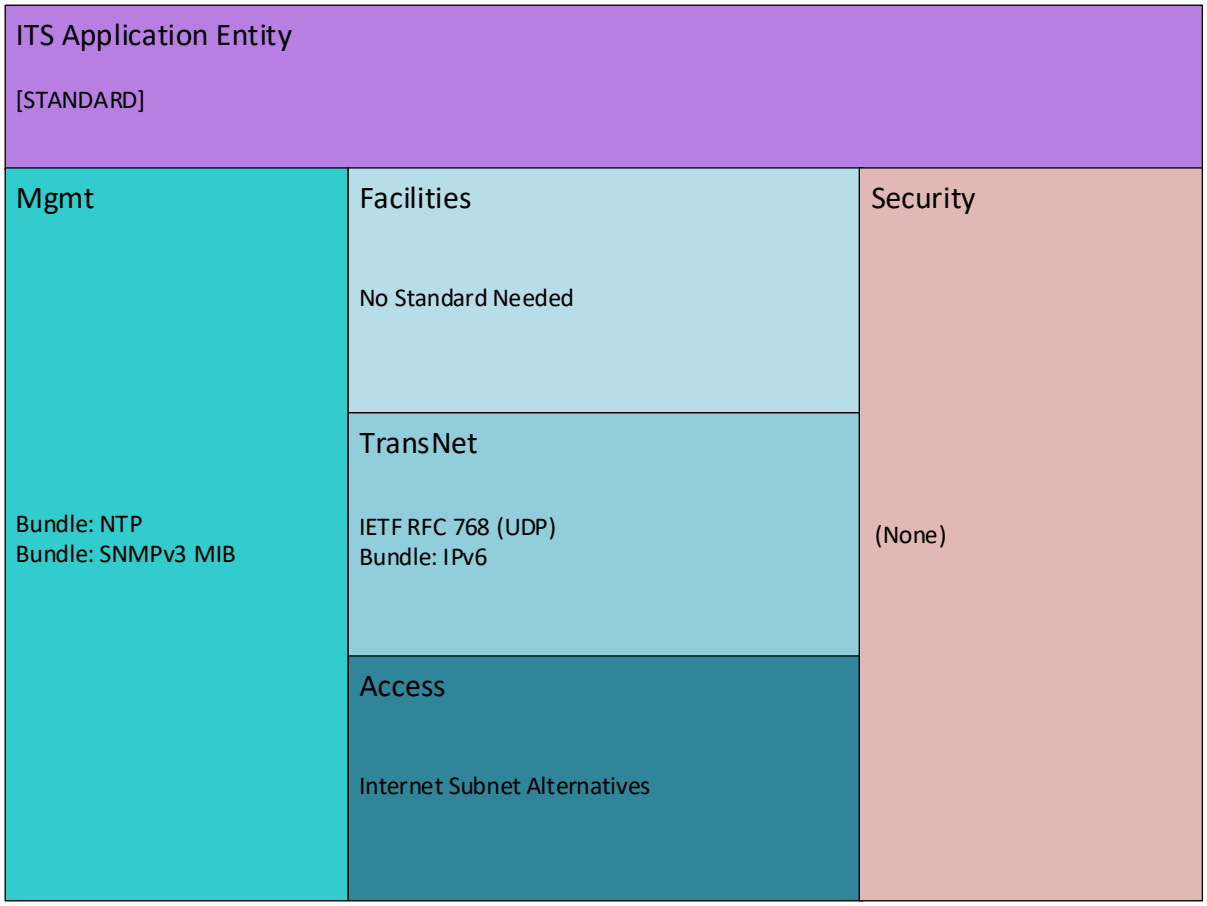


Figure 34: Time

Source: City of Columbus

Table 54: Time

Name	Source	Destination	Standard	Profile
time	Network Time Source	Traffic CV Management System	NTP	Time

Source: City of Columbus

2.3.9.1.11. Vehicle-Onboard

Table 55: Vehicle-Onboard

Name	Source	Destination	Standard	Profile
host emergency vehicle status	EV System	Emergency Vehicle OBE	(Unspecified)	Vehicle-OnBoard
host vehicle status	HDV System	Heavy Duty Vehicle OBE	(Unspecified)	Vehicle-OnBoard
host vehicle status	TrV System	Transit Vehicle OBE	(Unspecified)	Vehicle-OnBoard
host vehicle status	Vehicle System	Vehicle OBE	(Unspecified)	Vehicle-OnBoard

Source: City of Columbus

2.3.9.1.12. Wi-Fi

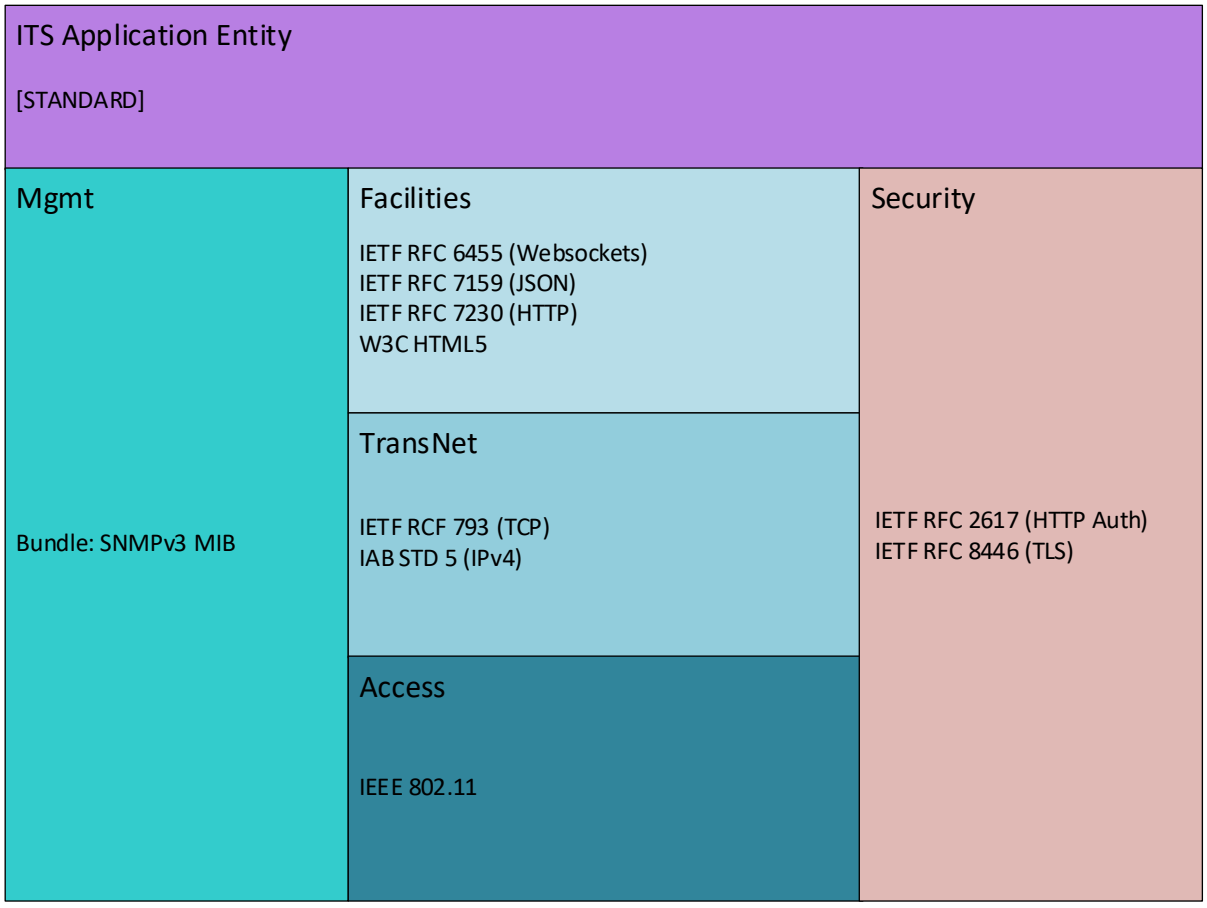


Figure 35: Wi-Fi

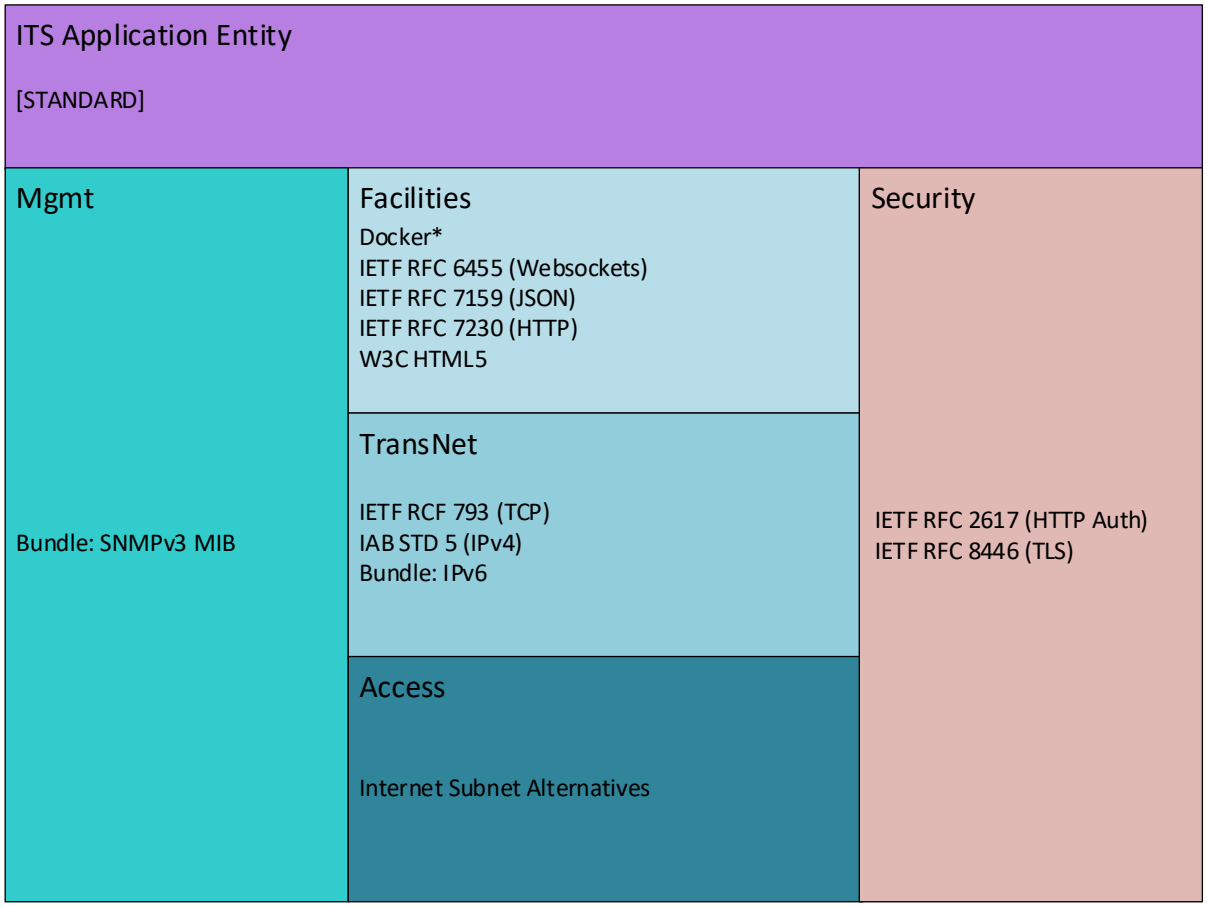
Source: City of Columbus

Table 56: Wi-Fi

Name	Source	Destination	Standard	Profile
vehicle situation data	Transit Vehicle OBE	Traffic CV Management System	(Unspecified)	Wi-Fi

Source: City of Columbus

2.3.9.1.13. World Wide Web Browser/JSON/Wide Area Wireless



** Non-standard protocol*

Note: Traffic CV Management System supports both IPv4 and IPv6.

Figure 36: World Wide Web Browser/JSON/Wide Area Wireless

Source: City of Columbus

Table 57: World Wide Web Browser/JSON/Wide Area Wireless

Name	Source	Destination	Standard	Profile
Data Archive Coordination	Traffic CV Management System	Smart Columbus Operating System	(Unspecified)	WAW-WWWBrowser-JSON

Name	Source	Destination	Standard	Profile
Data Archive Coordination	Traffic CV Management System	Smart Columbus Operating System	(Unspecified)	WAW-WWWBrowser-JSON
OBE status	Vehicle OBE	Vehicle Service Center	(Unspecified)	WAW-WWWBrowser-JSON
road network conditions	Traffic CV Management System	Smart Columbus Operating System	(Unspecified)	WAW-WWWBrowser-JSON
RSE fault data	Traffic CV Management System	Traffic Management Center	(Unspecified)	WAW-WWWBrowser-JSON
vehicle commands	Vehicle Service Center	Vehicle OBE	(Unspecified)	WAW-WWWBrowser-JSON
vehicle configuration settings	Vehicle Service Center	Vehicle OBE	(Unspecified)	WAW-WWWBrowser-JSON
vehicle service information	Vehicle Service Center	Vehicle OBE	(Unspecified)	WAW-WWWBrowser-JSON
vehicle service request	Vehicle OBE	Vehicle Service Center	(Unspecified)	WAW-WWWBrowser-JSON
vehicle service response	Vehicle Service Center	Vehicle OBE	(Unspecified)	WAW-WWWBrowser-JSON
vehicle situation data parameters	Vehicle Service Center	Transit Vehicle OBE	(Unspecified)	WAW-WWWBrowser-JSON
vehicle software install/upgrade	Vehicle Service Center	Vehicle OBE	(Unspecified)	WAW-WWWBrowser-JSON

Source: City of Columbus

2.3.9.1.14. Human Interface

Table 58: Human Interface

Name	Source	Destination	Standard	Profile
Device Credentials	TCVMS Staff	OBE	(Unspecified)	Human Interface
Device Credentials	TCVMS Staff	RSE	(Unspecified)	Human Interface

Name	Source	Destination	Standard	Profile
equipment status presentation	Field Maintenance Equipment	Maintenance Field Personnel	(Unspecified)	Human Interface
field personnel equipment input	Maintenance Field Personnel	Field Maintenance Equipment	(Unspecified)	Human Interface
LDV Driver Updates	Vehicle OBE	Vehicle Operator	(Unspecified)	Human Interface
request for service	Vehicle Operator	Vehicle OBE	(Unspecified)	Human Interface
traffic operator data	Traffic CV Management System	TCVMS Staff	(Unspecified)	Human Interface
traffic operator input	TCVMS Staff	Traffic CV Management System	(Unspecified)	Human Interface
driver information	Traffic Signal Controller	Vehicle Operator	(Unspecified)	Human Interface
transit operations personnel input	TrCVMS Staff	Transit CV Management System	(Unspecified)	Human Interface
transit operations status	Transit CV Management System	TrCVMS Staff	(Unspecified)	Human Interface

Source: City of Columbus

2.3.10. Functional View

The Functional Architecture View depicts each element of overall system and the logical interfaces among them. **Table 59** lists draft processes that developed based on discussion with the project team. These processes will be further refined and defined in detail during the design phase of the project.

Table 59: Connected Vehicle Environment Functional Architecture View

Physical Object	Functional Object	Process
Emergency Vehicle OBE	Emergency Vehicle (EV) On-board En Route Support	Provide Emergency Vehicle Location Provide Emergency Personnel Interface Process Mobile Emergency Requests
	Vehicle Location Determination	Process Vehicle Location Data Update Vehicle Navigable Map Database
Field Maintenance Equipment	FME On-Site Maintenance	Provide Field Equipment Maintenance

Physical Object	Functional Object	Process
Heavy Duty Vehicle OBE	CV On-board Signal Priority	Collect Onboard Commercial Vehicle Sensor Data Communicate Commercial Vehicle Onboard Data to Vehicle Manager
	Vehicle Location Determination	Process Vehicle Location Data Update Vehicle Navigable Map Database
RSE	ITS Management Support	Support ITS Object Management
	ITS Security Support	Support ITS Object Security
Security and Credential Management System	RSE Device Management	Process Vehicle Safety and Environmental Data for Output Manage CV Field Applications Control RSE Collect CV Field Equipment Status
	RSE Intersection Management	Collect Vehicle Roadside Safety Data Process Collected Vehicle Safety Data Manage Local Signal Priority Requests Process Intersection Safety Data Manage Local Signal Preemption Requests
	RSE Intersection Safety	Collect Vehicle Roadside Safety Data Process Collected Vehicle Safety Data Process Intersection Safety Data
Traffic CV Management System	RSE Map Management	Process Collected Vehicle Safety Data Process Vehicle Safety and Environmental Data for Output
	RSE Position Correction Support	Process Vehicle Safety and Environmental Data for Output
	RSE Situation Monitoring	Collect Vehicle Roadside Safety Data Collect CV Field Equipment Status
	RSE Speed Warning	Collect Vehicle Roadside Safety Data Process Collected Vehicle Safety Data Provide Short Range Traveler Information Collect CV Field Equipment Status
	RSE Support Services	Provide Field Data Sharing Services
Security and Credential Management System	CCMS Authorization	Authorize CV Devices
	CCMS Enrollment	Manage Enrollment of CV Devices
	CCMS Misbehavior Reporting and Action	Identify Misbehaving CV Devices
	CCMS Provisioning	Provision CV Devices
	CCMS Revocation	Revoke CV Device Credentials

Physical Object	Functional Object	Process
Traffic CV Management System	Center Connected Vehicle Infrastructure Management	Monitor RSE Fault Data Manage CV Applications
	Map Management	Collect Geographic Data for Transportation Maintain Geographic Information System for Transportation Distribute Map Updates Coordinate with Other Map Update Systems
	Signal Priority Authorization	Verify Vehicle Security Credentials
	SM Device Management	Provide Device Support Services Operator Interface Monitor System Activities
	TMC Data Collection	Manage Traffic Archive Data
	TMC Intersection Safety	Process Traffic Data Provide Traffic Operations Personnel Traffic Data Interface Determine Indicator State for Road Management Output Control Data for Roads Manage Roadway Warning System Collect Traffic Field Equipment Fault Data
	TMC Situation Data Management	Process Vehicle Situation Data
	TMC Speed Warning	Process Vehicle Situation Data Output Roadway Information Data Maintain Traffic and Sensor Static Data Provide Static Data Store Output Interface Collect Traffic Field Equipment Fault Data Manage Vehicle Speed on Roadway
Traffic Signal Controller	Roadway Signal Control	Process Traffic Sensor Data Process Indicator Output Data for Roads Provide Device Interface for Field Management Stations Process Signal Control Conflict Monitoring Monitor Roadside Equipment Operation
Traffic CV Management System	Center Data Collection	Data Distribution Performance Monitoring
Transit Vehicle OBE	Transit Vehicle Signal Priority	Process Onboard Systems Data Provide Transit Vehicle Location Data

Physical Object	Functional Object	Process
	Vehicle Basic Safety Monitoring	Produce Collision and Crash Avoidance Data Process Vehicle Onboard Data Communicate with Remote Vehicles Provide Vehicle Acceleration and Deceleration Inputs Process Vehicle Sensor Data Provide Driver Guidance Interface Process Vehicle Location Data Update Vehicle Navigable Map Database Provide Driver Information Interface
	Vehicle Location Determination	Process Vehicle Location Data Update Vehicle Navigable Map Database
	Vehicle Situation Data Monitoring	Process Vehicle Onboard Data
Vehicle OBE	ITS Management Support	Support ITS Object Management
	ITS Security Support	Provide Object Misbehavior Detection Support ITS Object Security
	Vehicle Basic Safety Communication	Produce Collision and Crash Avoidance Data Process Vehicle Onboard Data Communicate with Remote Vehicles Provide Vehicle Acceleration and Deceleration Inputs Process Vehicle Sensor Data Provide Driver Guidance Interface Process Vehicle Location Data Update Vehicle Navigable Map Database Provide Driver Information Interface

Physical Object	Functional Object	Process
	Vehicle Intersection Warning	Produce Collision and Crash Avoidance Data Carry-out Safety Analysis Process Vehicle Onboard Data Communicate with Remote Vehicles Provide Vehicle Acceleration and Deceleration Inputs Provide Driver Interface Provide Command Interface Process Vehicle Sensor Data Build Automatic Collision Notification Message Provide Driver Guidance Interface Process Vehicle Location Data Update Vehicle Navigable Map Database
	Vehicle Location Determination	Process Vehicle Location Data Update Vehicle Navigable Map Database
	Vehicle Map Management	Update Vehicle Navigable Map Database
	Vehicle Situation Data Monitoring	Process Vehicle Onboard Data
	Vehicle Speed Management Assist	Process Vehicle Onboard Data Process Vehicle Location Data Update Vehicle Navigable Map Database Provide Driver Information Interface
	Vehicle System Executive	Process Vehicle Onboard Data Manage Vehicle Onboard Systems
	Vehicle System Monitoring and Diagnostics	Process Vehicle Onboard Data Monitor Vehicle Onboard Diagnostics
Existing Functions		
Traffic Management Center	TMC Signal Control	Process Traffic Data Process Vehicle Situation Data Retrieve Traffic Data Manage Traffic Archive Data Exchange Data with Other Traffic Centers Select Strategy Determine Indicator State for Road Management Output Control Data for Roads Maintain Traffic and Sensor Static Data Collect Traffic Field Equipment Fault Data

Source: City of Columbus

2.4. PROJECT 3: MULTIMODAL TRIP PLANNING APPLICATION

2.4.1. Introduction

Columbus residents and visitors do not have access to a system that allows for the seamless planning of or paying for a trip involving multiple transportation service providers.

The MMTPA, known as Pivot, will make multimodal options easily accessible to all by providing a robust set of transit and alternative transportation options, including routes, schedules, and dispatching possibilities. The application will allow travelers to request and view multiple trip itineraries, and make reservations for shared-use transportation options such as bikeshare, scooter-share, ride-hailing, and car-share. Using the MMTPA, users will be able to compare travel options across modes and plan and pay for their travel based upon current traffic conditions and availability of services.

The City of Columbus identified the following objectives to evaluate the measurable impact the MMTPA project is intended to have:

- Facilitate improved access to multimodal trip planning information
- Increase usage of the available transportation services
- Improve ease of multimodal trip planning
- Provide travelers with more convenient access to transportation service options
- Increase access to jobs and services
- Increase customer satisfaction

2.4.2. System of Interest

The MMPTA project identified the following User Needs in MMTPA ConOps:

- Real-Time Travel Information
- Personal Devices
- Compare Trip Itineraries
- User Preferences
- Accept Bookings/Reservations
- Notifications and Alerts
- Trip History
- Trip Changes
- Graphical User Interface
- User Feedback
- Offline Usage
- Request Accessible Vehicles
- Traveler Web Portal
- Access to Trip and Payment Data
- Receive Real-Time Traveler Information

- Same-Day Paratransit Service

User needs may be reflected in the architecture or Operations and Maintenance plan. Through testing and development, some User Needs identified in the ConOps were considered obsolete and are not included above.

MMTPA is an app-based solution for providing multimodal trip planning. MMTPA will improve mobility for all travelers by providing access to different modes of transportation, such as scooter-sharing, options for door-to-door service, and personalized trip itineraries.

MMPTA will provide on-demand services for paratransit, reduce current paratransit costs, improve ridership, and work together with fixed-route to provide multimodal door-to-door service.

Travelers will also be able to access MMTPA from the SMH. Further discussion on the Wi-Fi interface between the Interactive Kiosk and the PWD for trip planning can be found in the SMH project architecture.

MMTPA will interface with Mobility Provider Central System (MPCS) to provide the services.

2.4.3. Physical Architecture View

The MMTPA project includes a single customized Service Package from the USDOT ARC-IT – Infrastructure Provided Trip Planning and Route Guidance. This Service Package provides the user trip planning and en route guidance services. The MMTPA will provide TIC services such as TIC Trip Planning and TIC Data Collection.

Figure 37 shows Layer 2 Physical Architecture View for the MMTPA project. Layer 2 view shows all the Elements, their associated Functional Objects, and the Information Flow between the elements. The description of the Elements, Functional Objects, and the Information Flow among the elements are shown in the following tables. Since there is only a single Service Package, only a Layer 2 diagram is shown.

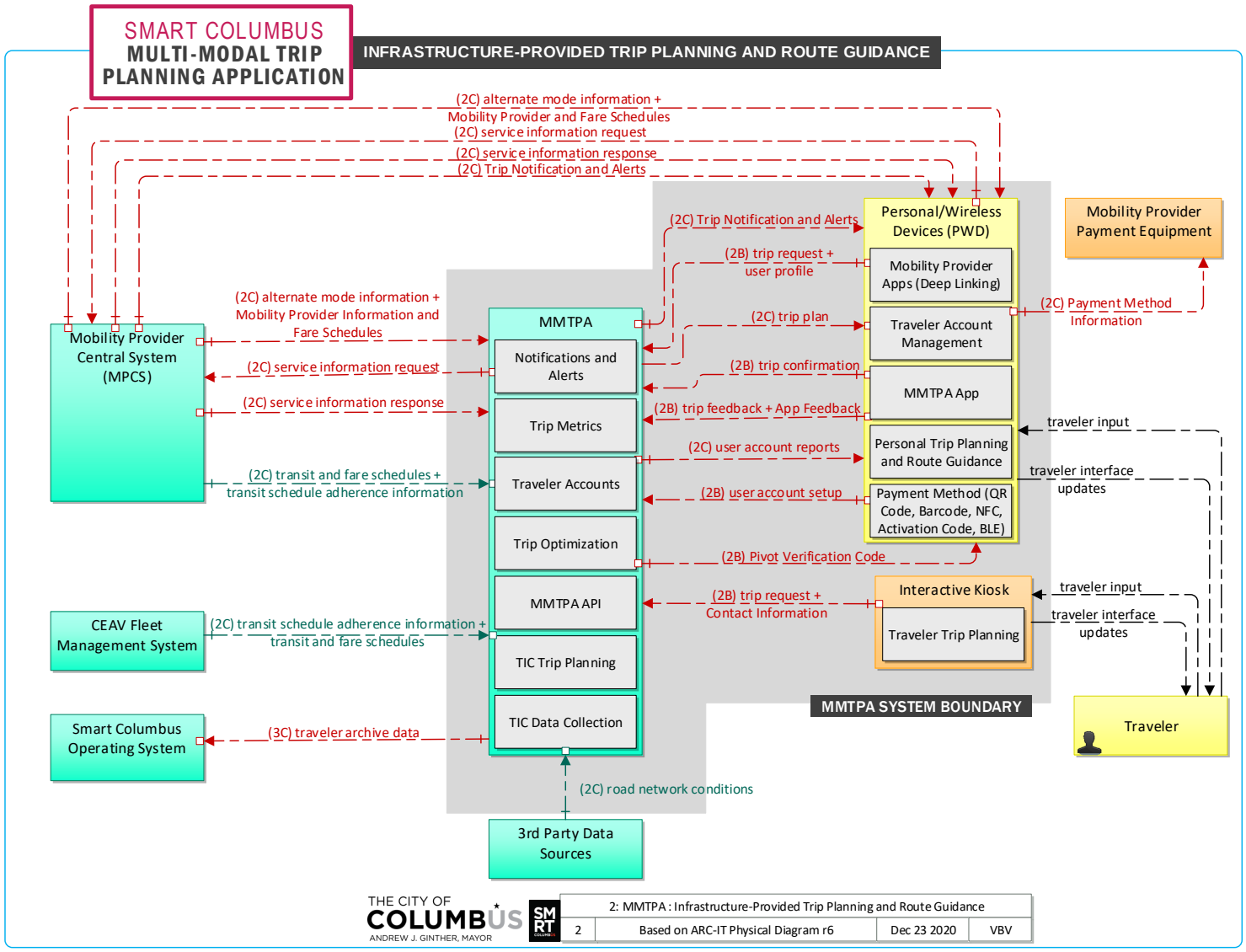


Figure 37: Multimodal Trip Planning Application Physical Architecture View

Source: City of Columbus

Table 60: Multimodal Trip Planning Application Physical Elements

Physical Object	Class	Description
3rd Party Data Sources	Center	The 3rd Party Data Sources provide additional data. For example, traffic and parking information providers and Experience Columbus.
CEAV Fleet Management System	Center	The CEAV Fleet Management System represents the system that manages CEAV including providing guidance/suggestion for onboard operator, and/or vehicle system to make decisions locally to maintain schedule, and/or even headways, or navigate around an unexpected situation.
Interactive Kiosk	Field	The Interactive Kiosk provides access to traveler information at SMH facilities, generally co-located with transit stations, transit stops, and major trip generation locations. The IK traveler information access points support varied levels of interaction and information access, comprehensive trip planning through MMTPA, traffic conditions, and transit schedules to support mode and route selection. Personalized route planning and route guidance information can also be sent via email or SMS text to travelers based on supplied criteria. In addition to the traveler information, the IK also provides Wi-Fi Internet access as well as enhances security in public areas by supporting traveler activated emergency call button (ECB) alarms.
MMTPA	Center	The MMTPA is an app available to travelers on both iOS and Android devices as well as a web-based platform. MMTPA accesses mobility provider service options from multiple Mobility Providers via APIs. The project will allow travelers to create multimodal trips and pay each mobility provider. Multimodal trip options include walking, fixed-route bus service, ride-hailing, bike-sharing, paratransit, and scooter services.
Mobility Provider Central System (MPCS)	Center	The Mobility Provider Central Systems (MPCS) are owned by companies that provide transportation services to travelers. These companies provide vehicle route, location, schedule, availability, and fare data to the System through integration with the MMTPA. Mobility Providers have the responsibility of access control on their vehicles and services. Mobility Providers include transportation network companies, car-sharing, bike-sharing, taxi/limo, and COTA.
Mobility Provider Payment Equipment	Field	The Mobility Provider Payment Equipment represents field equipment (such as readers) for mobility and Parking Providers.
Personal/Wireless Devices (PWD)	Traveler	Personal/Wireless Devices (PWD), including smartphones and computers, provide the capability for travelers to receive formatted traveler information wherever they are. This also includes the capability of the device to call others (call center) to accomplish the tasks. Capabilities include traveler information, trip planning, and route guidance (even when offline). These devices provide travelers with the capability to receive route planning and other personally focused transportation services from the infrastructure in the field, at home, at work, or while en route. These devices may also double up as a 'Payment Device', which enables the electronic transfer of funds from the user of a service (i.e. a traveler) through smart cards or credit cards to the provider of the service.

Physical Object	Class	Description
Smart Columbus Operating System	Center	The Smart Columbus Operating System covers the ingestion and organization of information stored in the Smart Columbus Operating System. The ingestion process is initiated by the Data Curator using a web interface to define and manage the data feeds.
Traveler	Traveler	The Traveler represents any individual who uses transportation services. The interfaces to the traveler provide general pre-trip and en route information supporting trip planning and personal guidance.

Source: City of Columbus

Table 61: Multimodal Trip Planning Application Information Flows

Information Flow	Description
alternate mode information	Schedule information for alternate mode transportation providers such as air, ferry, and passenger-carrying heavy rail. For this project, alternate mode includes ride-hailing, bike-sharing, and scooter-sharing, but does not include air, ferry, or heavy rail.
App Feedback	Feedback provided by the user after the use of the MMTPA.
Contact Information	Contact Information may be a phone number or email address.
Mobility Provider Information and Fare Schedules	Provide traveler with fare schedules for different multimodal options generated for the route.
Payment Method Information	Provide Quick Response (QR) code, bar code, Near-Field Communication (NFC), Bluetooth Low Energy (BLE), or activation code to use at the payment readers.
Pivot Verification Code	Verification code to verify account ownership.
road network conditions	Current and forecasted traffic information, road and weather conditions, and other road network status. Either raw data, processed data, or some combination of both may be provided by this flow. Information on diversions and alternate routes, closures, and special traffic restrictions (lane/shoulder use, weight restrictions, width restrictions, High-Occupancy Vehicle (HOV) requirements) in effect is included. For this project, HOV requirements are not applicable.
service information request	Request to multimodal (possibly non-roadway) transit provider for general services information and specific trip information or reservation. For this project, the information flow also includes coordination for carpool services.
service information response	Multimodal (possibly non-roadway) transit provider services information and trip reservation confirmations.
transit and fare schedules	Transit service information including routes, schedules, and fare information.
transit schedule adherence information	Dynamic transit schedule adherence and transit vehicle location information.
transit trip plan	An origin-destination transit trip that may involve multiple modes and connections.

Information Flow	Description
transit trip request	Request for a transit trip plan that is responsive to traveler requirements such as schedule, cost, or duration.
traveler archive data	Data associated with traveler information services including service requests, facility usage, rideshare, routing, and traveler payment transaction data. Content may include a catalog of available information, the actual information to be archived, and associated meta data that describes the archived information.
traveler input	User input from a traveler to summon assistance, request travel information, make a reservation, or request any other traveler service.
traveler interface updates	Visual or audio information (e.g., routes, messages, guidance, emergency information) that is provided to the traveler.
trip confirmation	Acknowledgement by the driver/traveler of acceptance of a trip plan with associated personal and payment information required to confirm reservations.
trip feedback	Information provided at the conclusion of a trip that supports performance monitoring and system optimization. Information provided may include a record of the trip, including HOV/High-Occupancy Toll Lane (HOT) lane usage, and user provided feedback at the conclusion of the trip. For this project, HOV/HOT lane usage is not applicable.
Trip Notification and Alerts	Traveler is provided with trip notification and alerts for the trip planned.
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 and parking reservation information.
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.
user account reports	Reports on services offered/provided and associated charges. For this project, user account reports also includes trip metrics.
user account setup	Billing information, vehicle information (or registration information), and requests for reports. For this project, set-up an account and provide security credentials, traveler account information, additions, deletions, modifications, and payment methods.
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.

Source: City of Columbus

Table 62: Multimodal Trip Planning Application Functional Objects

Physical Object	Functional Object	Description
MMTPA	MMTPA API	Provides a set of routines, protocols, and tools for interacting with MMTPA.
	Notifications and Alerts	Provides MMTPA related nofications and alerts to the Traveler to the traveler.
	Traveler Accounts	Each traveler creates a traveler account to take trips. Traveler accounts store personal information, alerts settings, and they can allow users to query and view individual trips.
	Trip Metrics	Provides the user with trip metrics including how many gallons of gas were saved, exercise, miles traveled, and more. Trip metrics are updated every 24 hours.
	Trip Optimization	Provides optimized route based on real-time road conditions and user parameters.
	TIC Data Collection	TIC Data Collection collects transportation-related data from other centers, performs data quality checks on the collected 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 are collected including traffic and road conditions, transit data, emergency information and advisories, weather data, special event information, traveler services, parking, multimodal data, and toll/pricing data. It also shares data with other transportation information centers. For this project, TIC Data Collection also sends trip and usage data to the Smart Columbus Operating System for data archival. It also supports trip optimization. Toll/pricing is not applicable for this project.
	TIC Trip Planning	TIC Trip Planning provides pre-trip and en route trip planning services for travelers. It receives origin, destination, constraints, preferences, and returns trip plan(s) that meet the supplied criteria. Trip plans may be based on current traffic and road conditions, transit 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, ferry, bicycle routes, and walkways) based on traveler preferences. It also confirms the trip for the traveler, supports reservations, and supports advanced payment for portions of the trip. The trip plan includes specific routing information and instructions for each segment of the trip, and may also include information and reservations for additional services (e.g., parking) along the route.
Personal/Wireless Devices (PWD)	MMTPA App	Provide access to MMTPA app.
	Mobility Provider Apps (Deep Linking)	Provide access to mobility provider apps. Deep linking enables the MMPTA app to lauch functionality in the mobility provider apps, including the ability to plan trips.

Physical Object	Functional Object	Description
	Payment Method (QR Code, Barcode, NFC, Activation Code, BLE)	Includes QR code, bar code, or activation code generated by the MMTPA and transmitted to the PWD.
	Personal Trip Planning and Route Guidance	Personal Trip Planning and Route Guidance provides a personalized trip plan to the traveler. The trip plan is calculated based on preferences and constraints supplied by the traveler, and provided to the traveler for confirmation. Coordination may continue during the trip so that the route plan can be modified to account for new information. Many equipment configurations are possible, including systems that provide a basic trip plan to the traveler as well as more sophisticated systems that can provide transition by transition guidance to the traveler along a multimodal route with transfers. Devices represented by this Functional Object include desktop computers at home, work, or at major trip generation sites, plus personal devices such as tablets and smartphones.
	Traveler Account Management	Provides interfaces designed to manage accounts, including updating personal information, alerts, and other settings.
Interactive Kiosk	Traveler Trip Planning	Traveler Trip Planning provides a personalized trip plan to the traveler. The trip plan is calculated based on preferences and constraints supplied by the traveler, and provided to the traveler for confirmation. It represents kiosks and other fixed public interactive displays that may be used by travelers in public areas.

Source: City of Columbus

2.4.4. Enterprise Architecture View

The following diagram shows the relationships between Smart Columbus stakeholders, the roles organizations play within the project, and the agreements among the stakeholders. The table provides the list of agreements and expectations and their descriptions.

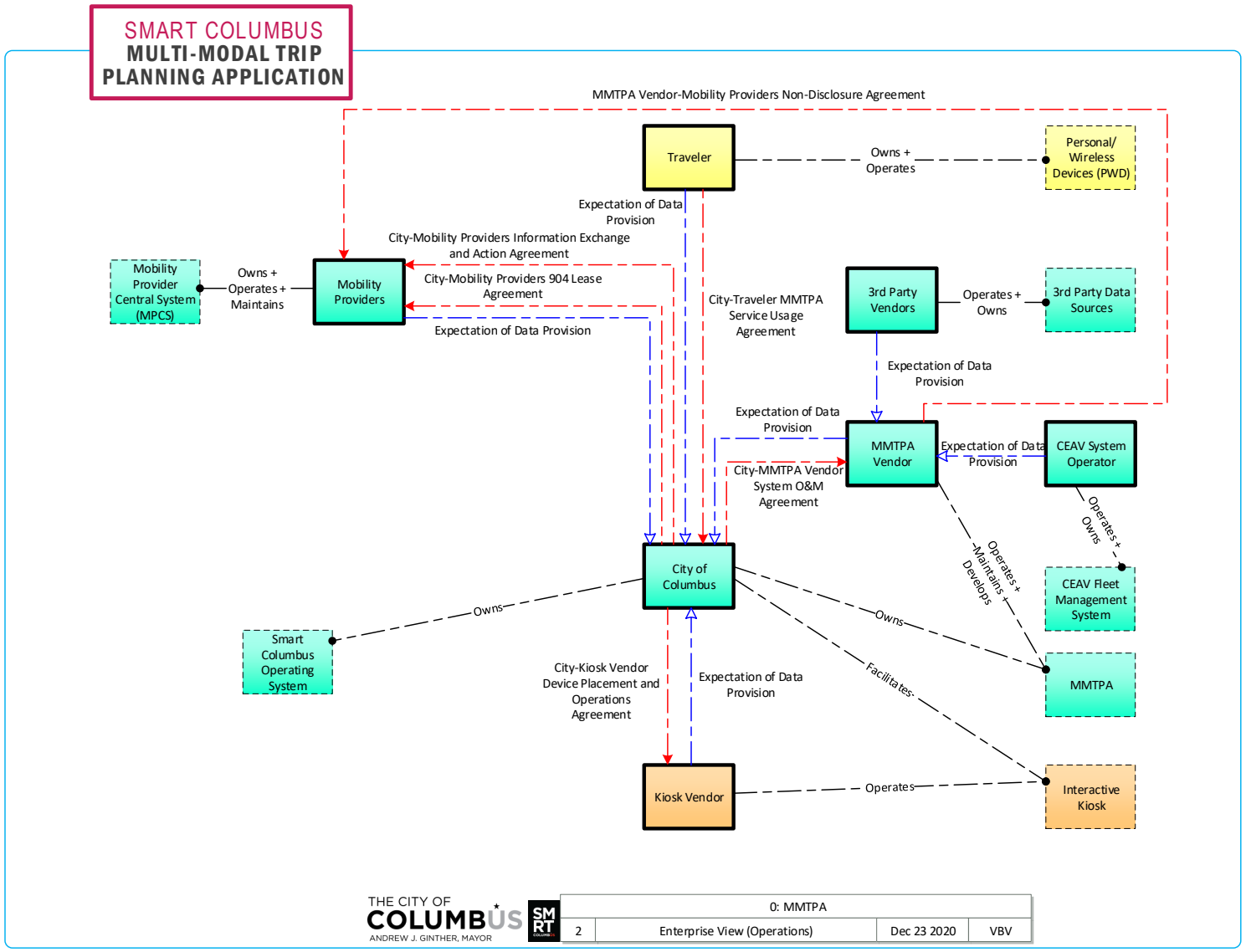


Figure 38: Multimodal Trip Planning Application Enterprise Architecture View

Source: City of Columbus

Table 63: Multimodal Trip Planning Application List of Agreements

Potential Agreement	Description
City-Kiosk Vendor Device Placement and Operations Agreement	An agreement between the City and the Kiosk Vendor to allow the installation and placement of interactive kiosks within City right-of-way. As part of the agreement, the Kiosk Vendor will allow the MMTPA app to be installed on the Interactive Kiosks. Vendor: IKE Smart City, LLC Status: Existing
City-MMTPA Vendor System O&M Agreement	An agreement for the MMTPA vendor to operate and maintain the MMTPA system on behalf of the City with ownership control of the system. Vendor: MTECH (dba Etch) Status: Existing
City-Mobility Providers Information Exchange and Action Agreement	This is an Information Exchange and Action Agreement between the City and Mobility Providers to participate in the MMTPA project. Vendors: Yellow Cab, CoGo Bikeshare, Gohio Status: Various stages of Existing and Planned
City-Mobility Providers 904 Lease Agreement	An agreement between the City and Mobility Providers to allow the installation and placement of shared mobility devices within City right-of-way. Vendors: Lime, Bird, Spin, LINK Status: Existing
City-Traveler MMTPA Service Usage Agreement	An agreement between the City and the Traveler to use MMTPA system. Stipulates the terms and conditions of service usage. Status: Existing
MMTPA Vendor-Mobility Providers Non-Disclosure Agreement	An agreement between the MMTPA Vendor and Mobility Providers where the MMTPA Vendor agrees not to disclose confidential information that was shared by the Mobility Providers. Status: Existing

Source: City of Columbus

2.4.4.1. ROLES AND RESPONSIBILITIES

Development:

- Smart Columbus PMO – concept and requirements development
  - HNTB (contract)
  - Etch (contract) – software development:
    - Etch GIS (subcontractor to Etch)
  - Smart Columbus Projects:
    - SMH: Kiosk requirements
    - OS: data integration
    - CEAV: schedule information integration
  - Mobility Providers: agreements to support integration into the application

- Data providers

Installation:

- Smart Columbus PMO:
  - HNTB (contract) – validation of requirements
  - Etch (contract) – software implementation
    - Etch GIS (subcontractor)
  - Smart Columbus Projects:
    - SMH: Kiosk requirements, loading of application onto kiosks
    - OS: data integration
  - Mobility Providers: agreements to support integration into the application
  - Data providers

Testing:

- Smart Columbus PMO – Test Lead
  - HNTB (contract) – test plan development
  - Michael Baker, Intl. – lead tester
  - Etch (contract) – software development
    - Etch GIS (subcontractor)
  - Smart Columbus Projects:
    - SMH: Kiosk requirements; coordination of SMH kiosks test cases
    - OS: data integration; validation of data exchange (test participant)

Operations:

- Smart Columbus PMO:
  - HNTB (contract) – O&M plan development
  - Etch (contract) – O&M plan development
    - Etch GIS (subcontractor)
  - Smart Columbus Projects:
    - OS: data integration
  - Mobility Providers: agreements to support integration into the application (will continue into operational period if new providers are interested in joining)
  - Data providers – agreements to support integration into the application (will continue into operational period if new providers are interested in joining)

Maintenance:

- Smart Columbus PMO:
  - Etch (contract) – Bug fixes and enhancements, performance reporting
    - Etch GIS (subcontractor)
  - Smart Columbus Projects:

- OS: data integration, trip optimization; bug fixes and enhancements with relevant components

2.4.5. Communications Architecture View

2.4.5.1. COMMUNICATION PROFILES USED

The following table describes the layered sets of communications protocols that are required to support communications among the elements that make up the MMTPA project.

2.4.5.1.1. World Wide Web Browser/JSON/Wide Area Wireless

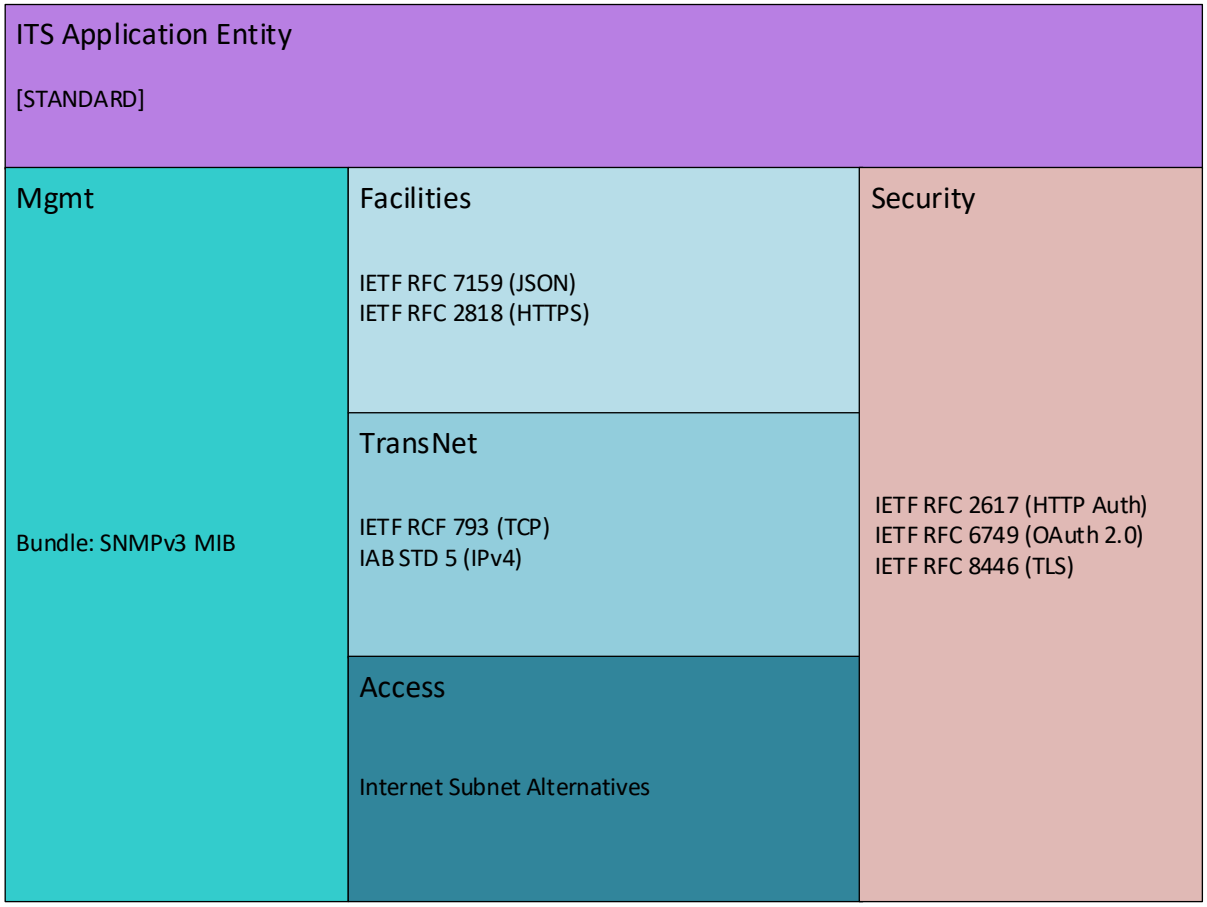


Figure 39: World Wide Web Browser/JSON/Wide Area Wireless

Source: City of Columbus

Table 64: World Wide Web Browser/JSON/Wide Area Wireless

Name	Source	Destination	Standard	Profile
alternate mode information	Mobility Provider Central System (MPCS)	MMTPA	(Unspecified)	WAW-WWWBrowser-JSON

Name	Source	Destination	Standard	Profile
alternate mode information	Mobility Provider Central System (MPCS)	Personal/Wireless Devices (PWD)	(Unspecified)	WAW-WWWBrowser-JSON
App Feedback	Personal/Wireless Devices (PWD)	MMTPA	(Unspecified)	WAW-WWWBrowser-JSON
Contact Information	Interactive Kiosk	MMTPA	(Unspecified)	WAW-WWWBrowser-JSON
Mobility Provider Information and Fare Schedules	Mobility Provider Central System (MPCS)	MMTPA	(Unspecified)	WAW-WWWBrowser-JSON
Mobility Provider Information and Fare Schedules	Mobility Provider Central System (MPCS)	Personal/Wireless Devices (PWD)	(Unspecified)	WAW-WWWBrowser-JSON
Payment Method Information	Personal/Wireless Devices (PWD)	Mobility Provider Payment Equipment	(Unspecified)	WAW-WWWBrowser-JSON
Pivot Verification Code	MMTPA	Personal/Wireless Devices (PWD)	(Unspecified)	WAW-WWWBrowser-JSON
road network conditions	3rd Party Data Sources	MMTPA	(Unspecified)	WAW-WWWBrowser-JSON
service information request	MMTPA	Mobility Provider Central System (MPCS)	(Unspecified)	WAW-WWWBrowser-JSON
service information request	Personal/Wireless Devices (PWD)	Mobility Provider Central System (MPCS)	(Unspecified)	WAW-WWWBrowser-JSON
service information response	Mobility Provider Central System (MPCS)	MMTPA	(Unspecified)	WAW-WWWBrowser-JSON
service information response	Mobility Provider Central System (MPCS)	Personal/Wireless Devices (PWD)	(Unspecified)	WAW-WWWBrowser-JSON
transit and fare schedules	CEAV Fleet Management System	MMTPA	GTFS	WAW-WWWBrowser-JSON
transit schedule adherence information	CEAV Fleet Management System	MMTPA	GTFS-Real Time	WAW-WWWBrowser-JSON
transit schedule adherence information	Mobility Provider Central System (MPCS)	MMTPA	GTFS-Real Time	WAW-WWWBrowser-JSON

Name	Source	Destination	Standard	Profile
transit trip plan	Mobility Provider Central System (MPCS)	MMTPA	(Unspecified)	WAW-WWWBrowser-JSON
traveler archive data	MMTPA	Smart Columbus Operating System	(Unspecified)	WAW-WWWBrowser-JSON
trip confirmation	Personal/Wireless Devices (PWD)	MMTPA	(Unspecified)	WAW-WWWBrowser-JSON
trip feedback	Personal/Wireless Devices (PWD)	MMTPA	(Unspecified)	WAW-WWWBrowser-JSON
Trip Notification and Alerts	Mobility Provider Central System (MPCS)	Personal/Wireless Devices (PWD)	(Unspecified)	WAW-WWWBrowser-JSON
Trip Notification and Alerts	MMTPA	Personal/Wireless Devices (PWD)	(Unspecified)	WAW-WWWBrowser-JSON
trip plan	MMTPA	Personal/Wireless Devices (PWD)	(Unspecified)	WAW-WWWBrowser-JSON
trip request	Personal/Wireless Devices (PWD)	MMTPA	(Unspecified)	WAW-WWWBrowser-JSON
trip request	Interactive Kiosk	MMTPA	(Unspecified)	WAW-WWWBrowser-JSON
user account reports	MMTPA	Personal/Wireless Devices (PWD)	(Unspecified)	WAW-WWWBrowser-JSON
user account setup	Personal/Wireless Devices (PWD)	MMTPA	(Unspecified)	WAW-WWWBrowser-JSON
user profile	Personal/Wireless Devices (PWD)	MMTPA	(Unspecified)	WAW-WWWBrowser-JSON

Source: City of Columbus

2.4.5.1.2. Human Interface

Table 65: Human Interface

Name	Source	Destination	Standard	Profile
traveler input	Traveler	Interactive Kiosk	(Unspecified)	Human Interface
traveler input	Traveler	Personal/Wireless Devices (PWD)	(Unspecified)	Human Interface
traveler interface updates	Interactive Kiosk	Traveler	(Unspecified)	Human Interface
traveler interface updates	Personal/Wireless Devices (PWD)	Traveler	(Unspecified)	Human Interface

Source: City of Columbus

2.4.6. Functional View

The Functional Architecture View depicts each element of overall system and the logical interfaces among them. The listed draft processes are developed based on discussion with the project team. These processes will be further refined and defined in detail during the design phase of the project.

Table 66: Multimodal Trip Planning Application Functional Architecture View

Physical Object	Functional Object	Process
MMTPA	MMTPA API	Receive Requests and Send Responses
	Notifications and Alerts	Process Traveler Payment Requests Provide Traveler Payment Status
	Traveler Accounts	Provide Traveler Interface Input Account Information Input Payment Information
	Trip Metrics	Provide Traveler Trip Metrics Calculate Trip Metrics
	TIC Data Collection	Collect Misc. Traveler Information Collect Transit Operations Data Collect Multimodal Data Process and Send Data (to Smart Columbus Operating System)
	TIC Trip Planning	Provide Interface for IK Provide Interface for Mobility Providers Provide Interface for COTA Back Office Provide Trip Planning Information to Traveler Confirm Traveler's Trip Plan Provide Operator Interface for Trip Planning Parameters Manage Traveler Profiles Process Travel Services Provider Data Provide Traveler Alert Interface Provide Vehicle Route Calculation Data Provide Operator Interface for Route Parameters Manage Trip History Collect Feedback
	Trip Optimization	Provide Multimodal Route Selection Collect Traffic Data Calculate Vehicle Route Select Transit Route Select Other Routes Provide traveler with optimized trip route
	MMTPA App	Provide Interface for Traveler

Physical Object	Functional Object	Process
Personal/Wireless Devices (PWD)	Mobility Provider Apps (Deep Linking)	Provide Traveler Interface Manage Traveler Payment Request
	Payment Method (QR Code, Barcode, NFC, Activation Code, BLE)	Provide Traveler Interface Process Traveler Method of Payment
	Personal Trip Planning and Route Guidance	Determine Personal Portable Device Guidance Method Provide Personal Portable Device Dynamic Guidance Provide Personal Portable Device Guidance Interface Update Traveler Navigable Map Database Get Traveler Personal Request Provide Traveler with Personal Travel Information Provide Traveler Personal Interface
	Traveler Account Management	Provide Traveler Interface Manage Traveler Account Updates Manage Contact Information Provide Individual Transactions View Booking Reports
Interactive Kiosk	Traveler Trip Planning	Provide Traveler Interface for Trip Planning Collect Traveler Information and Parameters for Trip Planning Provide Traveler with MMTPA Information Send SMS Text Messages

Source: City of Columbus

2.5. PROJECT 4: MOBILITY ASSISTANCE FOR PEOPLE WITH COGNITIVE DISABILITIES

2.5.1. Introduction

COTA offers origin-to-destination shared ride (paratransit) services, called Mainstream, for people with cognitive disabilities. Cognitive disabilities include clinical diagnoses of autism, Down Syndrome, traumatic brain injuries, and dementia in addition to less severe cognitive conditions such as Attention Deficit Disorder, dyslexia (difficulty reading), dyscalculia (difficulty with math), and learning disabilities.

The problem here is twofold. First, people with cognitive disabilities who wish to independently use public transportation must either qualify for paratransit services in accordance with the ADA, or they must be sufficiently independent that they are able to safely use fixed-route bus service without assistance. Second, the cost of providing paratransit service continues to grow. Like other transit systems across the United States, COTA is seeking ways to encourage paratransit riders to consider riding fixed-route service which, at an average trip cost of $6.18, is much less expensive to provide than a paratransit trip, which averages $35.86. While COTA offers free bus fares to paratransit customers as an incentive to use the fixed-route

service, few have made the switch. Paratransit ridership has remained relatively unchanged, despite the free bus fare incentive, at approximately 278,000 trips per year according to COTA.

The MAPCD solution allows eligible riders to use fixed-route bus services in a safe and easy-to-use manner. It will be a cost-efficient mobility option which provides a greater degree of independence to residents with cognitive disabilities. In addition to moving people from paratransit to fixed-route service for costs savings, the project holds a secondary objective of moving people from being transported by a caregiver in a privately-owned vehicle to independent travel. A caregiver is anyone who assists the MAPCD traveler to complete a trip. This fulfils the Smart Columbus vision of empowering citizens to live their best lives, and attracts new users with cognitive disabilities who are not already using bus or paratransit services.

2.5.2. System of Interest

MAPCD is a phone-based application solution (AbleLink WayFinder by AbleLink Smart Living Technologies, LLC). The solution includes an interface for the MAPCD traveler. The interface will provide voice and turn-by-turn directions and the ability to communicate with the caregiver. The traveler will be able to view the real-time bus location information, and can receive alerts to complete trips using COTA's fixed-route bus system. Travelers will also receive alerts on any changes in scheduled service that might impact their ability to complete a trip. The solution also includes an interface for the caregivers. Caregivers will be able to view the traveler's progress in real-time on a map to be assured that the traveler is safely en route and progressing towards a destination. Caregivers will also receive notifications of a traveler's progress en route via SMS or email messages to be assured that the traveler is safely en route and progressing towards a destination. Caregivers will be able to create routes and tailor the end-user experience to suit the individual needs of a traveler.

2.5.3. Physical Architecture View

The MAPCD project includes a single customized Service Package from the USDOT ARC-IT – Infrastructure-Provided Trip Planning and Route Guidance. This Service Package offers en route guidance services.

Figure 40 shows Layer 2 Physical Architecture View for the MAPCD project. Layer 2 view shows all the Elements, their associated Functional Objects, and the Information Flow between the elements. The description of the Elements, Functional Objects, and the Information Flow among the elements are shown in the following tables. Since there is only a single Service Package, only a Layer 2 diagram is shown.

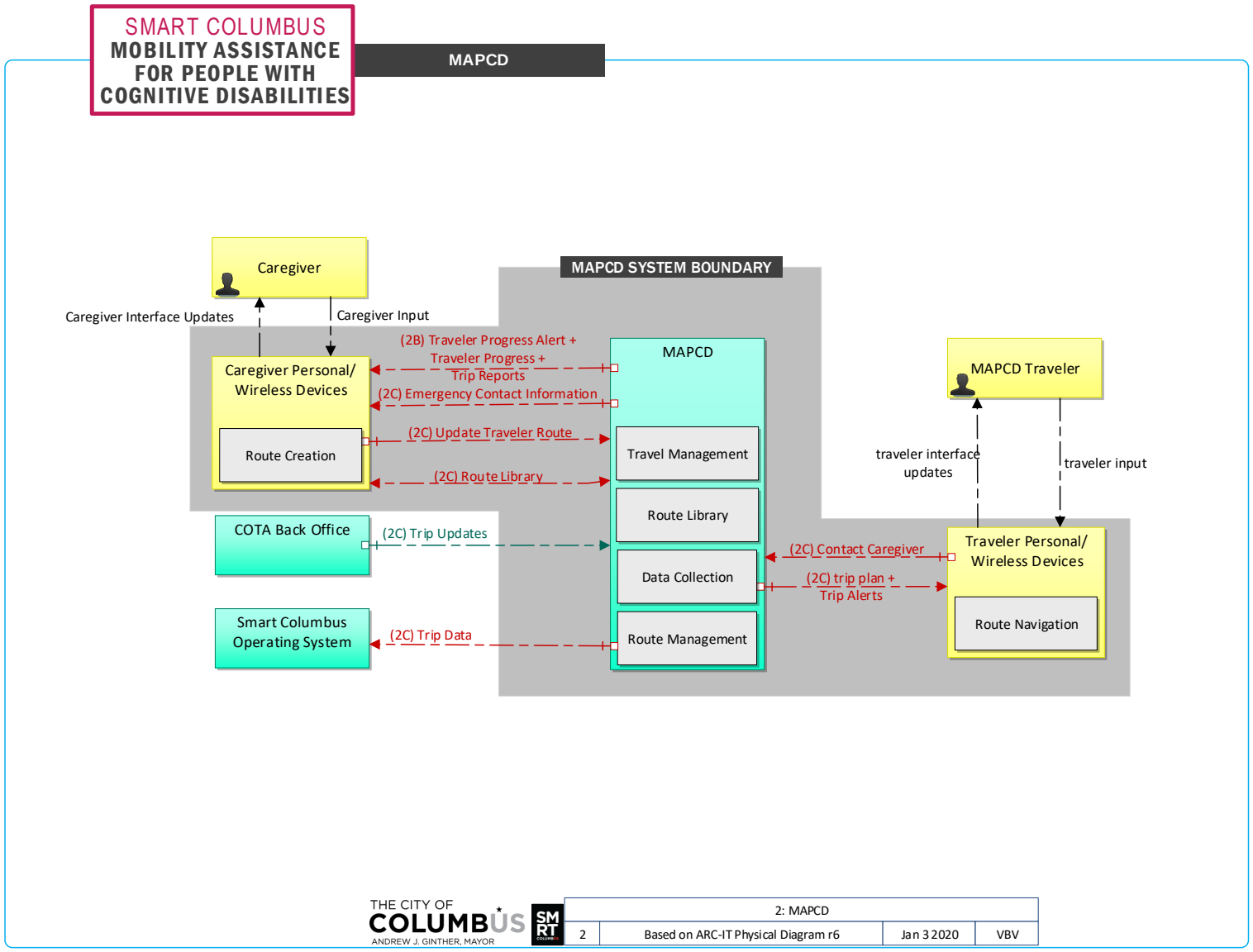


Figure 40: Mobility Assistance for People with Cognitive Disabilities Physical Architecture View

Source: City of Columbus

Table 67: Mobility Assistance for People with Cognitive Disabilities Physical Elements

Name	Class	Description
Caregiver	Traveler	The Caregiver is a relative or caregiver of the MAPCD Traveler who monitors the trip and intervenes as necessary. He or she creates and manages the trip on behalf of the MAPCD Traveler.
Caregiver Personal/Wireless Devices	Traveler	The Caregiver Personal/Wireless Devices will be able to locate the location of the traveler and be able to provide alternate route instructions when the traveler needs assistance to complete his/her trip.
COTA Back Office	Center	The COTA Back Office manages transit vehicle fleets and coordinates with other modes and transportation services. It provides operations, maintenance, customer information, planning, and management functions for the transit property. It spans distinct central dispatch and garage management systems, and supports the spectrum of fixed route, flexible route, paratransit services, and BRT service. The Physical Object's interfaces support communication between transit departments and with other operating entities, such as emergency response services and traffic management systems.
MAPCD	Center	The MAPCD is a mobile based application (available on both Android and iOS) to allow for personal choice and user preferences. It displays real-time bus location information and alerts to complete trips using COTA's fixed-route bus system. Travelers are alerted to any changes in scheduled service that might impact their ability to complete a trip. The application guides the user by voice commands and step-by-step visual instructions to complete a trip. Travelers will be able to communicate with a Caregiver for assistance in case of emergency to feel safe and secure while en route. The application notifies a Caregiver of a traveler's progress en route via SMS or email messages to be assured that the traveler is safely progressing towards a destination. A Caregiver can view a traveler's progress in real-time on a map to be assured that the traveler is safely en route and progressing toward a destination. Caregivers can easily and effectively create routes and tailor end-user experience to suit the individual needs of a traveler. The MAPCD also has several backend services that support the mobile-based application. These include the SMART Route Library, which stores previously created routes, and SMART Travel Manager, which can be used to view current or previously taken trips. Additionally, other backend components handle the processing of real-time alerts for the mobile application and trip data feeds for the Smart Columbus Operating System.
Smart Columbus Operating System	Center	The Smart Columbus Operating System covers the ingestion and organization of information stored in the Smart Columbus Operating System. The ingestion process is initiated by the Data Curator using a web interface to define and manage the data feeds.

Name	Class	Description
Traveler Personal/Wireless Devices	Traveler	The Traveler Personal/Wireless Devices provide the capability for travelers to receive formatted traveler information wherever they are. Capabilities include traveler information, trip planning, and route guidance. Frequently a smartphone, the Traveler PWDs provide travelers with the capability to receive route planning and other personally focused transportation services from the infrastructure in the field, at home, at work, or while en route.
MAPCD Traveler	Traveler	The MAPCD Traveler represents a qualified person with cognitive disabilities.

Source: City of Columbus

Table 68: Mobility Assistance for People with Cognitive Disabilities Information Flows

Name	Description
Caregiver Input	User input from a Caregiver.
Caregiver Interface Updates	Visual or audio information (e.g., routes, messages, guidance, emergency information) that is provided to the Caregiver.
Contact Caregiver	MAPCD Traveler will be able to request his/her emergency help person contact them when assistance is needed through MAPCD.
Emergency Contact Information	Emergency Contact Caregiver information of the MAPCD traveler will be in the MAPCD system, and a caregiver will be alerted when traveler needs assistance.
Route Library	Includes a library of traveler routes. Also includes options for adding additional map layers and data, or additional tools to assist in the creation of routes, or execution of a route by a traveler.
Traveler Progress	Includes traveler's progress in real-time on a map.
traveler input	User input from a traveler to summon assistance, request travel information, make a reservation, or request any other traveler service. For this project, reservation is not applicable since the Caregiver will request the trip on behalf of the Traveler.
traveler interface updates	Visual or audio information (e.g., routes, messages, guidance, emergency information) that is provided to the traveler.
Traveler Progress Alert	Provides alert on traveler progress.
Trip Alerts	Includes alerts on trips, including changes in trip plan.
Trip Data	Includes data on starting a particular route, completing a route, canceling a route before completion, pausing a route, resuming a route, loss of GPS connection, reacquisition of GPS connection, leaving the travel corridor for the route, reentering the travel corridor for the route, requests for assistance by the traveler, downloading a route with mode of travel used, caregiver updates, and communications.
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 and parking reservation information. For this project, it includes voice commands and step-by-step visual instructions to complete a trip.

Name	Description
Trip Reports	Includes information on traveler's application usage and travel behavior to make informed decisions, such as updates to existing routes or to determine the need for additional training or instruction.
Trip Updates	Includes transit vehicle information, including route, mode, and real-time vehicle location.
Update Traveler Route	Traveler will be provided with updated route instructions by the caregiver when assistance is needed.

Source: City of Columbus

Table 69: Mobility Assistance for People with Cognitive Disabilities Functional Objects

Physical Object	Functional Object	Description
MAPCD	Data Collection	Data Collection collects transportation-related data including trip and usage data, performs data quality checks on the collected data and then consolidates, verifies, and refines the data making it available in a consistent format to applications that support operational data sharing between centers and deliver traveler information to end-users. It allows request of the trip and usage data by the Smart Columbus Operating System for data archival as needed.
	Route Library	Route Library allows the caregiver to manage the route library, and provides routes to the traveler.
	Route Management	Route Management allows the Caregiver to manage the individual routes for the traveler.
	Travel Management	Travel Management provides alerts to the Caregiver during the trip (e.g., showing travel progress or for emergencies) and to the MAPCD traveler based on transit system alerts. The Caregiver is also able to receive real-time updates on a map. The system manages the Caregiver and the Traveler profile.
Caregiver Personal/Wireless Devices	Route Creation	Route Creation allows the Caregiver to create and update traveler route and route library.
Traveler Personal/Wireless Devices	Route Navigation	Route Navigation guides the travelers using voice commands and step-by-step visual instructions to complete a trip.

Source: City of Columbus

2.5.4. Enterprise Architecture View

Figure 41 shows the relationships between Smart Columbus stakeholders, the roles organizations play within the project, and the expectations and agreements among the stakeholders. The table provides the list of agreements and descriptions.

**It is anticipated that COTA or other agencies will take over the MAPCD facilitation responsibility at the end of project contract duration and will also own the traveler's PWD.*

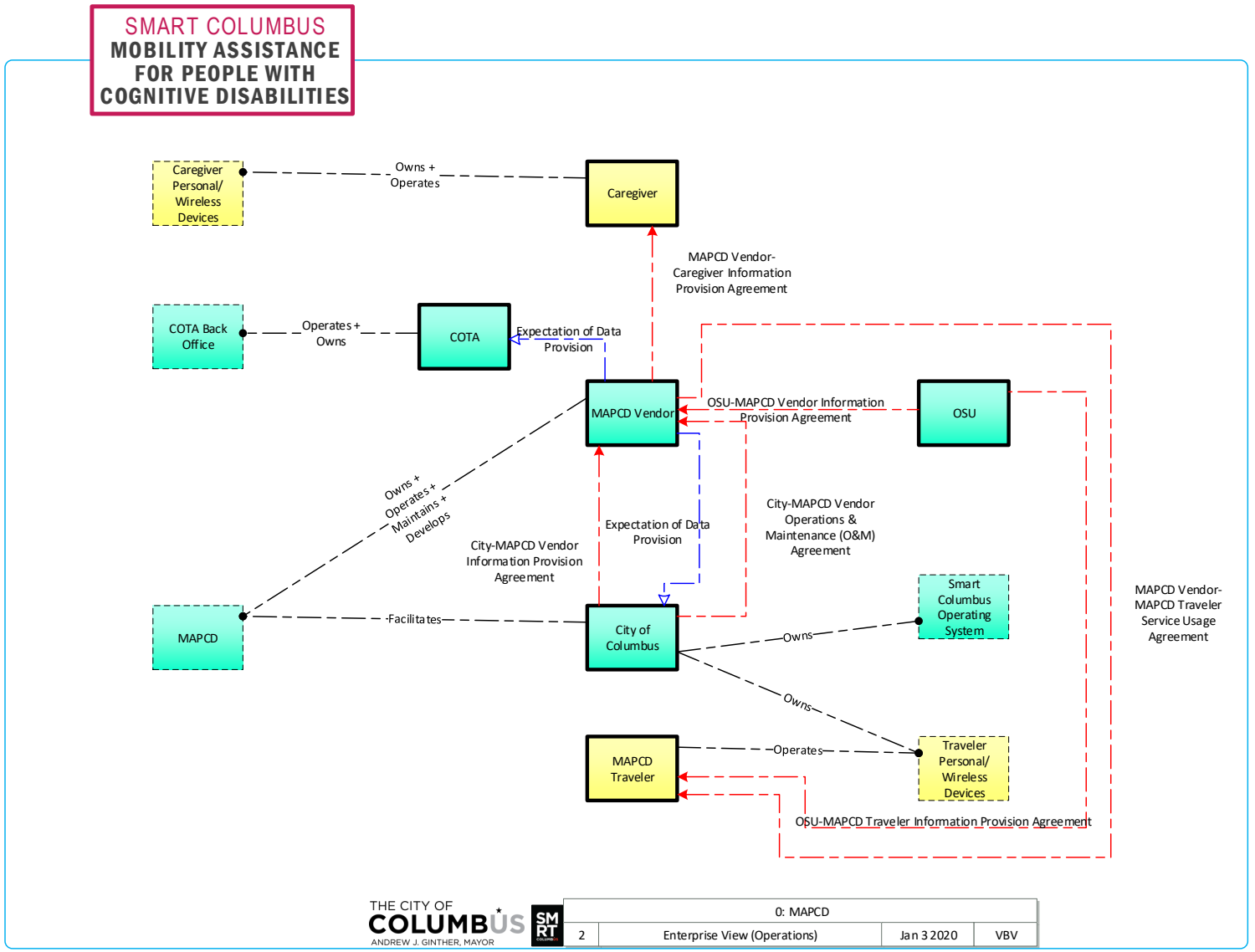


Figure 41: Mobility Assistance for People with Cognitive Disabilities Enterprise Architecture View

Source: City of Columbus

Table 70: Mobility Assistance for People with Cognitive Disabilities List of Agreements

Name	Description
City-MAPCD Vendor Operations & Maintenance Agreement	An agreement between the City and MAPCD Vendor for operations and maintenance of the MAPCD. Vendor: AbleLink Smart Living Technologies LLC Status: Existing
City-MAPCD Vendor Information Provision Data	An agreement where MAPCD Vendor agrees to provide information to the City. Vendor: AbleLink Smart Living Technologies LLC Status: Existing
OSU-MAPCD Vendor Information Provision Data	An agreement where MAPCD Vendor agrees to provide information to the OSU. Vendor: AbleLink Smart Living Technologies LLC Status: Existing
OSU-MAPCD Traveler Information Provision Agreement	An agreement between OSU and the MAPCD Traveler to receive MAPCD Traveler information. This is in the form of a Notice and Consent document. Status: Existing
MAPCD Vendor – MAPCD Traveler Service Usage Agreement	An agreement between the MAPCD Traveler and the MAPCD vendor. Stipulates the terms and conditions of service usage in their privacy policy which is accessed when they download the app. Vendor: AbleLink Smart Living Technologies LLC Status: Existing
MAPCD Vendor – Caregiver Service Usage Agreement	An agreement between the Caregiver and the MAPCD vendor. Stipulates the terms and conditions of service usage. Caregiver will have access to MAPCD participant user data. Vendor: AbleLink Smart Living Technologies LLC Status: Existing

Source: City of Columbus

2.5.4.1. ROLES AND RESPONSIBILITIES

Development:

- City of Columbus/Smart Columbus PMO: Owner
  - HNTB: Requirements
  - AbleLink: Software Development
  - OSU: Research & Recruiting
  - OS: Interface Development

Installation:

- City of Columbus/Smart Columbus PMO: Owner

- AbleLink: Software Development, Training, Interface to Smart Columbus Operating System and OSU
- OSU: Research, IRB and Training:
  - Traveler: wireless device (application download and training)
  - Caregiver: wireless device (application download and training)
- OS Team (Accenture): Interface Set Up

Testing:

- City of Columbus PMO: Owner, Tester
  - HNTB: Documentation, Tester
  - Michael Baker, Intl.: lead tester
  - AbleLink: Development Updates, Bug Fixes
  - OSU: Test Lead, Documentation
  - OS team (Accenture): Verifying Data Flows

Operations:

- City of Columbus/Smart Columbus PMO: Owner
  - HNTB: O&M Plan
  - AbleLink: Development Updates, Bug Fixes
  - OSU: Research and Recruiting, Participant Coordination and Training, IRB Updates as Needed, Performance Measurement
  - OS Team (Accenture): OS Administrator

Maintenance:

- City of Columbus/Smart Columbus PMO: Owner
  - HNTB: O&M Plan
  - AbleLink: Development Updates, Bug Fixes
  - OSU: Research and Recruiting, Participant Coordination and Training, IRB Updates as Needed
  - OS Team (Accenture): OS Development Updates and Bug Fixes

2.5.5. Communications Architecture View

2.5.5.1. COMMUNICATION PROFILES USED

The following sections describe the layered sets of communications protocols that are required to support communications among the elements that make up the MAPCD project. Refer to **Appendix B** for the standards used for each communication profile.

2.5.5.1.1. World Wide Web Browser/JSON/Wide Area Wireless

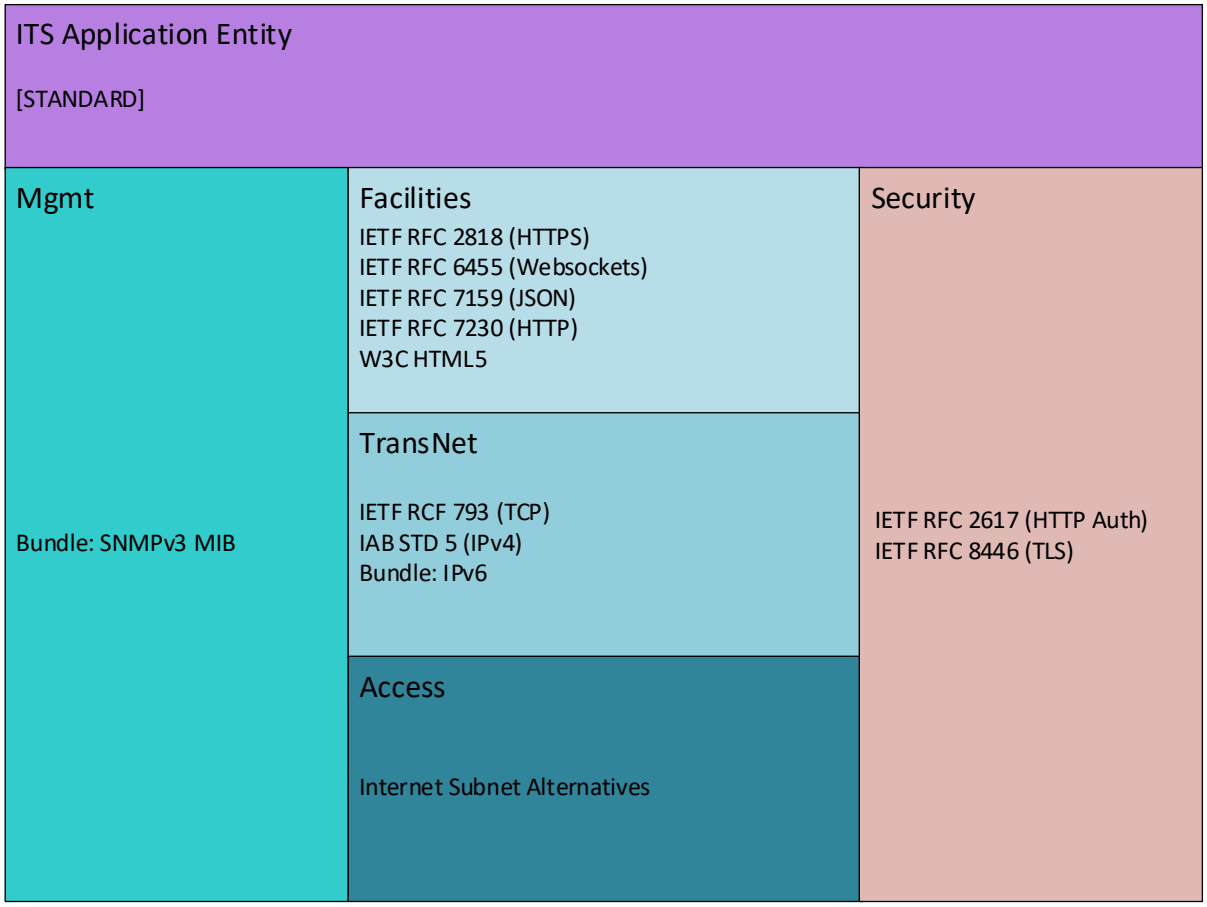


Figure 42: World Wide Web Browser/JSON/Wide Area Wireless

Source: City of Columbus

Table 71: World Wide Web Browser/JSON/Wide Area Wireless

Name	Source	Destination	Standard	Profile
Contact Caregiver	Traveler Personal/Wireless Devices	MAPCD	(Unspecified)	WAW-WWWBrowser-JSON
Emergency Contact Information	MAPCD	Caregiver Personal/Wireless Devices	(Unspecified)	WAW-WWWBrowser-JSON
Route Library	MAPCD	Caregiver Personal/Wireless Devices	SMART Wayfinding, GTFS	WAW-WWWBrowser-JSON
Route Library	Caregiver Personal/Wireless Devices	MAPCD	SMART Wayfinding, GTFS	WAW-WWWBrowser-JSON

Name	Source	Destination	Standard	Profile
Traveler Progress	MAPCD	Caregiver Personal/Wireless Devices	(Unspecified)	WAW-WWWBrowser-JSON
Traveler Progress Alert	MAPCD	Caregiver Personal/Wireless Devices	(Unspecified)	WAW-WWWBrowser-JSON
Trip Alerts	MAPCD	Traveler Personal/Wireless Devices	SMART Wayfinding	WAW-WWWBrowser-JSON
Trip Data	MAPCD	Smart Columbus Operating System	(Unspecified)	WAW-WWWBrowser-JSON
trip plan	MAPCD	Traveler Personal/Wireless Devices	SMART Wayfinding	WAW-WWWBrowser-JSON
Trip Reports	MAPCD	Caregiver Personal/Wireless Devices	(Unspecified)	WAW-WWWBrowser-JSON
Trip Updates	COTA Back Office	MAPCD	GTFS-Real Time	WAW-WWWBrowser-JSON
Update Traveler Route	Caregiver Personal/Wireless Devices	MAPCD	(Unspecified)	WAW-WWWBrowser-JSON

Source: City of Columbus

2.5.5.1.2. Human Interface

Table 72: Human Interface

Name	Source	Destination	Standard	Profile
Caregiver Input	Caregiver	Caregiver Personal/Wireless Devices	(Unspecified)	Human Interface
Caregiver Interface Updates	Caregiver Personal/Wireless Devices	Caregiver	(Unspecified)	Human Interface
traveler input	MAPCD Traveler	Traveler Personal/Wireless Devices	(Unspecified)	Human Interface
traveler interface updates	Traveler Personal/Wireless Devices	MAPCD Traveler	(Unspecified)	Human Interface

Source: City of Columbus

2.5.6. Functional Architecture View

The Functional Architecture View depicts each element of the overall system and the logical interfaces among them. The listed draft processes are developed based on discussion with the project team. These processes will be further refined and defined in detail during the design phase of the project.

Table 73: Mobility Assistance for People with Cognitive Disabilities Functional Architecture View

Physical Object	Functional Object	Process
MAPCD	Data Collection	Collect Trip Data Provide Trip Data (to Smart Columbus Operating System)
	Route Library	Manage Route Library
	Route Management	Manage Routes
	Travel Management	Provide Caregiver Interface Provide MAPCD Traveler Interface Provide Interface for Smart Columbus Operating System Process Caregiver Requests Process Traveler Requests Inform Caregiver Inform Traveler Manage Reports Manage Profile
Travelers Personal/Wireless Devices	Route Navigation	Provide Personal Portable Device Guidance Interface Provide Route Navigation Receive Alerts
Caregiver Personal/Wireless Devices	Route Creation	Create Routes Select Routes Update Route Library Receive Alerts

Source: City of Columbus

2.6. PROJECT 5: PRENATAL TRIP ASSISTANCE

2.6.1. Introduction

Columbus has one of the highest infant mortality rates in the country. Factors that affect infant mortality include prenatal medical care, housing, education, employment, and transportation. Receipt of early and adequate prenatal care is essential for preventing the two main causes of infant mortality: preterm birth (less than 37 weeks of gestation) and congenital anomalies. Safe and reliable transportation to prenatal care appointments remains a constant challenge for women living in poverty. The existing NEMT system delivery does not offer reliable transportation to and from medical appointments, customer friendly services like

detailed driver information, advanced technology, or on-demand services for scheduling NEMT services. Prenatal travelers, similar to Ohio Medicaid NEMT users, only have the option to schedule NEMT trips through a call center. On-demand services are considered an emergency and provided on an as-available basis. Prenatal travelers do not get reminded multiple times of their trip, and they have no portal to access for future trip reservations. They also do not know when their driver is about to arrive.

The goal of this PTA project is to provide a more streamlined and efficient NEMT system using technology and transportation services. Specifically, the PTA project has four main goals with respect to positive societal outcomes: enhanced mobility, increased opportunity, improved efficiency, and increased customer satisfaction to improve mobility and user satisfaction. The project's objectives include:

- Facilitate improved access to NEMT trips
- Increase usage of the NEMT benefit
- Increase customer satisfaction

It is Smart Columbus' goal to work with stakeholders to help bridge the gaps among health-care providers, pregnant women, and Medicaid NEMT services.

2.6.2. System of Interest

PTA system will address the following User Needs as identified in the PTA ConOps:

- Personal Devices
- Trip Scheduling
- Graphic User Interface (GUI) (Transaction Equipment)
- Delay of Arrival or Cancellation of Trip Request
- Timely Return Pickup
- Vehicle and Driver Description
- Prenatal Traveler Notification
- Cancel Option
- User Preference
- Accept Bookings/Reservations
- Delay/Cancellation Notification
- Trip History
- Feedback
- Offline Usage
- Account Ownership
- Trip Data
- PTA-MCO Integration
- Request Accessible vehicles
- Access to Data
- ODM Data Access

- MCO Data Needs MCO-PTA Integration
- MCO Complaints
- CelebrateOne Data
- Driver Feedback
- Driver Routing
- Driver Communication and Preference
- Driver Situation
- Access to Instructions and Educational Material
- Security and Encryption
- Open Standards

The PTA system is a technologically advanced and user-friendly solution for prenatal Medicaid members to schedule NEMT trips. Prenatal travelers can download and install the PTA application from public app stores, and begin using it immediately to plan trips either for the future or in real-time. They will also be able to visit a website or contact a call center to schedule their NEMT trips. Scheduling trips includes initial scheduling and/or canceling trips. The PTA system will also send multiple reminders to the prenatal travelers of upcoming trips. Just prior to the trip, the PTA system will provide driver and vehicle information to the prenatal traveler. Both the prenatal traveler and the NEMT vehicle driver will be able to communicate. During the trip, both the prenatal traveler and the NEMT vehicle driver will be able to follow the trip route using a map.

The PTA system will allow prenatal travelers to store their optional user preferences, including type of communication notification and address of pharmacy or frequently visited medical offices, through user accounts with password protection. The PTA system will allow access to instructions, education materials, and trip history. Both prenatal travelers and NEMT drivers can provide complaints and feedback on the application through the PTA system.

The PTA system will collect, store, and provide trip data to the Smart Columbus Operating System. The City, CelebrateOne, ODM, and MCOs will be able to access trip data through the Smart Columbus Operating System (outside system boundary) to make informed decisions regarding future improvements to the pilot itself, and to support broader transportation policy decisions. The PTA system will share the prenatal member information and their trip and usage data with the OSU Researchers as well.

MCOs will be the solution integrator, meaning all payment information will be handled between the MCOs and the technology vendor/transportation broker, which is outside the scope of this project.

Refer to the PTA ConOps for additional information on goals and objectives of the project, current system, justification for the changes, and concept for the proposed system. The ConOps also identifies the Operational Scenarios:

- Prenatal traveler installs and launches PTA.
- Prenatal traveler establishes an account and sets user preferences.
- Prenatal traveler plans a trip.
- Prenatal traveler takes a trip.
- Users connect to the Smart Columbus Operating System for data.
- Failure condition – Loss of Internet Connectivity.
- Failure condition – Temporary loss of communications.

The following subchapters provide the various Architecture Views for the PTA system.

2.6.3. Physical Architecture View

The PTA project includes a single customized Service Package from the ARC-IT – Infrastructure-Provided Trip Planning and Route Guidance. This Service Package offers the user trip planning and en route guidance services. It generates a trip plan based on traveler preferences and constraints. Routes may be based on static information or reflect real time network conditions. The trip plan may be confirmed by the traveler and Rides for Baby (R4B) NEMT Mobility Provider. The confirmed trip plan may include specific routing information that can be supplied to the traveler as general directions or as turn-by-turn route guidance, depending on the level of user equipment.

Figure 43 Physical Architecture View for the PTA project includes a Layer 2 diagram, which shows all the Elements, their associated Functional Objects, and the Information Flow between the elements. The description of the Elements, Functional Objects, and the Information Flow among the elements are shown in the following tables. Since there is only a single Service Package, only Layer 2 diagram are depicted.

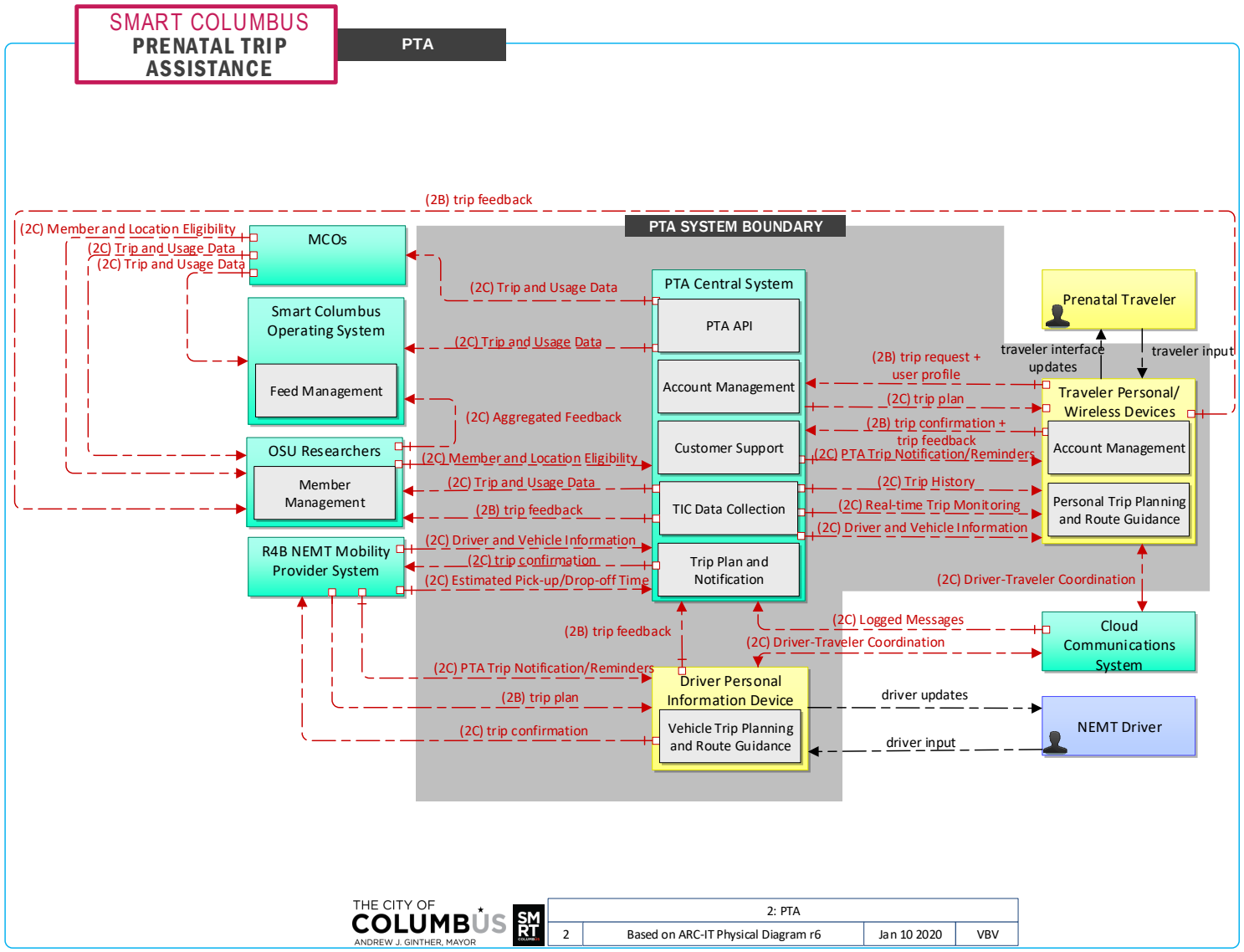


Figure 43: Prenatal Trip Assistance Physical Architecture View

Source: City of Columbus

Table 74: Prenatal Trip Assistance Physical Elements

Physical Object	Class	Description
Cloud Communications System	Center	The Cloud Communication System allows the Driver Personal Information Device to contact the Traveler PWDs. The Cloud Communications System is a 3rd party application that allows users to contact other users through masked phone numbers to protect the personal information of the parties involved.
Driver Personal Information Device	Traveler	The Driver Personal Information Device allows a NEMT Driver to interface with the PTA App, route navigation, and provide feedback.
MCOs	Center	The MCOs represent those who provide NEMT services for MCO members who are not involved in the pilot and for those PTA participants who are in the unexposed group. For the pilot program, MCOs will contract with the PTA system technology vendor to provide the PTA services described for the test group participants. OSU Researchers will work with the MCOs to verify eligibility of benefits with pilot participants. MCOs will receive the exposed group NEMT trip data from the PTA system for verification of services and payment.
NEMT Driver	Vehicle	The NEMT Drivers are employed by the Mobility Providers. The NEMT drivers are responsible to drive prenatal travelers on their trips.
R4B NEMT Mobility Provider System	Center	The R4B NEMT Mobility Provider Systems are owned by R4B NEMT Mobility Providers, who will contract directly with the PTA System technology vendor to deliver NEMT trips. The PTA system will send the NEMT mobility provider trip assignments based on the prenatal traveler reservation requests. The NEMT Mobility Providers will receive information on the prenatal traveler, such as pickup location, drop-off location, time of scheduled appointment, special needs, and number of guests. In turn, the R4B NEMT Mobility Provider System will share vehicle and driver information with the PTA system in order to share it with the prenatal traveler. The System will also have access to vehicle location data to share with the prenatal traveler. The NEMT Mobility Provider's driver can use the PTA system to give feedback on the prenatal traveler.
OSU Researchers	Center	OSU Researchers represent the team who will screen the prenatal traveler information provided by StepOne to see if she is qualified to be part of the pilot program. If the woman meets the qualifications and completes the baseline questionnaire, she will be admitted to the pilot. She will be randomized into the exposed or unexposed group. OSU Researchers will also evaluate the performance of the PTA project.
Prenatal Traveler	Traveler	The Prenatal Traveler represents a prenatal individual who uses NEMT services. The interfaces to the traveler provide access to account information, ability to schedule, and cancel an NEMT trip, and access to feedback.

Physical Object	Class	Description
PTA Central System	Center	The PTA Central System is a web- and smartphone-based software application that will be used to facilitate NEMT trips for expectant women enrolled in Medicaid within Franklin County. OSU Researchers will identify potential participants and verify Medicaid enrollment with the appropriate MCO and place the women into an exposed and unexposed group. For the exposed group, these trips will connect the pregnant women with on-demand transportation necessary to attend prenatal and post-partum care appointments, as well as all other medical appointments. The exposed group will also receive trips to the grocery store and free standing pharmacy trips. The system will also provide vehicle driver and location information to boost the data available, assisting government entities, MCOs, and NEMT Mobility Providers in making better informed decisions. The PTA system will ingest the NEMT reservation request through a web portal, smartphone application, or call center input process. Should any issues arise with the smartphone application or the web portal, the prenatal traveler will be able to contact the call center for service. The PTA system will act in place of an MCO's current Transportation Broker, and transfer approved reservation requests to the appropriate NEMT Mobility Providers. In return, the PTA system will receive information about the assigned driver, their vehicle and general trip data. The PTA system will send a confirmation of the transportation reservation and multiple notifications to the prenatal traveler to remind her of the upcoming transportation reservation. The methods of notification will be text or phone call. Trip optimization will be provided by the technology vendor/transportation broker to ensure the most efficient route is taken for the prenatal traveler.
Smart Columbus Operating System	Center	The Smart Columbus Operating System covers the ingestion and organization of information stored in the Smart Columbus Operating System. The ingestion process is initiated by the Data Curator using a web interface to define and manage the data feeds.
Traveler Personal/Wireless Devices	Traveler	The Traveler Personal/Wireless Devices provide the capability for travelers to receive formatted traveler information wherever they are. Capabilities include traveler information, trip planning, and route guidance. Frequently a smartphone, the Traveler PWDs provide travelers with the capability to receive route planning and other personally focused transportation services from the infrastructure in the field, at home, at work, or while en route. For this project, the Traveler PWD provide the capability for prenatal travelers to schedule, track, review, and give feedback on trips. This also includes the capability of the device to call others (call center) to accomplish the tasks. (Please note it is not a system connection, but just a phone call.)

Source: City of Columbus

Table 75: Prenatal Trip Assistance Information Flows

Information Flow	Description
Aggregated Feedback	De-identified general feedback from the users in the study.
Driver and Vehicle Information	The Drive and Vehicle Information includes information on driver's name and photo in addition to the vehicle's make, model, and license plate number.

Information Flow	Description
driver input	Driver input to the vehicle OBE including configuration data, settings and preferences, interactive requests, and control commands. For this project, the driver input includes traveler pick up and drop off confirmation.
Driver-Traveler Coordination	Messages or phone calls between the driver and the traveler.
driver updates	Information provided to the driver including visual displays, audible information and warnings, and haptic feedback. The updates inform the driver about current conditions, potential hazards, and the current status of vehicle OBE. For this project, information includes visual or audio information (e.g., routes, messages, guidance, emergency information) that is provided to the driver.
Estimated Pick-up/Drop-off Time	Estimated pick-up and drop-off time of the prenatal trip.
Logged Messages	Messages sent between the driver and traveler, including the sending and receiving phone numbers.
Member and Location Eligibility	The Member and Location Eligibility refers to ODM Benefits System list. MCO will transfer the ODM Benefits System list to the PTA System, allowing the PTA to validate eligibility.
PTA Trip Notification/Reminders	The PTA Trip Notification/Reminders includes the notification/reminders about the trip schedule, reschedule, delay, and cancellation.
Real-time Trip Monitoring	The Real-time Trip Monitoring includes the capability to track the location of the Mobility Provider vehicle in real-time.
traveler input	User input from a traveler to summon assistance, request travel information, make a reservation, or request any other traveler service.
traveler interface updates	Visual or audio information (e.g., routes, messages, guidance, emergency information) that is provided to the traveler.
Trip and Usage Data	The Trip and Usage Data consists of, at a minimum, the following: origin, destination, whether trip was scheduled in advance or on demand, trip start time, trip end time, type of trip, and vehicle identification. Trip and Usage Data will also include whether or not the user was a PTA participant or control group for the OSU study. All Trip and Usage Data that flows to the Smart Columbus Operating System will have personally identifiable information removed from the data.
trip confirmation	Acknowledgement by the driver/traveler of acceptance of a trip plan with associated personal and payment information required to confirm reservations. For this project, payment information is not applicable.
trip feedback	Information provided at the end of a trip that supports performance monitoring and system optimization. Information provided may include a record of the trip including HOV/HOT lane usage and user provided feedback at the end of the trip. For this project, HOV/HOT lane usage is not applicable. Trip feedback will also include general study feedback from prenatal traveler.
Trip History	Trip history provides traveler with previously scheduled and completed trips.

Information Flow	Description
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 and parking reservation information. For this project, parking reservation information is not applicable.
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 as well as parking reservations and ridesharing options associated with the trip. For this project, parking reservation information is not applicable.
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. For this project, payment transaction, traveler preferences, and device information are not applicable. MCO provider and communication preference will be sent as part of the user profile.

Source: City of Columbus

Table 76: Prenatal Trip Assistance Functional Objects

Physical Object	Functional Object	Description
Traveler Personal/Wireless Devices	Account Management	Account Management includes login/registration/forgot password features and view ride history.
	Personal Trip Planning and Route Guidance	For this PTA project, the Personal Trip Planning and Route Guidance allows the prenatal traveler to plan, change, and execute a trip, get reminders/notifications, and to contact NEMT driver. The device provides route navigation and ability to communicate with the prenatal traveler for the NEMT driver. Devices represented by this Functional Object include personal devices such as tablets and smartphones.
PTA Central System	Account Management	Account Management includes login/registration/forgot password features, the ability to search for participants, and view ride history.
	Customer Support	Customer Support includes the ability to handle customer support calls.
	PTA API	Provides a set of routines, protocols, and tools for interacting with the PTA Central System.

Physical Object	Functional Object	Description
	TIC Data Collection	For this PTA project, the TIC Data Collection collects transportation-related data, including trip plan and usage, performs data quality checks on the collected data, and then consolidates, verifies, and refines the data making it available in a consistent format to applications that support operational data-sharing between centers and deliver traveler information to end-users. It also shares data with other transportation information centers. It sends the trip and usage data to the Smart Columbus Operating System for data archival.
	Trip Plan and Notification	The Trip Plan and Notification means (smartphone application/mobile friendly web portal/call center) to schedule on-demand and pre-scheduled trips, change and cancel transportation based on origin, destination, constraints, and preferences and returns trip plan(s) that meet the supplied criteria. It confirms the trip plan for the traveler. It also provides notification/reminders to prenatal traveler and a means for the NEMT provider and MCOs to interact with the System.
OSU Researchers	Member Management	OSU will lead a research study around the effects of technologically enhanced transportation on pregnant women. This includes completing study parameters, participant recruiting, and final reporting.
Smart Columbus Operating System	Feed Management	The Smart Columbus Operating System can manage the ingestion of data feeds that are established by the ingestion process.
Driver Personal Information Device	Vehicle Trip Planning and Route Guidance	Vehicle Trip Planning and Route Guidance includes the in-vehicle system that coordinates with a traveler information center to provide a personalized trip plan to the driver. The trip plan is calculated by the TIC based on preferences and constraints supplied by the driver and provided to the driver for confirmation. Reservations and advanced payment may also be processed to confirm the trip plan. Coordination with the TIC may continue during the trip so that the route plan can be modified to account for new information. Many equipment configurations are possible, including in-vehicle systems that provide a basic trip plan to the driver as well as more sophisticated systems that can provide turn-by-turn guidance to the driver along the route.

Source: City of Columbus

2.6.4. Enterprise Architecture View

The following diagram shows the relationships between Smart Columbus stakeholders, the roles organizations play within the project, and the agreements among the stakeholders. The table provides the list of agreements and expectations and their descriptions.

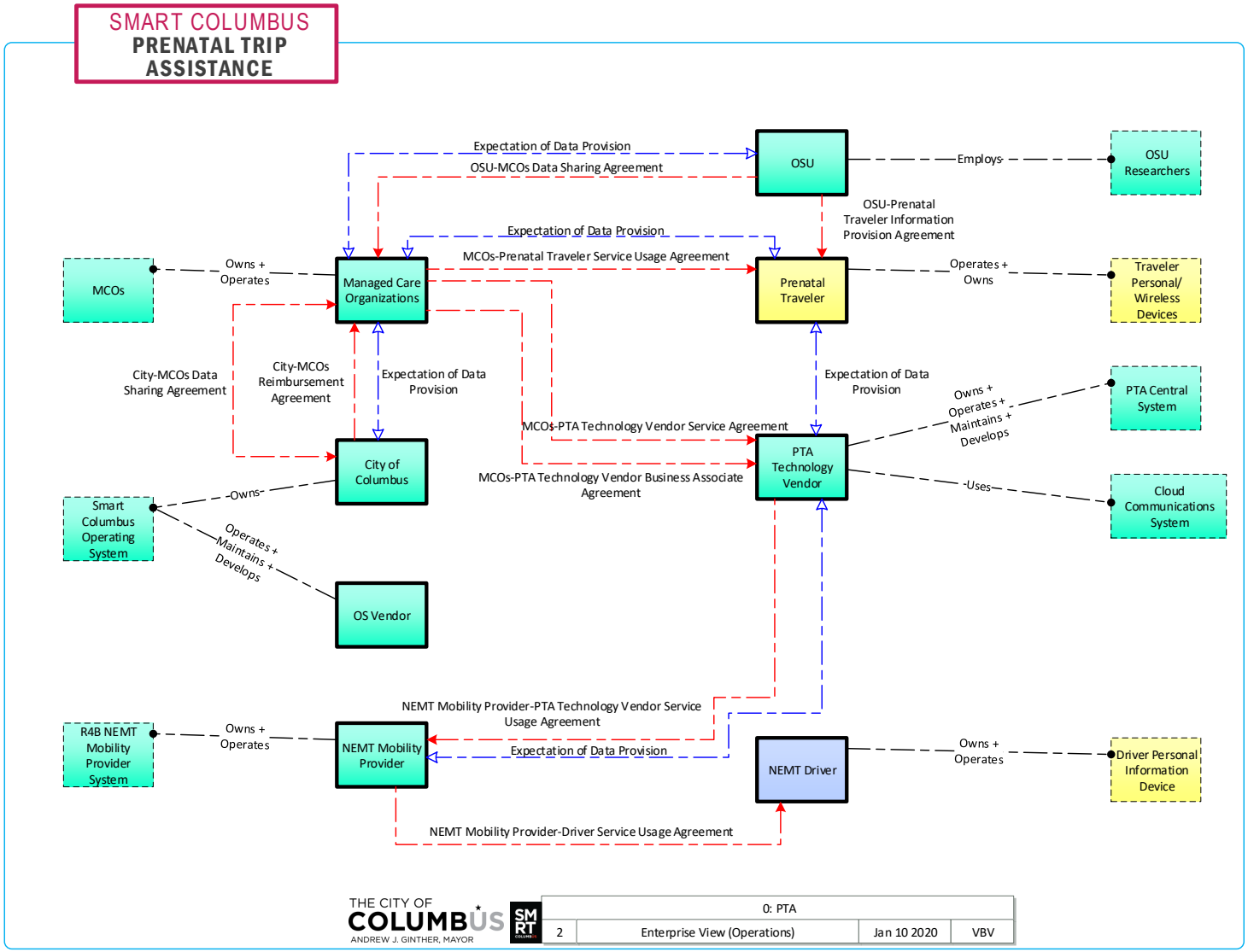


Figure 44: Prenatal Trip Assistance Enterprise Architecture View

Source: City of Columbus

Table 77: Prenatal Trip Assistance List of Agreements

Potential Agreement	Description
City-MCOs Data Sharing Agreement	An agreement between the City and the MCOs for the MCOs to share data with the City. MCOs: CareSource and Molina Healthcare of Ohio Status: Existing
OSU-MCOs Data Sharing Agreement	An agreement between OSU and the MCOs for the MCOs to share data with OSU. MCOs: CareSource and Molina Healthcare of Ohio Status: Existing
OSU-Prenatal Traveler Information Provision Agreement	An agreement between OSU and the prenatal traveler to receive prenatal traveler information. This is in the form of a Notice and Consent document. Status: Existing
City-MCO Reimbursement Agreement	An agreement between the MCOs and the City for the City to provide funding for the project. MCOs: CareSource and Molina Healthcare of Ohio Status: Existing
MCO-Prenatal Traveler Service Usage Agreement	An agreement (membership eligibility and benefits) between the MCOs and a prenatal traveler. Specific to this project, this stipulates the terms and conditions of NEMT service usage. MCOs: CareSource and Molina Healthcare of Ohio Status: Existing
MCOs-PTA Technology Vendor Business Associate Agreement	An agreement between the PTA Technology Vendor and MCOs. PTA Technology Vendor agrees to provide information to the MCO. MCOs: CareSource and Molina Healthcare of Ohio Status: Existing
MCOs-PTA Technology Vendor Service Agreement	An agreement between the PTA Technology Vendor/Transportation Broker and MCOs. Stipulates the terms and conditions of operations and maintenance of the system. MCOs: CareSource and Molina Healthcare of Ohio Vendor: Kaizen Health Status: Existing
NEMT Mobility Provider-Driver Service Usage Agreement	An agreement between the NEMT Mobility Service Provider and NEMT Driver. Stipulates the terms and conditions of service usage. Status: Existing
NEMT Mobility Provider-PTA Technology Vendor Service Usage Agreement	An agreement between the NEMT Mobility Service Provider and PTA Technology Vendor. Stipulates the terms and conditions of service usage. Vendor: Kaizen Health NEMT Mobility Provider: Various Status: Existing

Source: City of Columbus

2.6.4.1. ROLES AND RESPONSIBILITIES

Development:

- City of Columbus/Smart Columbus PMO: Owner
  - HNTB: concept and requirements development
  - OSU: research protocol
  - OS team (Accenture): interface requirements for data collection
  - MCOs: contracting entity for the software provider, data provider to OSU and City; provides terms and conditions of NEMT service usage for the potential participants (as the Medicaid administrator)
    - Kaizen Health: software development (contracted through MCOs, MCOs reimbursed by the City)

Installation:

- City of Columbus/Smart Columbus PMO: Owner
  - OSU: research protocol, participant recruiting:
    - Traveler: download application to personal device once integrated into the program
  - OS team (Accenture): interface set up with MCOs and OSU
  - MCOs: contracting entity for the software provider
    - Kaizen Health: software development (contracted through MCOs, MCOs reimbursed by the City)

Testing:

- City of Columbus/Smart Columbus PMO: Owner, Test Lead
  - HNTB: tester
  - Michael Baker, Intl: Test Lead
  - OSU: tester
  - MCOs: contracting entity for the software provider
    - Kaizen Health: updates and bug fixes identified during testing

Operations:

- City of Columbus/Smart Columbus PMO: Owner
  - OSU: research protocol, participant recruiting; data storage and management (from MCOs)
    - Traveler: owner of the personal device to book/plan/complete travel via the PTA application once integrated into the program
  - OS team (Accenture): storage of non-personally identifiable information data
  - MCOs: contracting entity for the software provider
    - Kaizen Health: software operations and maintenance (contracted through MCOs, MCOs reimbursed by the City); responsible for O&M plan; contracts with NEMT mobility providers (provides terms and conditions of operations and maintenance of the system).
      - NEMT mobility providers: provide service to travelers through the PTA application

Maintenance:

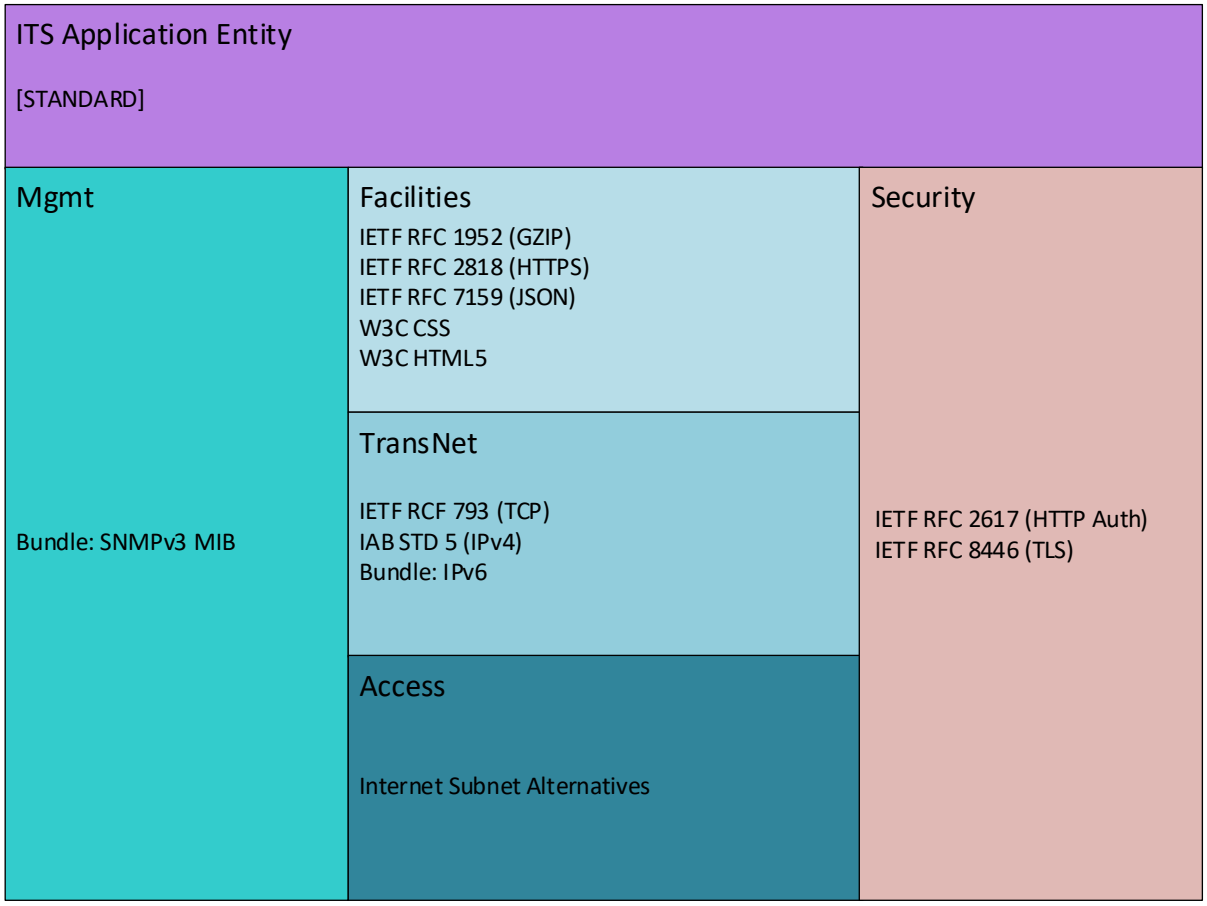
- City of Columbus/Smart Columbus PMO: Owner
  - OSU: research protocol, participant recruiting; data storage and management (from MCOs)
    - Traveler: owner of the personal device to book/plan/complete travel via the PTA application once integrated into the program
  - OS team (Accenture): storage of non-personally identifiable information data
  - MCOs: contracting entity for the software provider
    - Kaizen Health: software operations and maintenance (contracted through MCOs, MCOs reimbursed by the City); responsible for O&M plan; contracts with NEMT mobility providers (provides terms and conditions of operations and maintenance of the system).
      - NEMT mobility providers: provide service to travelers through the PTA application

2.6.5. Communications Architecture View

2.6.5.1. COMMUNICATION PROFILES USED

The following sections describe the layered sets of communications protocols that are required to support communications among the elements that make up the PTA project. Refer to **Appendix B** for the standards used for each communication profile.

2.6.5.1.1. World Wide Web Browser/JSON/Wide Area Wireless



(Note: The vendor currently uses IETF IPv4 for the network layer, but is planning on using IETF IPv6 in the future.)

Figure 45: World Wide Web Browser/JSON/Wide Area Wireless

Source: The City of Columbus

Table 78: World Wide Web Browser/JSON/Wide Area Wireless

Name	Source	Destination	Standard	Profile
Aggregated Feedback	OSU Researchers	Smart Columbus Operating System	(Unspecified)	WAW-WWWBrowser-JSON
Driver and Vehicle Information	R4B NEMT Mobility Provider System	PTA Central System	(Unspecified)	WAW-WWWBrowser-JSON
Driver and Vehicle Information	PTA Central System	Traveler Personal/Wireless Devices	(Unspecified)	WAW-WWWBrowser-JSON
Driver-Traveler Coordination	Cloud Communications System	Driver Personal Information Device	(Unspecified)	WAW-WWWBrowser-JSON

Name	Source	Destination	Standard	Profile
Driver-Traveler Coordination	Cloud Communications System	Traveler Personal/Wireless Devices	(Unspecified)	WAW-WWWBrowser-JSON
Driver-Traveler Coordination	Driver Personal Information Device	Cloud Communications System	(Unspecified)	WAW-WWWBrowser-JSON
Driver-Traveler Coordination	Traveler Personal/Wireless Devices	Cloud Communications System	(Unspecified)	WAW-WWWBrowser-JSON
Estimated Pick-up/Drop-off Time	R4B NEMT Mobility Provider System	PTA Central System	(Unspecified)	WAW-WWWBrowser-JSON
Logged Messages	Cloud Communications System	PTA Central System	(Unspecified)	WAW-WWWBrowser-JSON
Member and Location Eligibility	MCOs	OSU Researchers	(Unspecified)	WAW-WWWBrowser-JSON
Member and Location Eligibility	OSU Researchers	PTA Central System	(Unspecified)	WAW-WWWBrowser-JSON
PTA Trip Notification/Reminders	R4B NEMT Mobility Provider System	Driver Personal Information Device	(Unspecified)	WAW-WWWBrowser-JSON
PTA Trip Notification/Reminders	PTA Central System	Traveler Personal/Wireless Devices	(Unspecified)	WAW-WWWBrowser-JSON
Real-time Trip Monitoring	PTA Central System	Traveler Personal/Wireless Devices	(Unspecified)	WAW-WWWBrowser-JSON
Trip and Usage Data	PTA Central System	Smart Columbus Operating System	(Unspecified)	WAW-WWWBrowser-JSON
Trip and Usage Data	PTA Central System	MCOs	(Unspecified)	WAW-WWWBrowser-JSON
Trip and Usage Data	MCOs	OSU Researchers	(Unspecified)	WAW-WWWBrowser-JSON
Trip and Usage Data	MCOs	Smart Columbus Operating System	(Unspecified)	WAW-WWWBrowser-JSON
Trip and Usage Data	PTA Central System	OSU Researchers	(Unspecified)	WAW-WWWBrowser-JSON

Name	Source	Destination	Standard	Profile
trip confirmation	Driver Personal Information Device	R4B NEMT Mobility Provider System	(Unspecified)	WAW-WWWBrowser-JSON
trip confirmation	Traveler Personal/Wireless Devices	PTA Central System	(Unspecified)	WAW-WWWBrowser-JSON
trip confirmation	PTA Central System	R4B NEMT Mobility Provider System	(Unspecified)	WAW-WWWBrowser-JSON
trip feedback	Driver Personal Information Device	PTA Central System	(Unspecified)	WAW-WWWBrowser-JSON
trip feedback	PTA Central System	OSU Researchers	(Unspecified)	WAW-WWWBrowser-JSON
trip feedback	Traveler Personal/Wireless Devices	PTA Central System	(Unspecified)	WAW-WWWBrowser-JSON
trip feedback	Traveler Personal/Wireless Devices	OSU Researchers	(Unspecified)	WAW-WWWBrowser-JSON
Trip History	PTA Central System	Traveler Personal/Wireless Devices	(Unspecified)	WAW-WWWBrowser-JSON
trip plan	R4B NEMT Mobility Provider System	Driver Personal Information Device	(Unspecified)	WAW-WWWBrowser-JSON
trip plan	PTA Central System	Traveler Personal/Wireless Devices	(Unspecified)	WAW-WWWBrowser-JSON
trip request	Traveler Personal/Wireless Devices	PTA Central System	(Unspecified)	WAW-WWWBrowser-JSON
user profile	Traveler Personal/Wireless Devices	PTA Central System	(Unspecified)	WAW-WWWBrowser-JSON

Source: City of Columbus

2.6.5.1.2. Human Interface

Table 79: Human Interface

Name	Source	Destination	Standard	Profile
driver input	NEMT Driver	Driver Personal Information Device	(Unspecified)	Human Interface
driver updates	Driver Personal Information Device	NEMT Driver	(Unspecified)	Human Interface
traveler input	Prenatal Traveler	Traveler Personal/Wireless Devices	(Unspecified)	Human Interface
traveler interface updates	Traveler Personal/Wireless Devices	Prenatal Traveler	(Unspecified)	Human Interface

Source: City of Columbus

2.6.6. Functional Architecture View

The Functional Architecture View depicts each element of overall system and the logical interfaces among them. The listed draft processes are developed based on discussion with the project team. These processes will be further refined and defined in detail during the design phase of the project.

Table 80: Prenatal Trip Assistance Functional Architecture View

Physical Object	Functional Object	Process
Traveler Personal/Wireless Devices	Account Management	Provide Interface for Traveler Provide Ability to Login, Register, and Reset Password Provide Ability to View Ride History
	Personal Trip Planning and Route Guidance	Determine Personal Portable Device Guidance Method Provide Personal Portable Device Dynamic Guidance Provide Personal Portable Device Guidance Interface Update Traveler Navigable Map Database Get Traveler Personal Request Provide Traveler with Personal Travel Information Provide Prenatal Traveler Personal Interface Collect Feedback
PTA Central System	Account Management	Manage Traveler Profiles
	Customer Support	Receive Calls from Prenatal Travelers

Physical Object	Functional Object	Process
	PTA API	Receive Requests and Send Responses
	TIC Data Collection	Collect Trip and Usage Data Send Prenatal Traveler Information Store Driver and Prenatal Traveler Feedback Manage Trip History
	Trip Plan and Notification	Provide Interface for MCOs Provide Interface for Smart Columbus Operating System Provide Interface for R4B NEMT Mobility Provider System Provide Interface for Traveler PWDs Provide Trip Planning Information to Prenatal Traveler Manage Trip Notifications/Reminders Confirm Eligibility to Use the System Confirm Traveler's Trip Plan Manage Traveler Profiles Manage Driver and Vehicle Information Provide Traveler Alert Collect Prenatal Traveler Feedback
OSU Researchers	Member Management	Collect Trip and Usage Data Collect Traveler Feedback Store Prenatal Traveler Feedback Provide Aggregated Feedback Determine Member and Location Eligibility Provide Member and Location Eligibility
Smart Columbus Operating System	Feed Management	Manage Data Feeds
Driver Personal Information Device	Vehicle Trip Planning and Route Guidance	Provide Interface for NEMT Driver Collect Driver Feedback Provide Driver with Traveler Contact Information

Source: City of Columbus

2.7. PROJECT 6: SMART MOBILITY HUBS

2.7.1. Introduction

The SMH project is considered the future of consolidated transportation centers. The project establishes both a physical location for the traveler, and offers consolidated transportation amenities such as IKs as well as access to comprehensive trip-planning via the MMTPA . This is all driven by real-time transportation information designed to accommodate multiple modes of transit from a single location. SMH is focused on advancing mobility as a service amenities along the COTA BRT (CMAX) line within and adjacent to the

Linden neighborhood. Select SMH facilities will provide multiple modes of transportation in the form of designated bike-/scooter-sharing areas, pick-up and drop-off zones for ride-hailing, car-sharing, park and ride lots, and access to COTA services. These services are particularly useful in the completion of first-mile/last-mile and multimodal trip options. Benefits of the SMH system include enhanced integration and connectivity of the transportation system across and between modes, improved efficiency of the surface transportation system, and increased accessibility and mobility of travelers.

The MMTPA will also be known as Pivot. Travelers will be able to access the application at the IKs, allowing users to plan trips at one location.

2.7.2. System of Interest

The SMH project satisfies the following User Needs as identified in SMH ConOps:

- SMH Facilities
- User Interface Device
- Public Wi-Fi
- Real-time Information
- Mobility Provider Infrastructure
- Emergency Call Button (ECB)
- ECB Integration
- Maintenance and Operations
- Educational Information
- Bike Racks
- Data Collection
- Dockless Parking Zones
- COTA Data
- Language Support

User needs may be reflected in the architecture or Operations and Maintenance plan. Through testing and development, some User Needs identified in the ConOps were considered obsolete and are not included above.

The geographic scope of the proposed SMH project deployment includes the Cleveland Avenue corridor coinciding with COTA's BRT (CMAX) service and Easton, providing those in the Linden area better access to jobs and services in the Easton and Downtown Columbus areas.

These six initial SMH deployment locations were selected based on user feedback and surveys. The SMH facilities will provide multiple modes of transportation and other amenities.

Due to differences in the physical configuration and specific needs for each site, the proposed infrastructure and technology-based improvements will vary. The following provides a high-level overview of components that may be available at a SMH facility:

Table 81: Proposed Functionality Per Smart Mobility Hubs Facility

Location	Amenities												
	Interactive Kiosk	Wi-Fi	Park and Ride	Ride-Hailing	Car-Share	Bike-Share	Bike Racks	Dockless Parking	Real-Time Display	Comprehensive Trip-Planning	Emergency Call Button	Electric Vehicle Charging	AV Shuttle
Columbus State Community College	P	P	-	-	P	E	E	P	E	P	P	-	-
Linden Transit Center	P	E	-	P	-	P	-	P	E	P	P	-	P
St. Stephen's Community House	P	P	-	P	P	P	E	P	-	P	P	-	P
Columbus Metropolitan Library – Linden Branch	P	P	-	P	P	P	E	P	E	P	P	-	-
Northern Lights Park and Ride	P	P	E	P	P	-	E	P	E	P	P	P	-
Easton Transit Center	P	E	E	P	-	P	E	-	E	P	P	-	-

E = Existing; P = Proposed; - = Not Applicable

Source: City of Columbus

The SMH facility components are shown in the Layer 0 diagram to demonstrate a holistic view of the mobility as a service environment. The components themselves are Physical Objects that either have no Information Flows to/from them, or the Information Flows are existing or outside the scope of the system. For this reason, they have not been shown in the Layer 2 diagrams.

The COTA Transit Stop components of the SMH facilities have an existing real-time display. The development and integration of this real-time display are not a part of the Smart Columbus projects. There is an existing information flow between the COTA Back-Office and COTA Transit Stop element. This information flow has not been shown for simplicity, due to the fact that it is outside the scope of the system.

2.7.3. Physical Architecture View

The SMH project consists of various interconnected transportation amenities, all classified into three smaller, fit-to-purpose Service Packages addressing the mobility and safety user needs established early in the project planning phases. Each Service Package interconnects one or more Functional Objects that work together to deliver the service, and defines the Information Flows that connect them and other external systems. The following Service Packages address SMH user mobility and safety needs, and will be discussed in greater detail in sections to follow:

- **Comprehensive Trip Planning:** This Service Package focuses on the interaction between the traveler and the MMTPA to deliver the comprehensive trip planning service.
- **Mobility Amenities:** This Service Package depicts the collection of transportation options, field objects, centers, and support systems involved in delivering mobility as a service to travelers at SMH facilities.

- **Emergency Call Service**: This package provides information on how the SMH project, through hardware on the IK, will deliver emergency call services at the SMH facility.

Figure 46 provides a comprehensive overview – Layer 0, Physical Architecture – for the SMH system. Each Service Package is introduced as a Layer 2 diagram, which provides additional detail about the Information Flows and interactions among objects.

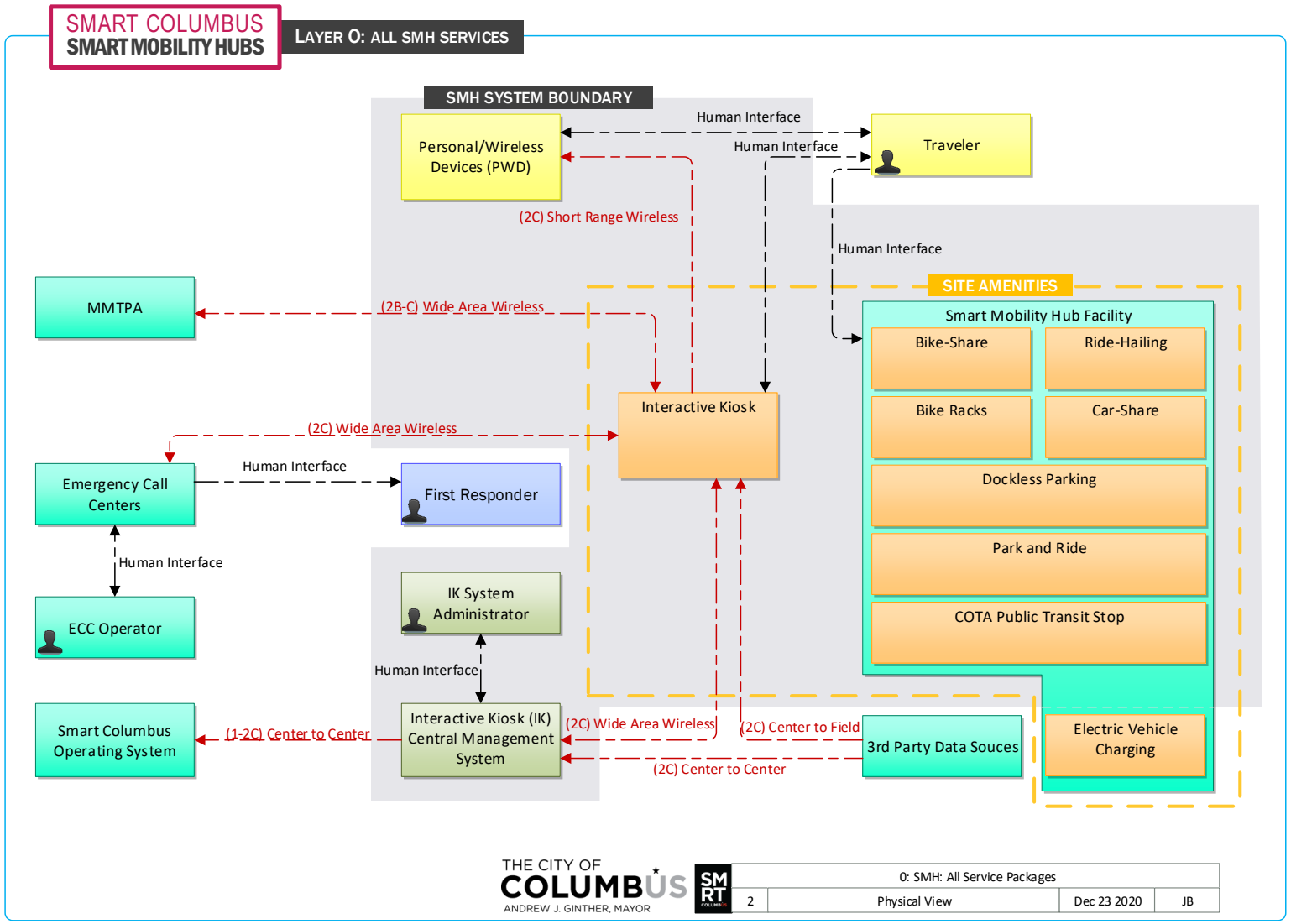


Figure 46: Smart Mobility Hubs Physical Architecture View (Layer 0)

Source: City of Columbus

2.7.3.1. COMPREHENSIVE TRIP PLANNING SERVICES

The IK is equipped with a software interface (i.e., an internal browser), which provides the traveler access to the MMTPA application to plan a multimodal trip. The physical architecture illustrates how the comprehensive trip planning service can be executed two distinct ways: (1) on the kiosk through the touch screen display, and (2) traveler connects a Wi-Fi enabled personal device to the kiosk's Wi-Fi hot spot, then uses the internet to access the MMTPA app.

Using this Service Package, travelers will be able to connect to MMTPA. The MMTPA will guide the traveler through a series of screens to enter destination, and then view routes, various modes, and travel times. Through the interactive kiosk, the MMTPA will allow the user to plan the trip and send the trip plan to the user's PWD using his or her email address or phone number. The user will then be able to book the trip through the MMTPA on their PWD and pay for the trip segments through the mobility provider apps.

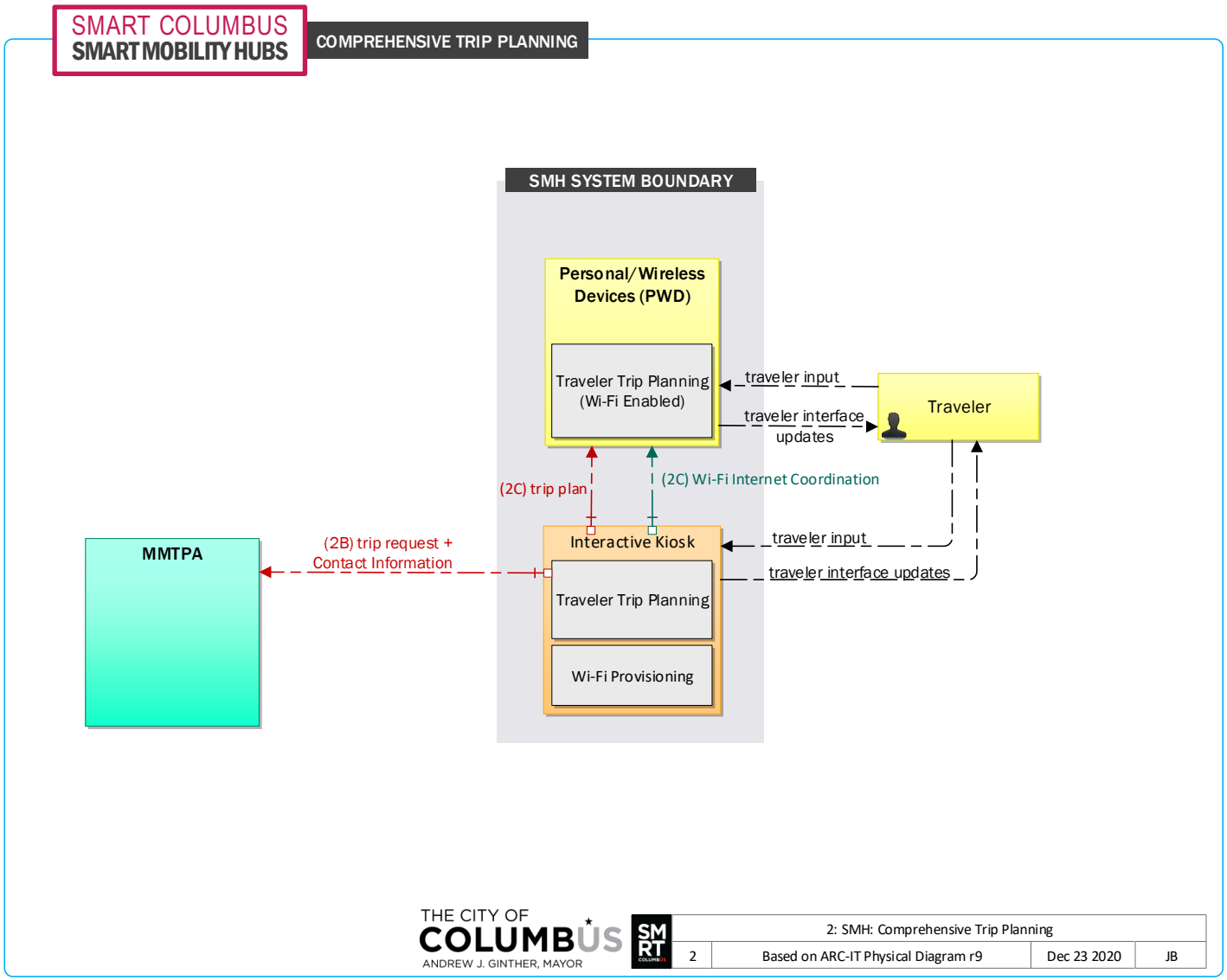


Figure 47: Smart Mobility Hubs Physical Comprehensive Trip Planning (Layer 2)

Source: City of Columbus

The following tables detail the Physical Elements, Information Flows, and Functional Objects associated with the SMH comprehensive trip planning Service Package.

Table 82: Smart Mobility Hubs Comprehensive Trip Planning Physical Elements

Name	Class	Description
Interactive Kiosk	Traveler	The Interactive Kiosk provides access to traveler information at SMH facilities, generally co-located with transit stations, transit stops, and major trip generation locations. The IK traveler information access points support varied levels of interaction and information access, comprehensive trip planning through MMTPA, traffic conditions, and transit schedules to support mode and route selection. Personalized route planning and route guidance information can also be sent via email or SMS text to travelers based on supplied criteria. In addition to the traveler information, the IK also provides Wi-Fi Internet access as well as enhances security in public areas by supporting traveler activated ECB alarms.
MMTPA	Center	The MMTPA is an app available to travelers on both iOS and Android devices as well as a web-based platform. MMTPA accesses mobility provider service options from multiple Mobility Providers via APIs. The project will allow travelers to create multimodal trips and pay each mobility provider. Multimodal trip options include walking, fixed-route bus service, ride-hailing, bike-sharing, and scooter services.
Personal/Wireless Devices (PWD)	Traveler	PWD, including smartphones and computers, provide the capability for travelers to receive formatted traveler information wherever they are. This also includes the capability of the device to call others (call center) to accomplish the tasks. Capabilities include traveler information, trip planning, and route guidance (even when offline). These devices provide travelers with the capability to receive route planning and other personally focused transportation services from the infrastructure in the field, at home, at work, or while en route. These devices may also double up as a 'Payment Device', which enables the electronic transfer of funds from the user of a service (i.e. a traveler) through smart cards or credit cards to the provider of the service.
Traveler	Traveler	The Traveler represents any individual who uses SMH amenities, including transportation services at any given SMH facility. The interfaces to the traveler provide general pre-trip and en route information supporting trip planning, personal guidance, and requests for assistance in an emergency that are relevant to all transportation system users. It also represents users of a public transportation system, and addresses interfaces these users have within a transit vehicle or at transit facilities, such as roadside stops and transit centers.

Source: City of Columbus

Table 83: Smart Mobility Hubs Comprehensive Trip Planning Information Flows

Name	Description
Contact Information	Contact Information may be a phone number or email address.
traveler input	User input from a traveler to summon assistance, request travel information, make a reservation, or request any other traveler service.
traveler interface updates	Visual or audio information (e.g., routes, messages, guidance, emergency information) that is provided to the traveler.
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 and parking reservation information.
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/parking reservations and ride-sharing options associated with the trip. For this project, the trip request may be for any mobility options associated with the trip.
Wi-Fi Internet Coordination	General internet access data between PWDs and kiosk vendor Internet Service Provider (ISP) via Wi-Fi hotspot. All users must accept the general terms and conditions of Wi-Fi usage.

Source: City of Columbus

Table 84: Smart Mobility Hubs Comprehensive Trip Planning Functional Objects

Physical Object	Functional Object	Description
Smart Mobility Hubs Project Functions		
Interactive Kiosk	Traveler Trip Planning	Traveler Trip Planning provides a personalized trip plan to the traveler. The trip plan is calculated based on preferences and constraints supplied by the traveler and provided to the traveler for confirmation. It represents kiosks and other fixed public interactive displays that may be used by travelers in public areas.
	Wi-Fi Provisioning	Complimentary, publicly accessible Wi-Fi will be provided at SMH locations. The IK will include a Wi-Fi hotspot, and the kiosk vendor will serve as an ISP. Travelers will be able to use this connection on their PWDs to access trip planning tools available on the kiosk, as well as access internet within constraints set by the kiosk vendor.
Personal/Wireless Devices (PWD)	Traveler Trip Planning (Wi-Fi Enabled)	Traveler Trip Planning is a service offered by the MMTPA, and is envisioned to be used throughout Columbus and outlying communities that are serviced by shared-use transportation services (Mobility Providers).

Source: City of Columbus

2.7.3.2. SMART MOBILITY HUBS AMENITIES

SMH facilities will provide multiple modes of transportation in the form of designated bike-sharing areas, pick-up and drop-off zones for ride-hailing, dockless device parking areas,car-share parking, park and ride lots, and access to COTA's real-time display. Due to differences in the physical configuration and specific needs for each site, the proposed infrastructure and technology-based improvements will vary.

Figure 48 provides a high-level illustration of the mobility amenities offered at SMH facilities. A number of the multimodal amenities rely on – and are enabled by – the MMTPA coordination. This includes mobility provider data collection, coordination of modes, and trip bookings. Since MMTPA was expressed as trip planning in the previous Service Package, the MMTPA terminal icon (MMTPA) is used in the diagram below to represent the interaction and presence the MMTPA manages between amenities. Likewise, safety services relating to the ECB are shown using the Emergency Call Center (ECC) terminal icon (ECC) as this service is presented in the Emergency Call Notification Service Package.

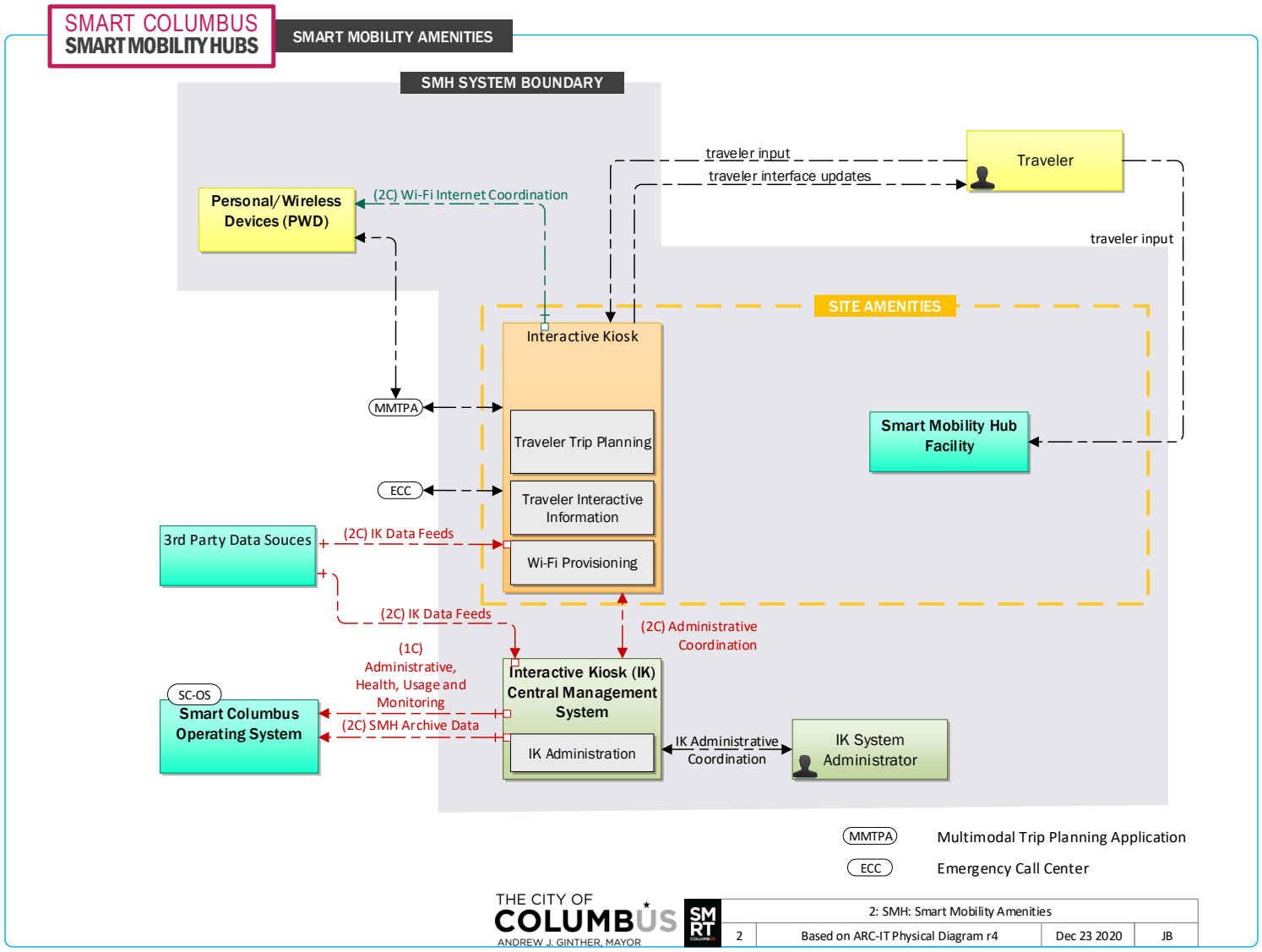


Figure 48: Smart Mobility Hubs Physical Smart Mobility Amenities (Layer 2)

Source: City of Columbus

The following tables detail the Physical Elements, Information Flows, and Functional Objects associated with the SMH smart mobility amenities Service Package.

Table 85: Smart Mobility Hubs Smart Mobility Amenities Physical Elements

Name	Class	Description
3rd Party Data Sources	Center	The 3rd Party Data Sources provide additional data. For example, traffic and parking information providers and Experience Columbus.
Interactive Kiosk (IK) Central Management System	Support	The Interactive Kiosk (IK) Central Management System is the central intelligence software for all kiosks installed in the field. It supports, configures, collects, archives, manages, and distributes data generated from kiosk sources for use in SMH project administration, policy evaluation, safety, planning, performance monitoring, program assessment, and operations.
IK System Administrator	Support	The IK System Administrator represents the human operator who provides overall management, administration, and service monitoring duties for the kiosks and the Central Management System.
Interactive Kiosk	Field	The IK provides access to traveler information at SMH facilities, generally co-located with transit stations, transit stops, and major trip generation locations. The IK traveler information access points support varied levels of interaction and information access, comprehensive trip planning through MMTPA, traffic conditions, and transit schedules to support mode and route selection. Personalized route planning and route guidance information can also be sent via email or SMS text to travelers based on supplied criteria. In addition to the traveler information, the IK also provides Wi-Fi Internet access as well as enhances security in public areas by supporting traveler activated ECB alarms.
Personal/Wireless Devices (PWD)	Traveler	PWD, including smartphones and computers, provide the capability for travelers to receive formatted traveler information wherever they are. This also includes the capability of the device to call others (call center) to accomplish the tasks. Capabilities include traveler information, trip planning, and route guidance (even when offline). These devices provide travelers with the capability to receive route planning and other personally focused transportation services from the infrastructure in the field, at home, at work, or while en route. These devices may also double up as a 'Payment Device', which enables the electronic transfer of funds from the user of a service (i.e. a traveler) through smart cards or credit cards to the provider of the service.
Smart Columbus Operating System	Center	The Smart Columbus Operating System covers the ingestion and organization of information stored in the Smart Columbus Operating System. The ingestion process is initiated by the Data Curator using a web interface to define and manage the data feeds.

Name	Class	Description
Smart Mobility Hubs Facility	Center	This general Physical Object is used to model core capabilities and amenities common to any mobility hub. The geographic area of the SMH deployments extends on the Cleveland Avenue corridor coinciding with COTA's BRT (CMAX) to Easton Transit Center. Individual SMH facilities will vary in size, configuration, and available services since the goal of the sites is to incorporate the amenities within the existing physical constraints.
Traveler	Traveler	The Traveler represents any individual who uses SMH amenities, including transportation services at any given SMH facility. The interfaces to the traveler provide general pre-trip and en route information supporting trip planning, personal guidance, and requests for assistance in an emergency that are relevant to all transportation system users. It also represents users of a public transportation system, and addresses interfaces these users have within a transit vehicle or at transit facilities, such as roadside stops and transit centers.

Source: City of Columbus

Table 86: Smart Mobility Hubs Smart Mobility Amenities Information Flows

Name	Description
Administrative, Health, Usage and Monitoring	Information flow for administrative, health, usage, and monitoring.
Administrative Coordination	Data associated with the technical administration of an information support system or center. This could include data elements, such as system configuration (parameters, filters, thresholds, etc.), API definitions, data ingestion rules, system usage data, health monitoring heartbeats, device states, security monitoring and compliance, software event triggers, network interface statistics, data governance and policy, etc.
IK Administrative Coordination	IK administrator is responsible for the administration of the kiosk and IK Central Management System.
IK Data Feeds	Information needed for interactive traveler information, such as web pages, traffic information data feeds, and more.
SMH Archive Data	Includes SMH archive data.
traveler input	User input from a traveler to summon assistance, request travel information, make a reservation, or request any other traveler service.
traveler interface updates	Visual or audio information (e.g., routes, messages, guidance, emergency information) that is provided to the traveler.
Wi-Fi Internet Coordination	General internet access data between PWDs and kiosk vendor ISP via Wi-Fi hotspot. All users must accept the general terms and conditions of Wi-Fi usage.

Source: City of Columbus

Table 87: Smart Mobility Hubs Smart Mobility Amenities Functional Objects

Physical Object	Functional Object	Description
Smart Mobility Hubs Project Functions		
Interactive Kiosk (IK) Central Management System	IK Administration	Provides administrative coordination for the management and monitoring of kiosk health, configuration information, field device state, kiosk usage, Wi-Fi security administration, and compliance administration. In addition to the technical coordination of hardware and software, kiosk administrators will be responsible for managing the content on each kiosk. This coordination includes configuring, uploading, and managing location-specific content, such as approved advertising, custom designs and messaging, photo booth, arcade, posters, configuring applications that require data feeds like local events, job boards, surveys, business listing and directory information for Eat and Drink, Play, Shop, Stay, Social Services, Shelter, Job Board, Civic Resources, and feeds from the Smart Columbus Operating System of various sorts.
Interactive Kiosk	Traveler Trip Planning	Traveler Trip Planning is a service offered by the MMTPA and is envisioned to be used throughout Columbus and outlying communities that are serviced by shared-use transportation services (Mobility Providers). The MMTPA project will offer travelers comprehensive trip planning services, including multimodal trips, trip optimization with dynamic route guidance, the ability to pay using linked accounts, and data services like profiles and accounts. Multimodal trip options include walking, fixed-route bus service, ride-hailing, bike-sharing, paratransit, and scooter services.
	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. The interactive traveler information capability is provided by a public traveler interface, such as a kiosk.
	Wi-Fi Provisioning	Complimentary, publicly accessible Wi-Fi will be provided at SMH locations. The IK will include a Wi-Fi hotspot, and the kiosk vendor will serve as an ISP. Travelers will be able to use this connection on their PWDs to access trip planning tools available on the kiosk, as well as access internet within constraints set by the kiosk vendor.

Source: City of Columbus

2.7.3.3. EMERGENCY CALL SERVICE

The IKs at the SMH facility will provide an ECB that, when activated, will send notification of the help request directly to the appropriate 911 ECC operated by the City of Columbus or Franklin County, and initiate an audio connection between the traveler and an operator at the ECC. Upon activation of the ECB, the kiosk's internal systerm will store the alert date stamp to assist in retrieving video of the incident, which will only be accessed by the IK System Administrator upon request from law enforcement. The ECC network is isolated, and does not receive other data for security reasons. The physical diagram below provides the architecture for the emergency call service at SMH locations.

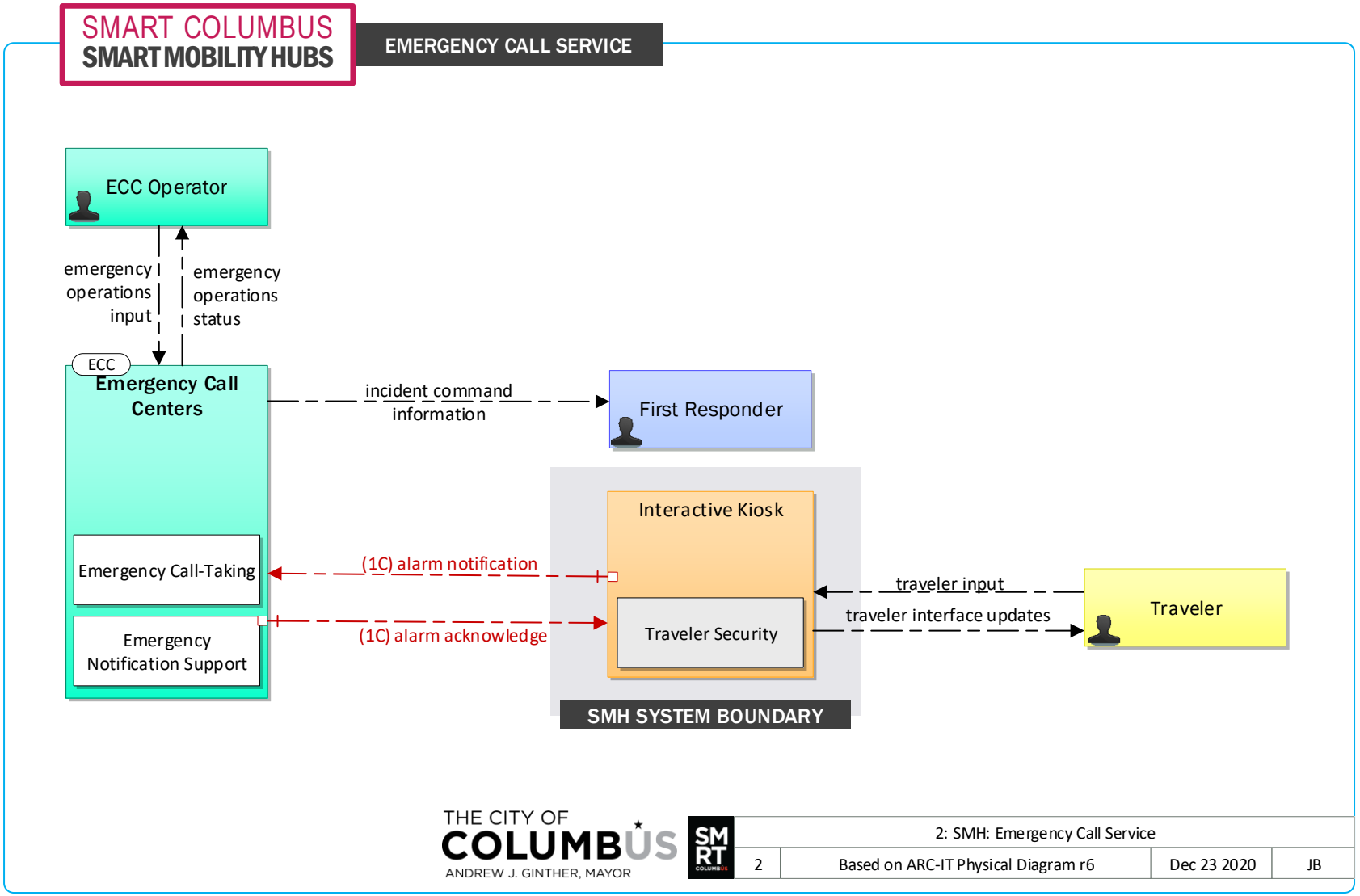


Figure 49: Smart Mobility Hubs Physical Emergency Call Service (Layer 2)

Source: City of Columbus

The following tables detail the Physical Elements, Information Flows, and Functional Objects associated with the SMH emergency call Service Package.

Table 88: Smart Mobility Hubs Emergency Call Service Physical Elements

Name	Class	Description
ECC Operator	Center	The ECC Operator represents the public safety personnel in Columbus that monitor emergency requests. The operator may also include dispatchers who manage an emergency fleet (police, fire, ambulance, HAZMAT, etc.) or higher order emergency managers who provide response coordination during emergencies.
Emergency Call Centers	Center	ECCs represent facilities that deliver a set of systems and services that support incident management, disaster response and evacuation, security monitoring, and other security and public safety-oriented applications at SMH facilities. It includes the functions associated with fixed and mobile public safety communications centers, including public safety call takers and dispatch centers operated by police, fire, and emergency medical services. It includes the functions associated with Emergency Operations Centers in Columbus and Franklin County that are activated locally for emergencies and the portable and transportable systems that support Incident Command System operations.
First Responder	Vehicle	First Responder represents personnel that are responsible for police, fire, emergency medical services, towing, service patrols, and other special response team (e.g., HAZMAT clean-up) activities at an incident site. These personnel are associated with the emergency vehicle during dispatch to the incident site, but often work independently of the emergency vehicle while providing their incident response services.
Interactive Kiosk	Field	The Interactive Kiosk provides access to traveler information at SMH facilities, generally co-located with transit stations, transit stops, and major trip generation locations. The IK traveler information access points support varied levels of interaction and information access, comprehensive trip planning through MMTPA, traffic conditions, and transit schedules to support mode and route selection. Personalized route planning and route guidance information can also be sent via email or SMS text to travelers based on supplied criteria. In addition to the traveler information, the IK also provides Wi-Fi Internet access as well as enhances security in public areas by supporting traveler activated ECB alarms.
Traveler	Traveler	The Traveler represents any individual who uses SMH amenities, including transportation services at any given SMH facility. The interfaces to the traveler provide general pre-trip and en route information supporting trip planning, personal guidance, and requests for assistance in an emergency that are relevant to all transportation system users. It also represents users of a public transportation system, and addresses interfaces these users have within a transit vehicle or at transit facilities, such as roadside stops and transit centers.

Source: City of Columbus

Table 89: Smart Mobility Hubs Emergency Call Service Information Flows

Name	Description
alarm acknowledge	Confirmation that alarm was received, instructions and additional information for the alarm initiator, and requests for additional information.

Name	Description
alarm notification	Notification of activation of an audible or silent alarm by a traveler in a public area or by a transit vehicle operator using an onboard device. For this project, notification of activation is an audible ECB alarm by a traveler, at the kiosk, in a public area.
emergency operations input	Emergency operator input supporting call taking, dispatch, emergency operations, security monitoring, and other operations and communications center operator functions.
emergency operations status	Presentation of information to the operator including emergency operations data, supporting a range of emergency operating positions, including call taker, dispatch, emergency operations, security monitoring, and various other operations and communications center operator positions.
incident command information	Presentation of information to emergency personnel in the field that supports local tactical decision-making within an incident command system structure.
traveler input	User input from a traveler to summon assistance, request travel information, make a reservation, or request any other traveler service. For this project, traveler input includes traveler's physical activation of the ECB.
traveler interface updates	Visual or audio information (e.g., routes, messages, guidance, emergency information) that is provided to the traveler. For this project, traveler interface updates includes Voice over Internet Protocol (VoIP) audio response updates from the ECC and audiovisual components. Audio will be used for communicating from the kiosk to the ECC, while activated video is stored locally for police access upon request.

Source: City of Columbus

Table 90: Smart Mobility Hubs Emergency Call Service Functional Objects

Physical Object	Functional Object	Description
Smart Mobility Hubs Project Functions		
Interactive Kiosk	Traveler Security	Traveler Security provides the capability to report an emergency or summon assistance from secure areas such as transit stops, transit stations, modal transfer facilities, rest stops and picnic areas, park-and-ride areas, tourism and travel information areas, and emergency pull off areas. This object includes interfaces that support initiation of an alarm and presentation of the returned alarm acknowledgement, as well as a broadcast message to advise or warn the traveler. For this project, the IK will provide an ECB to support incident response and emergency calls. When activated by the traveler, the emergency call service initiates an incident/event notification along with location information and direct audio connection VoIP to the ECC.

Physical Object	Functional Object	Description
Existing Functions (External to SMH)		
Emergency Call Centers	Emergency Call-Taking	Emergency Call-Taking supports the emergency call-taker, collecting available information about the caller and the reported emergency, and forwarding this information to other objects that formulate and manage the emergency response. It receives 911, 10-digit local access, and an automated alarm system will assist in the verification and assessment of the emergency. It will forward the emergency information to the appropriate response agency.
	Emergency Notification Support	Emergency Notification Support receives emergency notification messages from vehicles or personal handheld devices, determines an appropriate response, and either uses internal resources or contacts a local agency to provide that response. The nature of the emergency is determined based on the information in the received message as well as other inputs. This object serves as an interface between automated collision notification systems and the local public safety answering point for messages that require a public safety response. This capability depends on an up-to-date registry of public safety answering points/response agencies by coverage area, the type of emergency, and hours of service.

Source: City of Columbus

2.7.4. Enterprise Architecture View

The following diagram shows the relationships between Smart Columbus stakeholders, the roles organizations play within the project, and the agreements among the stakeholders. The table provides the list of existing or expected agreements with a brief description.

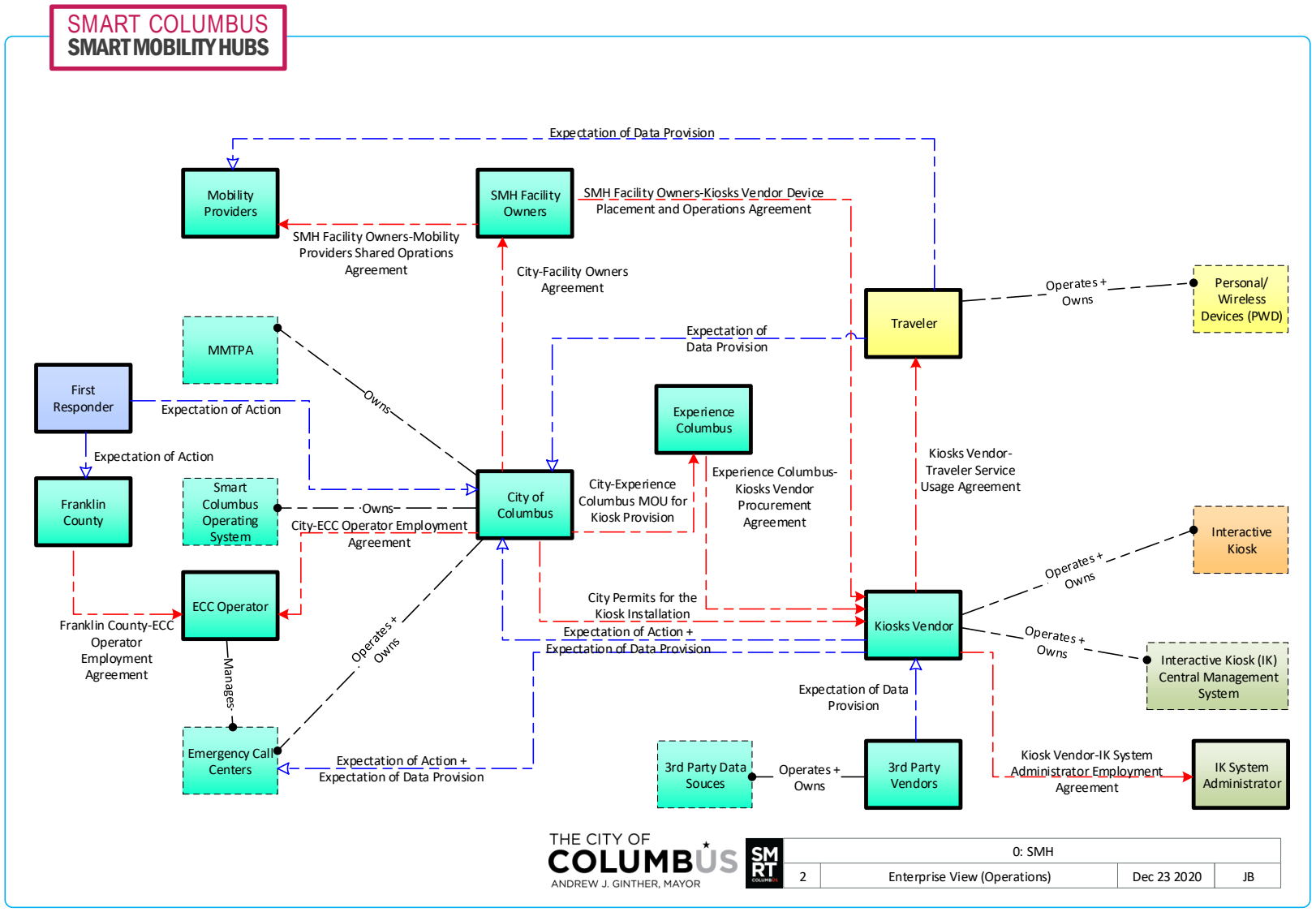


Figure 50: Smart Mobility Hubs Enterprise Architecture View

Source: City of Columbus

Table 91: Smart Mobility Hubs List of Agreements

Potential Agreement	Description
City-SMH Facility Owners Agreement	An agreement between the City and SMH Facility Owners for locations/amenities not in public right-of-way. Facility Owners: COTA, St. Stephen's Community House, Columbus Metropolitan Library – Linden Branch Status: • COTA: Existing • St. Stephen's Community House: Existing • Columbus Metropolitan Library – Linden Branch: Existing
SMH Facility Owners-Mobility Providers Shared Operations Agreement	An agreement between SMH Facility Owners and Mobility Providers documenting responsibilities for all activities associated with shared systems being operated and/or maintained and for bikeshare, any installation or electricity needs. Facility Owners: COTA, St. Stephen's Community House, Columbus Metropolitan Library – Linden Branch Mobility ProvidersLime, Spin, Yellow Cab, and CoGo Status: Existing
SMH Facility Owners-Kiosks Vendor Device Placement and Operations Agreement	An agreement that enables the kiosk provider to install and operate Kiosks at SMH facilities. At select facilities, this also includes procurement of electricity to operate the kiosk. Facility Owners: COTA, St. Stephen's Community House, Columbus Metropolitan Library – Linden Branch Kiosk Vendor: IKE Smart City LLC Status: • COTA: Existing • St. Stephen's Community House: Existing • Columbus Metropolitan Library – Linden Branch: Existing
City-Experience Columbus Memorandum of Understanding (MOU) for Kiosk Provision	An agreement between the City and Experience Columbus for the provision of kiosks and kiosk data for each of the SMH facilities. Status: Existing
Experience Columbus-Kiosks Vendor Procurement Agreement	An agreement between Experience Columbus and the Kiosks Vendor to procure the kiosks. The agreement existed before Smart Columbus but was modified to include additional kiosks for the Smart Columbus project. As part of the agreement, Experience Columbus has input into some of the advertising content on the kiosks. Status: Existing
Kiosks Vendor-IK System Administrator Employment Agreement	An agreement between the Kiosks Vendor and IK System Administrator, whereupon the staff agrees to provide labor to the Kiosk Vendor, which in turn compensates the employee. Stipulates level of compensation, working conditions, necessary equipment and training and expectations of employee performance. Status: Existing

Potential Agreement	Description
Kiosks Vendor-Traveler Service Usage Agreement	An agreement between the Kiosks Vendor and Traveler to use the Wi-Fi at the IK. Stipulates the terms and conditions of service usage. Status: Existing
Franklin County-ECC Operator Employment Agreement	An agreement between Franklin County and ECC Operator, whereupon the staff agrees to provide labor to Franklin County, which in turn compensates the employee. Stipulates level of compensation, working conditions, necessary equipment and training and expectations of employee performance. Status: Existing
City-ECC Operator Employment Agreement	An agreement between the City and ECC Operator, whereupon the staff agrees to provide labor to the City, which in turn compensates the employee. Stipulates level of compensation, working conditions, necessary equipment and training and expectations of employee performance. Status: Existing
City Permits for the Kiosk Installation	Permits issued by the City for the kiosk vendor to install the kiosks in the public right-of-way, where applicable. Status: Existing

Source: City of Columbus

2.7.4.1. ROLES AND RESPONSIBILITIES

Development:

- City of Columbus/Smart Columbus PMO:
  - Michael Baker, Intl.: project management
  - HNTB: systems engineering
  - IKE/Orange Barrel: kiosk requirements/design
  - Other Smart Columbus Projects:
    - MMTPA Team (Etch): integration
    - CEAV (EasyMile): integration of CEAV stops into planning/design
    - OS: data integration of IK Central Management System to OS
- Property owners: concept and requirements development; agreements to install infrastructure
- Mobility providers: agreements to provide infrastructure/assets at SMH locations

Installation:

- City of Columbus/Smart Columbus PMO:
  - Michael Baker, Intl.: project management
  - HNTB: installation plans
  - IKE/Orange Barrel: kiosk installation
  - Other City Departments: installation of other SMH infrastructure (besides kiosks)
- Property owners: concept and requirements development; agreements to install infrastructure

- Mobility providers: agreements to provide infrastructure/assets at SMH locations

Testing:

- City of Columbus/Smart Columbus PMO:
  - Michael Baker, Intl.: project management, lead tester
  - HNTB: Test plan development, test participant
  - IKE/Orange Barrel: kiosk testing
  - Other Smart Columbus Projects:
    - MMTPA Team (Etch): Testing MMTPA function on SMH kiosks
    - OS: testing of SMH/OS interface
- Property owners: concept and requirements development; agreements to install infrastructure (include COTA) – test participants

Operations:

- City of Columbus/Smart Columbus PMO:
  - Michael Baker, Intl.: project management, O&M plan development and review, safety management
  - HNTB: O&M plan development
  - IKE/Orange Barrel: O&M plan input
  - City Department of Public Service: safety and response (emergency notification service)
  - OS Team (Accenture): data collection
  - MMTPA Team (Etch): MMTPA operations
- Property owners: facility access (where necessary for indoor or private property kiosks), responsibility for notifying City/PMO of issues with kiosks or other SMH infrastructure

Maintenance:

- City of Columbus/Smart Columbus PMO: infrastructure maintenance
  - IKE/Orange Barrel: kiosks update/maintenance
  - MMTPA Team (Etch): MMTPA bug fixes, maintenance
- Property owners: facility maintenance outside of SMH system boundary

2.7.5. Communications Architecture View

2.7.5.1. COMMUNICATION PROFILES USED

The following sections describe the layered sets of communication protocols that are required to support communications among the elements that make up the SMH project.

Source: City of Columbus

2.7.5.1.1. VoIP

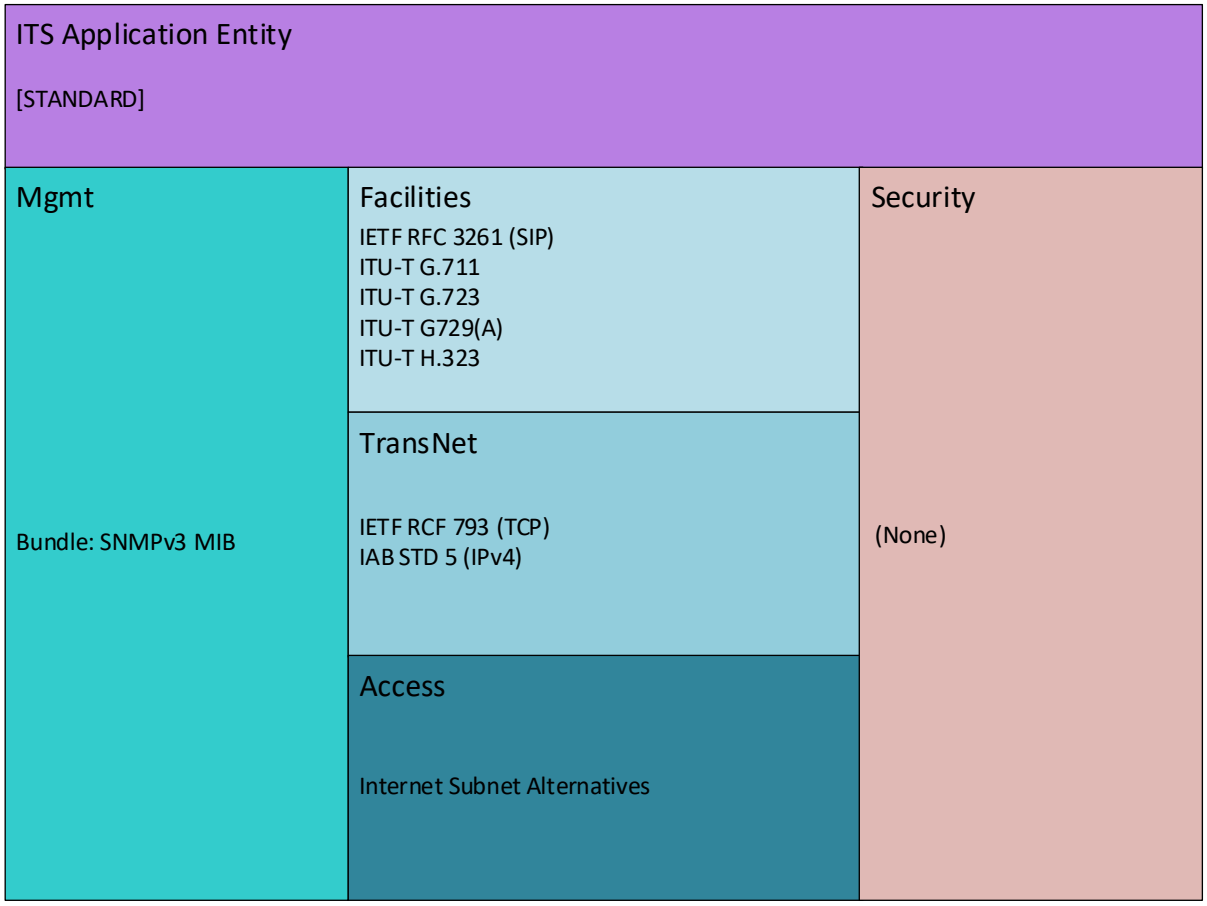


Figure 51: VoIP

Source: City of Columbus

Table 92: VoIP

Name	Source	Destination	Standard	Profile
alarm acknowledge	Emergency Call Centers	Interactive Kiosk	(Unspecified)	VoIP
alarm notification	Interactive Kiosk	Emergency Call Centers	(Unspecified)	VoIP

Source: City of Columbus

2.7.5.1.2. Wi-Fi

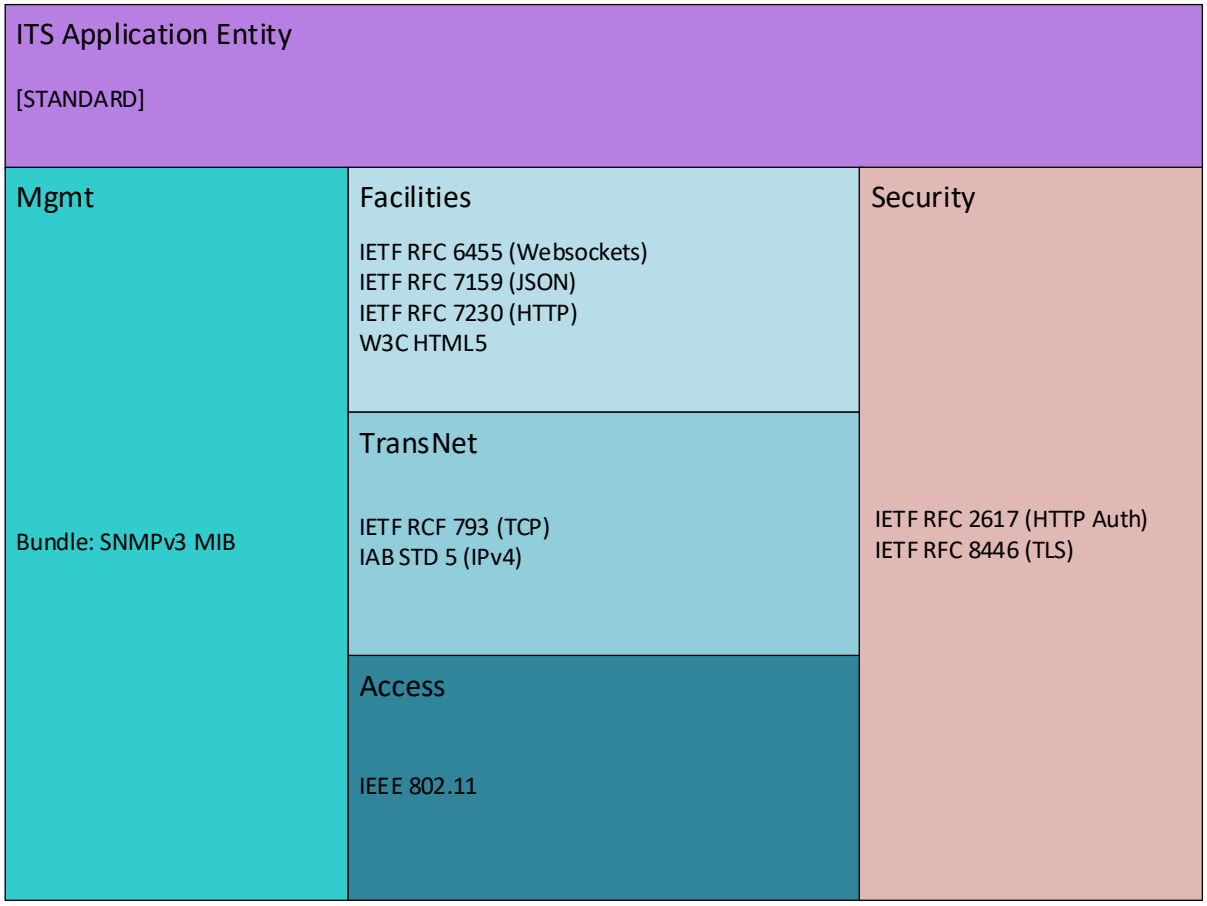


Figure 52: Wi-Fi

Source: City of Columbus

Table 93: Wi-Fi

Name	Source	Destination	Standard	Profile
trip plan	Interactive Kiosk	Personal/Wireless Devices (PWD)	(Unspecified)	Wi-Fi
Wi-Fi Internet Coordination	Interactive Kiosk	Personal/Wireless Devices (PWD)	(Unspecified)	Wi-Fi

Source: City of Columbus

2.7.5.1.3. World Wide Web Browser/JSON/Wide Area Wireless

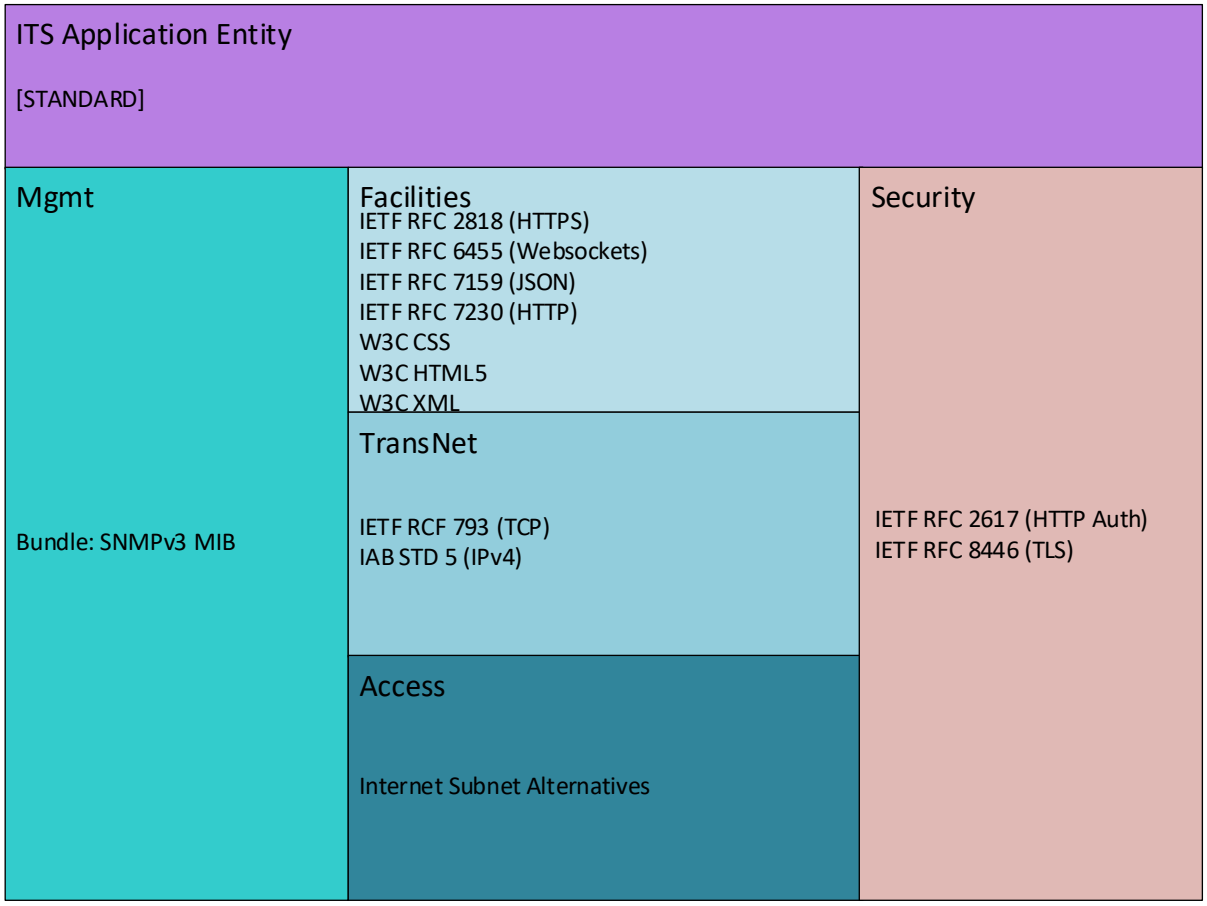


Figure 53: World Wide Web Browser/JSON/Wide Area Wireless

Source: City of Columbus

Table 94: World Wide Web Browser/JSON/Wide Area Wireless

Name	Source	Destination	Standard	Profile
Administrative Coordination	Interactive Kiosk	Interactive Kiosk (IK) Central Management System	(Unspecified)	WAW-WWWBrowser-JSON
Administrative Coordination	Interactive Kiosk (IK) Central Management System	Interactive Kiosk	(Unspecified)	WAW-WWWBrowser-JSON
Administrative, Health, Usage and Monitoring	Interactive Kiosk (IK) Central Management System	Smart Columbus Operating System	(Unspecified)	WAW-WWWBrowser-JSON
Contact Information	Interactive Kiosk	MMTPA	(Unspecified)	WAW-WWWBrowser-JSON

Name	Source	Destination	Standard	Profile
IK Data Feeds	3rd Party Data Sources	Interactive Kiosk	(Unspecified)	WAW-WWWBrowser-JSON
IK Data Feeds	3rd Party Data Sources	Interactive Kiosk (IK) Central Management System	(Unspecified)	WAW-WWWBrowser-JSON
SMH Archive Data	Interactive Kiosk (IK) Central Management System	Smart Columbus Operating System	(Unspecified)	WAW-WWWBrowser-JSON
trip request	Interactive Kiosk	MMTPA	(Unspecified)	WAW-WWWBrowser-JSON

Source: City of Columbus

2.7.5.1.4. Human Interface

Table 95: Human Interface

Name	Source	Destination	Standard	Profile
emergency operations input	ECC Operator	Emergency Call Centers	(Unspecified)	Human Interface
emergency operations status	Emergency Call Centers	ECC Operator	(Unspecified)	Human Interface
Incident command information	Emergency Call Centers	First Responder	(Unspecified)	Human Interface
IK Administrative Coordination	IK System Administrator	Interactive Kiosk (IK) Central Management System	(Unspecified)	Human Interface
IK Administrative Coordination	Interactive Kiosk (IK) Central Management System	IK System Administrator	(Unspecified)	Human Interface
traveler input	Traveler	Interactive Kiosk	(Unspecified)	Human Interface
traveler input	Traveler	Personal/Wireless Devices (PWD)	(Unspecified)	Human Interface
traveler interface updates	Interactive Kiosk	Traveler	(Unspecified)	Human Interface

Name	Source	Destination	Standard	Profile
traveler interface updates	Personal/Wireless Devices (PWD)	Traveler	(Unspecified)	Human Interface

Source: City of Columbus

2.7.6. Functional Architecture View

The Functional Architecture View depicts each element of overall system and the logical interfaces among them. **Table 96** lists draft processes which are developed based on discussion with the project team. These processes will be further refined and defined in detail during the design phase of the project.

Table 96: Smart Mobility Hubs Functional Architecture View

Physical Object	Functional Object	Process
Interactive Kiosk (IK) Central Management System	IK Administration	Kiosk Content Management Kiosk Hardware and Software Management Identity and Access Management System Monitoring and Notification Management
Emergency Call Centers	Emergency Call-Taking	Coordinate Emergency Inputs Collect Incident and Event Data Determine Coordinated Response Plan Communicate Emergency Status Manage Emergency Response
	Emergency Notification Support	Determine Coordinated Response Plan Communicate Emergency Status Process ECB Activation Notifications
Interactive Kiosk	Traveler Interactive Information	Get Traveler Personal Request Provide Traveler with Personal Travel Information Provide Traveler Personal Interface Update Traveler Personal Display Map Data
	Traveler Security	Provide ECB Notification Interface Process Kiosk Emergency Requests Provide Kiosk Location

Physical Object	Functional Object	Process
	Traveler Trip Planning	Provide Traveler Interface for Trip Planning Collect Traveler Information and Parameters for Trip Planning Provide Traveler with MMTPA Information Dissemination Send SMS Text Messages
	Traveler Interactive Information	Get Traveler Personal Request Provide Traveler with Personal Travel Information Provide Traveler Personal Interface Update Traveler Personal Display Map Data Provide Personal Safety Messages Provide Personal Payment Device Interface
	Wi-Fi Provisioning	Provide Traveler Interface for Trip Planning Collect Traveler Information and Parameters for Trip Planning Provide Traveler with MMTPA Information Dissemination Send SMS Text Messages
Personal/Wireless Devices (PWD)	Traveler Trip Planning (Wi-Fi Enabled)	Provide Traveler Interface for Trip Planning Collect Traveler Information and Parameters for Trip Planning Provide Traveler with MMTPA Information Dissemination Send SMS Text Messages

Source: City of Columbus

2.8. PROJECT 7: EVENT PARKING MANAGEMENT

2.8.1. Introduction

The City of Columbus lacks an integrated system for residents and visitors to easily and efficiently view, reserve, and book available parking spaces at parking garages, surface lots, and parking meters--especially at large events. Also, non-direct routing of travelers causes congestion and inefficiency in the transportation network.

The EPM application will integrate parking information from multiple parking facilities into a single availability and reservation services solution. This will allow travelers to plan and search for parking options near their destination and, at certain locations, to reserve and book a parking space. More direct routing of travelers during large events is expected to reduce congestion during those times. The City of Columbus identified the following objectives to measure the impact the EPM project:

- Reduce parking related congestion
- Reduce vehicle emissions
- Increase knowledge of available parking around events

2.8.2. System of Interest

EPM system will address the following User Needs as identified in the EPM ConOps:

- EPM Real-Time Parking Information
- EPM Map Display
- EPM Parking Meter Availability
- EPM One-Stop-Shop
- EPM Parking Reservation
- EPM Facility Access
- EPM Navigation
- EPM Parking Meter Time Left
- EPM Probe Vehicle Data
- EPM Parking Facility Information
- EPM Parking Facility Reservation
- EPM Demand-Based Pricing
- EPM Communications Reliability
- EPM Utilization Information
- EPM Integration with Current City Systems
- EPM Integration with the Smart Columbus Operating System
- EPM Loading Zone Availability
- EPM User Feedback
- EPM Reports
- EPM Parking Meter Time Extension
- EPM Report a Problem
- EPM Anonymous Search
- EPM Create a Profile
- EPM Guest Accounts

The EPM system will provide real-time parking information including the location, hours of operation, restrictions, availability, price (comparison), number of parking spaces available, and other information to help locate available parking including loading zones, surface lots, electric vehicle charging, and Americans with Disability Act accessible parking spaces.

The EPM system will provide access to this information from a single location, which could be through a smartphone application (iOS and Android) or through a website.

The EPM system will provide the ability to book/reserve and pay for parking in accordance with the policies of individual facilities, and to receive confirmation that bookings/reservations have been processed and accepted.

The EPM system will provide the City with updated information on parking usage and availability to assist in the creation of more comprehensive management plans, better utilization of parking facilities and parking meters.

For participating parking facilities, a reservation and single payment service will be available.

The EPM system will also provide an interface with the Smart Columbus Operating System to receive the parking information maintained by the City and the probability of finding a metered parking space. The Smart Columbus Operating System will receive availability information from the Traffic Information Providers and parking meter time extensions from the City Parking Meter System.

2.8.3. Physical Architecture View

The EPM project includes a single customized Service Package from the USDOT ARC-IT – Smart Park and Ride System. This Service Package provides real-time information on Park and Ride capacity and supports the traveler's decision-making on where to park.

Figure 54 shows Layer 2 Physical Architecture View for the EPM project. Layer 2 view shows all the Elements, their associated Functional Objects, and the Information Flow between the elements. The description of the Elements, Functional Objects, and the Information Flow among the elements are shown in the following tables. Because there is only a single Service Package, only a Layer 2 diagram is shown.

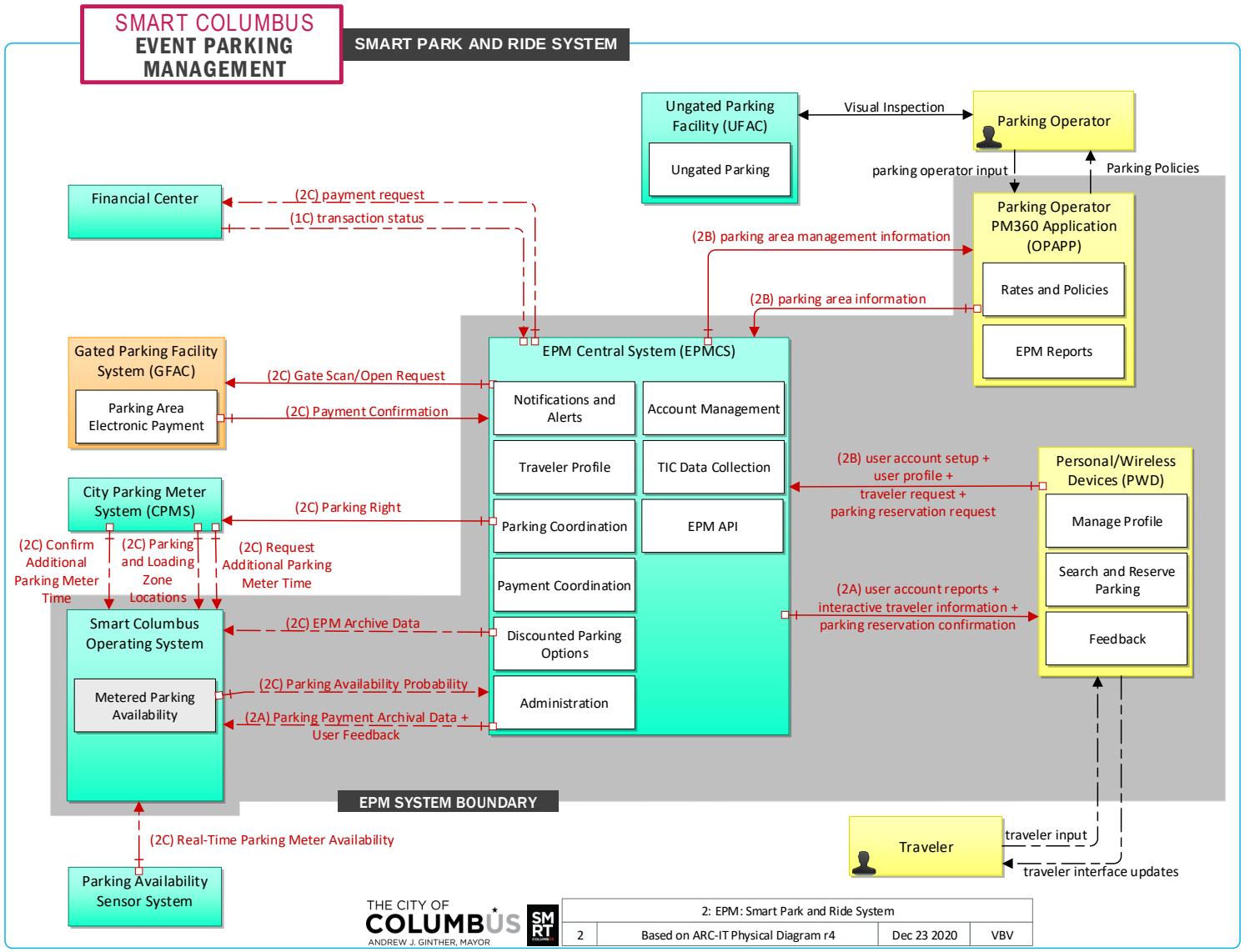


Figure 54: Event Parking Management Physical Architecture View

Source: City of Columbus

Table 97: Event Parking Management Physical Elements

Physical Object	Class	Description
City Parking Meter System (CPMS)	Center	The CPMS will send meter usage and general meter and loading zone information to the Smart Columbus Operating System. Loading zone information includes locations and hourly restrictions.
EPM Central System (EPMCS)	Center	The EPMCS is a system to search, find, schedule, and reserve parking. It maintains the traveler profile, coordinates parking payment, sends reminder/notifications, provides discounted parking options, and calculates the probability of finding parking meter space in the City.
Financial Center	Center	The Financial Center represents the organization that handles electronic fund transfer requests to enable the transfer of funds from the user of the service to the provider of the service. The functions and activities of financial clearinghouses are covered by this physical object.
Gated Parking Facility System (GFAC)	Field	The GFAC refers to facilities, which have a system to manage parking.
Parking Availability Sensor System	Center	The Parking Availability Sensor System collects, processes, and distributes real-time parking sensor information. The system provides real-time information for parking space occupancy for several zones in the Short North area.
Parking Operator	Traveler	The Parking Operator interfaces with the parking operator application.
Parking Operator PM360 Application (OPAPP)	Traveler	The OPAPP will send and receive data with the EPMCS. A web-based application will allow parking facilities to interface to the EPM.
Personal/Wireless Devices (PWD)	Traveler	PWD, including smartphones and computers, provide the capability for travelers to receive formatted traveler information wherever they are. This also includes the capability of the device to call others (call center) to accomplish the tasks. Capabilities include traveler information, trip planning, and route guidance (even when offline). These devices provide travelers with the capability to receive route planning and other personally focused transportation services from the infrastructure in the field, at home, at work, or while en route. These devices may also double up as a Payment Device, which enables the electronic transfer of funds from the user of a service (i.e. a traveler) through smart cards or credit cards to the provider of the service.
Smart Columbus Operating System	Center	The Smart Columbus Operating System covers the ingestion and organization of information stored in the Smart Columbus Operating System. The ingestion process is initiated by the Data Curator using a web interface to define and manage the data feeds.
Traveler	Vehicle	The Traveler represents any individual who uses transportation services. The interfaces to the traveler provide general pre-trip and en route information supporting trip planning and personal guidance.
Ungated Parking Facility (UFAC)	Center	The UFAC refers to a manually operated parking facility without a system to manage ingress/egress.

Source: City of Columbus

Table 98: Event Parking Management Information Flows

Information Flow	Description
Confirm Additional Parking Meter Time	Confirmation of the additional parking meter time.
EPM Archive Data	Includes EPM archive data.
Gate Scan/Open Request	Request for the GFAC to open or scan a traveler's access code.
interactive traveler information	Traveler information provided in response to a traveler request. The provided information includes traffic and road conditions, advisories, incidents, payment information, transit services, parking information, weather information, and other travel-related data updates and confirmations. For this project, only parking information is applicable.
Parking and Loading Zone Locations	The locations of parking space and loading zones.
parking area information	Current status for the parking area. This includes information on general parking area status (operating hours, open entrances and exits, entrance queue status, parking operator information, current parking occupancy and availability).
parking area management information	Parameters that support management of a parking area. Hours of operation, parking rules and regulations, parking operator (attendant) information, etc.
Parking Availability Probability	The probability that parking spaces in a region will be available.
parking operator input	User input from the parking operator to query current status and control the operation of the parking management system.
Parking Payment Archival Data	Data used to analyze and monitor trends in parking demand, pricing, and operational actions. Content may include a catalog of available information, the actual information to be archived, and associated meta data that describes the archived information.
Parking Policies	Presentation of information will include parking rates, policies, EPM Reports, and other facility information.
parking reservation confirmation	Confirmation for parking reservation.
parking reservation request	Reservation request for parking.
Parking Right	Start/stop time, location, amount paid, license plate number, QR code, and other information needed to enforce parking.
Payment Confirmation	Confirmation that a user who has reserved parking has accessed a parking facility.
payment request	Request for payment from financial institution.

Information Flow	Description
Real-Time Parking Meter Availability	Real-time parking meter availability information based on field sensor data.
Request Additional Parking Meter Time	Renew parking meter to extend the expiry time.
transaction status	Response to transaction request. Normally dealing with a request for payment.
traveler input	User input from a traveler to summon assistance, request travel information, make a reservation, or request any other traveler service.
traveler interface updates	Visual or audio information (e.g., routes, messages, guidance, emergency information) that is provided to the traveler.
traveler request	A request for traveler information including traffic, transit, toll, parking, road weather conditions, event, and passenger rail information. The request identifies the type of information, the area of interest, parameters that are used to prioritize or filter the returned information, and sorting preferences. For this project, only parking information is applicable.
user account reports	Reports on services offered/provided and associated charges.
user account setup	Billing information, vehicle information (or registration information), and requests for reports.
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.
User Feedback	Feedback provided by the user after the use of the EPM application.
Visual Inspection	Perform visual check at the facility.

Source: City of Columbus

Table 99: Event Parking Management Functional Objects

Physical Object	Functional Object	Description
EPM Central System (EPMCS)	Account Management	Provides Account Management for parking entities.
	Administration	Provides administrative access for the City of Columbus.
	Discounted Parking Options	Ability to offer discounted parking options with local merchants.
	EPM API	Provides a set of routines, protocols, and tools for interacting with the EPM Central System.
	Parking Coordination	Coordination with parking facilities and the OPAPP through APIs to exchange parking and reservation information and to update the EPM application.

Physical Object	Functional Object	Description
	Payment Coordination	Integration with the Financial Center to provide payment services.
	TIC Data Collection	TIC Data Collection collects transportation-related data from other centers and performs data quality checks on the collected data. Then it consolidates, verifies, and refines the data, making 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 are collected including traffic and road conditions, transit data, emergency information and advisories, weather data, special event information, traveler services, parking, multimodal data, and toll/pricing data. It also shares data with other transportation information centers. For this project, only parking data will be collected and shared with the Smart Columbus Operating System.
	Traveler Notifications	Notification of reservation confirmation, changes to an existing reservation, warnings of expiration of a paid parking session, and notification of expiration of paid parking session.
	Traveler Profile	The traveler profile contains account information and preferences.
Gated Parking Facility System (GFAC)	Parking Area Electronic Payment	Parking Electronic Payment supports electronic payment of parking fees using in-vehicle equipment (e.g., tags) or contact or proximity cards. It includes the field elements that provide the interface to the in-vehicle or card payment device and the back-office functionality that performs the transaction.
Parking Operator PM360 Application (OPAPP)	EPM Reports	Ability to provide parking reports to the Parking Operator.
	Rates and Policies	Ability for the Parking Operator to enter parking facility information.
Personal/Wireless Devices (PWD)	Feedback	User feedback on the EPM application is stored in the Smart Columbus Operating System.
	Manage Profile	Ability to create and manage profile information that is stored in the EPMCS.
	Search and Reserve Parking	Access to parking information through integration with the EPMCS. Map-based navigation using the GPS device of a traveler's phone or personal information device to determine location.
Smart Columbus Operating System	Metered Parking Availability	Provide metered parking availability to the EPM application.
Ungated Parking Facility (UFAC)	Ungated Parking	Ability for users to park their vehicles in ungated parking facilities, and parking operators to visually inspect lot usage.

Source: City of Columbus

2.8.4. Enterprise Architecture View

The following diagram shows the relationships between Smart Columbus stakeholders, the roles organizations play within the project, and the agreements among the stakeholders. The table provides the list of agreements and expectations and their descriptions.

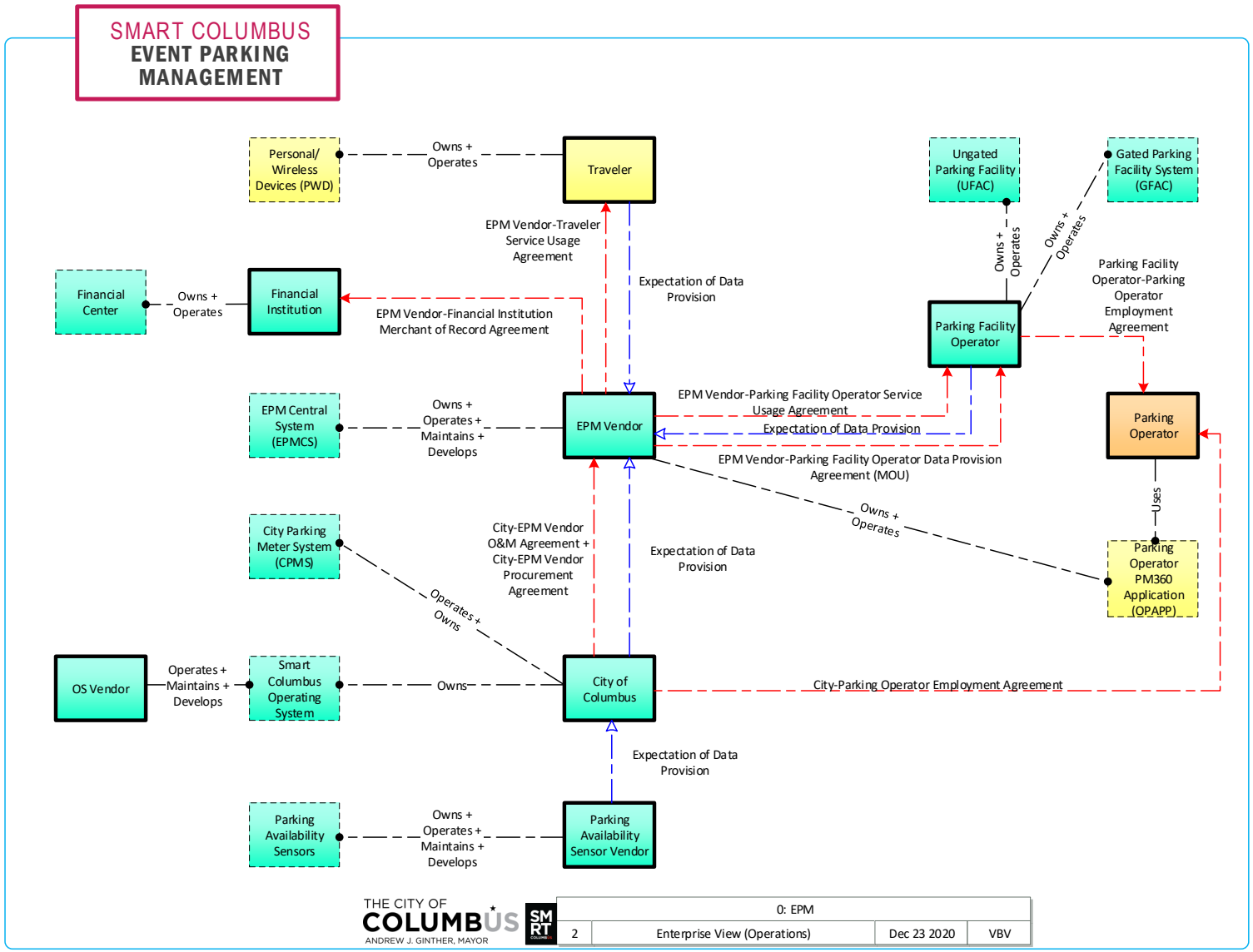


Figure 55: Event Parking Management Enterprise Architecture View

Source: City of Columbus

Table 100: Event Parking Management List of Agreements

Potential Agreement	Description
City-EPM Vendor O&M Agreement	An agreement between the City and EPM Vendor to operate and maintain the EPMCS. Vendor: ParkMobile Status: Existing
City-EPM Vendor Procurement Agreement	An agreement between the City and EPM Vendor for procuring the EPMCS. Vendor: ParkMobile Status: Existing
EPM Vendor-Traveler Service Usage Agreement	An agreement between the EPM Vendor and Traveler to use EPMCS. Stipulates the terms and conditions of service usage. Vendor: ParkMobile Status: Existing
EPM Vendor-Parking Facility Operator Data Provision Agreement MOU	An MOU between the EPM Vendor and Parking Facility Operator. Parking Facility Operator agrees to provide data collected to the City. Vendor: ParkMobile Status: Existing
EPM Vendor-Parking Facility Operator Service Usage Agreement	An agreement between the EPM Vendor and Parking Facility Operator to use EPMCS. Stipulates the terms and conditions of service usage. Vendor: ParkMobile Status:Existing
EPM Vendor-Financial Institution Merchant of Record Agreement	A financial agreement between the EPM Vendor and Financial Institution. Vendor: ParkMobile Status: Existing
City-Parking Operator Staff Employment Agreement	An agreement between the City and Parking Operator, whereupon the staff agrees to provide labor to the Operator, which in turn compensates the employee. Stipulates level of compensation, working conditions, required employee qualifications, necessary equipment and training and expectations of employee performance. Qualifications that need to be met before an employee is hired, and that need to be maintained for them to remain employed. Status: Existing
Parking Facility Operator-Parking Operator Staff Employment Agreement	An agreement between the Parking Facility Operator and Parking Operator, whereupon the staff agrees to provide labor to the Operator, which in turn compensates the employee. Stipulates level of compensation, working conditions, required employee qualifications, necessary equipment and training and expectations of employee performance. Qualifications that need to be met before an employee is hired, and that need to be maintained for them to remain employed. Status: Existing

Source: City of Columbus

2.8.4.1. ROLES AND RESPONSIBILITIES

Development:

- City of Columbus/Smart Columbus PMO: Owner
  - HNTB: systems engineering (concept and requirements)
  - Parking Services: City parking data (parking management system), coordination with ParkColumbus project and other parking efforts in the City
  - Smart Columbus Operating System team: interface definition/data; development of on-street and loading zone prediction of availability algorithm.
  - ParkMobile:
    - EPMCS software provider
    - Agreements with parking operators (EPM)

Installation:

- City of Columbus/Smart Columbus PMO: Owner
  - Parking Services: City parking data, coordination with ParkColumbus project and other parking efforts in the City
  - Smart Columbus Operating System team: interface definition/data
  - ParkMobile: EPMCS software provider:
    - Agreements with parking operators

Testing:

- City of Columbus/Smart Columbus PMO: Owner
  - HNTB: Test plan development, validation of requirements
  - Parking Services: City parking data, coordination with ParkColumbus project and other parking efforts in the City
  - Smart Columbus Operating System team: interface definition/data
  - ParkMobile: EPM central system software provider

Operations:

- City of Columbus/Smart Columbus PMO: Owner
  - HNTB: systems engineering (concept and requirements)
  - Parking Services: City parking data, coordination with ParkColumbus project and other parking efforts in the City
  - Smart Columbus Operating System team: interface definition/data
  - ParkMobile: EPM central system software provider:
    - Agreements with parking operators (gated and ungated)
- Traveler:
  - EPM user, who agrees to application's terms of use

Maintenance:

- City of Columbus/Smart Columbus PMO: Owner
  - HNTB: systems engineering (concept and requirements)

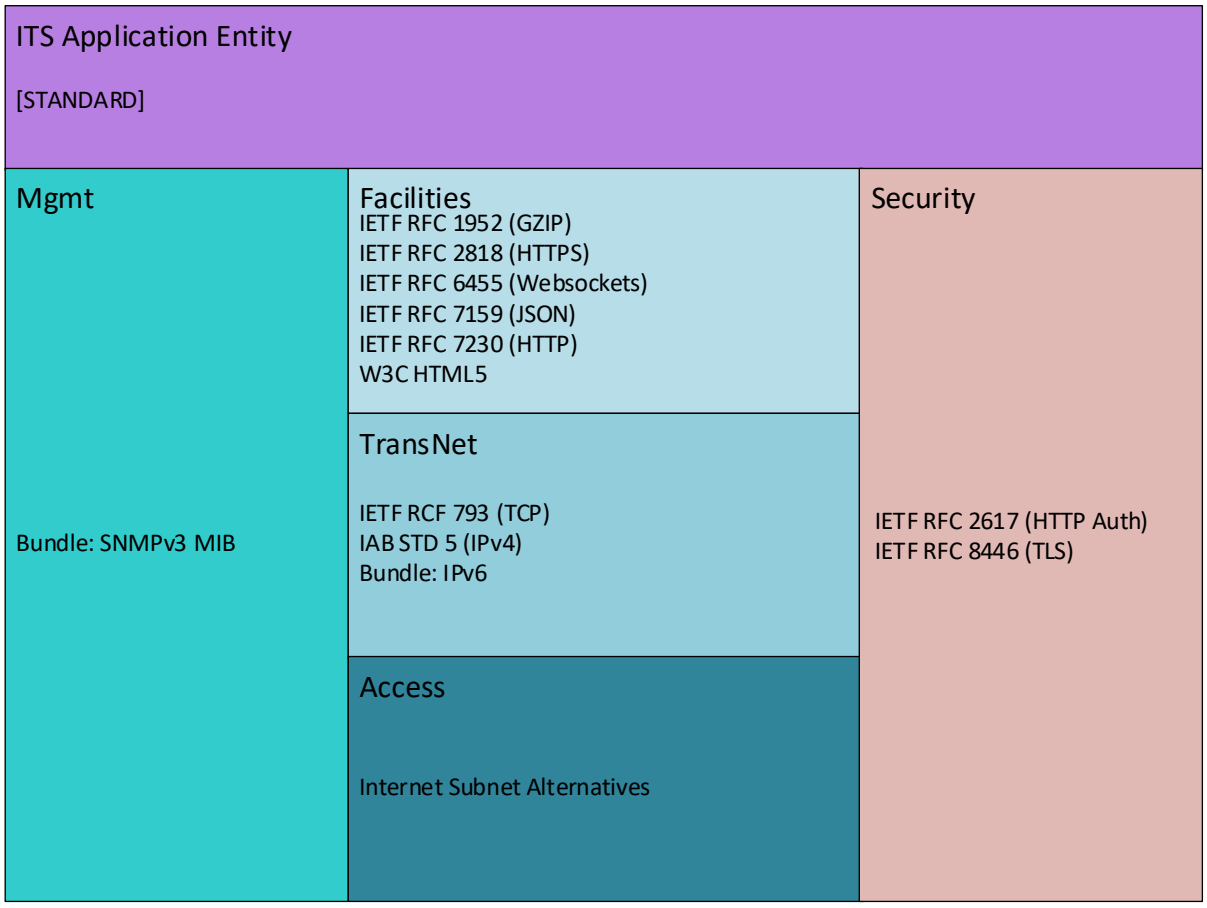
- Parking Services: City parking data, coordination with ParkColumbus project and other parking efforts in the City
- Smart Columbus Operating System team: interface definition/data
- ParkMobile: EPM central system software provider:
  - Agreements with parking operators (gated and ungated)

2.8.5. Communications Architecture View

2.8.5.1. COMMUNICATION PROFILES USED

The following table describes the layered sets of communications protocols that are required to support communications among the elements that make up the EPM project. Refer to **Appendix B** for the standards used for each communication profile.

2.8.5.1.1. World Wide Web Browser/JSON/Wide Area Wireless



(Note: The vendor currently uses IETF IPv4 for the network layer, but is planning on using IETF IPv6 in the future.)

Figure 56: World Wide Web Browser/JSON/Wide Area Wireless

Source: City of Columbus

Table 101: World Wide Web Browser/JSON/Wide Area Wireless

Name	Source	Destination	Standard	Profile
Confirm Additional Parking Meter Time	City Parking Meter System (CPMS)	Smart Columbus Operating System	(Unspecified)	WAW-WWWBrowser-JSON
EPM Archive Data	EPM Central System (EPMCS)	Smart Columbus Operating System	(Unspecified)	WAW-WWWBrowser-JSON
Gate Scan/Open Request	EPM Central System (EPMCS)	Gated Parking Facility System (GFAC)	(Unspecified)	WAW-WWWBrowser-JSON
interactive traveler information	EPM Central System (EPMCS)	Personal/Wireless Devices (PWD)	(Unspecified)	WAW-WWWBrowser-JSON
Parking and Loading Zone Locations	City Parking Meter System (CPMS)	Smart Columbus Operating System	(Unspecified)	WAW-WWWBrowser-JSON
parking area information	Parking Operator PM360 Application (OPAPP)	EPM Central System (EPMCS)	(Unspecified)	WAW-WWWBrowser-JSON
parking area management information	EPM Central System (EPMCS)	Parking Operator PM360 Application (OPAPP)	(Unspecified)	WAW-WWWBrowser-JSON
Parking Availability Probability	Smart Columbus Operating System	EPM Central System (EPMCS)	(Unspecified)	WAW-WWWBrowser-JSON
Parking Payment Archival Data	EPM Central System (EPMCS)	Smart Columbus Operating System	(Unspecified)	WAW-WWWBrowser-JSON
parking reservation confirmation	EPM Central System (EPMCS)	Personal/Wireless Devices (PWD)	(Unspecified)	WAW-WWWBrowser-JSON
parking reservation request	Personal/Wireless Devices (PWD)	EPM Central System (EPMCS)	(Unspecified)	WAW-WWWBrowser-JSON
Parking Right	EPM Central System (EPMCS)	City Parking Meter System (CPMS)	(Unspecified)	WAW-WWWBrowser-JSON
Payment Confirmation	Gated Parking Facility System (GFAC)	EPM Central System (EPMCS)	(Unspecified)	WAW-WWWBrowser-JSON
payment request	EPM Central System (EPMCS)	Financial Center	(Unspecified)	WAW-WWWBrowser-JSON

Name	Source	Destination	Standard	Profile
Real-Time Parking Meter Availability	Parking Availability Sensor System	Smart Columbus Operating System	(Unspecified)	WAW-WWWBrowser-JSON
Request Additional Parking Meter Time	City Parking Meter System (CPMS)	Smart Columbus Operating System	(Unspecified)	WAW-WWWBrowser-JSON
transaction status	Financial Center	EPM Central System (EPMCS)	(Unspecified)	WAW-WWWBrowser-JSON
traveler request	Personal/Wireless Devices (PWD)	EPM Central System (EPMCS)	(Unspecified)	WAW-WWWBrowser-JSON
user account reports	EPM Central System (EPMCS)	Personal/Wireless Devices (PWD)	(Unspecified)	WAW-WWWBrowser-JSON
user account setup	Personal/Wireless Devices (PWD)	EPM Central System (EPMCS)	(Unspecified)	WAW-WWWBrowser-JSON
User Feedback	EPM Central System (EPMCS)	Smart Columbus Operating System	(Unspecified)	WAW-WWWBrowser-JSON
user profile	Personal/Wireless Devices (PWD)	EPM Central System (EPMCS)	(Unspecified)	WAW-WWWBrowser-JSON

Source: City of Columbus

2.8.5.1.2. Human Interface

Table 102: Human Interface

Name	Source	Destination	Standard	Profile
parking operator input	Parking Operator	Parking Operator PM360 Application (OPAPP)	(Unspecified)	Human Interface
Parking Policies	Parking Operator PM360 Application (OPAPP)	Parking Operator	(Unspecified)	Human Interface
traveler input	Traveler	Personal/Wireless Devices (PWD)	(Unspecified)	Human Interface
traveler interface updates	Personal/Wireless Devices (PWD)	Traveler	(Unspecified)	Human Interface

Name	Source	Destination	Standard	Profile
Visual Inspection	Parking Operator	Ungated Parking Facility (UFAC)	(Unspecified)	Human Interface

Source: City of Columbus

2.8.6. Functional Architecture View

The Functional Architecture View depicts each element of overall system and the logical interfaces among them. The listed draft processes are developed based on discussion with the project team. These processes will be further refined and defined in detail during the design phase of the project.

Table 103: Event Parking Management Functional Architecture View

Physical Object	Functional Object	Process
EPM Central System (EPMCS)	Account Management	Manage Accounts
	Administration	Provide Administration Access
	Discounted Parking Options	Provide Discounted Parking Options
	EPM API	Receive Requests and Send Responses
	Parking Coordination	Provide Interface for Current City Parking Management System Provide Interface for the Smart Columbus Operating System Provide Interface for the Parking Facilities/Operators Provide Parking Availability Information Process Parking Requests Confirm Parking Requests Update Parking Availability Information
	Payment Coordination	Process Parking Reservation Payments Provide Reservation Confirmations
	TIC Data Collection	Collect Parking Data Manage Reports
	Traveler Notifications	Manage Parking Reservation Notifications Manage Payment Request Notifications
	Traveler Profile	Manage Traveler Profiles

Physical Object	Functional Object	Process
Gated Parking Facility System (GFAC)	Parking Area Electronic Payment	Process Parking Lot Violations Read Parking Lot Vehicle Payment Data Determine Advanced Charges Calculate Vehicle Parking Lot Charges Collect Bad Charge Payment Data Check for Advanced Parking Lot Payment Bill Driver for Parking Lot Charges Manage Parking Lot Financial Processing Update Parking Lot Data Register for Advanced Parking Lot Payment Produce Parking Lot Displays Obtain Parking Lot Violator Image Detect Vehicle for Parking Lot Payment
Parking Operator PM360 Application (OPAPP)	EPM Reports	Provide Operator Interface Provide EPM Reports to the Parking Operator Receive Parking Data Request Parking Data Process Parking Data
	Rates and Policies	Provide Operator Interface Update Facility Rates and Policies Save Rates and Policies
Personal/Wireless Devices (PWD)	Feedback	Collect Feedback
	Manage Profile	Provide Traveler Interface Process Traveler Personal Information Process Parking Preferences Information Save Traveler Information
	Search and Reserve Parking	Provide Traveler Interface Search Parking Availability Request for Reservation Receive Parking Reservation Confirmation Navigate to Parking
Smart Columbus Operating System	Metered Parking Availability	Receive Metered Parking Availability Information Calculate Metered Parking Availability Probability Provide Information to EPMCS
Ungated Parking Facility (UFAC)	Ungated Parking	Provide Ability for Parking Operator to Inspect Vehicles

Source: City of Columbus

2.9. PROJECT 8: CONNECTED ELECTRIC AUTONOMOUS VEHICLES

2.9.1. Introduction

The City of Columbus is interested in deploying CEAV technology to evaluate the ability of this technology and associated vehicles to enhance the mobility of residents and visitors, to operate on public roadways in Ohio, and to satisfy the specific operating purposes for which each service is intended. Further, the team is interested in better understanding the infrastructure required to implement and support the operation of this technology, the approach to public adoption, the types and value of data produced, the associated cost, and the benefits derived from the use of Autonomous Vehicles. Vehicle performance will be recorded, such as time in service, miles traveled, ridership, high-accuracy positioning, speed, battery usage, number of and reasons for disengagements, hard braking, evasive maneuvers, and more. The data collected by the CEAV will be the primary focus and positioned as a user story in the Smart Columbus Operating System, which will provide information, lessons learned, and best management practices to benefit the national community.

After this project was developed and publically launched, passenger service was discontinued due to an on-board safety incident and COVID-19 safety precautions. The SASP reflects the system as designed and capable of functioning. For the remainder of the project duration, the CEAVs will work as grocery delivery vehicles. Data that's being collected for grocery delivery includes boxes transported, boxes distributed, mask packs distributed, walk-up pickups, datestamp, and notes.

2.9.2. System of Interest

The City of Columbus aims to deploy and evaluate automated shuttles against a series of use cases. The proposed technology solution involves vehicles that are Level 4 automated, as defined in SAEJ3016,[12] electric and connected, serving the public on short trips where other modes are not presently available or convenient. Operations of the fleet are expected to be similar to that of a traditional transit service, with pre-determined routes and signed stops along the routes for passengers to board and alight.

The CEAVs will be traveling on roads with mixed-traffic between St. Stephen's Community Center and Linden Transit Center and will need to be able to respond to traditional regulatory signs and signals. The CEAV passengers will be able to use the City's MMTPA to plan their multimodal trip.

The CEAVs will have the ability to communicate with the roadside equipment in Smart Columbus's CVE using DSRC. The CEAV will enroll in the commercial SCMS provided by the City of Columbus as part of the CVE project. Hence SCMS is not discussed in this architecture.

A CEAV System Operator will be responsible for CEAV operations and maintenance. The System Operator may include a CEAV Fleet Management System responsible for ensuring the service is operating as designed, and that any potential issues are communicated before a potential incident may occur. Onboard CEAV Operations staff will also be available as a backup in case the vehicle can't autonomously operate due to a route impact, and also to assist the passengers. The CEAV System Operator may also provide a CEAV charging, storage, and maintenance facility in close proximity to the service route.

It is expected that a CEAV System Operator will, in addition to its own services, provide GTFS, GTFS Real Time, and routing data to the Smart Columbus Operating System to be made available for other applications.

[12] *SAE International, J3016_201806: Taxonomy and Definitions for Terms Related to Driving Automation Systems for On-Road Motor Vehicles, revised June 2018,* https://www.sae.org/standards/content/j3016_201806/.

2.9.3. Physical Architecture View

The CEAV project includes nine Service Packages. Each Service Package interconnects one or more Functional Objects that work together to deliver the service and defines the Information Flows that connect them to other external system. The following Service Packages address CEAV project needs, and will be discussed in greater detail in the sections that follow:

- **CEAV Fixed-Route Operations:** This Service Package performs dispatch and system monitoring for CEAV routes.
- **CEAV Fleet Management:** This Service Package supports maintenance scheduling and monitoring of the CEAV fleet.
- **CEAV Passenger Counting:** This Service Package counts the number of passengers entering and exiting CEAVs.
- **CEAV Security:** This Service Package provides for the physical security of CEAV passengers and CEAV Operations Staff.
- **CEAV Traveler Information:** This Service Package provides transit users at CEAV designated stops and on board CEAVs with ready access to transit information.
- **CEAV Tracking:** This Service Package monitors current transit vehicle location.
- **CEAV Safety Systems:** This Service Package improves vehicle safety using onboard sensors that monitor the driving environment surrounding the vehicle.
- **CEAV V2V Basic Safety:** This service package exchanges basic safety messages with surrounding Connected Vehicles to support and augment the safety warning and control automation features.
- **CEAV RSE Interface:** This Service Package supports communications between the vehicles and supporting infrastructure equipment.

A comprehensive overview – Layer 0 Physical Architecture for the CEAV project shown in **Figure 57** – is presented first, then each Service Package is introduced as a Layer 2 diagram, which provides additional detail about the Information Flows and interactions among objects.

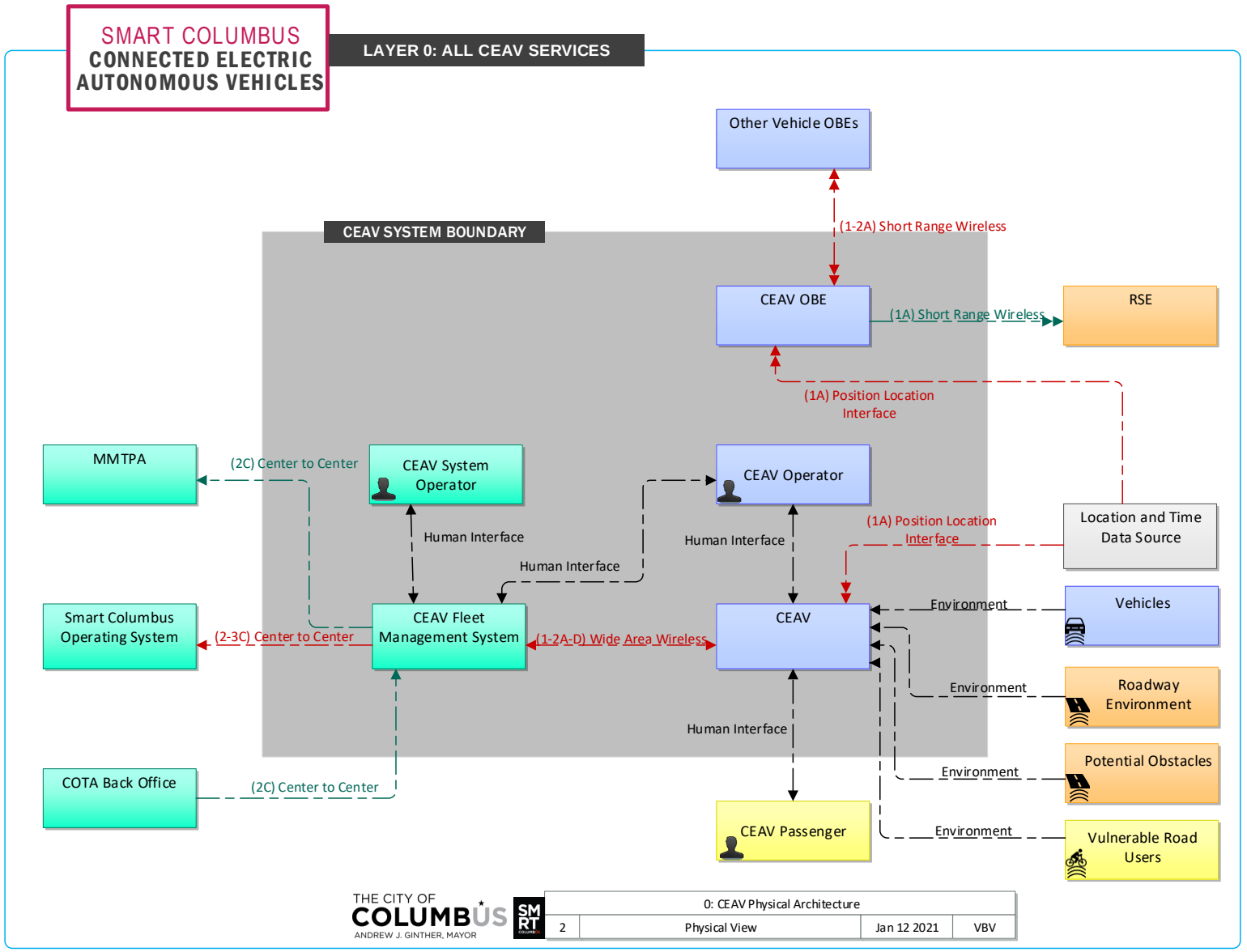


Figure 57: Connected Electic Autonomous Vehicles Physical Architecture View (Layer 0)

Source: City of Columbus

2.9.3.1. CONNECTED ELECTRIC AUTONOMOUS VEHICLES FIXED-ROUTE OPERATIONS

This Service Package performs dispatch and system monitoring for CEAV routes. This service performs scheduling activities including the creation of schedules, blocks and runs, as well as operator assignment. This service monitors the transit vehicle trip performance against the schedule. Due to the size of the fleet (less than 10 vehicles) and focus on the CEAV technology rather than the operation for this demonstration project, many of these functions, including dispatching, scheduling activities, and operator assignment, will be performed manually.

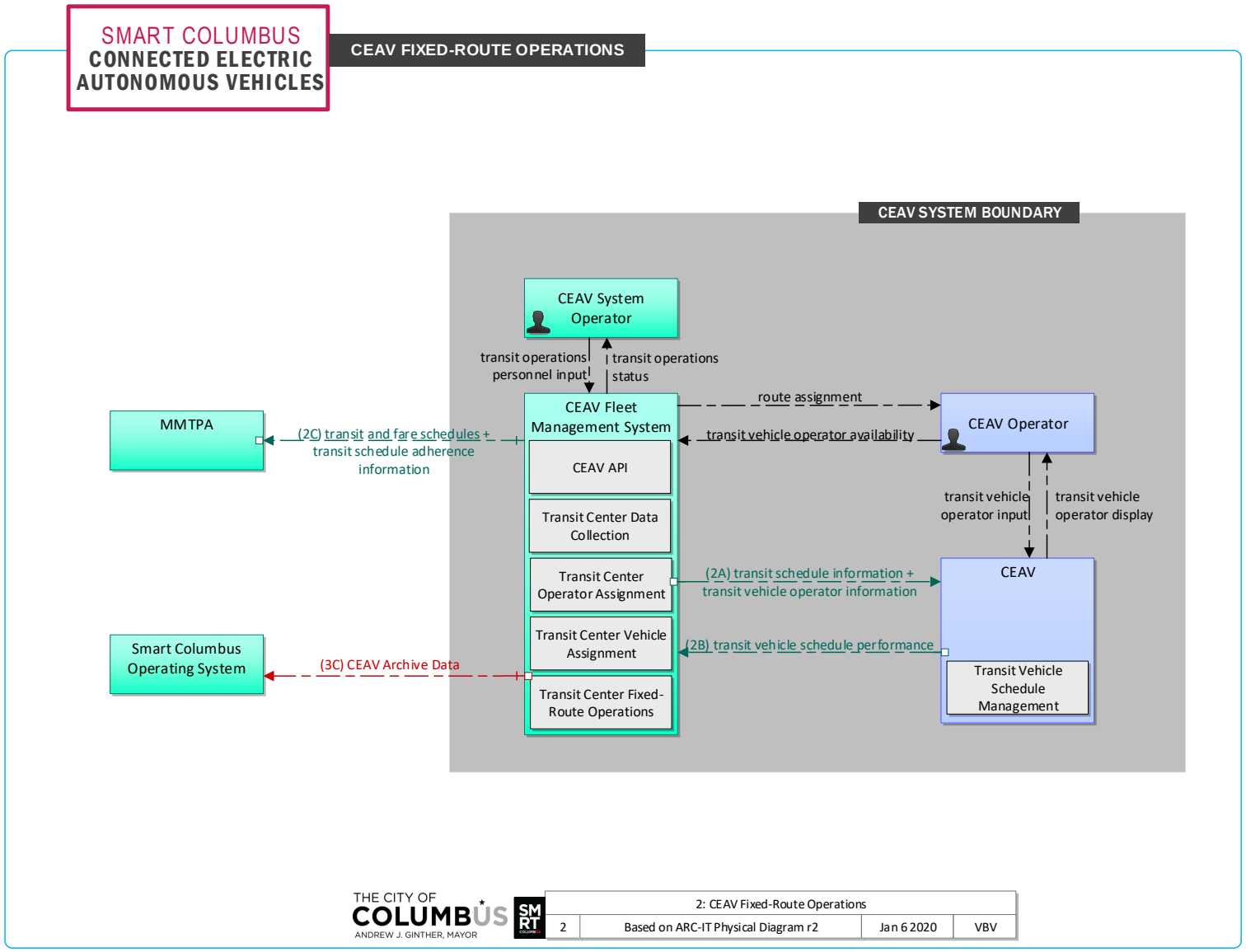


Figure 58: Connected Electric Autonomous Vehicles Transit Fixed-Route Operations (Layer 2)

Source: City of Columbus

Table 104: Connected Electric Autonomous Vehicles Fixed-Route Operations Physical Elements

Physical Object	Class	Description
CEAV	Vehicle	CEAV represents vehicles that provide service for the CEAV system. This Physical Object supports all six levels of driving automation as defined in SAE J3016. The CEAV is a Level 4 vehicle. Initial collision avoidance functions provide vigilant co-pilot operator warning capabilities. More advanced functions assume limited control of the vehicle to maintain lane position and safe headways. In the most advanced implementations, this Physical Object supports full automation of all aspects of the driving task, aided by communications with other vehicles in the vicinity and in coordination with supporting infrastructure subsystems.
CEAV Fleet Management System	Center	The CEAV Fleet Management System represents the system that manages CEAV, including providing guidance/suggestion for onboard operator and/or vehicle system to make decisions locally to maintain schedule and/or even headways.
CEAV Operator	Center	The CEAV Operator refers to the company and staff hired by the CEAV System Operator to perform tasks for the CEAV that require human assistance, including onboard operators and vehicle maintenance staff.
CEAV System Operator	Traveler	The CEAV System Operator refers to transportation operations and management entity.
MMTPA	Center	The MMTPA is an app available to travelers on both iOS and Android devices and a web-based platform. MMTPA accesses mobility provider service options from multiple Mobility Providers via APIs. The project will allow travelers to create multimodal trips and pay each mobility provider. Multimodal trip options include walking, fixed-route bus service, ride-hailing, bike-sharing, paratransit, and scooter services.
Smart Columbus Operating System	Center	The Smart Columbus Operating System covers the ingestion and organization of information stored in the Smart Columbus Operating System. The ingestion process is initiated by the Data Curator using a web interface to define and manage the data feeds.

Source: City of Columbus

Table 105: Connected Electric Autonomous Vehicles Fixed-Route Operations Information Flows

Information Flow Name	Description
CEAV Archive Data	At the minimum, CEAV archive data will include time in service, miles traveled, ridership, high-accuracy positioning, speed, battery usage, and number and reasons for disengagements and hard braking.
route assignment	Route assignment information for transit vehicle operator.
transit and fare schedules	Transit service information including routes, schedules, and fare information. For this project, fare information is not applicable.

Information Flow Name	Description
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.
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. For this project, fare information is not applicable.
transit schedule adherence information	Dynamic transit schedule adherence and transit vehicle location information.
transit schedule information	Current and projected transit schedule information used to initialize the transit vehicle with a vehicle assignment, monitor schedule performance, and develop corrective actions on board.
transit vehicle operator information	Information regarding onboard transit operator authentication.
transit vehicle operator availability	Transit vehicle operator availability data that can be used to develop vehicle operator assignments and detailed operations schedules.
transit vehicle schedule performance	Estimated times of arrival and anticipated schedule deviations reported by a transit vehicle.
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 onboard ITS services.
transit vehicle operator input	Transit vehicle operator inputs to onboard ITS equipment, including tactile and verbal inputs. Includes authentication information, onboard system control, emergency requests, and fare transaction data. For this project, fare transaction data is not applicable.

Source: City of Columbus

Table 106: Connected Electric Autonomous Vehicles Fixed-Route Operations Functional Objects

Physical Object	Functional Object	Description
CEAV	Transit Vehicle Schedule Management	Transit Vehicle Schedule Management monitors schedule performance, and identifies corrective actions when a deviation is detected. It provides two-way communication between the transit vehicle and center, enabling the center to communicate with the vehicle operator and monitor onboard systems.
CEAV Fleet Management System	CEAV API	Provides a set of routines, protocols, and tools for interacting with CEAV. The API provides the following information: mileage, speed, status, door state, ramp state, payload of vehicle, battery level, internal/external temperature, and passenger count.

Physical Object	Functional Object	Description
	Transit Center Operator Assignment	Transit Center Operator Assignment automates and supports the assignment of transit vehicle operators to runs. It assigns operators to runs in a fair manner while minimizing labor and overtime services, considering operator preferences and qualifications, and automatically tracking and validating the number of work hours performed by each individual operator. It also provides an exception handling process for the operator assignment function to generate supplemental operator assignments when required by changes during the operating day. For this project, operator assignment will be performed manually.
	Transit Center Data Collection	Transit Center Data Collection collects and stores transit information that is collected in the course of transit operations performed by the Transit Management Center. This data can be used directly by operations personnel, or it can be made available to other data users and archives in the region.
	Transit Center Fixed-Route Operations	Transit Center Fixed-Route Operations manages fixed route transit operations. It supports creation of schedules, blocks, and runs for fixed and flexible route transit services. It allows fixed-route and flexible-route transit services to disseminate schedules, and automatically updates customer service operator systems with the most current schedule information. It also supports automated dispatch of transit vehicles. Current vehicle schedule adherence and optimum scenarios for schedule adjustment are also provided. It also receives and processes transit vehicle loading data. For this project, schedule management and vehicle dispatch will be performed manually.
	Transit Center Vehicle Assignment	Transit Center Vehicle Assignment assigns individual transit vehicles to vehicle blocks, and downloads this information to the transit vehicle. It also provides an exception handling process for the vehicle assignment function to generate new, supplemental vehicle assignments when required by changes during the operating day. It provides an inventory management function for the transit facility, which stores functional attributes about each of the vehicles owned by the transit operator. These attributes permit the planning and assignment functions to match vehicles with routes based on suitability for the types of service required by the particular routes. For this project, vehicle assignment will be performed manually.

Source: City of Columbus

2.9.3.2. CONNECTED ELECTRIC AUTONOMOUS VEHICLES FLEET MANAGEMENT

This Service Package supports transit maintenance, scheduling, and monitoring. Onboard condition sensors monitor system status, and transmit critical status information to the CEAV Fleet Management System. It also supports software configuration management and updates as part of maintenance of the software-based onboard systems. The CEAV charging, storage, and maintenance facility, which is part of the CEAV Fleet Management System, processes this data, monitors the charge of the vehicles, and schedules preventative and corrective maintenance.

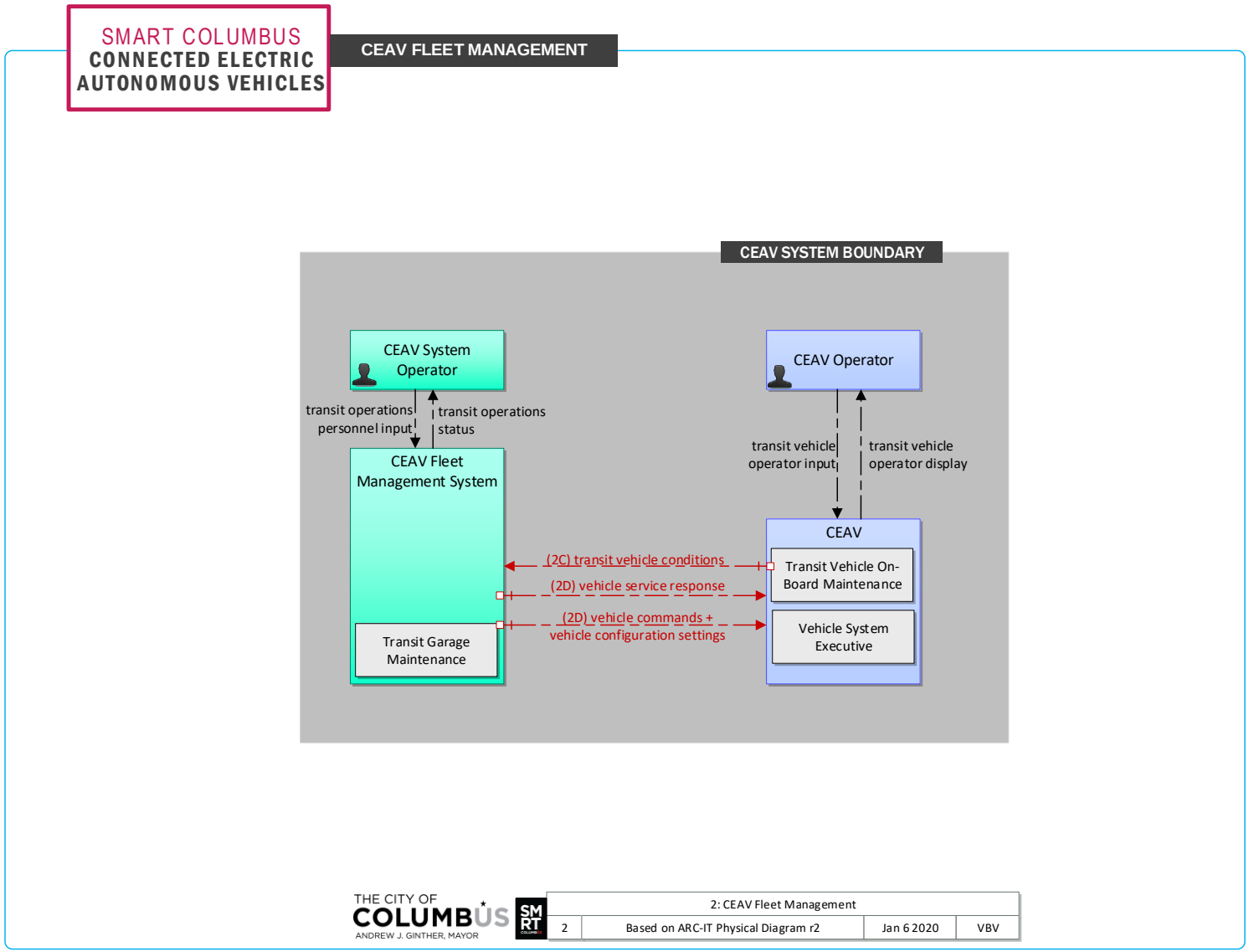


Figure 59: Connected Electric Autonomous Vehicles Fleet Management (Layer 2)

Source: City of Columbus

Table 107: Connected Electric Autonomous Vehicles Fleet Management Physical Elements

Physical Object	Class	Description
CEAV	Vehicle	CEAV represents vehicles that provide service for the CEAV system. This Physical Object supports all six levels of driving automation as defined in SAE J3016. The CEAV is a Level 4 vehicle. Initial collision avoidance functions provide vigilant co-pilot operator warning capabilities. More advanced functions assume limited control of the vehicle to maintain lane position and safe headways. In the most advanced implementations, this Physical Object supports full automation of all aspects of the driving task, aided by communications with other vehicles in the vicinity and in coordination with supporting infrastructure subsystems.
CEAV Fleet Management System	Center	The CEAV Fleet Management System represents the system that manages CEAV, including providing guidance/suggestion for onboard operator and/or vehicle system to make decisions locally to maintain schedule and/or even headways.
CEAV Operator	Center	The CEAV Operator refers to the company and staff hired by the CEAV System Operator to perform tasks for the CEAV that require human assistance, including onboard operators and vehicle maintenance staff.
CEAV System Operator	Traveler	The CEAV System Operator refers to transportation operations and management entity.

Source: City of Columbus

Table 108: Connected Electric Autonomous Vehicles Fleet Management Information Flows

Information Flow Name	Description
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.
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. For this project, fare information is not applicable.
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 onboard ITS services.
transit vehicle operator input	Transit vehicle operator inputs to onboard ITS equipment, including tactile and verbal inputs. Includes authentication information, onboard system control, emergency requests, and fare transaction data. For this project, fare transaction data is not applicable.

Information Flow Name	Description
transit vehicle conditions	Operating conditions of transit vehicle (e.g., engine running, oil pressure, fuel level and usage). For this project, oil pressure is not applicable. Fuel level is the battery level.
vehicle service response	Response to a request for service reservation.
vehicle commands	System-level control commands issued to vehicle equipment, such as reset and remote diagnostics.
vehicle configuration settings	Control settings and parameters that are used to configure vehicle equipment.

Source: City of Columbus

Table 109: Connected Electric Autonomous Vehicles Fleet Management Functional Objects

Physical Object	Functional Object	Description
CEAV	Transit Vehicle On-Board Maintenance	Transit Vehicle On-Board Maintenance collects and processes transit vehicle maintenance data on board the vehicle, including mileage and vehicle operating conditions. This maintenance information is provided to the management center and used to schedule future vehicle maintenance and repair.
	Vehicle System Executive	Vehicle System Executive provides the Smart Columbus Operating System kernel and executive functions that manage the software configuration and operation, and support computer resource management, security, and software installation and upgrade.
CEAV Fleet Management System	Transit Garage Maintenance	Transit Garage Maintenance provides advanced maintenance functions for the transit property. It collects operational and maintenance data from transit vehicles, manages vehicle service histories, and monitors operators and vehicles. It collects vehicle mileage data, and uses it to automatically generate preventative maintenance schedules for each vehicle by utilizing vehicle tracking data. In addition, it provides information to service personnel to support maintenance activities, and records and verifies that maintenance work was performed.

Source: City of Columbus

2.9.3.3. CONNECTED ELECTRIC AUTONOMOUS VEHICLES PASSEGER COUNTING

This Service Package counts the number of passengers entering and exiting the CEAV using sensors mounted on the vehicle, and communicates the collected passenger data back to the CEAV Fleet Management System. The collected data can be used to calculate reliable ridership figures, and measure passenger load information at particular stops.

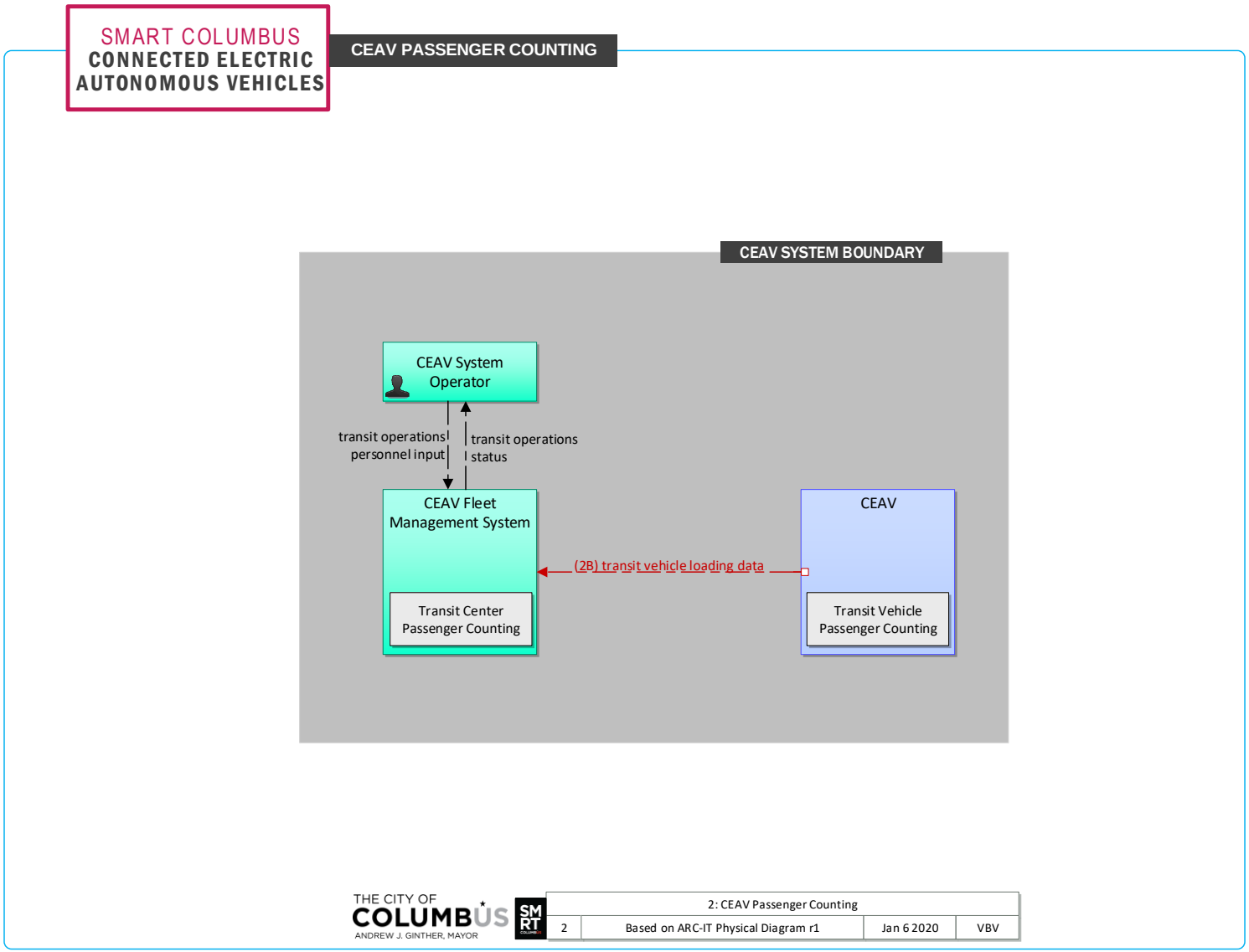


Figure 60: Connected Electric Autonomous Vehicles Passenger Counting (Layer 2)

Source: City of Columbus

Table 110: Connected Electric Autonomous Vehicles Passenger Counting Physical Elements

Physical Object	Class	Description
CEAV	Vehicle	CEAV represents vehicles that provide service for the CEAV system. This Physical Object supports all six levels of driving automation as defined in SAE J3016. The CEAV is a Level 4 vehicle. Initial collision avoidance functions provide vigilant co-pilot operator warning capabilities. More advanced functions assume limited control of the vehicle to maintain lane position and safe headways. In the most advanced implementations, this Physical Object supports full automation of all aspects of the driving task, aided by communications with other vehicles in the vicinity and in coordination with supporting infrastructure subsystems.
CEAV Fleet Management System	Center	The CEAV Fleet Management System represents the system that manages CEAV, including providing guidance/suggestion for onboard operator and/or vehicle system to make decisions locally to maintain schedule and/or even headways.
CEAV System Operator	Traveler	The CEAV System Operator refers to transportation operations and management entity.

Source: City of Columbus

Table 111: Connected Electric Autonomous Vehicles Passenger Counting Information Flows

Information Flow Name	Description
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.
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. For this project, fare information is not applicable.
transit vehicle loading data	Data collected on-board the transit vehicle relating to passenger boarding and alighting.

Source: City of Columbus

Table 112: Connected Electric Autonomous Vehicles Passenger Counting Functional Objects

Physical Object	Functional Object	Description
CEAV	Transit Vehicle Passenger Counting	Transit Vehicle Passenger Counting collects transit vehicle loading data, and makes it available to the center.
CEAV Fleet Management System	Transit Center Passenger Counting	Transit Center Passenger Counting receives and processes transit vehicle loading data using two-way communications from equipped transit vehicles.

Source: City of Columbus

2.9.3.4. CONNECTED ELECTRIC AUTONOMOUS VEHICLES SECURITY

This Service Package provides for the physical security of CEAV passengers and the CEAV Operator. The CEAV system performs surveillance and sensor monitoring in order to identify potentially hazardous situations. The surveillance equipment includes video systems such as CCTV cameras, audio systems, and/or event recorder systems. CEAV passenger or CEAV Operator activated alarms are provided on board. Most of the surveillance and sensor data that is collected by this Service Package are monitored by the CEAV Fleet Management System. This Service Package also supports remote transit vehicle disabling and transit vehicle operator authentication by the CEAV Fleet Management System.

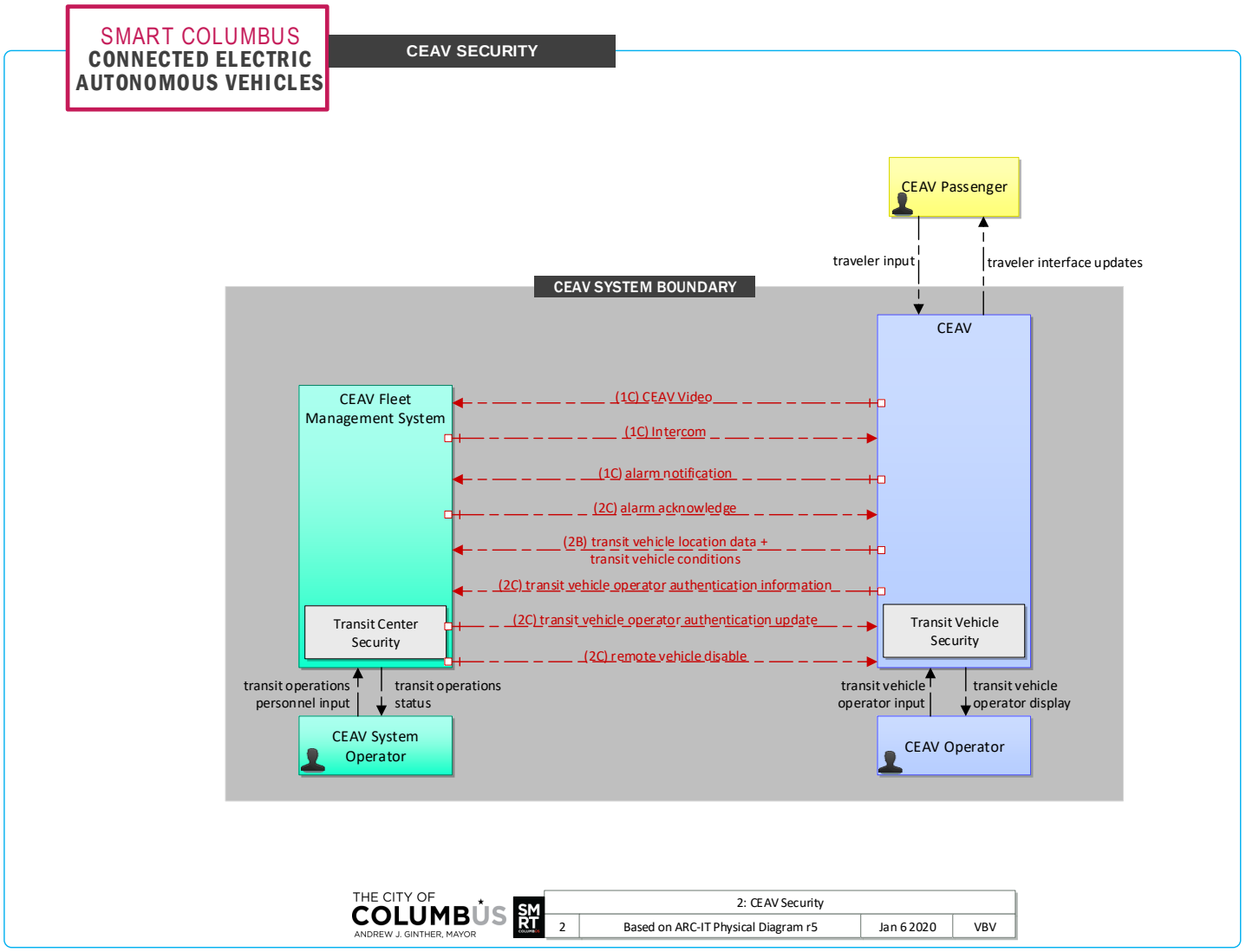


Figure 61: Connected Electric Autonomous Vehicles Security (Layer 2)

Source: City of Columbus

Table 113: Connected Electric Autonomous Vehicles Security Physical Elements

Physical Object	Class	Description
CEAV	Vehicle	CEAV represents vehicles that provide service for the CEAV system. This Physical Object supports all six levels of driving automation as defined in SAE J3016. The CEAV is a Level 4 vehicle. Initial collision avoidance functions provide vigilant co-pilot operator warning capabilities. More advanced functions assume limited control of the vehicle to maintain lane position and safe headways. In the most advanced implementations, this Physical Object supports full automation of all aspects of the driving task, aided by communications with other vehicles in the vicinity and in coordination with supporting infrastructure subsystems.
CEAV Fleet Management System	Center	The CEAV Fleet Management System represents the system that manages CEAV, including providing guidance/suggestion for onboard operator and/or vehicle system to make decisions locally to maintain schedule and/or even headways.
CEAV Operator	Center	The CEAV Operator refers to the company and staff hired by the CEAV System Operator to perform tasks for the CEAV that require human assistance, including onboard operators and vehicle maintenance staff.
CEAV Passenger	Traveler	The CEAV Passenger refers to the area residents, employees, visitors, etc., some of whom have limited mobility and other disabilities.
CEAV System Operator	Traveler	The CEAV System Operator refers to transportation operations and the management entity.

Source: City of Columbus

Table 114: Connected Electric Autonomous Vehicles Security Information Flows

Information Flow Name	Description
alarm acknowledge	Confirmation that alarm was received, instructions and additional information for the alarm initiator, and requests for additional information.
alarm notification	Notification of activation of an audible or silent alarm by a traveler in a public area, or by a transit vehicle operator using an onboard device.
CEAV Video	Live video stream from the security camera(s) inside of the CEAV.
Intercom	Live audio information given by the CEAV System Operator to the passengers inside the CEAV.
remote vehicle disable	Signal used to remotely disable a transit vehicle.
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.

Information Flow Name	Description
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. For this CEAV project, fare information is not applicable.
transit vehicle conditions	Operating conditions of transit vehicle (e.g., engine running, oil pressure, fuel level and usage). For this project, oil pressure is not applicable. Fuel level is the battery level.
transit vehicle location data	Current transit vehicle location and related operational conditions data provided by a transit vehicle.
transit vehicle operator authentication information	Information regarding onboard transit operator authentication.
transit vehicle operator authentication update	Results of authentication process or update of onboard authentication database.
traveler input	User input from a traveler to summon assistance, request travel information, make a reservation, or request any other traveler service. For this CEAV project, reservation is not applicable.
traveler interface updates	Visual or audio information (e.g., routes, messages, guidance, emergency information) that is provided to the traveler.
transit vehicle operator input	Transit vehicle operator inputs to onboard ITS equipment, including tactile and verbal inputs. Includes authentication information, onboard system control, emergency requests, and fare transaction data. For this project, fare transaction data is not applicable.
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 onboard ITS services.

Source: City of Columbus

Table 115: Connected Electric Autonomous Vehicles Security Functional Objects

Physical Object	Functional Object	Description
CEAV	Transit Vehicle Security	Transit Vehicle Security provides security and safety functions on board the transit vehicle. It includes surveillance and sensor systems that monitor the onboard environment, silent alarms that can be activated by transit user or vehicle operator, operator authentication, and a remote vehicle disable function. The surveillance equipment includes video (e.g. CCTV cameras), audio systems, and/or event recorder systems. The sensor equipment includes threat sensors (e.g. chemical agent, toxic industrial chemical, biological, explosives, and radiological sensors) and object detection sensors (e.g. metal detectors). For this CEAV project, threat sensors and object detection sensors are not currently planned.
CEAV Fleet Management System	Transit Center Security	Transit Center Security monitors transit vehicle operator or traveler activated alarms received from on board a transit vehicle. It supports transit vehicle operator authentication, and provides the capability to remotely disable a transit vehicle. It also includes the capability to alert operators and police to potential incidents identified by these security features.

Source: City of Columbus

2.9.3.5. CONNECTED ELECTRIC AUTONOMOUS VEHICLES TRAVELER INFORMATION

This Service Package provides readily accessible transit information to CEAV passengers on transit vehicles.

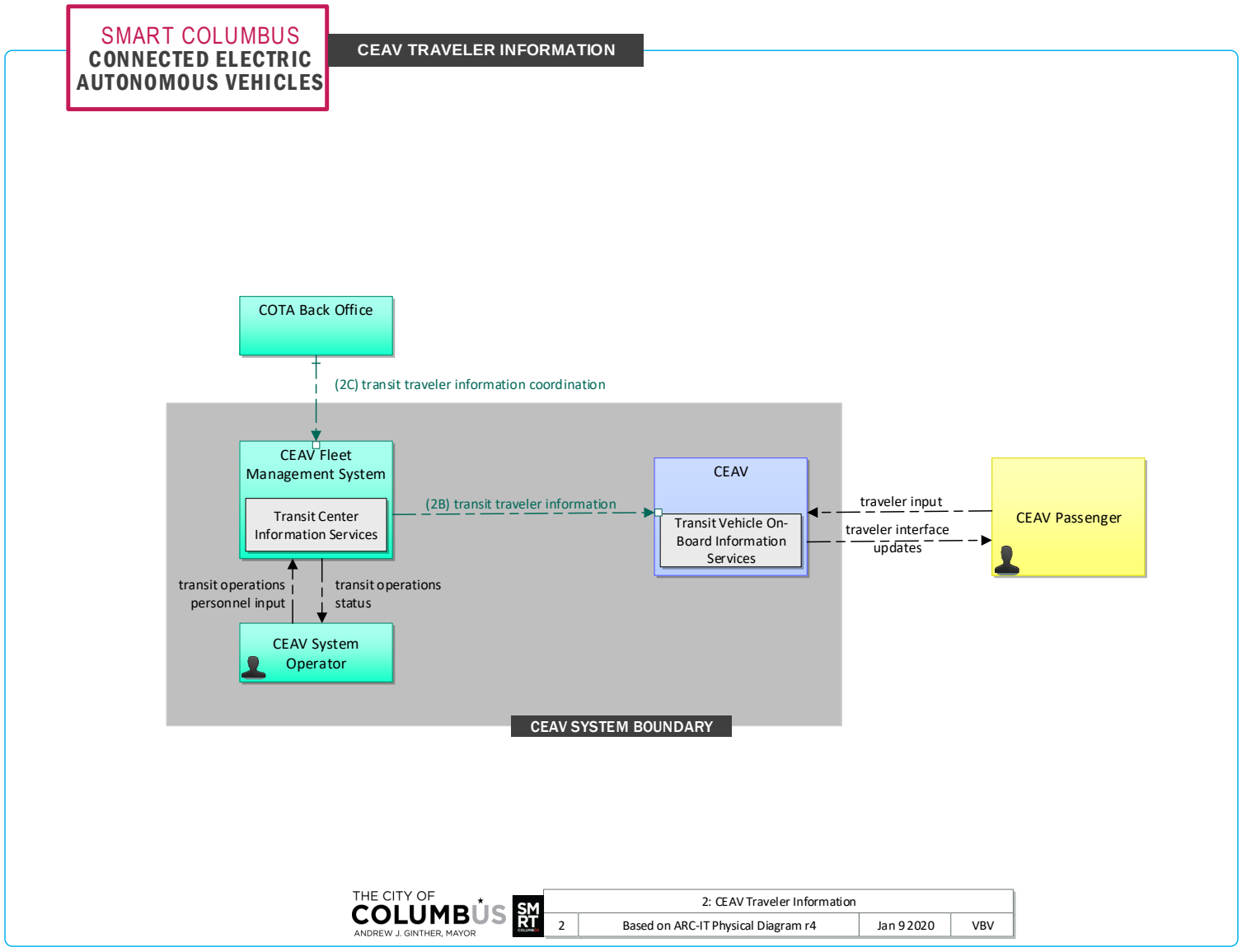


Figure 62: Connected Electric Autonomous Vehicles Traveler Information (Layer 2)

Source: City of Columbus

Table 116: Connected Electric Autonomous Vehicles Traveler Information Physical Elements

Physical Object	Class	Description
CEAV	Vehicle	CEAV represents vehicles that provide service for the CEAV system. This Physical Object supports all six levels of driving automation as defined in SAE J3016. The CEAV is a Level 4 vehicle. Initial collision avoidance functions provide vigilant co-pilot operator warning capabilities. More advanced functions assume limited control of the vehicle to maintain lane position and safe headways. In the most advanced implementations, this Physical Object supports full automation of all aspects of the driving task, aided by communications with other vehicles in the vicinity and in coordination with supporting infrastructure subsystems.
CEAV Fleet Management System	Center	The CEAV Fleet Management System represents the system that manages CEAV, including providing guidance/suggestion for onboard operator and/or vehicle system to make decisions locally to maintain schedule and/or even headways.
CEAV Passenger	Traveler	The CEAV Passenger refers to the area residents, employees, visitors, etc., some of whom have limited mobility and other disabilities.
CEAV System Operator	Traveler	The CEAV System Operator refers to transportation operations and management entity.
COTA Back Office	Center	The COTA Back Office manages transit vehicle fleets and coordinates with other modes and transportation services. It provides operations, maintenance, customer information, planning, and management functions for the transit property. It spans distinct central dispatch and garage management systems, and supports the spectrum of fixed route, flexible route, paratransit services, and BRT service. The Physical Object's interfaces support communication between transit departments and with other operating entities, such as emergency response services and traffic management systems.

Source: City of Columbus

Table 117: Connected Electric Autonomous Vehicles Traveler Information Information Flows

Information Flow Name	Description
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.
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. For this project, fare information is not applicable.

Information Flow Name	Description
transit traveler information	Transit information prepared to support transit users and other travelers. It contains transit schedules, real-time arrival information, fare schedules, alerts and advisories, and general transit service information. For this project, fare schedules are not applicable.
transit traveler information coordination	Transit schedules, real-time arrival information, fare schedules, and general transit service information shared between transit organizations to support transit traveler information systems. For this project, fare schedules are not applicable.
traveler input	User input from a traveler to summon assistance, request travel information, make a reservation, or request any other traveler service. For this CEAV project, reservation is not applicable.
traveler interface updates	Visual or audio information (e.g., routes, messages, guidance, emergency information) that is provided to the traveler.

Source: City of Columbus

Table 118: Connected Electric Autonomous Vehicles Traveler Information Functional Objects

Physical Object	Functional Object	Description
CEAV	Transit Vehicle On-Board Information Services	Transit Vehicle On-Board Information Services furnishes en route transit users with real-time travel-related information on a transit vehicle. Current information that can be provided to transit users includes transit routes, schedules, transfer options, fares, real-time schedule adherence, current incidents, weather conditions, non-motorized transportation services, and special events are provided. In addition to tailored information for individual transit users, it also supports general annunciation and/or display of general schedule information, imminent arrival information, and other information of general interest to transit users. For this project, fares are not applicable as CEAV will be a free service. In addition, tailored information for individual transit users is not applicable.
CEAV Fleet Management System	Transit Center Information Services	Transit Center Information Services collects the latest available information for a transit service, and makes it available to transit customers and to TICs for further distribution. Customers are provided information at transit stops and other public transportation areas before they embark/board the transit vehicle as well as once they are en route. Information provided can include the latest available information on transit routes, schedules, transfer options, fares, real-time schedule adherence, current incidents, weather conditions, yellow pages, and special events. In addition to general service information, tailored information (e.g., itineraries) is provided to individual transit users. For this project, yellow pages information will not be provided. In addition, fare and tailored information is not applicable.

Source: City of Columbus

2.9.3.6. CONNECTED ELECTRIC AUTONOMOUS VEHICLES TRACKING

This Service Package monitors current CEAV vehicle location using an Automated Vehicle Location System. The location data may be used to determine real-time schedule adherence and to update the transit system's schedule in real time.

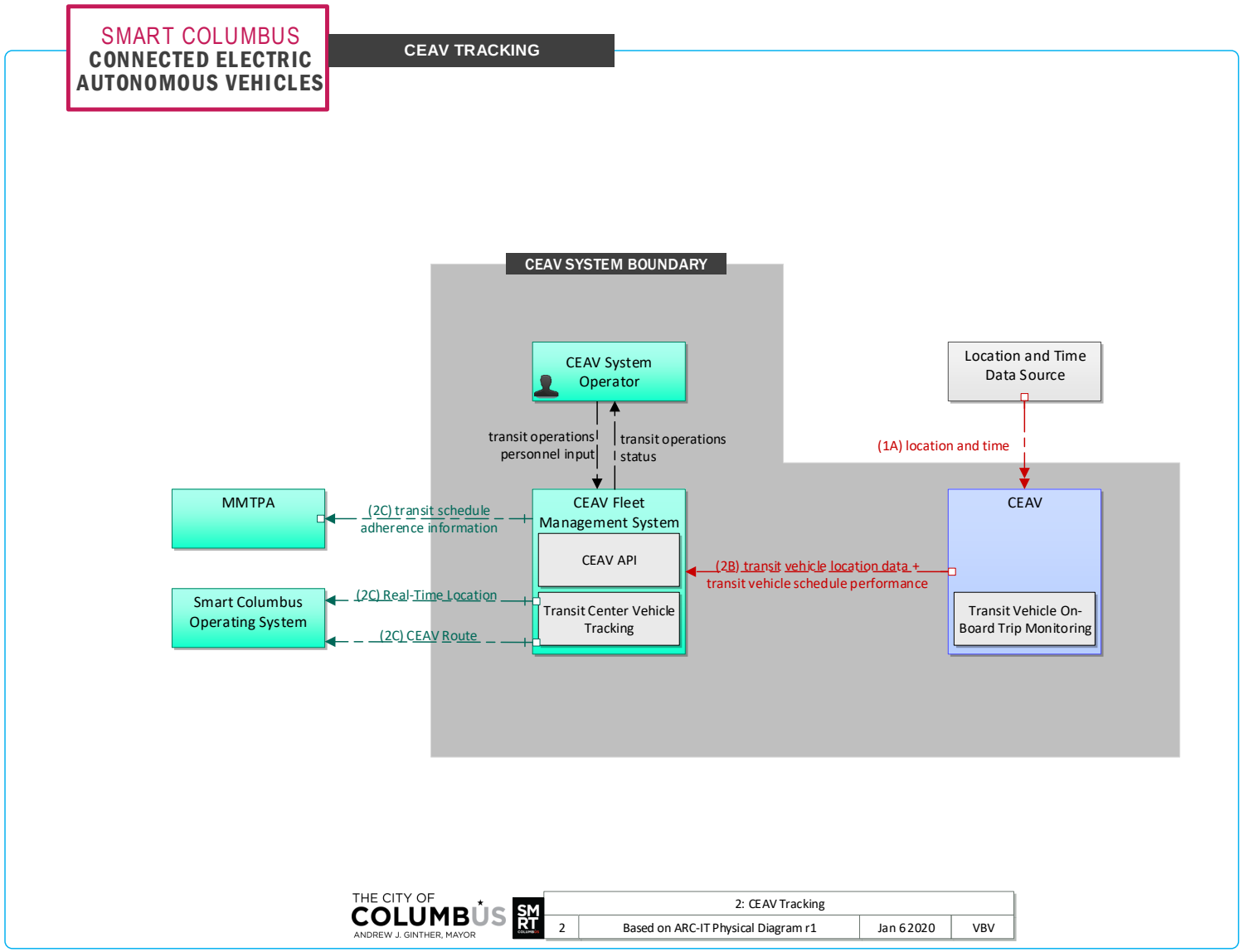


Figure 63: Connected Electric Autonomous Vehicles Tracking (Layer 2)

Source: City of Columbus

Table 119: Connected Electric Autonomous Vehicles Tracking Physical Elements

Physical Object	Class	Description
CEAV	Vehicle	CEAV represents vehicles that provide service for the CEAV system. This Physical Object supports all six levels of driving automation as defined in SAE J3016. The CEAV is a Level 4 vehicle. Initial collision avoidance functions provide vigilant co-pilot operator warning capabilities. More advanced functions assume limited control of the vehicle to maintain lane position and safe headways. In the most advanced implementations, this Physical Object supports full automation of all aspects of the driving task, aided by communications with other vehicles in the vicinity, and in coordination with supporting infrastructure subsystems.
CEAV Fleet Management System	Center	The CEAV Fleet Management System represents the system that manages CEAV, including providing guidance/suggestion for onboard operator and/or vehicle system to make decisions locally to maintain schedule and/or even headways.
CEAV System Operator	Traveler	The CEAV System Operator refers to transportation operations and management entity.
Location and Time Data Source	ITS	The Location and Time Data Source is a GNSS that provides accurate position information for vehicle-based mobile devices. GNSS data are used to provide position, speed, and heading for vehicles. While a GPS Receiver is the most common implementation, this Physical Object represents the technology that provides a position fix in three dimensions and time with sufficient accuracy.
MMTPA	Center	The MMTPA is an app available to travelers on both iOS and Android devices and a web-based platform. MMTPA accesses mobility provider service options from multiple Mobility Providers via APIs. The project will allow travelers to create multimodal trips and pay each mobility provider. Multimodal trip options include walking, fixed-route bus service, ride-hailing, bike-sharing, paratransit, and scooter services.
Smart Columbus Operating System	Center	The Smart Columbus Operating System covers the ingestion and organization of information stored in the Smart Columbus Operating System. The ingestion process is initiated by the Data Curator using a web interface to define and manage the data feeds.

Source: City of Columbus

Table 120: Connected Electric Autonomous Vehicles Tracking Information Flows

Information Flow Name	Description
CEAV Route	Includes CEAV Route information.
location and time	The current geographic location in three dimensions (latitude, longitude, elevation) and the current time.
Real-Time Location	Includes the real-time location information of the CEAV.

Information Flow Name	Description
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.
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. For this project, fare information is not applicable.
transit schedule adherence information	Dynamic transit schedule adherence and transit vehicle location information.
transit vehicle location data	Current transit vehicle location and related operational conditions data provided by a transit vehicle.
transit vehicle schedule performance	Estimated times of arrival and anticipated schedule deviations reported by a transit vehicle.

Source: City of Columbus

Table 121: Connected Electric Autonomous Vehicles Tracking Functional Objects

Physical Object	Functional Object	Description
CEAV	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 Transit Management Center. For this project, this Functional Object tracks electric charge usage.
CEAV Fleet Management System	CEAV API	Provides a set of routines, protocols, and tools for interacting with CEAV. The API provides the following information: mileage, speed, status, door state, ramp state, payload of vehicle, battery level, internal/external temperature, passenger count.
	Transit Center Vehicle Tracking	Transit Center Vehicle Tracking monitors transit vehicle location. The location information is collected via a data communication link between the transit vehicles and the transit center. The location information is presented to the transit operator on a digitized map of the transit service area. The location data may be used to determine real time schedule adherence and update the transit system's schedule in real-time. The real-time schedule information is disseminated to other information providers, which furnish the information to travelers.

Source: City of Columbus

2.9.3.7. CONNECTED ELECTRIC AUTONOMOUS VEHICLES SAFETY SYSTEMS

This Service Package improves vehicle safety using onboard sensors that monitor the driving environment surrounding the vehicle. All levels of driving automation are supported, ranging from basic warning systems that warn the operator through full automation where the vehicle controls the steering and acceleration/deceleration in all scenarios and environments without operator intervention. This Service Package includes autonomous capabilities that rely only on onboard systems without communication with other vehicles or the infrastructure.

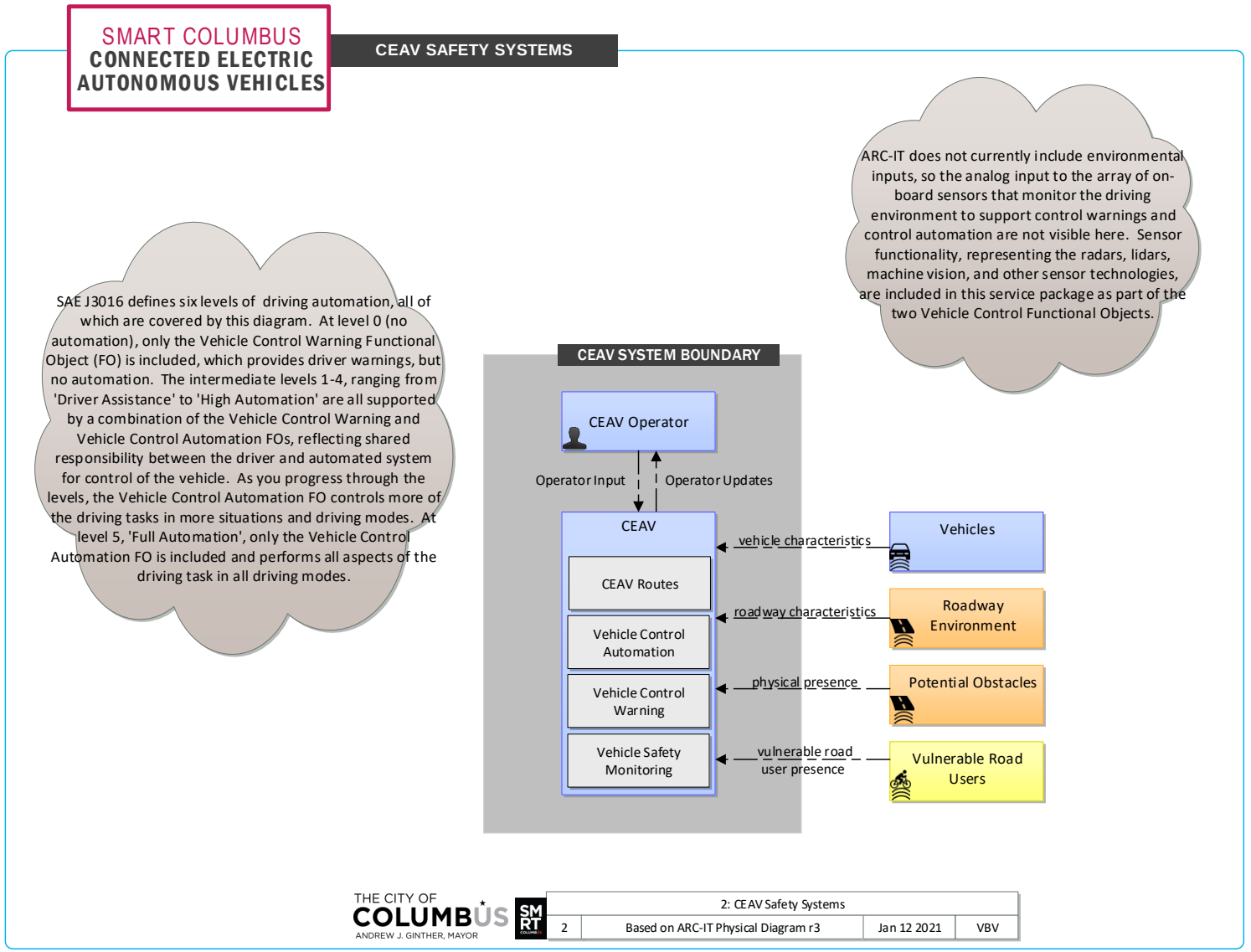


Figure 64: Connected Electric Autonomous Vehicles Safety Systems (Layer 2)

Source: City of Columbus

Table 122: Connected Electric Autonomous Vehicles Safety Systems Physical Elements

Physical Object	Class	Description
CEAV	Vehicle	CEAV represents vehicles that provide service for the CEAV system. This Physical Object supports all six levels of driving automation as defined in SAE J3016. The CEAV is a Level 4 vehicle. Initial collision avoidance functions provide vigilant co-pilot driver warning capabilities. More advanced functions assume limited control of the vehicle to maintain lane position and safe headways. In the most advanced implementations, this Physical Object supports full automation of all aspects of the driving task, aided by communications with other vehicles in the vicinity and in coordination with supporting infrastructure subsystems.
CEAV Operator	Center	The CEAV Operator refers to the company and staff hired by the CEAV System Operator to perform tasks for the CEAV that require human assistance, including onboard operators and vehicle maintenance staff.
Potential Obstacles	Field	'Potential Obstacles' represents any object that possesses the potential of being sensed and struck and thus also possesses physical attributes. Potential Obstacles include roadside obstructions, debris, animals, infrastructure elements (barrels, cones, barriers, etc.) or any other element that is in a potential path of the vehicle. Note that roadside objects and pieces of equipment that can become obstacles in a vehicle's path can include materials, coatings, or labels (e.g., barcodes) that will improve the performance of the vehicle-based sensors that must detect and avoid these obstacles. See also 'Vulnerable Road Users' that more specifically represents the physical properties of shared users of the roadway that must also be detected.
Roadway Environment	Field	'Roadway Environment' represents the physical condition and geometry of the road surface, markings, signs, and other objects on or near the road surface. It also represents the environmental conditions immediately surrounding the roadway. The roadway environment must be sensed and interpreted to support automated vehicle services. Surrounding conditions may include fog, ice, snow, rain, wind, etc. which will influence the way in which a vehicle can be safely operated on the roadway. The roadway environment must be monitored to enable corrective action and information dissemination regarding roadway conditions which may adversely affect travel. Infrastructure owner/operators can improve the roadway environment to improve the performance and accuracy of vehicle-based sensors that must sense and interpret this environment. Improvements could include changes in the shape, size, design, and materials used in signs, pavement markings, and other road features.
Vehicles	Vehicle	'Vehicles' represents the external view of individual vehicles. It includes vehicle physical characteristics such as height, width, length, weight, and other properties (e.g., magnetic properties, number of axles) of individual vehicles that can be sensed and measured or classified. This physical object represents the physical properties of vehicles that can be sensed by vehicle-based or infrastructure-based sensors to support vehicle automation and traffic sensor systems. The analog properties provided by this terminator represent the sensor inputs that are used to detect and assess vehicle(s) within the sensor's range to support safe AV operation and/or safe traffic management.

Physical Object	Class	Description
Vulnerable Road Users	Traveler	'Vulnerable Road Users' represents any roadway user not in a motorized vehicle capable of operating at the posted speed for the roadway in question, and also any roadway user in a vehicle not designed to encase (and thus protect) its occupants. This includes pedestrians, cyclists, wheelchair users, two-wheeled scooter micromobility users, as well as powered scooters and motorcycles. Note that this terminator represents the physical properties of vulnerable road users and their conveyance that may be sensed to support safe vehicle automation and traffic management in mixed mode applications where a variety of road users share the right-of-way. See also 'Pedestrian' and 'Cyclist' Physical Objects that represent the human interface to these vulnerable road users.

Source: City of Columbus

Table 123: Connected Electric Autonomous Vehicles Safety Systems Information Flows

Information Flow Name	Description
Operator Input	Operator input to the CEAV, including configuration data, settings and preferences, interactive requests, and control commands.
Operator Updates	Information provided to the operator, including visual displays, audible information and warnings, and haptic feedback. The updates inform the driver about current conditions, potential hazards, and the current status of CEAV.
physical presence	Detection of an obstacle. Obstacle could include animals, incident management and construction elements such as cones, barrels and barriers, rocks in roadway, etc.
roadway characteristics	Detectable or measurable road characteristics such as friction coefficient and general surface conditions, road geometry and markings, etc. These characteristics are monitored or measured by ITS sensors and used to support advanced vehicle safety and control and road maintenance capabilities.
vehicle characteristics	The physical or visible characteristics of individual vehicles that can be used to detect, classify, and monitor vehicles and imaged to uniquely identify vehicles.
vulnerable road user presence	Detection of pedestrians, cyclists, and other vulnerable road users. This detection is based on physical characteristics of the user and their conveyance, which may be enhanced by design and materials that facilitate sensor-based detection and tracking of vulnerable road users.

Source: City of Columbus

Table 124: Connected Electric Autonomous Vehicles Safety Systems Functional Objects

Physical Object	Functional Object	Description
CEAV	CEAV Routes	CEAV Routes provides the ability to program routes into the CEAV and select the route that the CEAV will operate on. This function provides the an interface for the CEAV Operator and allows the CEAV Operator to select the route for operations.

Physical Object	Functional Object	Description
	Vehicle Control Automation	Vehicle Control Automation provides lateral and/or longitudinal control of a vehicle to allow 'hands off' and/or 'feet off' driving, automating the steering, accelerator, and brake control functions. It builds on the sensors included in Vehicle Safety Monitoring and Vehicle Control Warning, and uses the information about the area surrounding the vehicle to safely control the vehicle. It covers the range of incremental control capabilities, from driver assistance systems that take over steering or acceleration/deceleration in limited scenarios (with direct monitoring by the driver) to full automation- where all aspects of driving are automated under all roadway and environmental conditions.
	Vehicle Control Warning	Vehicle Control Warning monitors areas around the vehicle, and provides warnings to an operator so the driver can take action to recover and maintain safe control of the vehicle. It includes lateral warning systems that warn of lane departures and obstacles/vehicles to the sides of the vehicle and longitudinal warning systems that monitor areas in the vehicle path, and provides warnings when headways are insufficient or obstacles are detected in front of or behind the vehicle. It includes onboard sensors, including radars and imaging systems, and the driver information system that provides the visual, audible, and/or haptic warnings to the driver.
	Vehicle Safety Monitoring	Vehicle Safety Monitoring monitors critical components of the vehicle, and warns the operator of safety issues. These capabilities are provided by onboard sensors that monitor vehicle condition and performance, including steering, braking, acceleration, emissions, fuel economy, engine performance, etc. This Functional Object can also monitor the driver's condition, and warn the driver of potential safety issues. It includes sensors and behavior monitoring capabilities that assess the suitability of the driver (e.g., fitness and alertness) to assume or maintain manual control of the vehicle.

Source: City of Columbus

2.9.3.8. CONNECTED ELECTRIC AUTONOMOUS VEHICLES VEHICLE-TO-VEHICLE BASIC SAFETY

This Service Package improves vehicle safety using OBE to send the vehicle's position and movement to vehicles in the vicinity. While this Service Package allows the vehicle to send and receive information with other vehicles, information that is received will not be acted upon. Other vehicles with OBE may choose to react to the information that they receive, however, these vehicles are not within the scope of this system.

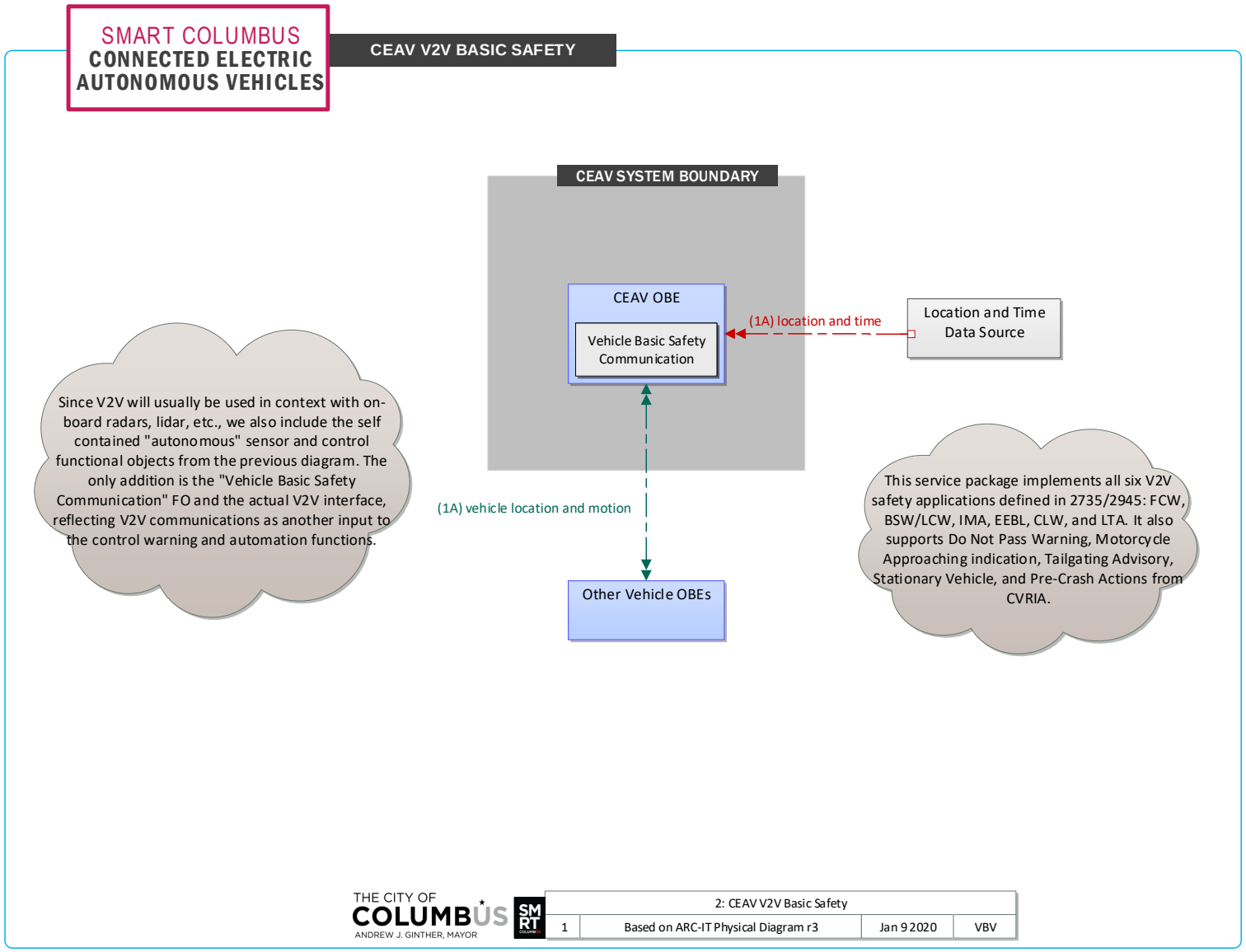


Figure 65: Connected Electric Autonomous Vehicles Vehicle-to-Vehicle Basic Safety (Layer 2)

Source: City of Columbus

Table 125: Connected Electric Autonomous Vehicles Vehicle-to-Vehicle Basic Safety Physical Elements

Physical Object	Class	Description
CEAV OBE	Vehicle	The CEAV OBE provides the vehicle-based sensory, processing, storage, and communications functions that support efficient, safe, and convenient travel. The Vehicle OBE includes general capabilities that apply to passenger cars, trucks, and motorcycles. Many of these capabilities (e.g., see the Vehicle Safety Service Packages) apply to all vehicle types, including personal vehicles, commercial vehicles, emergency vehicles, transit vehicles, and maintenance vehicles. From this perspective, the CEAV OBE includes the common interfaces and functions that apply to all motorized vehicles. The radio(s) supporting V2V and V2I communications are a key component of the Vehicle OBE. Both one-way and two-way communications options support a spectrum of information services, from basic broadcast to advanced personalized information services. Route guidance capabilities assist in formulation of an optimal route and step-by-step guidance along the travel route. Advanced sensors, processors, enhanced driver interfaces, and actuators complement the driver information services to make informed mode and route selections, allowing the driver to travel these routes in a safer and more consistent manner. For this project, CEAV doesn't take any actions based on OBE. It just receives the information.
Location and Time Data Source	ITS	The Location and Time Data Source is a GNSS that provides accurate position information for vehicle-based mobile devices. GNSS data are used to provide position, speed, and heading for vehicles. While a GPS Receiver is the most common implementation, this Physical Object represents the technology that provides a position fix in three dimensions and time with sufficient accuracy.
Other Vehicle OBEs	Vehicle	Other Vehicle OBEs represent other CVs that are communicating with the host vehicle. This includes all connected motorized vehicles, including passenger cars, trucks, motorcycles, and specialty vehicles (e.g., maintenance vehicles, transit vehicles) with the basic Vehicle OBE functionality that supports V2V communications. This object provides a source and destination for information transfers between CVs. The host vehicle OBE, represented by the Vehicle OBE physical object, sends information to, and receives information from the Other Vehicle OBEs to model all CV V2V communications in ARC-IT.

Source: City of Columbus

Table 126: Connected Electric Autonomous Vehicles Vehicle-to-Vehicle Basic Safety Information Flows

Information Flow Name	Description
location and time	The current geographic location in three dimensions (latitude, longitude, elevation) and the current time.

Information Flow Name	Description
vehicle location and motion	Data describing the vehicle's position, heading, speed, acceleration, transmission, steering wheel angle, braking status, size information, and trajectory. For this project, only the CEAV's position, heading, speed, acceleration, and trajectory are applicable.

Source: City of Columbus

Table 127: Connected Electric Autonomous Vehicles Vehicle-to-Vehicle Basic Safety Functional Objects

Physical Object	Functional Object	Description
CEAV OBE	Vehicle Basic Safety Communication	Vehicle Basic Safety Communication exchanges current vehicle location and motion information with other vehicles in the vicinity, uses that information to calculate vehicle paths, and warns the driver when the potential for an impending collision is detected. If available, map data are used to filter and interpret the relative location and motion of vehicles in the vicinity. Information from onboard sensors (e.g., radars and image processing) are also used, if available, in combination with the V2V communications to detect non-equipped vehicles and corroborate CV data. Vehicle location and motion broadcasts are also received by the infrastructure, and used by the infrastructure to support a wide range of roadside safety and mobility applications. This object represents a broad range of implementations, ranging from basic Vehicle Awareness Devices that only broadcast vehicle location and motion without driver warnings to advanced integrated safety systems that may, in addition to warning the driver, provide collision warning information to support automated control functions supporting control intervention. For this project, the CEAV OBE will not provide warning information to support automated control functions.

Source: City of Columbus

2.9.3.9. CONNECTED ELECTRIC AUTONOMOUS VEHICLES ROADSIDE EQUIPMENT INTERFACE

This Service Package supports communications between the vehicles and supporting infrastructure RSE. The CEAV will provide basic messages to the RSE for data logging purposes only.

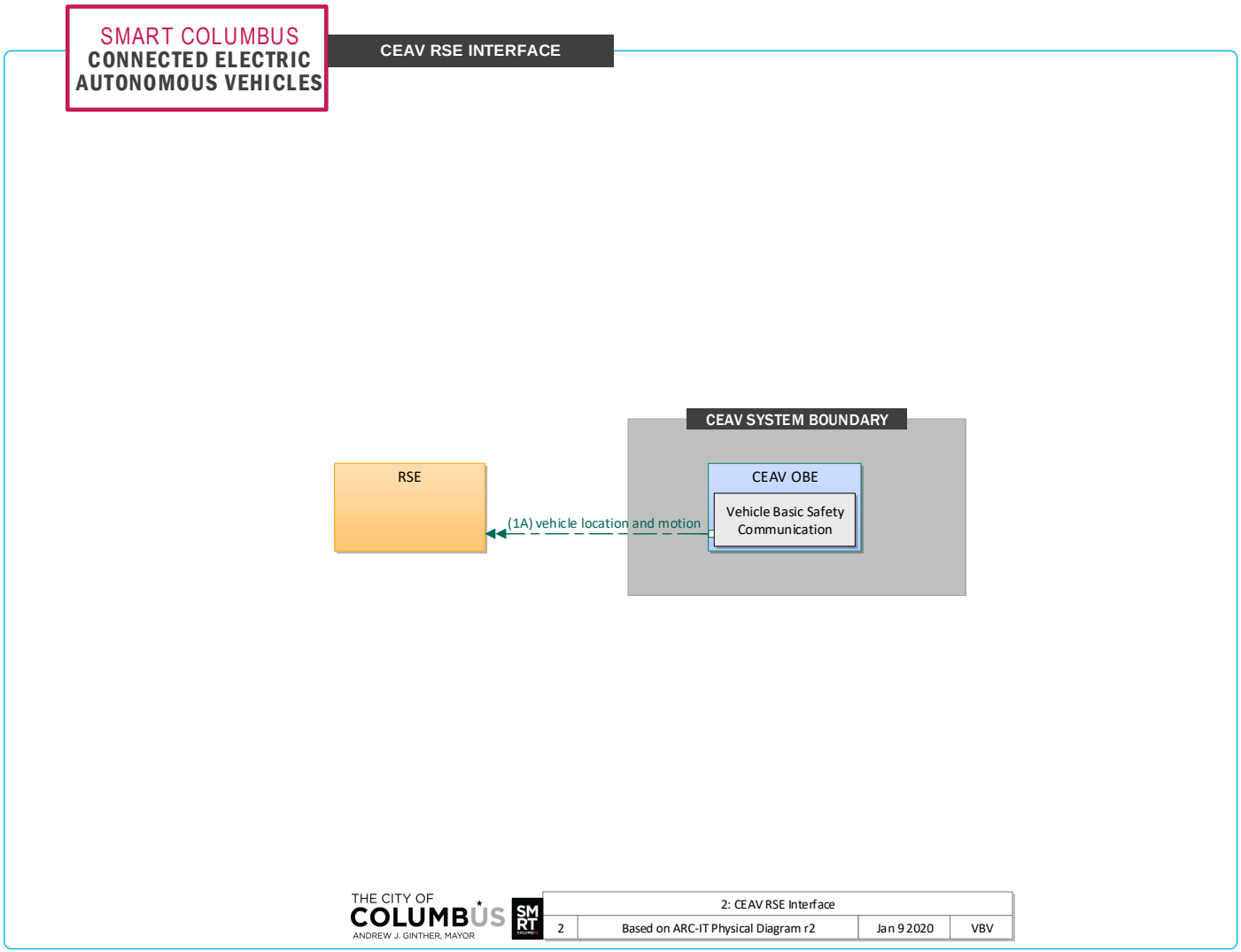


Figure 66: Connected Electric Autonomous Vehicles Roadside Equipment Interface (Layer 2)

Source: City of Columbus

Table 128: Connected Electric Autonomous Vehicles Roadside Equipment Interface Physical Elements

Physical Object	Class	Description
CEAV OBE	Vehicle	The CEAV OBE provides the vehicle-based sensory, processing, storage, and communications functions that support efficient, safe, and convenient travel. The Vehicle OBE includes general capabilities that apply to passenger cars, trucks, and motorcycles. Many of these capabilities (e.g., see the Vehicle Safety Service Packages) apply to all vehicle types, including personal vehicles, commercial vehicles, emergency vehicles, transit vehicles, and maintenance vehicles. From this perspective, the CEAV OBE includes the common interfaces and functions that apply to all motorized vehicles. The radio(s) supporting V2V and V2I communications are a key component of the Vehicle OBE. Both one-way and two-way communications options support a spectrum of information services, from basic broadcast to advanced personalized information services. Route guidance capabilities assist in formulation of an optimal route and step-by-step guidance along the travel route. Advanced sensors, processors, enhanced driver interfaces, and actuators complement the driver information services to make informed mode and route selections, allowing the driver to travel these routes in a safer and more consistent manner. For this project, CEAV doesn't take any actions based on OBE. It just receives the information.
RSE	Field	The RSE represents the CV roadside devices that are used to send messages to, and receive messages from, nearby vehicles using DSRC or other alternative wireless communications technologies. Communications with adjacent ITS field equipment and the back office TCVMS that monitors and controls the RSE are also supported. The RSU portion operates from a fixed position on vertical strain poles, mast arms, or spanwire on which signal heads are installed for permanent deployment. The RSE includes a processor, data storage, and communications capabilities that support secure communications with passing vehicles, other field equipment, and centers.

Source: City of Columbus

Table 129: Connected Electric Autonomous Vehicles Roadside Equipment Interface Information Flows

Information Flow Name	Description
vehicle location and motion	Data describing the vehicle's position, heading, speed, acceleration, transmission, steering wheel angle, braking status, size information, and trajectory. For this project, only the CEAV's position, heading, speed, acceleration, and trajectory are applicable.

Source: City of Columbus

Table 130: Connected Electric Autonomous Vehicles Roadside Equipment Interface Functional Objects

Physical Object	Functional Object	Description
CEAV OBE	Vehicle Basic Safety Communication	Vehicle Basic Safety Communication exchanges current vehicle location and motion information with other vehicles in the vicinity, uses that information to calculate vehicle paths, and warns the driver when the potential for an impending collision is detected. If available, map data are used to filter and interpret the relative location and motion of vehicles in the vicinity. Information from onboard sensors (e.g., radars and image processing) are also used, if available, in combination with the V2V communications to detect non-equipped vehicles, and corroborate CV data. Vehicle location and motion broadcasts are also received by the infrastructure, and used by the infrastructure to support a wide range of roadside safety and mobility applications. This object represents a broad range of implementations, ranging from basic Vehicle Awareness Devices that only broadcast vehicle location and motion without driver warnings to advanced integrated safety systems that may, in addition to warning the driver, provide collision warning information to support automated control functions to support control intervention. For this project, the CEAV OBE will not provide warning information to support automated control functions.

Source: City of Columbus

2.9.4. Enterprise Architecture View

The following diagram shows the relationships between Smart Columbus stakeholders, the roles organizations play within the project, and the agreements among the stakeholders. The table provides the list of agreements and expectations and their descriptions.

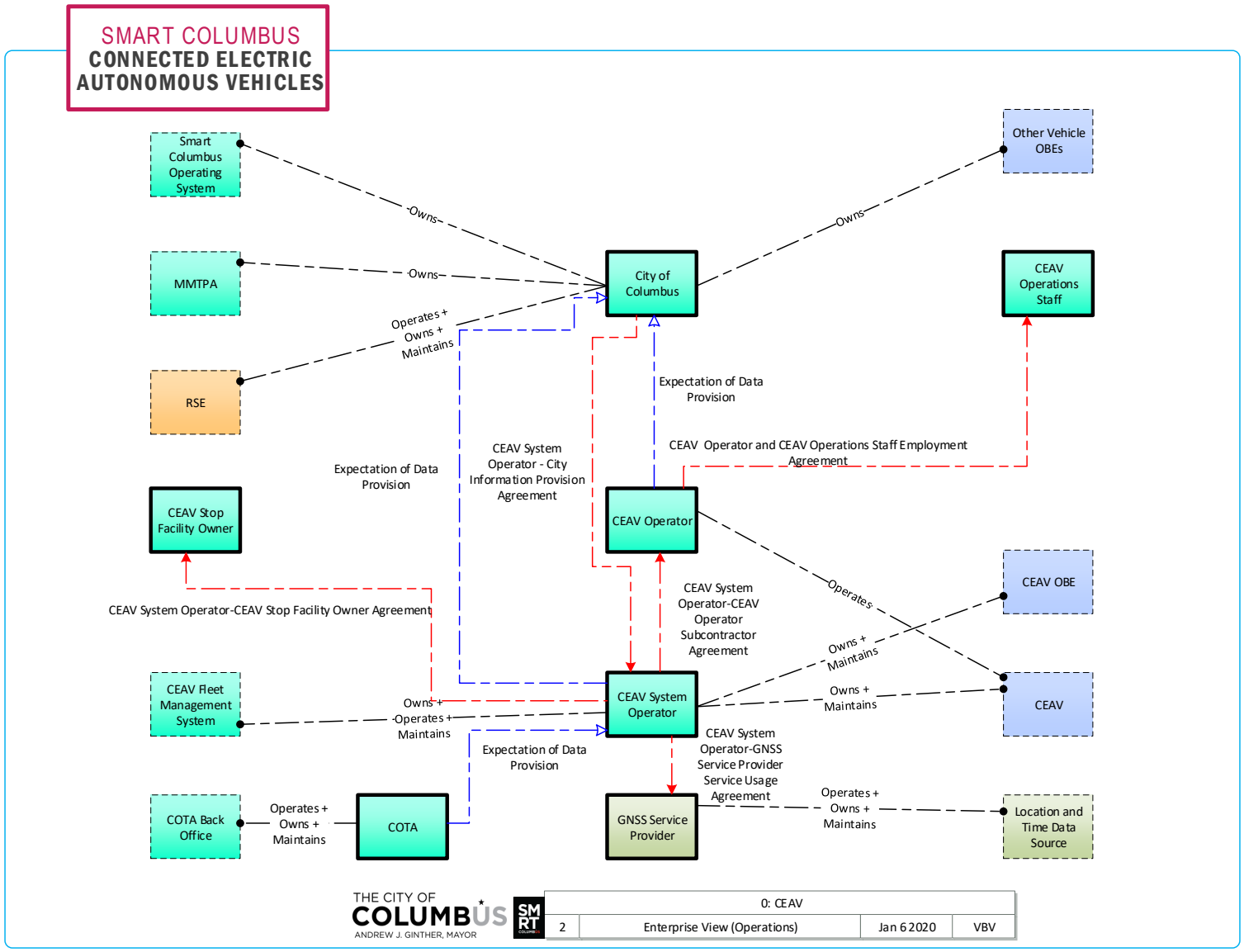


Figure 67: Connected Electric Autonomous Vehicles Enterprise Architecture View

Source: City of Columbus

Table 131: Connected Electric Autonomous Vehicles List of Agreements

Potential Agreement	Description
CEAV Operator and CEAV Operations Staff Employment Agreement	An agreement between the CEAV Operator and CEAV Operations Staff, whereupon the staff agrees to provide labor to the Operator, which in turn compensates the employee. Stipulates level of compensation, working conditions, required employee qualifications, necessary equipment, training, and expectations of employee performance. The employee qualification includes, but is not limited to, maintaining a clean driving record, driver's license, etc. Qualifications need to be met before an employee is hired, and need to be maintained for them to remain employed. Vendor: EasyMile Status: Existing
CEAV System Operator - City Information Provision Agreement	An agreement where CEAV System Operator agrees to provide information to the City. Vendor: EasyMile Status: Existing
CEAV System Operator-CEAV Operator Subconsultant Agreement	An agreement for the CEAV Operator to operate and maintain CEAV in exchange for compensation of services from the CEAV System Operator. Vendor: EasyMile Status: Existing
CEAV System Operator-CEAV Stop Facility Owner Agreement	This agreement provides Vendor with the ability to operate on and utilize the restrooms for operators at the CEAV stop. • Vendor: EasyMile • St. Stephen's Community House: Existing • COTA: Existing
NHTSA FMVSS Exemption	Approval for the CEAV System Operator to operate during the specified hours on the defined route without traditional vehicle control systems. Parties: EasyMile and NHTSA Status: Existing (This agreement is not shown in the Enterprise Architecture View)
Vehicle Licensure	Registration of the vehicles to operate on roadways in the State of Ohio. Parties: EasyMile; State of Ohio, BMV; State of Ohio, PUCO; State of Ohio, DriveOhio Status: In Progress (This agreement is not shown in the Enterprise Architecture View)

Source: City of Columbus

2.9.4.1. ROLES AND RESPONSIBILITIES

Development:

- City of Columbus/Smart Columbus PMO: owner, CVE (RSE), OS and MMTPA owner
  - Michael Baker, Intl.: project manager
  - HNTB/WSP: requirements, route development
  - EasyMile: vendor/vehicle provider, development of NHTSA Exemption request for Federal Motor Vehicle Safety Standards (FMVSS) for the demonstration period
  - GNSS Service provider: location and time data source
  - OS Team (Accenture): interface requirements for OS
  - MMTPA Team (Etch): integrating EasyMile as mobility provider in MMTPA (Pivot)

Installation:

- City of Columbus/Smart Columbus PMO: owner, CVE (RSE), OS and MMTPA owner. Sign and concrete installation at stop locations.
  - Michael Baker, Intl.: project manager
  - EasyMile: vendor/vehicle provider, installation of storage and charging infrastructure
  - OS Team (Accenture): Implementation of interface between OS and EasyMile
  - City Department of Public Service – installation at stop locations
- Property owners – coordination of signage; agreements for operations:
  - St. Stephen's Community House
  - COTA – Linden Transit Center
  - City of Columbus - Douglas Community Recreation
  - Columbus Metropolitan Housing Authority - Rosewind
- NHTSA – approver of FMVSS exemption request

Testing:

- City of Columbus/Smart Columbus PMO: owner, CVE (RSE), OS and MMTPA owner
  - Michael Baker, Intl.: project manager; on-site acceptance test lead
  - HNTB/WSP: Test plan development
  - EasyMile: vendor/vehicle provider; factory acceptance test lead for vehicles
  - OSU: test simulation
  - MMTPA Team (Etch): integrating shuttles into trip plans; testing MMTPA integration
- NHTSA: authorizing entity for testing with exemption approval

Operations:

- City of Columbus/Smart Columbus PMO: owner, CVE (RSE), OS and MMTPA owner
  - Michael Baker, Intl.: project manager
  - HNTB/WSP: O&M plan input

- EasyMile: vendor/vehicle provider, Fleet management system operator; O&M plan; Standard Operating Procedures
- OS Team (Accenture): data collection
- MMTPA Team (Etch): MMTPA (Pivot) operations

Maintenance:

- City/Smart Columbus PMO:
  - Michael Baker, Intl.: project manager
  - HNTB/WSP: O&M plan updates
  - EasyMile: vendor/vehicle provider and vehicle maintenance, Fleet Management System operator; O&M plan:
  - Property owners: notify City of infrastructure or operational issue

2.9.5. Communications Architecture View

2.9.5.1. COMMUNICATION PROFILES USED

The following table describes the layered sets of communications protocols that are required to support communications among the elements that make up the CEAV project. Refer to **Appendix B** for the standards used for each communication profile.

2.9.5.1.1. DSRC-WSMP

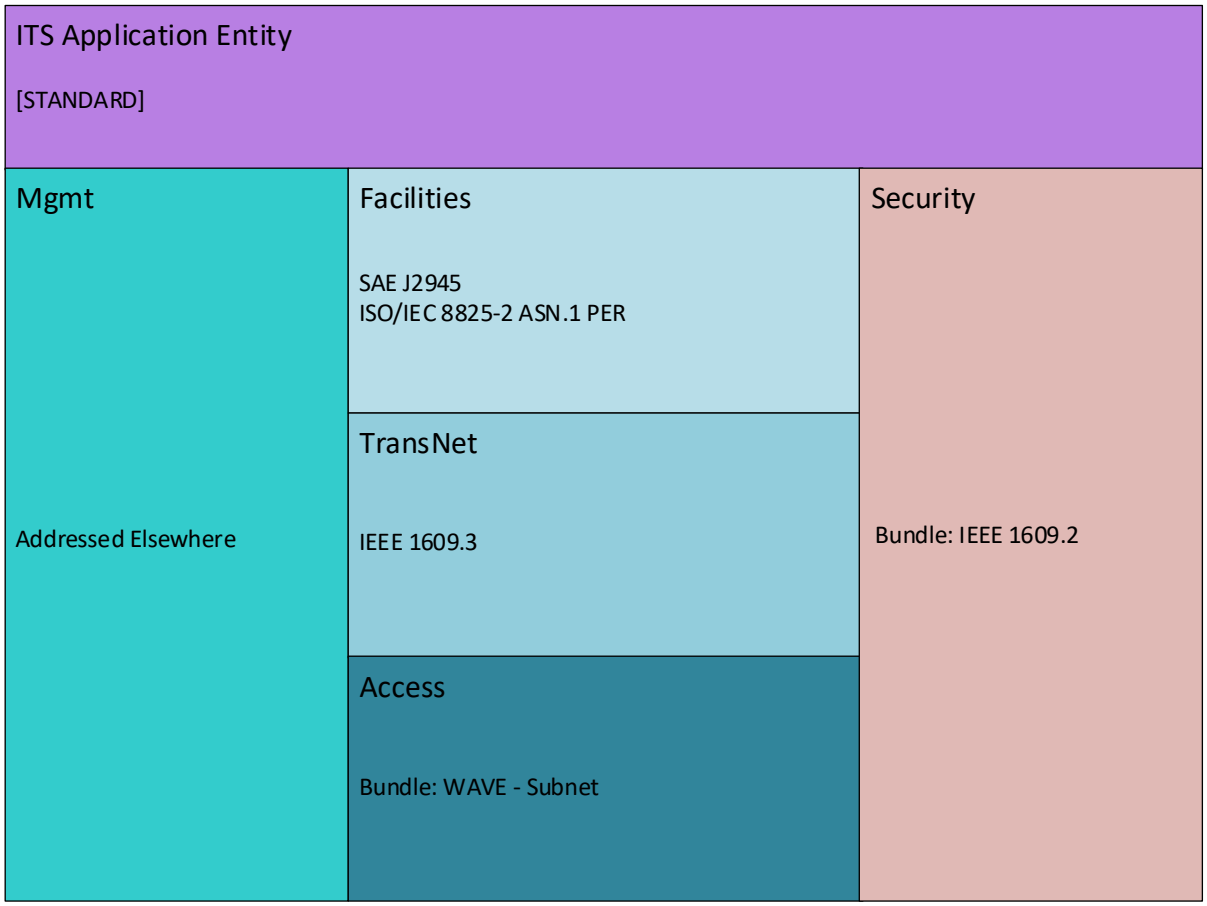


Figure 68: DRSC-WSMP

Source: City of Columbus

Table 132: DRSC-WSMP

Name	Source	Destination	Standard	Profile
vehicle location and motion	CEAV OBE	Other Vehicle OBEs	SAE J2735	DSRC-WSMP
vehicle location and motion	CEAV OBE	Other Vehicle OBEs	SAE J2945/1	DSRC-WSMP
vehicle location and motion	CEAV OBE	RSE	SAE J2735	DSRC-WSMP
vehicle location and motion	CEAV OBE	RSE	SAE J2945/1	DSRC-WSMP
vehicle location and motion	Other Vehicle OBEs	CEAV OBE	SAE J2735	DSRC-WSMP
vehicle location and motion	Other Vehicle OBEs	CEAV OBE	SAE J2945/1	DSRC-WSMP

Source: City of Columbus

2.9.5.1.2. Position-Location-Interface

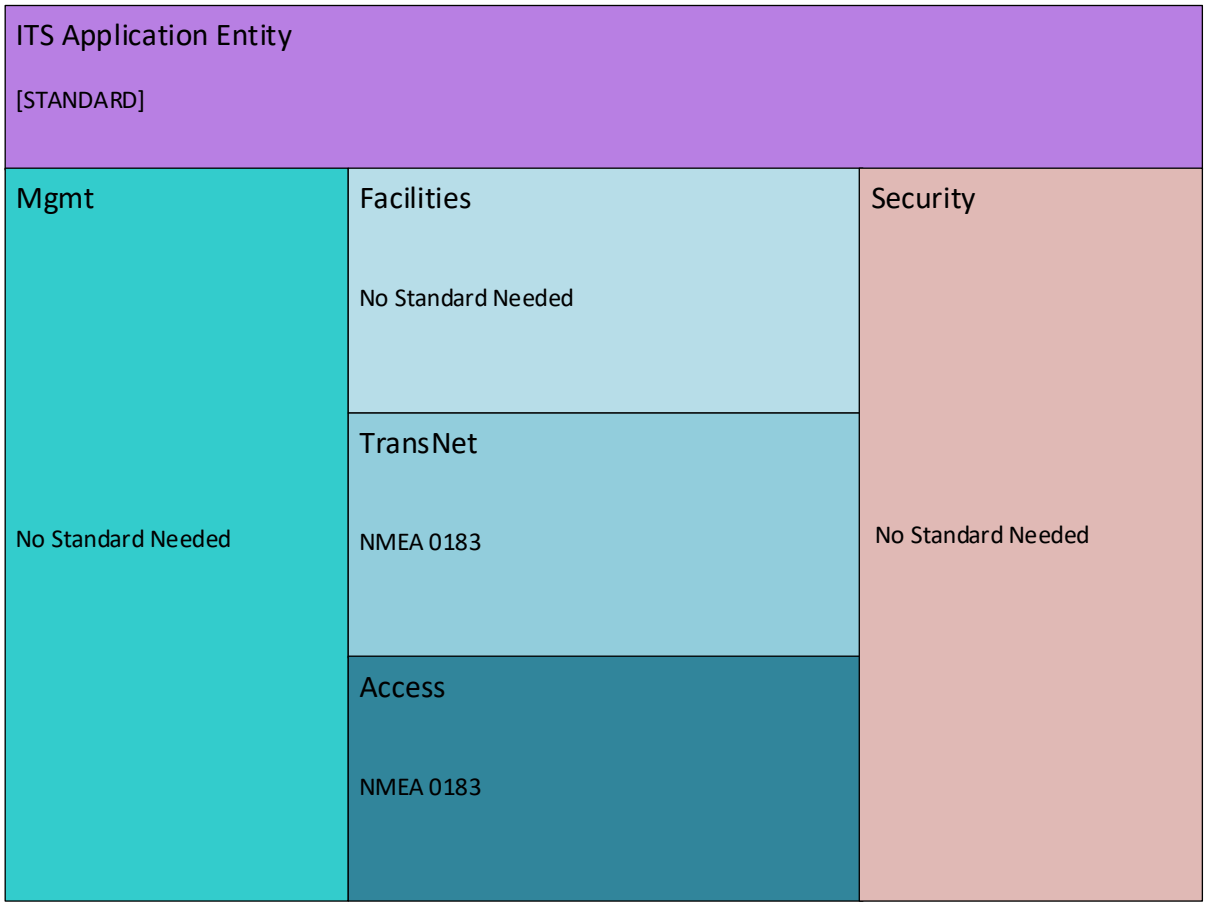


Figure 69: Position-Location-Interface

Source: City of Columbus

Table 133: Position-Location-Interface

Name	Source	Destination	Standard	Profile
location and time	Location and Time Data Source	CEAV	(Unspecified)	Position-Location-Interface
location and time	Location and Time Data Source	CEAV OBE	(Unspecified)	Position-Location-Interface

Source: City of Columbus

2.9.5.1.3. Fleet Management-Connected Electric Autonomous Vehicles

Note: This communication profile contains proprietary intellectual property and cannot be included in public documents.

Table 134: Fleet Management-Connected Electric Autonomous Vehicles

Name	Source	Destination	Standard	Profile
alarm acknowledge	CEAV Fleet Management System	CEAV	(Unspecified)	Fleet Management-CEAV
alarm notification	CEAV	CEAV Fleet Management System	(Unspecified)	Fleet Management-CEAV
CEAV Video	CEAV	CEAV Fleet Management System	(Unspecified)	Fleet Management-CEAV
Intercom	CEAV Fleet Management System	CEAV	(Unspecified)	Fleet Management-CEAV
remote vehicle disable	CEAV Fleet Management System	CEAV	(Unspecified)	Fleet Management-CEAV
transit schedule information	CEAV Fleet Management System	CEAV	GTFS	Fleet Management-CEAV
transit traveler information	CEAV Fleet Management System	CEAV	SAE J2735	Fleet Management-CEAV
transit vehicle conditions	CEAV	CEAV Fleet Management System	(Unspecified)	Fleet Management-CEAV
transit vehicle loading data	CEAV	CEAV Fleet Management System	(Unspecified)	Fleet Management-CEAV
transit vehicle location data	CEAV	CEAV Fleet Management System	(Unspecified)	Fleet Management-CEAV
transit vehicle location data	CEAV	CEAV Fleet Management System	SAE J2735	Fleet Management-CEAV
transit vehicle operator authentication information	CEAV	CEAV Fleet Management System	(Unspecified)	Fleet Management-CEAV
transit vehicle operator authentication update	CEAV Fleet Management System	CEAV	(Unspecified)	Fleet Management-CEAV
transit vehicle operator information	CEAV Fleet Management System	CEAV	(Unspecified)	Fleet Management-CEAV

Name	Source	Destination	Standard	Profile
transit vehicle schedule performance	CEAV	CEAV Fleet Management System	(Unspecified)	Fleet Management-CEAV
vehicle commands	CEAV Fleet Management System	CEAV	(Unspecified)	Fleet Management-CEAV
vehicle configuration settings	CEAV Fleet Management System	CEAV	(Unspecified)	Fleet Management-CEAV
vehicle service response	CEAV Fleet Management System	CEAV	(Unspecified)	Fleet Management-CEAV

Source: City of Columbus

2.9.5.1.4. World Wide Web Browser/JSON/Wide Area Wireless

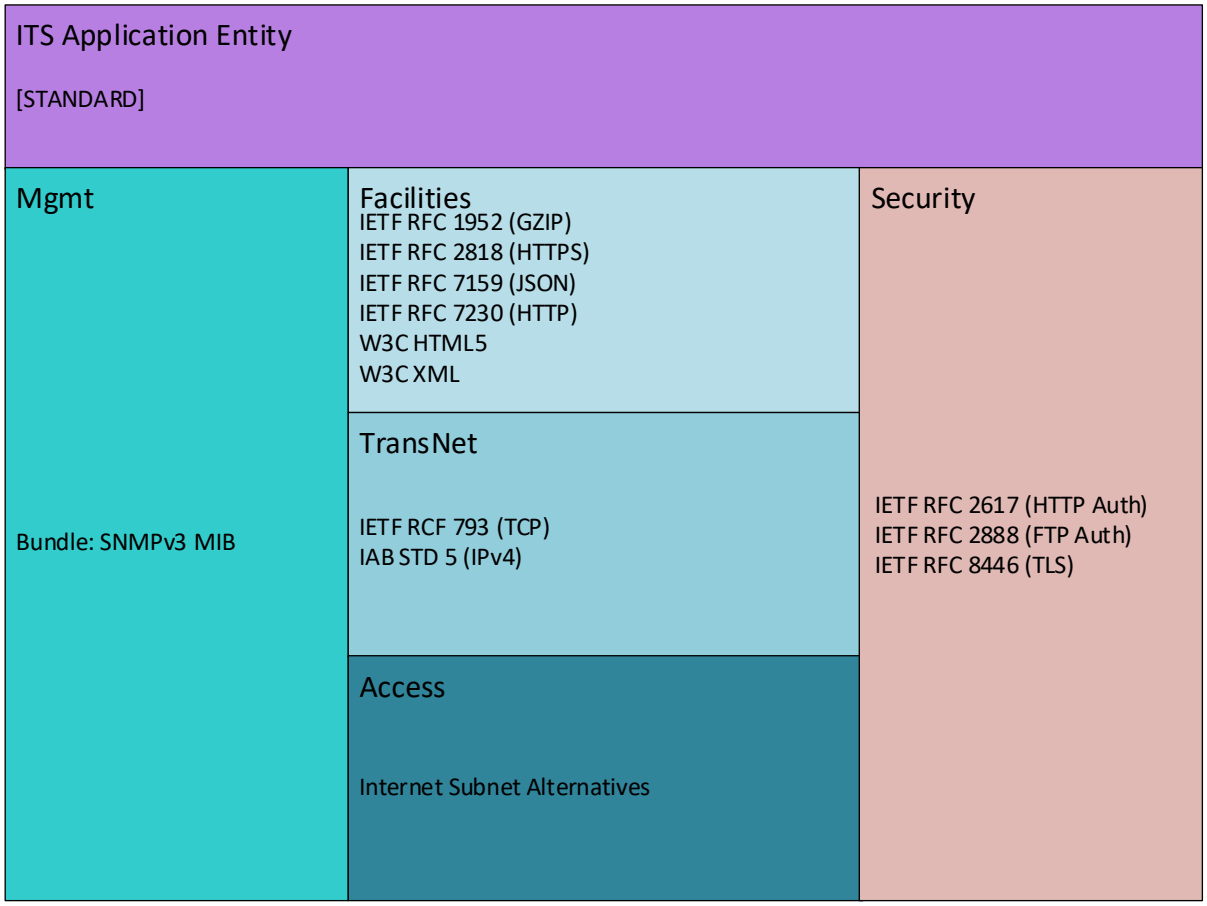


Figure 70: World Wide Web Browser/JSON/Wide Area Wireless

Source: City of Columbus

Table 135: World Wide Web Browser/JSON/Wide Area Wireless

Name	Source	Destination	Standard	Profile
CEAV Archive Data	CEAV Fleet Management System	Smart Columbus Operating System	(Unspecified)	WAW-WWWBrowser-JSON
CEAV Route	CEAV Fleet Management System	Smart Columbus Operating System	(Unspecified)	WAW-WWWBrowser-JSON
Real-Time Location	CEAV Fleet Management System	Operating	(Unspecified)	WAW-WWWBrowser-JSON
transit and fare schedules	CEAV Fleet Management System	MMTPA	GTFS	WAW-WWWBrowser-JSON
transit schedule adherence information	CEAV Fleet Management System	MMTPA	GTFS-Real Time	WAW-WWWBrowser-JSON
transit traveler information coordination	COTA Back Office	CEAV Fleet Management System	GTFS-Real Time	WAW-WWWBrowser-JSON

Source: City of Columbus

2.9.5.1.5. Human Interface

Table 136: Human Interface

Name	Source	Destination	Standard	Profile
route assignment	CEAV Fleet Management System	CEAV Operator	(Unspecified)	Human Interface
Operator Input	CEAV Operator	CEAV	(Unspecified)	Human Interface
Operator Updates	CEAV	CEAV Operator	(Unspecified)	Human Interface
transit operations personnel input	CEAV System Operator	CEAV Fleet Management System	(Unspecified)	Human Interface
transit operations status	CEAV Fleet Management System	CEAV System Operator	(Unspecified)	Human Interface
transit vehicle operator availability	CEAV Operator	CEAV Fleet Management System	(Unspecified)	Human Interface
transit vehicle operator display	CEAV	CEAV Operator	(Unspecified)	Human Interface

Name	Source	Destination	Standard	Profile
transit vehicle operator input	CEAV Operator	CEAV	(Unspecified)	Human Interface
traveler input	CEAV Passenger	CEAV	(Unspecified)	Human Interface
traveler interface updates	CEAV	CEAV Passenger	(Unspecified)	Human Interface

Source: City of Columbus

2.9.5.1.6. Environmental

Table 137: Environmental

Name	Source	Destination	Standard	Profile
physical presence	Potential Obstacles	CEAV	(Unspecified)	Environmental
roadway characteristics	Roadway Environment	CEAV	(Unspecified)	Environmental
vehicle characteristics	Vehicles	CEAV	(Unspecified)	Environmental
vulnerable road user presence	Vulnerable Road Users	CEAV	(Unspecified)	Environmental

Source: City of Columbus

2.9.6. Functional Architecture View

The Functional Architecture View depicts each element of overall system and the logical interfaces among them. The listed draft processes are developed based on discussion with the project team. These processes will be further refined and defined in detail during the design phase of the project.

Table 138: Connected Electric Autonomous Vehicles Functional Architecture View

Physical Object	Functional Object	Process
CEAV	CEAV Routes	Provide Interface for Route Selection and Programming Process Route Programming Manage Routes Monitor Route Position
	Transit Vehicle On-Board Information Services	Process Onboard Systems Data Determine Transit Vehicle Service Status Provide Transit Advisory Interface on Vehicle Determine Traveler Needs on Vehicle
	Transit Vehicle On-Board Maintenance	Process Onboard Systems Data

Physical Object	Functional Object	Process
	Transit Vehicle On-Board Trip Monitoring	Process Onboard Systems Data Determine Transit Vehicle Service Status Provide Transit Vehicle Location Data Determine Traveler Needs on Vehicle
	Transit Vehicle Passenger Counting	Process Onboard Systems Data Determine Transit Vehicle Service Status
	Transit Vehicle Schedule Management	Process Onboard Systems Data Determine Transit Vehicle Service Status Provide Transit Vehicle Location Data
	Transit Vehicle Security	Process Onboard Systems Data Provide Transit Vehicle Location Data Surveil Secure Vehicle Area Process Secure Vehicle Area Surveillance Collect Secure Vehicle Area Sensor Data Process Secure Vehicle Area Sensor Data Manage Secure Vehicle Emergencies Provide Transit Vehicle Operator Interface for Emergencies
	Vehicle Control Automation	Process Data for Vehicle Actuators Provide Servo Control Provide Vehicle Control Data Interface
	Vehicle Control Warning	Produce Collision and Crash Avoidance Data Process Vehicle Onboard Data Process Data for Vehicle Actuators Process Vehicle Sensor Data Provide Driver Information Interface
	Vehicle Safety Monitoring	Carry-out Safety Analysis Communicate with Remote Vehicles Enhance Driver's Vision Provide Driver Information Interface
	Vehicle System Executive	Process Vehicle Onboard Data Manage Vehicle Onboard Systems
CEAV OBE	Vehicle Basic Safety Communication	Communicate with Remote Vehicles Process Vehicle Location Data

Physical Object	Functional Object	Process
CEAV Fleet Management System	Transit Garage Maintenance	Collect and Process Transit Vehicle Data Monitor Transit Vehicle Condition Generate Transit Vehicle Maintenance Schedules Generate Technician Work Assignments Monitor and Verify Maintenance Activity Report Transit Vehicle Information Manage Transit Vehicle Inventory Manage Transit Vehicle Operations Data Store
	CEAV API	Receive Requests and Send Responses.
	Transit Center Operator Assignment	Assess Transit Vehicle Operator Performance Assess Transit Vehicle Operator Availability Access Transit Vehicle Operator Cost Effectiveness Assess Transit Vehicle Operator Eligibility Generate Transit Vehicle Operator Route Assignments Report Transit Vehicle Operator Information Provide Transit Vehicle Operator Information Store Interface
	Transit Center Information Services	Produce Transit Service Data for External Use Produce Transit Service Data for Manage Transit Use Provide Interface for Other Transit Management Data
	Transit Center Data Collection	Manage Transit Archive Data

Physical Object	Functional Object	Process
	Transit Center Fixed-Route Operations	Manage Transit Vehicle Operations Manage Transit Vehicle Deviations Generate Transit Routes Generate Transit Schedules Produce Transit Service Data for External Use Provide Transit Operations Personnel Interface for Services Generation Manage Transit Operational Data Store Produce Transit Service Data for Manage Transit Use Provide Transit Plans Store Interface Assess Transit Vehicle Operator Performance Assess Transit Vehicle Operator Availability Access Transit Vehicle Operator Cost Effectiveness Assess Transit Vehicle Operator Eligibility Generate Transit Vehicle Operator Route Assignments Report Transit Vehicle Operator Information Provide Transit Vehicle Operator Information Store Interface
	Transit Center Passenger Counting	Collect and Process Transit Vehicle Data Manage Transit Vehicle Deviations Manage Transit Operational Data Store
	Transit Center Security	Manage Transit Driver Authentication Provide Interface for Other Transit Management Data Provide Transit Security and Emergency Management Coordinate Multiple Agency Responses to Transit Incidents Generate Responses for Transit Incidents Provide Transit Operations Personnel Security Interface
	Transit Center Vehicle Assignment	Manage Transit Vehicle Operations Generate Transit Vehicle Schedule Assignments
	Transit Center Vehicle Tracking	Collect and Process Transit Vehicle Data Manage Transit Vehicle Operations Update Transit Map Data

Source: City of Columbus

Chapter 3. Intelligent Transportation Systems Standards Plan

3.1. INTRODUCTION

The Smart Columbus Program defines and demonstrates the integration of ITS systems with other systems to build a smart city. The Standards define how systems, products, and components can interconnect, exchange information, and interact to deliver services within the Smart Cities framework. The Standards allow for open-interfaces that establish communication rules for how systems can perform, how they can connect, and how they can exchange data in order to interoperate. It is important to note the Standards identified in this chapter are not design standards. They do not specify specific products or designs to use. Instead, the use of Standards gives the City of Columbus confidence that applications developed by different manufacturers will work together, without removing the incentive for designers and manufacturers to compete to provide products that are more efficient or offer more features.

Although a stand-alone project/application creates benefits, the integration of these systems results in the greatest efficiencies and improvements in mobility and safety. The Standards are an important element in the integration of advanced technologies and systems. The Standards allow both like and different systems to exchange and interpret data directly through a common communications interface. This exchange and recognition of data can take place between devices located within a single system or between devices operating in different systems. By using a standards-based system, the City of Columbus can extend the reach and capabilities of the infrastructure and technology investments made as part of the demonstration program.

The Standards cover different "communications layers" in their description of how data are communicated between the relevant transportation systems. These layers start with the description of how bits of data are combined and transmitted, and extend to the meaning of the entire message sent over the communications path. The Standards specify consistency and compatibility of the interconnects and interfaces, both hardware and software, within an advanced transportation system.

The ability of different systems to exchange and interpret data directly through a common communications interface, and to use the exchanged data to operate together effectively, is called interoperability. Interoperability is key to achieving the full potential of Smart Columbus. Seamless data exchange would allow a transit vehicle (owned by COTA) to request for traffic signal (owned by the City) priority to maintain the transit schedule.

Interoperability is defined as the ability of the systems to:

- Provide information and services to other systems
- Use exchanged information and services to operate together effectively

A standards-based approach to integration helps to facilitate the exchange of transportation data as well as accommodate future equipment replacements, systems upgrades, and system expansions.

One of the main goals for the creation of the National ITS Reference Architecture (ARC-IT) was to define the key interfaces for standardization. Information Flows (and their constituent detailed data flows) serve as the basis for much of the standards work on the ITS Standards Program. ITS Standards have been developed for many of the Information Flows in ARC-IT, and this mapping of standards to Information Flows is available in the Physical View. By selecting an Information Flow triple, potential ITS and other communications standards to consider during deployment are listed on the Communications Diagrams.

Within the framework of the National ITS Reference Architecture, ITS standards developers can identify standards for development that will meet the user's needs. ITS planners can integrate regional ITS elements using these ITS standards and achieve their interoperability goals, and ITS deployers can select the ITS standards that reduce risk to their deployment, helping to manage costs and schedule.

For this SASP, the City considered both the ITS Standards and other Standards from other industries and documented them in the Table below for each of the project. In addition, the City identified certain application areas for potential standards development.

- For the ITS Standards, the City used ARC-IT to identify the ITS Standards applicable. The City started with identifying the interface class and the Information Flow between the source and destination as defined in the Physical View. Based on the selected interface and the identified Information Flows, the SET-IT tool provided a list of applicable ITS Standards. In addition, the City evaluated the ITS Standards that are under development and identified them as well.
- For other industry standards, the City identified the applicable Standards based on the project team's industry knowledge and discussions with the technology vendors.

The intent of identifying potential standards for this project is to encourage the interoperability among the systems and vendor products. Multiple standard options are identified for some of the Communication Layers to encourage and offer flexibility to the vendors. However, some of the systems that may be procured for the Smart Columbus projects may be commercial-off-the-shelf or current systems with minimal modifications. Requiring these systems to adhere to the identified Standards may increase the projects' costs. In addition, several of the systems are totally new to the transportation industry and are evolving. Requiring them to adhere to already established standards may curb innovation. As the projects progress, a trade-off between requiring the systems to adhere to the identified standards and the projects will be evaluated.

3.2. APPLICABLE PROJECT ITS STANDARDS

This subchapter identifies the list of applicable project ITS Standards reported by SET-IT based on the source Physical Object, destination Physical Object, and the Information Flows selected between these source and destination objects, which are currently considered for the project.

- GTFS[13]
- GTFS-Real Time*
- IEEE 1609.2/CAMP SCMS
- ISO 19091
- NMEA 0183
- NTCIP 1202-ASC
- NTP
- Networked Transport of Radio Technical Commission for Maritime Services via Internet Protocol
- RSU 4.1
- SAE J2735-2016
- SAE J2945/1

[13] *While GTFS is not an official standard, it is a widely accepted and used specification.*

- SMART Wayfinding Specification (FHWA-JPO-19-772)

Table 139 shows Triples and the associated standard for each of the Information Flow, a list of published ITS Standards categorized by project, and the definition of published standards.

Table 139: Project Intelligent Transportation System Standards

Source	Information Flow	Destination	Standard
Smart Columbus Operating System			
COTA Back Office	Real-Time Arrivals	Information Management	GTFS-Real Time
COTA Back Office	transit schedule information	Information Management	GTFS
Connected Vehicle Environment			
Location and Time Data Source	location and time	Vehicle OBU	NMEA 0183
Location and Time Data Source	location and time	Transit Vehicle OBU	NMEA 0183
Location and Time Data Source	location and time	RSE	NMEA 0183
Remote Vehicle OBE	vehicle control event	Vehicle OBE	SAE J2735, SAE J2945/1
Vehicle OBE	vehicle control event	Remote Vehicle OBE	SAE J2735, SAE J2945/1
Vehicle OBE	device enrollment information	Security and Credential Management System	CAMP SCMS
Remote Vehicle OBE	vehicle location and motion	Vehicle OBE	SAE J2735, SAE J2945/1
Vehicle OBE	vehicle location and motion	Remote Vehicle OBE	SAE J2735, SAE J2945/1
Traffic Signal Controller	intersection control status	RSE	NTCIP 1202-ASC
RSE	intersection geometry	Emergency Vehicle OBE	SAE J2735, ISO 19091
RSE	intersection geometry	Transit Vehicle OBE	SAE J2735, ISO 19091
RSE	intersection geometry	Heavy Duty Vehicle OBE	SAE J2735, ISO 19091
RSE	intersection status	Emergency Vehicle OBE	SAE J2735, ISO 19091
RSE	intersection status	Transit Vehicle OBE	SAE J2735, ISO 19091
RSE	intersection status	Heavy Duty Vehicle OBE	SAE J2735, ISO 19091

Source	Information Flow	Destination	Standard
RSE	location correction	Vehicle OBE	RSU 4.1
Emergency Vehicle OBE	local signal preemption request	RSE	SAE J2735, ISO 19091
Transit Vehicle OBE	local signal priority request	RSE	SAE J2735, ISO 19091
Heavy Duty Vehicle OBE	local signal priority request	RSE	SAE J2735, ISO 19091
RSE	signal priority service request	Traffic Signal Controller	NTCIP 1202-ASC
RSE	signal priority status	Transit Vehicle OBE	SAE J2735, ISO 19091
RSE	signal priority status	Heavy Duty Vehicle OBE	SAE J2735, ISO 19091
RSE	signal priority status	Emergency Vehicle OBE	SAE J2735, ISO 19091
RSE	device enrollment information	Security and Credential Management System	IEEE 1609.2/CAMP SCMS
Vehicle OBE	vehicle location and motion for surveillance	RSE	SAE J2735, SAE J2945/1
RSE	traffic situation data	Traffic CV Management System	NTCIP 1209-TSS
Remote Vehicle OBE	vehicle control event	Transit Vehicle OBE	SAE J2735, SAE J2945/1
Transit Vehicle OBE	vehicle control event	Remote Vehicle OBE	SAE J2735, SAE J2945/1
Remote Vehicle OBE	vehicle location and motion	Transit Vehicle OBE	SAE J2735, SAE J2945/1
Transit Vehicle OBE	vehicle location and motion	Remote Vehicle OBE	SAE J2735, SAE J2945/1
RSE	intersection control status	Traffic Signal Controller	NTCIP 1202-ASC
RSE	intersection geometry	Vehicle OBE	SAE J2735, ISO 19091
RSE	intersection status	Vehicle OBE	SAE J2735, ISO 19091
RSE	reduced speed notification	Vehicle OBE	SAE J2735
Traffic CV Management System	equipment control commands	RSE	RSU 4.1 SNMP
Traffic CV Management System	intersection geometry	RSE	SAE J2735
Traffic CV Management System	intersection management application info	RSE	RSU 4.1 SNMP

Source	Information Flow	Destination	Standard
Traffic CV Management System	intersection safety application info	RSE	RSU 4.1 SNMP
Traffic CV Management System	RSE application information	RSE	RSU 4.1 SNMP
Traffic CV Management System	situation data collection parameters	RSE	RSU 4.1 SNMP
Traffic CV Management System	speed warning application info	RSE	RSU 4.1 SNMP
Security and Credential Management System	security credential revocations	RSE	IEEE 1609.2/CAMP SCMS
Security and Credential Management System	security credential revocations	Vehicle OBE	CAMP SCMS
Security and Credential Management System	security credentials	RSE	IEEE 1609.2/CAMP SCMS
Security and Credential Management System	security credentials	Vehicle OBE	CAMP SCMS
Security and Credential Management System	security policy and networking information	RSE	IEEE 1609.2/CAMP SCMS
Security and Credential Management System	security policy and networking information	Vehicle OBE	CAMP SCMS
CORS	RTCM Reference Station Information Message	RSE	Networked Transport of Radio Technical Commission for Maritime Services via Internet Protocol
Field Maintenance Equipment	equipment control commands	RSE	RSU 4.1 SNMP
RSE	RSE status	Field Maintenance Equipment	RSU 4.1 SNMP
Network Time Source	time	Traffic CV Management System	NTP
Multimodal Trip Planning Application			
COTA Back Office	transit and fare schedules	MMTPA	GTFS
COTA Back Office	transit schedule adherence information	MMTPA	GTFS-Real Time
CEAV Fleet Management System	transit and fare schedules	MMTPA	GTFS
CEAV Fleet Management System	transit schedule adherence information	MMTPA	GTFS-Real Time
Mobility Assistance for People with Cognitive Disabilities			

Source	Information Flow	Destination	Standard
MAPCD	trip plan	Traveler Personal/Wireless Devices	SMART Wayfinding
MAPCD	Route Library	Caregiver Personal/Wireless Devices	SMART Wayfinding, GTFS
Caregiver Personal/Wireless Devices	Route Library	MAPCD	SMART Wayfinding, GTFS
MAPCD	Trip Alerts	Traveler Personal/Wireless Devices	SMART Wayfinding
COTA Back Office	Trip Updates	MAPCD	GTFS-Real Time
Prenatal Traveler Assistance			
None	None	None	None
Event Parking Management			
None	None	None	None
Smart Mobility Hubs			
None	None	None	None
Connected Electric Autonomous Vehicles			
CEAV Fleet Management System	transit and fare schedules	MMTPA	GTFS
CEAV Fleet Management System	transit schedule adherence information	MMTPA	GTFS-Real Time
CEAV Fleet Management System	transit schedule information	CEAV	GTFS
CEAV Fleet Management System	transit traveler information	CEAV	SAE J2735
CEAV Fleet Management System	transit schedule adherence information	MMTPA	GTFS-Real Time
CEAV	transit vehicle location data	CEAV Fleet Management System	SAE J2735[14]
CEAV OBE	vehicle location and motion	RSE	SAE J2735, SAE J2945/1
CEAV OBE	vehicle location and motion	Other Vehicle OBEs	SAE J2735, SAE J2945/1
Other Vehicle OBEs	vehicle location and motion	CEAV OBE	SAE J2735, SAE J2945/1

[14] *SAE J2735 does not support user feedback.*

Source	Information Flow	Destination	Standard
COTA Back Office	transit traveler information coordination	CEAV Fleet Management System	GTFS-Real Time

Note: This table does not include all the Information Flows. This table identifies the Triples with Information Flows, which has identified ITS standards.

Source: City of Columbus

3.3. OTHER APPLICABLE STANDARDS

This list identifies the potential standards which may be used on this project. The applicability of these standards will be evaluated for all projects as we progress the projects through the design. A link for each of these standards are provided.

- USDOT Autonomous Vehicle-related Standardization Activities
  - https://www.transportation.gov/av/3
- Federal Motor Vehicle Safety Standards
  - https://www.nhtsa.gov/laws-regulations/fmvss
- Transit Safety Standards
  - https://www.transit.dot.gov/regulations-and-guidance/safety/compendium-transit-safety-standards
- Amazon Web Services – AWS Well-Architected Framework
  - https://aws.amazon.com/blogs/apn/the-5-pillars-of-the-aws-well-architected-framework/
- International Organization for Standards – ISO 9001 Quality Management Systems
  - https://www.iso.org/iso-9001-quality-management.html
- Health Insurance Portability and Accountability Act (HIPAA)
  - https://www.hhs.gov/hipaa/index.html
- SOC 2
  - https://www.aicpa.org/interestareas/frc/assuranceadvisoryservices/aicpasoc2report.html
- PCI-DSS 3.2
  - https://www.pcisecuritystandards.org/document_library
- LADOT Mobility Data Specification
  - https://learn.sharedusemobilitycenter.org/overview/data-standard-for-shared-mobility-providers-los-angeles-california-2018/

Appendix A. Architecture Reference for Cooperative and Intelligent Transportation Tables

Table 140: Classes of Physical Objects

Name	Description
Center	Covers the vehicle-related elements on vehicles. Vehicle Physical Objects include general driver information and safety systems applicable to all vehicle types. Five fleet-vehicle objects (transit, emergency, commercial, freight equipment, and maintenance and construction vehicles) add connected capabilities unique to these special vehicle types.
Field Equipment	Covers the intelligent infrastructure distributed along the transportation network which performs surveillance, information provision, and plan execution control functions and whose operation is governed by center Physical Objects. Field systems/devices also directly interface to vehicle or mobile Physical Objects.
Vehicle-Based Equipment	Covers the vehicle-related elements onboard vehicles. Vehicle Physical Objects include general driver information and safety systems applicable to all vehicle types. Five fleet vehicle objects (transit, emergency, commercial, freight equipment, and maintenance and construction Vehicles) add connected capabilities unique to these special vehicle types.
Traveler Devices	Covers equipment used by travelers to access transportation services pre-trip and en route. This includes equipment that is owned and operated by the traveler as well as equipment that is owned by transportation and information providers.
Support Systems	Covers systems which provides support to other systems and functions.

Source: City of Columbus

Table 141: Types of P-Interconnects

Name	Description
Center to Center	A communications link that provides communications between centers. It may be implemented using a variety of public or private communication networks and technologies.
Center to Field	A communications link that provides communications between centers and field devices. It may be implemented using a variety of public or private communication networks and technologies.
Contact or Proximity	Card reader interface using contact or proximity communications technologies.
Environment	This represents the 'real world' environment that is monitored and analyzed by ITS sensors. It represents the environmental conditions and the physical features of objects in the ITS environment that are sensed to support automation, adaptive control systems, and all other ITS services that rely on sensor input.
Field to Field	Communications between field devices, including RSE and traditional ITS equipment such as traffic signal controllers.

Name	Description
Human Interface	Interface between a person and a device. Can be a user interface to a computer system, an operator interface, or the driver's interface to a vehicle.
Low Power Radio Broadcast	Analog communications using AM or FM radio frequencies to broadcast audio information to motorists
Network Time Protocol	This client-server connection allows NTP servers to provide time synchronization services to other NTP servers and clients. Packets are exchanged between the client and server using an on-wire protocol that is resistant to lost, replayed or spoofed packets.
Personal Area Network	Communications technologies such as Bluetooth that are intended for exchanging data over distances sufficient to connect personal devices. In ITS, Personal Area Network communications within a vehicle may be monitored external to the vehicle to identify a communication signature that can be used to identify the same vehicle at different points in the network and calculate travel times, etc.
Position Location Interface	Interface between position location equipment and an ITS device that uses location information. This typically represents the interface between GPS equipment and a vehicle or mobile device, but it covers any interface between a location provider and a location consumer application.
Short Range Wireless	A wireless communications channel used for close-proximity communications between vehicles and between vehicles and/or traveler devices and the immediate infrastructure.
Vehicle Onboard	Communications between components within an individual vehicle. This may represent communications across an intelligent vehicle bus or any other communications medium internal to the vehicle.
Wide Area Broadcast	A wide area wireless communications system that offers broadcast services with regional, national, or continental coverage, enabling communications with vehicles and traveler mobile devices at any location on or off the road network. Examples of this link include satellite and terrestrial radio digital broadcast services.
Wide Area Wireless	A wireless communications system that offers broad coverage, enabling communications with vehicles and traveler mobile devices at any location on or off the road network.

Source: City of Columbus

Table 142: Type of Agreements

Agreement Type	Description
904 Lease Agreement*	An agreement which allows for the installation and placement of shared mobility devices within the City right-of-way.
Acquisition Agreement	An agreement where one party agrees to provide a system (hardware and or software) to another party, typically in exchange for compensation.
Agreement for RSE Devices*	An agreement where one party agrees to supply RSE hardware devices and the accompanying hardware for another party.
Agreement for RSE Installation*	An agreement where one party agrees to install RSE devices.

Agreement Type	Description
Agreement for Space Use and Installation*	An agreement where one party agrees to provide space to use a garage in conduct installation of OBE.
Application Interface Specification	The definition of an interface between two application components that operate on two distinct pieces of hardware. The Application Interface Specification is specific to the application in question.
Application Usage Agreement	An agreement in which one entity that controls an application-component's use gives the other entity the necessary tools and permission to operate that application or application component.
Business Associate Agreement*	An agreement where one party agrees to provide information to an associated business.
Device Placement and Operations Agreement	An agreement that enables the controller of a physical device to install it (so as to make it operational) at a fixed location controlled by another entity.
Device Usage Agreement	Agreement between the owner of a device and an operator of the device, granting the operator permission to use the device. Specifies who is responsible in the case of device failure and application failure, describes parameters of use including communications provisions, and sets expectations of device and application performance.
Employment Agreement	An agreement between an individual and a corporation or government entity, whereupon the individual agrees to provide labor to the corporation/agency, which in turn compensates the employee. Stipulates level of compensation, working conditions, necessary equipment and training and expectations of employee performance.
Equipment Operations Agreement	An agreement relating to the use of a specific piece of equipment, where one party agrees to use and/or not tamper with the equipment according to a set of condition.
Financial Agreement*	An agreement where one party agrees to have a party act as the merchant of record an provide pass through financial services.
Funding Agreement	An agreement that documents the funding arrangements for ITS projects. At minimum, includes standard funding clauses, detailed scope, services to be performed, and project budgets.
Handshake Agreement	An informal agreement typically arrived at in the early stages of a project or regional architecture development. Not suitable for long term operations.
Information Exchange Agreement	An agreement to exchange information, which may include data or control information. The exact information to be exchanged may vary from agreement to agreement.
Information Exchange and Action Agreement	An agreement to exchange information, which may include data or control information. The exact information to be exchanged may vary from agreement to agreement. This also includes a specification for action that shall, should, or may be taken by one party in response to this information.
Information Provision Agreement	An agreement where one party agrees to provide information to another party. This is a unidirectional agreement.

Agreement Type	Description
Information Provision and Action Agreement	An agreement where one party agrees to provide information to another party. This is a unidirectional agreement. This also includes a specification for action that shall, should or may be taken by one party in response to this information.
Installation Agreement	An agreement whereupon one party installs a system on behalf of a second party.
Interagency Agreement	An agreement between public agencies for operations, services or funding. Documents responsibilities, functions, and liability of each party, at minimum.
Interface Description	Documentation of the interface between two systems, where one system does not have an application component that is part of the application, but does provide and/or receive data and/or information that is used by or sourced from the application. In many cases, this is an existing interface used by the application. The description of the interface already exists, and is imposed by the terminator.
Maintenance Data Exchange Agreement	An agreement that states one entity will provide data related to maintenance of an application component to the other entity.
Master Agreement	An agreement that serves as a master agreement for a specific agency, defining how business is done. Includes standard contract and/or legal verbiage. Allows states, cities, and other public agencies that do business with the same agencies over and over to have a single agreement that uses smaller agreements (e.g., Memorandum of Understanding) to modify or expand the boundaries of the larger agreement to include more specific language.
Memorandum of Understanding	An early-stage agreement, typically providing minimal detail but demonstrating general consensus. Typically used to expand on an interagency agreement. May also serve as a means to modify a broader Master Funding Agreement, where the master agreement covers various ITS projects and the Memorandum of Understanding specify the scope and differences between the projects.
Merchant of Record Agreement*	An agreement where one party agrees to provide merchant of record services for another party.
Non-Disclosure Agreement*	An agreement where a party agrees not to disclose confidential information that was shared with them by another party.
Operations Agreement	An agreement where one entity agrees to operate a device or application on behalf of another device/application controlling entity.
Project Blanket Agreement	An agreement between all stakeholders involved in a project that covers data provision, information exchange, and related actions.
Reimbursement Agreement*	An agreement where one party agrees to provide funding to another party.
Security Credentials License and Usage Agreement	An agreement in which a device owner gains access to security credentials, and agrees to protect and use those credentials in accordance with restrictions and safeguards documented in this agreement.
Service Coordination Agreement	An agreement between two or more parties that operate similar or geographically adjacent/ overlapping services, stipulating coordination, information sharing and other aspects of service provision relevant between these services.

Agreement Type	Description
Service Delivery Agreement	A relationship where one party agrees to provide a service to the other party. This agreement may specify the expected performance of this service in terms of availability and/or actions/time-type performance specifications.
Service Package Blanket Agreement	An agreement between all stakeholders involved in a service that covers data provision, information exchange, and related actions.
Service Usage Agreement	An agreement between the provider of a service and a user. Stipulates the terms and conditions of service usage.
Shared Operations Agreement	An agreement between any agency involved in the funding, operation, maintenance, or right-of-way use of another public or private agency's assets. Documents responsibilities for all activities associated with shared systems being operated and/or maintained. May assign responsibilities and liabilities related to joint contracting and/or procurement activities, define mechanisms for standardizing operating procedures of shared assets, define joint training programs, and describe real-time and archived data sharing.
Subconsultant Agreement*	An agreement where a party agrees to provide sub consulting services for another party.
Sub-Merchant Agreement*	An agreement where one party agrees to provide financial merchant of record services to another party.
System Maintenance Agreement	An agreement for one party to maintain the operational status of a system on behalf of the party with ownership control of the system.
System Monitoring Agreement	An agreement in which a CV device owner grants permission for another entity to remotely monitor the status of applications and services operating on that device.
System Usage Agreement	An agreement granting operational use of a system to a human with the role responsible for management of the system.
Unspecified	Unspecified agreement used as a placeholder for user-defined agreements, to be used in special circumstances with tools (Regional Architecture Development for Intelligent Transportation, SET-IT) only.
Vehicle Data Access Agreement	An agreement whereby the party that controls access to onboard vehicle data grants another party the right and ability to access that data. Includes the conditions under which data may be accessed, and specifies the mechanisms, including physical and functional access methods, data formats and any other considerations necessary for the accessing party to acquire data. May also include caveats regarding responsibility for data quality and responsibility for use of the data.
Vehicle Operating Agreement	An agreement whereupon the controller of a vehicle grants another entity permission and rights to operate the vehicle.
Verification Agreement	An agreement for one party to verify that a system owned by the second party operates according to the system's design.
Warranty	A guarantee or promise made by one entity to another that provides assurance of the functionality and performance of a subsystem.

*Non-Standard Agreement

Source: City of Columbus

Table 143: Type of Expectation

Role Name	Description
Expectation of Action	An expectation where one party expects another party to take a specific action, typically in response to data or information provided by the first party, but without any formal agreement.
Expectation of Data Provision	An expectation where one party believes another party will provide data on a regular and recurring basis, and that that data will be useful to the receiver in the context of the receiver's application. This thus includes some expectation of data fields, timeliness, quality, precision and similar qualities of data.
Expectation of Information Provision	An expectation where one party believes another party will provide it information whenever such information is likely relevant to the recipient.
Expectation of Privacy Proxy Services	Expectation whereby one party expects to provide data to a second party that proxies that data, provides it to a destination suggested by the first party, and protects the originator's contact information.
Expectation of Safety Provision	Users of the transportation environment expect that the entities that operate the environment do so in such a way as to preserve and enhance user's safety. This is inherent to current operations and is an underlying assumption of drivers and pedestrians when accepting information from ITS. This expectation is explicitly noted for connected vehicle applications where this is a new relationship, whereupon the transportation system user expects a transportation service provider to do something (i.e., actuate a system or deliver information) that will protect and/or enhance the user's safety.
Presumption of Correct Operation	The assumption made by one party that another party operates their device in a similar and correct fashion. Specific to devices in the transportation environment, this assumption is relevant when devices interact, where one party's device receives information from another's. The operator of the device implicitly trusts that the other device is operating according to a similar set of governing rules as its device.
Presumption of Non-Interference	The assumption made by one party that another party's device that uses similar resources operates in manner that does not conflict with their device.

Source: City of Columbus

Table 144: Type of Roles

Role Name	Description
Advises	An Enterprise that can provide information about a Resource or Document.
Certifies	An Enterprise verifies that a target Resource meets relevant performance, functional, environmental and quality requirements. This could be an independent 3rd party or it could be the same entity that has the Develops role. For instance, an automotive original equipment manufacturer practicing "self-certification" would have this role with respect to the Basic Vehicle, whereas an independent certification body might have this role with respect to a Vehicle OBE (though of course the original equipment manufacturer could also fill this role).
Develops	An Enterprise creates the target Resource or Document. The Enterprise that engineers a traffic signal controller (ITS RSE) or designs a vehicle (Basic Vehicle) or authors a technical standard will have the Develops role.

Role Name	Description
Employs	An Enterprise employs to perform tasks.
Facilitates	An Enterprise helps forward the implementation of a project.
Installs	An Enterprise performs the initial delivery, integration and configuration of the target Resource. This might be a system integrator, a state Department of Transportation Enterprise performing its own installation, or a device supplier that performs on-site installation.
Maintains	An Enterprise administers the hardware and software that comprise the target Resource. The entity that takes the "maintains" role typically is delegated authority by the entity with the "Owns" or "Manages" roles, depending on the environment. The maintainer interacts with the target Resource so as to keep that Resource in the Operational state.
Manages	The Enterprise that is accountable for performing actions with a Resource, typically in support of one of the key operations-related roles (operates, installs, maintains). This authority is typically delegated by the Enterprise with the "Owns" role, and commonly accomplished by delegation to Human E-Objects with the "operates", "installs" or "maintains" roles, depending on the context.
Operates	A Human that is accountable for performing actions with a Resource, typically in support of one of the key operations-related roles (operates, installs, maintains). This is the person at the console or behind the wheel.
Owns	An Enterprise has financial ownership and control over the Resource. An Enterprise that Owns a resource is considered accountable for the resource and all of its contents. The Owns role includes ownership during Operations and Maintenance and Acquisition during the Installation phase. The entity that takes the "owns" role is ultimately responsible for ensuring the resource provides its promised functionality, and for securing data the resources holds and exchanges. The owner is similarly responsible for the facilities inherent to the resource that are used to exchange data with other systems. The owner is responsible for ensuring that any data stored by the resource and any data communicated by the resource are protected to the extent necessary considering the contents of the data and the consequences of its exposure or alteration.
Provides	The Enterprise that provides the basic service of a Service Package.
Supplies	The Enterprise that supplies a device or software product. The Supplier delivers the target resource to the Owner.
Uses	An Enterprise or Human that interacts with a Resource or Document in a way not captured by other roles. For instance, the person that reviews a document, or the agency informed of project status would have this role.
Verifies	The Enterprise that determines whether or not a target Resource meets documented requirements. This action is typically on behalf of the Owner.

Source: City of Columbus

Appendix B. List of Published Intelligent Transportation Systems Standards

B.1 COMMUNICATION PROFILE – STANDARDS MAPPING

Table 145: List of Standards

Name	SDO	Doc No.	Title	Description	User Defined
FTP Auth	IETF	RFC 2888	FTP Security Extensions	Defines extensions to the FTP specification STD 9, RFC 959, "FILE TRANSFER PROTOCOL (FTP)" (October 1985). These extensions provide strong authentication, integrity, and confidentiality on both the control and data channels with the introduction of new optional commands, replies, and file transfer encodings.	No

Name	SDO	Doc No.	Title	Description	User Defined
FTPS	IETF	IETF RFC:4217	Securing FTP with TLS	IETF RFC 4217 describes a mechanism that can be used by FTP clients and servers to implement security and authentication using the TLS protocol defined by RFC 2246, The TLS Protocol Version 1.0., and the extensions to the FTP protocol defined by RFC 2228, FTP Security Extensions.	No
GTFS	GTFS Discussion Group	GTFS	General Transit Feed Specification (GTFS) Static	The General Transit Feed Specification (GTFS), also known as GTFS static or static transit to differentiate it from the GTFS real-time extension, defines a common format for public transportation schedules and associated geographic information. GTFS "feeds" let public transit agencies publish their transit data and developers write applications that consume that data in an interoperable way.	No

Name	SDO	Doc No.	Title	Description	User Defined
GTFS-Realtime	GTFS Discussion Group	GTSF-Realtime	General Transit Feed Specification (GTFS) Realtime	GTFS real-time is a feed specification that allows public transportation agencies to provide application developers with real-time updates about their fleet. This feed is an extension to GTFS (General Transit Feed Specification), an open data format for public transportation schedules and associated geographic information. GTFS real-time is designed for ease of implementation, good GTFS interoperability, and a focus on passenger information.	No
HTTP Auth	IETF	IETF RFC:2617	HTTP Authentication: Basic and Digest Access Authentication	IETF RFC 2617 provides a specification for an HTTP authentication framework, the original Basic authentication scheme plus a scheme based on cryptographic hashes, referred to as Digest Access Authentication.	No

Name	SDO	Doc No.	Title	Description	User Defined
HTTPS	IETF	IETF RFC:2818	HTTP Over TLS	IETF RFC 2818 describes how to use TLS to secure HTTP connections over the Internet. Current practice is to layer HTTP over SSL (the predecessor to TLS), distinguishing secured traffic from insecure traffic by the use of a different server port. This document documents that practice using TLS.	No
IEEE 1609.2	IEEE	IEEE 1609.2-2016	Standard for Wireless Access in Vehicular Environments (WAVE) – Security Services for Applications and Management Messages	Defines secure message formats and processing. This standard also defines the circumstances for using secure message exchanges and how those messages should be processed upon receipt.	No

Name	SDO	Doc No.	Title	Description	User Defined
IEEE 802.11	IEEE	IEEE 802.11-2016	IEEE Standard for Information technology—Telecommunications and information exchange between systems Local and metropolitan area networks—Specific requirements – Part 11: Wireless LAN MAC and Physical Layer (PHY) Specifications	Technical corrections and clarifications to IEEE Std 802.11 for wireless local area networks (WLANs) as well as enhancements to the existing MAC and physical layer (PHY) functions are specified in this revision. Amendments 1 to 5 published in 2012 and 2013 have also been incorporated into this revision.	No

Name	SDO	Doc No.	Title	Description	User Defined
IETF FTP	IETF	IETF RFC:959	File Transfer Protocol (FTP)	IETF RFC 959, File Transfer Protocol (FTP), defines methods to: 1) promote sharing of files (computer programs and/or data), 2) encourage indirect or implicit (via programs) use of remote computers, 3) shield a user from variations in file storage systems among hosts, and 4) transfer data reliably and efficiently. FTP, though usable directly by a user at a terminal, is designed mainly for use by programs.	No

Name	SDO	Doc No.	Title	Description	User Defined
IETF GZIP	IETF	IETF RFC:1952	GZIP File Format Specification, version 4.3	IETF RFC 1952, GZIP File Format, defines a lossless compressed data format that is compatible with the widely used GZIP utility. The format includes a cyclic redundancy check value for detecting data corruption. The format presently uses the DEFLATE method of compression but can be easily extended to use other compression methods. The format can be implemented readily in a manner not covered by patents.	No

Name	SDO	Doc No.	Title	Description	User Defined
IETF HTTP	IETF	IETF RFC:7230	Hypertext Transfer Protocol -- HTTP/1.1	IETF RFC 7230, The Hypertext Transfer Protocol (HTTP), is an application-level protocol for distributed, collaborative, hypermedia information systems. It is a generic, stateless, protocol which can be used for many tasks beyond its use for hypertext, such as name servers and distributed object management systems, through extension of its request methods, error codes and headers. A feature of HTTP is the typing and negotiation of data representation, allowing systems to be built independently of the data being transferred.	No

Name	SDO	Doc No.	Title	Description	User Defined
IETF IPv4	IETF	IETF RFC:791	Internet Protocol DARPA Internet Program Protocol Specification	IETF RFC 791, The Internet Protocol, is provides for transmitting blocks of data called datagrams from sources to destinations, where sources and destinations are hosts identified by fixed length addresses. The internet protocol also provides for fragmentation and reassembly of long datagrams, if necessary, for transmission through small packet networks.	No
IETF IPv6	IETF	IETF RFC:2046	Internet Protocol, Version 6 (IPv6) Specification	IETF RFC 2460, Internet Protocol, Version 6 (IPv6) Specification, is a new version of the Internet Protocol, designed as the successor to IP version 4 (IPv4) [RFC 791]. The changes from IPv4 to IPv6 fall primarily into the following categories: 1) Expanded Addressing Capabilities, and 2) Header Format Simplification.	No

Name	SDO	Doc No.	Title	Description	User Defined
IETF JSON	IETF	RFC 7159	The JavaScript Object Notation (JSON) Data Interchange Format	JavaScript Object Notation (JSON) is a lightweight, text-based, language-independent data interchange format. It was derived from the ECMAScript Programming Language Standard. JSON defines a small set of formatting rules for the portable representation of structured data.	No

Name	SDO	Doc No.	Title	Description	User Defined
IETF NTP	IETF	RFC 5905	Network Time Protocol Version 4	The Network Time Protocol (NTP) is widely used to synchronize a computer to Internet time servers or other sources, such as a radio or satellite receiver. It can also be used as a server for dependent clients. It provides accuracies typically less than a millisecond on LANs and up to a few milliseconds on WANs. Typical NTP configurations utilize multiple redundant servers and diverse network paths in order to achieve high accuracy and reliability.	No

Name	SDO	Doc No.	Title	Description	User Defined
IETF SNMP	IETF	IETF RFC:1157	A Simple Network Management Protocol (SNMP)	IETF RFC 1157, A Simple Network Management Protocol (SNMP), defines a simple protocol by which management information for a network element may be inspected or altered by logically remote users. In particular, together with its companion memos which describe the structure of management information along with the management information base, these documents provide a simple, workable architecture and system for managing TCP/IP-based internets and in particular the Internet.	No

Name	SDO	Doc No.	Title	Description	User Defined
IETF TCP	IETF	IETF RFC:793	Transmission Control Protocol DARPA Internet Program Protocol Specification	IETF RFC 793, The Transmission Control Protocol (TCP) is intended for use as a highly reliable host-to-host protocol between hosts in packet-switched computer communication networks, and in interconnected systems of such networks.	No
IETF TLS	IETF	IETF RFC:5246	The Transport Layer Security (TLS) Protocol Version 1.2	IETF RFC 5246, The Transport Layer Security (TLS) protocol provides communications security over the Internet. The protocol allows client/server applications to communicate in a way that is designed to prevent eavesdropping, tampering, or message forgery.	No

Name	SDO	Doc No.	Title	Description	User Defined
IETF UDP	IETF	IETF RFC:768	User Datagram Protocol	IETF RFC 768, The User Datagram Protocol (UDP), is defined to make available a datagram mode of packet-switched computer communication in the environment of an interconnected set of computer networks. This protocol assumes that the Internet Protocol (IP) is used as the underlying protocol.	No

Name	SDO	Doc No.	Title	Description	User Defined
IETF WebSockets	IETF	RFC 6455	The WebSocket Protocol	The WebSocket Protocol enables two-way communication between a client running untrusted code in a controlled environment to a remote host that has opted-in to communications from that code. The security model used for this is the origin-based security model commonly used by web browsers. The protocol consists of an opening handshake followed by basic message framing, layered over TCP. The goal of this technology is to provide a mechanism for browser-based applications that need two-way communication with servers that does not rely on opening multiple HTTP connections.	No

Name	SDO	Doc No.	Title	Description	User Defined
NTCIP 1201-GO	AASHTO/ITE/ NEMA	NTCIP 1201	Global Object Definitions	NTCIP 1201, Global Object (GO) Definitions, is a data dictionary standard defining those data elements which may be used by a wide variety of ITS devices, such as data related to device identification, time, scheduling capabilities, event reporting, auxiliary device monitoring and control, and security.	No
NTCIP 1202-ASC	AASHTO/ITE/ NEMA	NTCIP 1202	Object Definitions for Actuated Traffic Signal Controller (ASC) Units	NTCIP 1202, Actuated Signal Controllers (ASC), defines the information elements for configuration, control, and status associated with the functions of a traffic signal controller. The functions addressed include: Phases, Rings and Sequence; Detectors; Special Functions; Coordination; Time Base Control; Preemption; Overlaps; and Upload and Download.	No

Name	SDO	Doc No.	Title	Description	User Defined
NTCIP 1210-FMS	AASHTO/ITE/ NEMA	NTCIP 1210	Field Management Stations (FMS) – Part 1: Object Definitions for Signal System Masters	NTCIP 1210, Field Master Station (FMS), defines an information level communications interface between a management station and a Signal System Master. This standard would only apply to projects intending to deploy multi-tier traffic signal control.	No

NTCIP 1211-SCP	AASHTO/ITE/ NEMA	NTCIP 1211	Object Definitions for Signal Control and Prioritization (SCP)	NTCIP 1211, Signal Control Priority (SCP), defines the management information base for Signal Control and Prioritization (SCP) systems through parameters that represent the configuration, status, and control information. NTCIP 1211 defines the functional entities of a Priority Request Generator and a Priority Request Server, which respectively originates and performs triage on requests. After performing triage in terms of importance and priority, the requests are sent to the Coordinator entity in a Traffic Signal Controller. This standard was developed with participation of the transit community, though the scenarios described in the concept of operations may apply for emergency vehicle preemption.	No

Name	SDO	Doc No.	Title	Description	User Defined
SAE J2735	SAE	SAE J2735	Dedicated Short Range Communications (DSRC) Message Set Dictionary	SAE J2735, DSRC Message Set Dictionary standard, specifies standard message sets, data frames and data elements for use by applications intended to utilize the 5.9 GHz DSRC for DSRC/WAVE (which this document refers to simply as DSRC) communications systems.	No

Name	SDO	Doc No.	Title	Description	User Defined
SAE J2945/1	SAE	J2945/1	Onboard System Requirements for V2V Safety Communications	This standard specifies the system requirements for an onboard V2V safety communications system for light vehicles, including standards profiles, functional requirements, and performance requirements. The system is capable of transmitting and receiving the Society of Automotive Engineers (SAE) J2735-defined Basic Safety Message (BSM) [1] over a DSRC wireless communications link as defined in the Institute of Electrical and Electronics Engineers (IEEE) 1609 suite and IEEE 802.11 standards [2] – [6].	No

Name	SDO	Doc No.	Title	Description	User Defined
USDOT RSU	USDOT	RSU V4.1	USDOT Roadside Unit (RSU) Specification Document - Version 4.1	This document defines the fourth-generation of DSRC Roadside Units (RSUs) by establishing the base functionality of a carrier-grade device capable of acting as the infrastructure first point-of-contact for vehicles and other mobile devices.	No
W3C HTML5	W3C	HTML5	A Vocabulary and Associated APIs for HTML and XHTML	This specification defines the 5th major revision of the core language of the World Wide Web.	No
W3C XML	W3C	W3C XML	Extensible Markup Language (XML) 1.0 (Fifth Edition)	The Extensible Markup Language (XML) is a subset of SGML that is described in this document. Its goal is to enable generic SGML to be served, received, and processed on the Web in the way that is now possible with HTML. XML has been designed for ease of implementation and for interoperability with both SGML and HTML.	No

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B.2 CONNECTED VEHICLE STANDARDS

- NTCIP 8002 Annex B1 Content Outline for NCTIP 1200 Series Standards
- IEEE 802.11-2016 Standard for Information Technology – Telecommunications and Information Exchange Between Systems – Local and Metropolitan Area Networks – Specific Requirements – Part II: Wireless LAN Medium Access Control (MAC) and Physical Layer (PHY) Specification
- IEEE 1609.0-2013 Standard for Wireless Access in Vehicular Environments (WAVE) – Architecture
- IEEE 1609.11-2010 Standard for Wireless Access in Vehicular Environments (WAVE) – Over-the-Air Electronic Payment Data Exchange Protocol for Intelligent Transportation Systems (ITS)
- IEEE 1609.12-2016 Standard for Wireless Access in Vehicular Environments (WAVE) – Identifier Allocations
- IEEE 1609.2-2016 Standard for Wireless Access in Vehicular Environments – Security Services for Applications and Management Messages
- IEEE 1609.3-2016 Standard for Wireless Access in Vehicular Environments (WAVE) – Networking Services
- IEEE 1609.4-2016 Standard for Wireless Access in Vehicular Environments (WAVE) – Multi-Channel Operation
- ISO 21210:2012 Intelligent transport systems – Communications access for land mobiles (CALM) – IPv6 Networking
- ISO TS 19091:2017 Intelligent transport systems – Cooperative ITS – Using V2I and I2V communications for applications related to signalized intersections
- SAE J2945/1 Onboard Minimum Performance Requirements for V2V Safety Communications
- SAE J2945/2 J2945/2_201810 – Dedicated Short Range Communications (DSRC) Performance Requirements for V2V Safety Awareness
- SAE J2735 Dedicated Short Range Communications (DSRC) Message Set Dictionary

B.3 INFRASTRUCTURE STANDARDS

- ITE TMDD Guide TMDD & MS/ETMCC Guide Standard for Functional Level Traffic Management Data Dictionary (TMDD) and Message Sets for External Traffic Management Center Communications
- ITE TMDD 3.3 ITE TMDD Traffic Management Data Dictionary (TMDD) Standard for Center to Center Communications
- NTCIP 8005 NTCIP 8005 Process, Control & Info Mgmt. Policy
- NTCIP 1213 Object Definitions for Electrical and Lighting Management Systems (ELMS)
- NTCIP 9001 NTCIP Guide
- NTCIP 2306 Application Profile for XML Message Encoding and Transport in ITS Center-to-Center Communications (C2C XML)
- NTCIP 9012 Testing Guide for Users

- NTCIP 8007 Testing and Conformity Assessment Documentation within NTCIP Standards Publications
- NTCIP 9010 XML in ITS Center-to-Center Communications
- NTCIP 1211 Object Definitions for Signal Control and Prioritization (SCP)
- NTCIP 8004 Structure and Identification of Management Information
- NTCIP 2201 Transportation Transport Profile
- NTCIP 2304 Application Profile for DATEX-ASN (AP-DATEX)
- NTCIP 2303 File Transfer Protocol (FTP) Application Profile
- NTCIP 2301 Simple Transportation Management Framework (STMF) Application Profile
- NTCIP 2302 Trivial File Transfer Protocol (TFTP) Application Profile
- NTCIP 1102 Octet Encoding Rules (OER) Base Protocol
- NTCIP 1104 Center-to-Center Naming Convention Specification
- NTCIP 1205 Object Definitions for Closed Circuit Television (CCTV) Camera Control
- NTCIP 1201 Global Object Definitions
- NTCIP 2202 Internet (TCP/IP and UDP/IP) Transport Profile
- NTCIP 1209 Data Element Definitions for Transportation Sensor Systems (TSS)
- NTCIP 1202 Object Definitions for Actuated Traffic Signal Controller (ASC) Units
- NTCIP 1206 Object Definitions for Data Collection and Monitoring (DCM) Devices
- NTCIP 1203 Object Definitions for Dynamic Message Signs (DMS)
- NTCIP 1204 Object Definitions for Environmental Sensor Stations (ESS)
- NTCIP 1208 Object Definitions for Closed Circuit Television (CCTV) Switching
- NTCIP 1210 Field Management Stations (FMS) – Part 1: Object Definitions for Signal System Masters
- NTCIP 2101 Point to Multi-Point Protocol Using RS-232 Subnetwork Profile
- NTCIP 8003 Profile Framework
- NTCIP 1207 Object Definitions for Ramp Meter Control (RMC) Units
- NTCIP 1101 Simple Transportation Management Framework (STMF)
- NTCIP 1103 Transportation Management Protocols (TMP)
- NTCIP 2103 Point-to-Point Protocol Over RS-232 Subnetwork Profile
- NTCIP 2104 Ethernet Subnetwork Profile
- NTCIP 2102 Point to Multi-Point Protocol Using FSK Modem Subnetwork Profile
- ATC 5201 (ITE ATC Controller) Advanced Transportation Controller (ATC)
- ITE ATC API Application Programming Interface (API) Standard for the Advanced Transportation Controller (ATC)
- ITE ITS Cabinet ITS Standard Specification for Roadside Cabinets

- ATC 5202 (ITE ATC Type 2070) Model 2070 Controller Standard

B.4 TRANSIT STANDARDS

- APTA TCIP-S-001 4.0.0 APTA Standard for Transit Communications Interface Profiles

B.5 INCIDENT MANAGEMENT STANDARDS

- IEEE 1512.3-2006 Standard for Hazardous Material Incident Management Message Sets for Use by Emergency Management Centers
- IEEE 1512 -2006 Standard for Common Incident Management Message Sets for use by Emergency Management Centers
- IEEE 1512.1-2006 Standard for Traffic Incident Management Message Sets for Use by Emergency Management Centers

B.6 OTHER ITS STANDARDS

- ASTM E2259 – 03a (2011) Standard Guide for Archiving and Retrieving ITS-Generated Data
- ASTM E2665-08 Standard Specifications for Archiving ITS-Generated Traffic Monitoring Data
- ASTM E2213-03 Standard Specification for Telecommunications and Information Exchange Between Roadside and Vehicle Systems – 5 GHz Band Dedicated Short Range Communications (DSRC) Medium Access Control (MAC) and Physical Layer (PHY) Specifications
- ASTM E2468-05(2012) Standard Practice for Metadata to Support Archived Data Management Systems
- IEEE 1570-2002 Standard for the Interface Between the Rail Subsystem and the Highway Subsystem at a Highway Rail Intersection
- SAE J2540/2 ITIS (International Traveler Information Systems) Phrase Lists
- SAE J2540/3 National Names Phrase List
- SAE J2540/1 Radio Data System Phrase Lists
- SAE J2630 Converting ATIS Message Standards from ASN.1 to XML
- SAE J1663 Truth-in-Labeling Standard for Navigation Map Databases
- SAE J2399 Adaptive Cruise Control Operating Characteristics and User Interface
- SAE J1757/1 Standard Metrology for Vehicular Displays
- SAE J2366/1L ITS Data Bus – Low Impedance Stereo Audio
- SAE J2365 Calculation of the Time to Complete In-Vehicle Navigation and Route Guidance Tasks
- SAE J2266 Location Referencing Message Specification
- SAE J2539 Comparison of GATS Messages to SAE ATIS Standards Information Report
- SAE J2372 Field Test Analysis Information Report
- SAE J2400 Human Factors in Forward Collision Warning Systems: Operating Characteristics and User Interface Requirements

- SAE J1746 ISP-Vehicle Location Referencing Standard
- SAE J2355 ITS Data Bus Architecture Reference Model Information Report
- SAE J1760 ITS Data Bus Data Security Services
- SAE J2366/7 ITS Data Bus – Application Message Layer
- SAE J2366/2 ITS Data Bus – Link Layer
- SAE J2366/1 ITS Data Bus – IDB-C Physical Layer
- SAE J2366/4 ITS Data Bus – Thin Transport Layer
- SAE J2395 ITS In-Vehicle Message Priority
- SAE J2352 Mayday Industry Survey Information Report
- SAE J2396 Definitions and Experimental Measures Related to the Specification of Driver Visual Behavior Using Video Based Techniques
- SAE J2354 Message Set for Advanced Traveler Information System (ATIS)
- SAE J2540 Messages for Handling Strings and Look-Up Tables in ATIS Standards
- SAE J2313 Onboard Land Vehicle Mayday Reporting Interface
- SAE J1708 Serial Data Communications Between Microcomputer Systems in Heavy-Duty Vehicle Applications
- SAE J2373 Stakeholders Workshop Information Report
- SAE J2369 Standard for ATIS Message Sets Delivered Over Reduced Bandwidth Media
- SAE J3067_201408 Candidate Improvements to Dedicated Short Range Communications (DSRC) Message Set Dictionary [SAE J2735] Using Systems Engineering Methods

Appendix C. Acronyms and Definitions

Table 146: Acronyms and Definitions

Acronym	Definition
API	Application Programming Interface
Apps	Smart Applications
APTA	American Public Transportation Association
ARC-IT	Architecture Reference for Cooperative and Intelligent Transportation
ATIS	Advanced Traveler Information System
BLE	Bluetooth Low Energy
C2C	Center to Center
C2F	Center to Field
CEAV	Connected Electric Autonomous Vehicle
CCMS	Cooperative ITS Credential Management System
CMS	Central Management System
ConOps	Concept of Operations
CORS	Continuously Operating Reference Station
COTA	Central Ohio Transit Agency
CPMS	City Parking Meter System
CV	Connected Vehicle
CVE	Connected Vehicle Environment
CVRIA	Connected Vehicle Reference Implementation Architecture
DSRC	Dedicated Short-Range Communications
ECB	Emergency Call Button
ECC	Emergency Call Center
ELMS	Electrical and Lighting Management Systems
EPM	Event Parking Management
EPMCS	Event Parking Management Central System
EV	Emergency Vehicle
GFAC	Gated Parking Facility System
GNSS	Global Navigation Satellite System
GTFS	General Transit Feed Specification
GPS	Global Positioning System

Acronym	Definition
HDV	Heavy-Duty Vehicle
HOV	High-Occupancy Vehicle Lane
HOT	High-Occupancy Toll Lane
IEC	International Electrotechnical Commission
IEEE	Institute of Electrical and Electronics Engineers
IETF	Internet Engineering Task Force
IK	Interactive Kiosk
ISO	International Organization of Standardization
ISP	Internet Service Provider
ITS	Intelligent Transportation Systems
JSON	JavaScript Object Notation
LDV	Light-Duty Vehicle
MAC	Media Access Control
MCO	Managed Care Organizations
MAPCD	Mobility Assistance for People with Cognitive Disabilities
MMTPA	Multimodal Trip Planning Application
MOU	Memorandum of Understanding
MPCS	Mobility Provider Central Systems
NEMT	Non-Emergency Medical Transportation
NFC	Near Field Communication
NTP	Network Time Protocol
OBE	Onboard Equipment
OBU	Onboard Unit
ODM	Ohio Department of Medicaid
ODOT	Ohio Department of Transportation
OPAPP	Parking Operator PM360 Application
OS-SM	Operating System Security Management
OSU	Ohio State University
PMO	Program Management Office
PTA	Prenatal Trip Assistance
PWD	Personal Wireless Device
QR	Quick Response
REST	Representational State Transfer
RSE	Roadside Equipment

Acronym	Definition
RSU	Roadside Unit
SAE	Society of Automotive Engineers
SASP	System Architecture and Standards Plan
SCMS	Security Credential Management System
SEMP	Systems Engineering Management Plan
SET-IT	Systems Engineering Tool for Intelligent Transportation
SMH	Smart Mobility Hubs
SMS	Short Message Service
TCIP	Transit Communications Interface Profiles
TCP	Transmission Control Protocol
TCVMS	Traffic Connected Vehicle Management System
TLS	Transport Layer Security
TrCVMS	Transit Connected Vehicle Management System
TIC	Transportation Information Center
UDP	User Datagram Protocol
UFAC	Ungated Parking Facility
URL	Uniform Resource Locator
USDOT	U.S. Department of Transportation
V2I	Vehicle-to-Infrastructure
V2V	Vehicle-to-Vehicle
VoIP	Voiceover Internet Protocol
WAVE	Wireless Access in a Vehicle Environment
WAW	Wide Area Wireless
WWW	World Wide Web
XML	Extensible Markup Language

Source: City of Columbus

THE CITY OF
COLUMBUS
ANDREW J. GINTHER, MAYOR