Phase 2 System Architecture Document

University of Washington ITS4US Deployment Project

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ITS4US
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16. Abstract

This document is the System Architecture Document (SAD) for the University of Washington's (UW) Transportation Data Equity Initiative (TDEI) Project for the United States Department of Transportation's (USDOT) ITS4US Program. The SAD describes the system architecture from various architecture perspectives including: Enterprise Architecture View; Physical Architecture View of Systems, Interfaces, and Service Packages; Functional Architecture View; Data and Information Flow View; Communications Architecture View; and Security Architecture View. The System-of-Interest described in this document is a data management system that collects, stores, and distributes detailed sidewalk, transit station, and on-demand transit data. This data management system is supported by Application Program Interfaces, or APIs, through which data generators can submit data and data consumers can request data. In addition, as part of this work, a tool will be developed to help data generators convert their existing sidewalk and/or transit databases into the data standards used by this system. This document describes the System Architecture for these systems, their interfaces, data flows and functional components.

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1 Introduction

1.1 Document Purpose

This document is the System Architecture Document (SAD) for the University of Washington's (UW) Transportation Data Equity Initiative (TDEI) Project for the United States Department of Transportation's (USDOT) ITS4US Program. The SAD describes the system architecture from various architecture perspectives, including:

- Enterprise Architecture View
- Physical Architecture View of Systems, Interfaces, and Service Packages
- Functional Architecture View
- Data and Information Flow View
- Communications Architecture View
- Security Architecture View

This document identifies the subsystems, internal and external interfaces, and interface standards necessary to develop and build the UW TDEI project. Requirements for these subsystems were previously defined in the System Requirements Specification[1] (SyRS), prepared as part of Phase 1 of the effort. The requirements are traceable to user needs that were described in the Concept of Operations[2] (ConOps) created for the project in Phase 1. Further design information is detailed in the System Design Document (SDD).

1.1.1 Organization of this Document

This document is organized as follows:

- Section 1 outlines the document purpose, project scope, approach, and rationale for key decisions.
- Section 2 outlines stakeholders and concerns, as well as notes the User Needs identified in Phase 1 and updated as part of Phase 2.
- Section 3 discusses the System of Interest.

[1] System Requirements Specification (SyRS) University of Washington ITS4US Deployment Project. https://rosap.ntl.bts.gov/view/dot/60129 (accessed Sept 13, 2022)

[2] Phase 1 Concept of Operations (ConOps) – University of Washington ITS4US Deployment Project. https://rosap.ntl.bts.gov/view/dot/58675 (accessed Sept 13, 2022)

- Section 4 shows the different architectural views, including the enterprise, physical, functional, and communications view.
- Section 5 shows a functional component diagram for the software portion of the TDEI system, which is a critical element and represents that vast majority of the proposed system. This diagram will appear in the Agile pre-release and release memorandums to serve as reference for where work activities are occurring in a given release.
- Section 6 identifies references that are relevant to this effort.

1.2 Identifying Information

Architecture Name: University of Washington TDEI System Architecture

System-of-Interest: The TDEI system is one of four systems being developed as part of the USDOT's ITS4US program that aim to provide transportation services to underserved communities. The system of interest for the TDEI is a data management system that collects, stores, and distributes detailed sidewalk, transit station, and on-demand transit data. This data management system is supported by Application Program Interfaces, or APIs, through which data generators can submit data and data consumers can request data. As part of this work, a tool will be developed to help data generators convert their existing sidewalk and/or transit databases into the data standards used by this system.

1.3 Project Background

The project will develop a national pipeline to create, disseminate, and share standardized data about pedestrian environments, transportation environments, and on-demand transportation services to enable better use, discoverability, and data analytics of these assets and services. The goal of the UW ITS4US Deployment project is to build a sustainable, inclusive data infrastructure to enable and accelerate the future of equitable mobility and access to transportation for the benefit of all travelers. Through community leadership, this proposed system, the associated standards development, and the adoption by users (including both data generators and data consumers) will help provide a means to offer appropriate travel services, automate routing, and map out the transportation network in ways appropriate for every traveler. With this in place, previously underrepresented individuals will have tools available to make informed, customized travel decisions under any situation.

Systems developed in this project will enable users to have improved awareness of routes (specifically routes that align with their unique travel preferences) and transit services available to them. At a very high level, the TDEI system aims to achieve USDOT ITS4US Program goals by deploying the following key technology elements:

1. **Develop a Centralized Data Repository**. The UW Team will develop a centralized data repository that services many functions, including receipt/validation of data (including sidewalk, transit station pathways, and on-demand transit), storage of data, and distribution of data through an Application Programming Interface (API) in response to requests for geographically focused data for trip making. This centralized data repository represents the focal point of the project for moving data from those who produce it to those who want to use it.

2. **Create tools to support data collection**. The UW Team will develop tools for sidewalk infrastructure owner-operators and transit agencies to collect data, translate it into the data standards supported by TDEI, and submit data to the data repository. The goal of the tools is to simplify the level of effort required to collect data, thus, encouraging agencies to undertake this data collection initiative.
3. **Demonstrate use of the data by under-represented communities through three accessibility-focused mobility applications.** This project will utilize accessible mobility applications in the evaluation and testing of the usability and efficacy of the data standards and the supporting infrastructure.

The UW Team will publish collected data for the six U.S. counties that are part of this project. The six counties, as shown in **Figure 1**, are King and Snohomish Counties in Washington State, Multnomah and Columbia Counties in Oregon, and Harford and Baltimore Counties in Maryland. Our pilot area focuses on regions that combine urban centers with suburban sprawl and rural areas, in order to demonstrate the use of these data in different conditions of travel networks.

Figure 1. Map. Washington, Oregon, and Maryland Counties.

Source: United States Department of Transportation, University of Washington, and Cambridge Systematics.

1.4 Approach

The SAD loosely follows the format and requirements in ISO/IEC/IEEE 42010:2011 Systems and Software Engineering – Architecture[3], which is an international standard for documenting system architecture. Since this standard is more applicable to complex hardware-focused systems than the software-focused nature of the proposed TDEI system, the SAD discussed herein intends to adapt the traditional SAD requirements to a software architecture and to convey the necessary points.

The system architecture provided in this document is the planned TDEI architecture. As the TDEI is being developed using Agile software methodology, it is possible that changes to the architecture will be identified in the Agile process. Such changes will be communicated through the Agile release memos. In addition, this document will be updated so that the final SAD for this project reflects the as-built TDEI architecture.

1.5 Rationale for Key Decisions

The architecture described in this document was prepared by the project team in a manner that supports scalability of the system. The Concept of Operations document developed in Phase 1 identified the preferred concept that addressed the goals of the system and the associated key decisions that supported that concept. Several alternative methods for addressing the goals of the system were also compared in the ConOps, with each alternative method having a different architecture design than that proposed herein. Each of those proposed alternatives overall either failed to fully address the goals of the system or incurred additional challenges or costs that made it less efficient. As such, the proposed system and the associated architecture are selected because it is believed to find the appropriate balance between achieving the goals of the proposed system while minimizing challenges or costs.

Key decisions and their associated rationale are listed below:

- **Use of OpenSidewalks[4], GTFS-Pathways[5], and GTFS-Flex Data[6] Schema:** Use of these data schemas simplifies the data structure of the proposed system by limiting the schemas of data stored in the system thereby allowing the TDEI to focus on desired data

[3] ISO/IEC/IEEE 42010:2011 Systems and software engineering – Architecture description https://www.iso.org/standard/50508.html (accessed 10/6/2022)

[4] "Open Sidewalks." https://www.opensidewalks.com (accessed Sept 6, 2022)

[5] "GTFS Schedule Reference", May 9, 2022, https://gtfs.org/schedule/reference/ (accessed September 6, 2022)

[6] "GTFS Flex V2", Nov 9, 2021. https://github.com/MobilityData/gtfs-flex/blob/master/spec/reference.md (acessed Sept 6, 2022)

attributes and to provide data consistency. These standards have been vetted closely by stakeholders to help inform the necessary desired attributes.

- **Use of a Microservices Architecture:** Use of a microservices architecture for data collection, aggregation, transformations, and other lifecycle activities will enable the actions of joining data from multiple sources, in multiple formats, and perform data aggregations, transformations and integrations to bring input data into the consistent data schemas promoted by the TDEI.
- **Use of Application Program Interfaces (APIs):** An API enables different entities and partners to open their applications' data and functionality to external third-party developers, business partners, and internal departments within their organizations. APIs also support authentication and authorization so that functionality such as data uploads and retrievals can be restricted to only authorized parties. This allows services and products to communicate with each other and leverage each other's data and functionality through a documented interface. Developers don't need to know how an underlying service is implemented; they simply use the API to communicate with other products and services.
- **Provide data translation tools to agencies that want to submit data to the TDEI:** Since not all agencies collect sidewalk and transit-related data in the data schema used in this project, these translation tools will aid in the agencies' ability to translate their data to the TDEI-supported schemas.
- **Use of Demonstration Applications to show system in use**: The demonstration applications, developed separately from the TDEI project, will make use of the TDEI's data to provide travel options to the digital device end user. The TDEI is working with several application developers as stakeholders to help make sure data is structured in a manner and that APIs are developed in a way such that the APIs and data can be incorporated into the application developers' systems.

2 Stakeholders and Concerns

2.1 Introduction

This section defines the stakeholders, user needs, and concerns involved with the proposed system.

2.2 Stakeholders

The following stakeholders are involved in the operations, usage, and maintenance of the proposed TDEI system. Since no system exists today with which to map roles and responsibilities, the roles and responsibilities of stakeholders will be defined in the context of the proposed system:

- **University of Washington** — The UW is leading this project through the Taskar Center for Accessible Technology (TCAT), with support from the UW's Washington State Transportation Center (TRAC). TCAT and TRAC have worked together to develop the concept, pursue the ITS4US grant through the USDOT, and will be responsible for delivering and maintaining the proposed system through the grant period. TCAT developed and is currently supporting the AccessMap application (an open source, public, interactive, and individualized pedestrian accessibility map), which will be used as one of the demonstration applications for this effort.
- **Digital Device End Users** – The Digital Device End Users represent the stakeholder and actors that need enhanced data to make informed travel decisions. They may include blind or vision disabled travelers, deafblind travelers, travelers with hearing disabilities, sighted older adults, low-income transit users, rural transit users, veterans, multilingual/multicultural travelers, and any other traveler that has specific travel preferences that may be covered by the proposed system. These travelers currently utilize available applications that provide routing information, but not at the level necessary to help them make informed decisions on route choices that align with their preferences.
- **Data Generators** – The Data Generators include state transportation agencies, cities, counties, transit agencies, and other public infrastructure owners that facilitate pedestrian pathway routes, or other groups involved in the data collection and digitization of sidewalk data. While many of these groups install sidewalk infrastructure to support mobility, they currently do not digitize this information in a standard format that can be easily adopted.
- **Transportation Service Providers** – The Transportation Service Provider include transit agencies, state transportation agencies, cities, counties, and other public infrastructure owners that facilitate pedestrian pathway routes (in transit stations) or provide on-demand transit services, or other groups involved in the data collection and digitization of transit data. While many of these groups provide path infrastructure and on-demand transit service to support mobility, they currently do not digitize this information in a standard format that can be easily adopted.

- **Application Developers** – The Application Developers include any application developer looking to provide a service to their end users, such as routing information and/or enhanced transit information. These developers currently draw upon their own resources to publish information, which may not fully meet the needs and requirements for end users to make informed decisions. In the context of the proposed system, application developers receive data from the system and incorporate it as part of their service offerings to digital device end users to demonstrate the system.
- **U.S. Department of Transportation** – The USDOT is funding the ITS4US program, which is supporting development of the proposed system. The USDOT will ensure that the project aligns with the goals of the ITS4US Program, support coordination with other ITS4US projects, conduct evaluation of the project outputs, and guarantee the project meets all federal requirements.

2.2.1 User Profiles

Table 1 lists the user profiles that are impacted by development and operation of the proposed system. These user profiles are subsets of the stakeholders identified in the previous section.

Table 1 User Profiles

User Group	Owner	Short Description	Changes to Responsibilities and Interaction with the System
Taskar Center for Accessible Technology	University of Washington	Taskar Center for Accessible Technology is developing the system and maintaining it during the ITS4US project.	Staff will have direct involvement with the design, deployment, maintenance, and updates to the proposed system during the ITS4US project.
Washington State Transportation Center	University of Washington	Washington State Transportation Center is supporting the Taskar Center for Accessible Technology with developing the system and maintaining it during the ITS4US project.	Staff will have direct involvement with the design, deployment, maintenance, and updates to the proposed system during the ITS4US project.
Sidewalk Data Generator	Data Generator	Transportation agencies responsible for sidewalk infrastructure.	Agency staff will have tools to convert certain existing sidewalk data into a data format that is accepted by the proposed system. This converted data and other approved data can then be submitted to the proposed system.

User Group	Owner	Short Description	Changes to Responsibilities and Interaction with the System
Transit Data Generator	Transportation Service Provider	Transit agencies or other public agencies responsible for path infrastructure in transit stations or on-demand transit service.	Agency staff will have tools to convert certain existing transit data into a data format that is accepted by the proposed system. This converted data and other approved data can then be submitted to the proposed system.
Application Developer	Application Developer	Application developers that provide navigation services to digital device end users.	Application developers will have access (with approval) to APIs to download currently available sidewalk and/or transit-related data for inclusion in their navigation services to digital device end users.
Blind or Disabled Travelers	Digital Device End Users	Traveler with distinct travel preferences that may not be addressed by supporting navigation applications.	Through application developers that incorporate the proposed system's data, these users will receive greater insights on travel routes and features that align with their preferences.
Deafblind Travelers	Digital Device End Users	Traveler with distinct travel preferences that may not be addressed by supporting navigation applications.	Through application developers that incorporate the proposed system's data, these users will receive greater insights on travel routes and features that align with their preferences.
Travelers with hearing disabilities	Digital Device End Users	Traveler with distinct travel preferences that may not be addressed by supporting navigation applications.	Through application developers that incorporate the proposed system's data, these users will receive greater insights on travel routes and features that align with their preferences.
Sighted Older Adults	Digital Device End Users	Traveler with distinct travel preferences that may not be addressed by supporting navigation applications.	Through application developers that incorporate the proposed system's data, these users will receive greater insights on travel routes and features that align with their preferences.

User Group	Owner	Short Description	Changes to Responsibilities and Interaction with the System
Low-Income Transit Users	Digital Device End Users	Traveler with distinct travel preferences that may not be addressed by supporting navigation applications.	Through application developers that incorporate the proposed system's data, these users will receive greater insights on travel routes and features that align with their preferences.
Rural Transit Users	Digital Device End Users	Traveler with distinct travel preferences that may not be addressed by supporting navigation applications.	Through application developers that incorporate the proposed system's data, these users will receive greater insights on travel routes and features that align with their preferences.
Veterans	Digital Device End Users	Traveler with distinct travel preferences that may not be addressed by supporting navigation applications.	Through application developers that incorporate the proposed system's data, these users will receive greater insights on travel routes and features that align with their preferences.
Multilingual/Multicultural Travelers	Digital Device End Users	Traveler with distinct travel preferences that may not be addressed by supporting navigation applications.	Through application developers that incorporate the proposed system's data, these users will receive greater insights on travel routes and features that align with their preferences.
Travelers with specific travel preferences	Digital Device End Users	Traveler with distinct travel preferences that may not be addressed by supporting navigation applications.	Through application developers that incorporate the proposed system's data, these users will receive greater insights on travel routes and features that align with their preferences.

2.2.2 Other Involved Personnel

Other involved Personnel, described below, include other Data Generators who may be involved in the system and the USDOT that will be involved in the system.

- **Other Data Generators**: The vision for the proposed system is to collect sidewalk and pedestrian path data from a variety of sources beyond simply traditional transportation or transit agencies. Some examples may include civic groups or accessibility activists that are looking to better inform underserved users of routes available in the community. While these may be participants in the proposed system (by submitting their own sidewalk and/or transit-related data), the tools developed as part of ITS4US are focusing

on agencies with existing infrastructure databases. The Phase 1 Institutional, Partnership, and Financial Plan identifies many groups that would qualify as Other Data Generators.

- **USDOT:** The USDOT is funding the development of the proposed system through the ITS4US program. The USDOT will evaluate the project and will use data from the project in that evaluation; the USDOT is not expected to generate data for the system. Finally, the USDOT also has an oversight role to ensure that the project aligns with the goals of the ITS4US program and meets federal requirements.

2.3 User Needs

User needs were identified in the Phase 1 Concept of Operations effort. User needs were defined by identifying the shortcomings of the current situation that provide justification for the changes offered by the proposed system. Some of the key shortcomings of the current situation included:

- Lack of Widely Available Data Objectively Describing the Pedestrian Built Environment
- Lack of Widely Available On-Demand Transportation Service Data
- Lack of Widely Available Transit Station Data
- Lack of Scalable Solutions to Easily Facilitate Availability of New Services Across a Larger Geographic Region
- Lack of Data Standards in Practice that are Sustainable
- Lack of Demonstrable Workspace for Proposed Standards

During TCAT's ongoing work on the development or enhancement of data standards, TCAT has identified user needs through comprehensive stakeholder engagement, in addition to an extensive review of previous research studies, including the U.S. DOT's Accessible Transportation Technologies Research Initiative (ATTRI) program, and published work by the Transportation Cooperative Research Program (TCRP), such as TCRP-210, Development of Transactional Data Specifications for Demand-Responsive Transportation.

TCAT was engaged with the following five specific stakeholder involvement groups for several years as part of its co-design process during the development of the OpenSidewalks data standard and AccessMap application. The following stakeholder involvement groups provided insight into the real-world usability of data for the OpenSidewalks data standard and the AccessMap accessible mobility application in development. Much of the user needs for the TDEI project were based on these stakeholder groups:

- People with disabilities and disability advocacy groups.
- Organizations involved in active transportation developments and audits.
- State and city DOTs.
- Paratransit operators.
- Commercial entities involved in producing urban map data and, in some cases, in consuming those data as well as in creating mobility applications and user experiences.

User needs were divided among owner groups that include most identified in Table 1. These groups are defined below, as listed in the Phase 1 Concept of Operations Document, and each group has their own defined set of user needs.

1. **Data Generators (DG)—**Entities in this group include data producers from governmental bodies, transportation agencies, or the private sector. Governmental bodies and transportation agencies that own and operate sidewalk infrastructure or transportation hubs typically produce data about these assets. Private-sector data companies typically produce data about travel environments in support of their own mobile applications, some of their customers who consume these data, and digital cartography. Entities in this group may or may not be regulated under other data collection requirements and/or restrictions.
2. **Transportation Service Providers (TS)—**Entities in this group include data contributors from public- or private-sector transit agencies or transportation operators. They may offer fixed-route or on-demand transit service or may own, operate, and maintain transit station facilities. This user group wishes to inform customers of transportation service or transit station facility options and may share data directly with application developers or make data available to data aggregators.
3. **Data Service Providers (DS)—**Entities in this group include both transportation service providers that make their own data available to outside application developers and, more importantly, data aggregators that obtain data from multiple sources (e.g., transit service data from multiple transit agencies, or sidewalk data from multiple cities); fuse those data into a seamless data structure; and provide that seamless data structure to application developers.
4. **Application Developers (AD)—**Entities in this group include data consumers that create digitally based, user-facing applications with data from public- or private-sector organizations that disseminate data for mapping or travel. Application developers depend on the availability of data from providers of those data to generate solutions that meet the needs of digital-device-users.
5. **Digital Device End Users Experiencing Travel Barriers (DU)—**Users in this group include a specific group of data consumers, primarily individuals with the lived experience of some disability or their caretakers who utilize digital cartography and information to make informed travel decisions. These decisions include, but are not limited to, identifying optional routes for desired trips and obtaining specific navigational directions for route plans they select. The needs of the end users drive the intent and design of the applications but not the data tools and infrastructure.

The full list of user needs is outlined in Phase 1 Concept of Operations document.

2.4 Concerns

This section describes the concerns of stakeholders listed in Section 2.2. Concerns are defined as any topic of interest pertaining to the system that are held by the stakeholders and impact the system architecture. These concerns are based on ongoing conversations with stakeholders that inform both user needs and system design. These concerns are listed in Table 2.

Table 2 Stakeholder Concerns and Architecture Considerations

User Group	Concern	Considerations for Architecture
Data Generators	Data must be easy and straightforward to collect to facilitate preparation.	Development of a data translation tool for this effort will help agencies convert existing data sources into the correct data schema.
Digital Device End Users	Application developers may not adopt the proposed system, and thus not demonstrate its services via their applications.	Ongoing coordination with application developers during all phases of design and development will help recruit interested parties for demonstration.
Data Generators, Application Developers, Digital Device End Users	Geographic limitations may only allow the system to work in certain geographic locations.	The system is inherently designed to not be geographically constrained. If participation exists among these three groups in a particular geographic region, then the proposed system is a feasible avenue for gathering and distributing the data.

3 System of Interest (SOI)

As noted in Section 1.3, the project will develop a national pipeline to create, disseminate, and share standardized data about pedestrian environments, transportation environments, and on-demand transportation services to enable better use, discoverability, and data analytics of these assets and services. The context diagram from Phase 1 is provided in Figure 2, and it shows the interactions between users and the subsystems. This context diagram will be broken down into the four architectural views (enterprise, physical, functional, and communications). The key elements of the TDEI system are:

1. **Develop a Centralized Data Repository**. The UW Team will develop a centralized data repository that services many functions. The repository receives and validates incoming sidewalk, transit station pathways and on-demand transit data that are provided by data generators. The data is then stored in the repository. Requests for data are made through an API; applications typically request geographically focused data for trip making. The centralized repository represents the focal point of the project for moving data from those who produce it to those who want to use it. On the context diagram in Figure 2, components that the UW Team will directly develop and test, and are labeled with a "1". These components include the data processing pipelines, the data repository itself, and the service pipelines.
2. **Create tools to support data collection**. The UW Team will develop tools for sidewalk infrastructure owner-operators and transit agencies to collect data, translate it into the preferred data standard, and submit data to the data repository. The goal of this component is to simplify the level-of-effort required to collect this data, thus, encouraging agencies to undertake this data collection initiative. Components that the UW Team will assist in developing to encourage data contributions, namely tool sets through which the data providers will be encouraged to submit data. In the context diagram in Figure 2, these items are labeled with a "2" and consist of tool sets that will serve groups, such as municipal governments, transit agencies, and other data providers. These tools will be maintained in the TDEI GitHub repository which will provide version control for the tools. The tools will be web sites that are accessible by or scripts that are downloadable by infrastructure owner-operators and agencies. Updates to the tools will be provided through the web site or email notifications.
3. **Demonstrate use of the data by under-represented communities through three accessibility-focused mobility applications.** This project will deploy accessible mobility applications in the evaluation and testing of the usability and efficacy of the data standards and the supporting infrastructure. Components that represent software demonstrations whose development the UW Team will support to demonstrate the success of the pipelines. These include the three applications that have been vetted to provide the services needed by underserved end users. On the context diagram in Figure 2, these components are labeled with a "3".

Other components that provide data used within the TDEI and that both already exist and can be obtained via existing APIs operated by data service providers, such as weather and topographic elevation data, are shown in the context diagram as Other Non-System Services but are not

labeled with a number. Such data are valuable in interpreting mobility data but are not core to the project mission. These data are outside the current TDEI system but are included because it is expected that application developers will want to use these other data sources. If such data were to be provided through a future version of the TDEI, these data would need to be translated so they can be geographically correlated with the TDEI data. Similarly, third-party applications which will be supported by the TDEI, but that are not part of the formal TDEI deliverables are not labeled with a number.

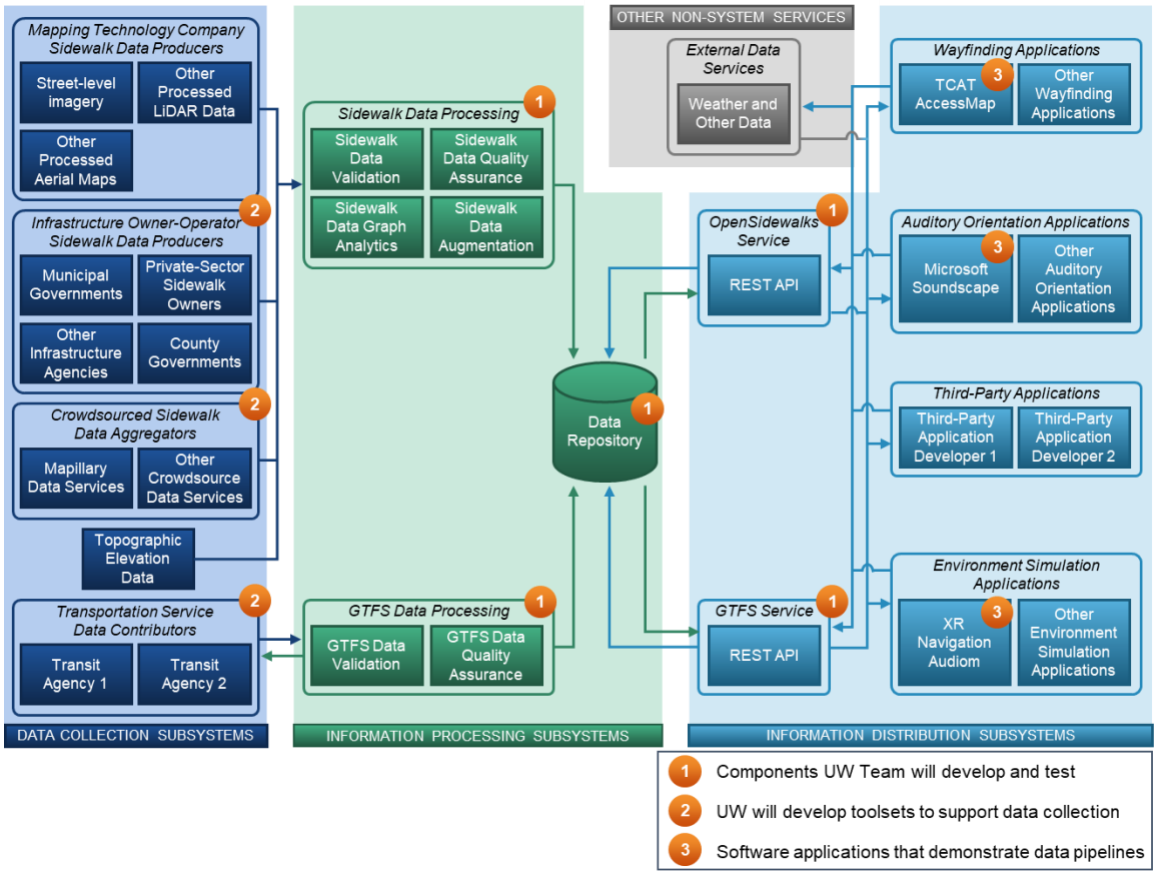

Figure 2 TDEI Context Diagram

4 Architectural Views

This section contains the multiple architecture views that are relevant to the TDEI project. Each view provides information about the construction of the view, the stakeholders served and their concerns, and the tools for understanding the architecture view, as well as the methods used to create, interpret, analyze, and implement the view. This section provides the four main architecture views as defined in Architecture Reference for Cooperative and Intelligent Transportation (ARC-IT) v9.1[7], which includes Enterprise, Physical, Functional, and Communication viewpoints of the proposed system.

4.1 Enterprise View

The enterprise architecture view shows the relationships between organizations that are required to support the overall system architecture. It includes the active stakeholders that are involved in this USDOT-funded part of the ITS4US project, ignoring stakeholders who would likely be involved in the future as the system expands both geographically and operationally.

For reference, the four objects relevant to the enterprise view, as defined by ARC-IT, include:

1. **Enterprise Object:** An organization or individual that interacts with other Enterprise Objects and/or physical objects. An Enterprise Object may be a component of another larger Enterprise Object, which may in turn be a component of a third, even larger, Enterprise Object. Enterprise Objects may participate wholly or in part in other Enterprise Objects (e.g., a Device Developer is a component of Auto Manufacturer but also participates in Standards Bodies).
2. **Resource:** An asset that can support the achievement of enterprise objects. This may be a physical or virtual element and may be of limited availability. All physical objects are resources, but other resources may include policies and documents.
3. **Relationship:** Formal or informal coordination between Enterprise Objects, e.g., agreements, contracts, funding, expectations.
4. **Role:** The way in which an object participates in a relationship; an object's set of behaviors and actions associated with the relationship of that object with other objects.

[7] "Architecture Reference for Cooperative and Intelligent Transportation," ARC-IT v9.1, Aug. 10, 2022. https://www.arc-it.net/ (accessed September 6, 2022).

4.1.1 Project Partners and Stakeholders

This section provides a list of project partners, stakeholders, and users for this deployment in the form of a table, as well as their roles in the deployment as defined by ARC-IT. Table 3 provides a summary of user roles for project partners and stakeholders.

Table 3 Summary of User Roles

User	Role
University of Washington	Owner
The Taskar Center for Accessible Technology	Developer, Installer, Maintainer, Operator, Verifier
Washington State Transportation Center	Developer, Installer, Maintainer, Operator, Verifier
USDOT	Sponsor and Advisor
Sidewalk Data Generator	Provider
Transit Pathways Data Generator	Provider
Transit Flex Data Generator	Provider
Application Developer	User
Blind or Low-Vision Travelers	User
Deafblind Travelers	User
Travelers with hearing disabilities	User
Sighted Older Adults	User
Low-Income Transit Users	User
Rural Transit Users	User
Veterans	User
Multilingual/Multicultural Travelers	User
Travelers with mobility disabilities	User
Travelers with specific travel preferences	User

The primary focus of this project is travelers with mobility disabilities (e.g. use a wheelchair) and blind and deafblind travelers. However, other travelers, such as low-income transit users, rural transit users and veterans are also expected to benefit as they too will have access to and can utilize services provided by this project. For example, an older veteran who lives in a rural area might use on-demand transit to get to a doctor’s appointment or hospital, and low-income residents in rural areas may not own a personal vehicle and rely on on-demand transit services to conduct trips. The project has three demonstration counties that are rural for this reason. While wheelchair and blind users are the stakeholders the team plans to engage with directly, the overall goal of this system is to provide services to all groups that have travel preferences and aren't currently served by traditional applications.

4.1.2 Resource Objects

This section identifies the resource objects affiliated with this deployment, and the user with which these objects are connected. Table 4 provides a summary of relationships between resource objects and users. These resource objects align with the physical objects that are discussed in Section 4.2.

Table 4 Resource Objects for Users

Resource Object	User
TDEI Gateway	TCAT
TDEI Data Pipeline	TCAT
TDEI Data Repository	TCAT
Data Translation Computer	Sidewalk Data Generator, Transit Pathways Data Generator, Transit Flex Data Generator
OpenSidewalks Database	Sidewalk Data Generator
GTFS-Pathways Database	Transit Pathways Data Generator
GTFS-Flex Database	Transit Flex Data Generator
Application Developer Server	Application Developer
Personal Device	Blind or Disabled Travelers, Deafblind Travelers, Travelers with hearing disabilities, Sighted Older Adults, Low-Income Transit Users, Rural Transit Users, Veterans, Multilingual/Multicultural Travelers, Travelers with specific travel preferences

4.1.3 Relationships

This section outlines the relationships among stakeholder organizations. Since the system is not a real-time data service and relies on data submissions through structured and authenticated APIs, the relationships in place will be far less structured than a similar ITS project that relies on multiple city agencies to succeed. The UW TDEI project has several relationship types between enterprises:

- Employment and Operations Agreements
- Expectations of Data or Information Exchange
- Memorandum of Understanding (MOU) and ASD Usage Agreement

Table 5 identifies the enterprise stakeholder pairs that have employment and operations agreements.

Table 5 Enterprise Relationships with Employment and Operations Agreements

Enterprise 1	Enterprise 2
US Department of Transportation	University of Washington
University of Washington	The Taskar Center for Accessible Technology
University of Washington	Washington State Transportation Center
The Taskar Center for Accessible Technology	Washington State Transportation Center

Table 6 identifies the enterprise stakeholder pairs that have expectations of data or information exchange.

Table 6 Enterprise Relationships with Expectations of Data or Information Exchange

Enterprise 1	Enterprise 2
The Taskar Center for Accessible Technology	US Department of Transportation
The Taskar Center for Accessible Technology	Sidewalk Data Generator
The Taskar Center for Accessible Technology	Transit Pathways Data Generator
The Taskar Center for Accessible Technology	Transit Flex Data Generator
The Taskar Center for Accessible Technology	Application Developers
The Taskar Center for Accessible Technology	Blind or Low-Vision Travelers
The Taskar Center for Accessible Technology	Deafblind Travelers
The Taskar Center for Accessible Technology	Travelers with hearing disabilities
The Taskar Center for Accessible Technology	Sighted older adults
The Taskar Center for Accessible Technology	Low-income transit users
The Taskar Center for Accessible Technology	Rural transit users
The Taskar Center for Accessible Technology	Veterans
The Taskar Center for Accessible Technology	Multilingual/ Multicultural Travelers
The Taskar Center for Accessible Technology	Travelers with mobility disabilities
The Taskar Center for Accessible Technology	Travelers with specific travel preferences

Table 7 identifies the enterprise stakeholder pairs that have a Memorandum of Understanding (MOU) and/or Usage Agreement. It is anticipated that data generators would have an MOU, whereas application developers would agree to a data usage agreement.

Table 7 Enterprise Relationships with Memorandums of Understanding and/or Usage Agreements

Enterprise 1	Enterprise 2
University of Washington	Sidewalk Data Generator
University of Washington	Transit Pathways Data Generator
University of Washington	Transit Flex Data Generator
University of Washington	Application Developers

4.1.4 Relationships Diagram

This section presents an Enterprise view diagram, shown in Figure 3.

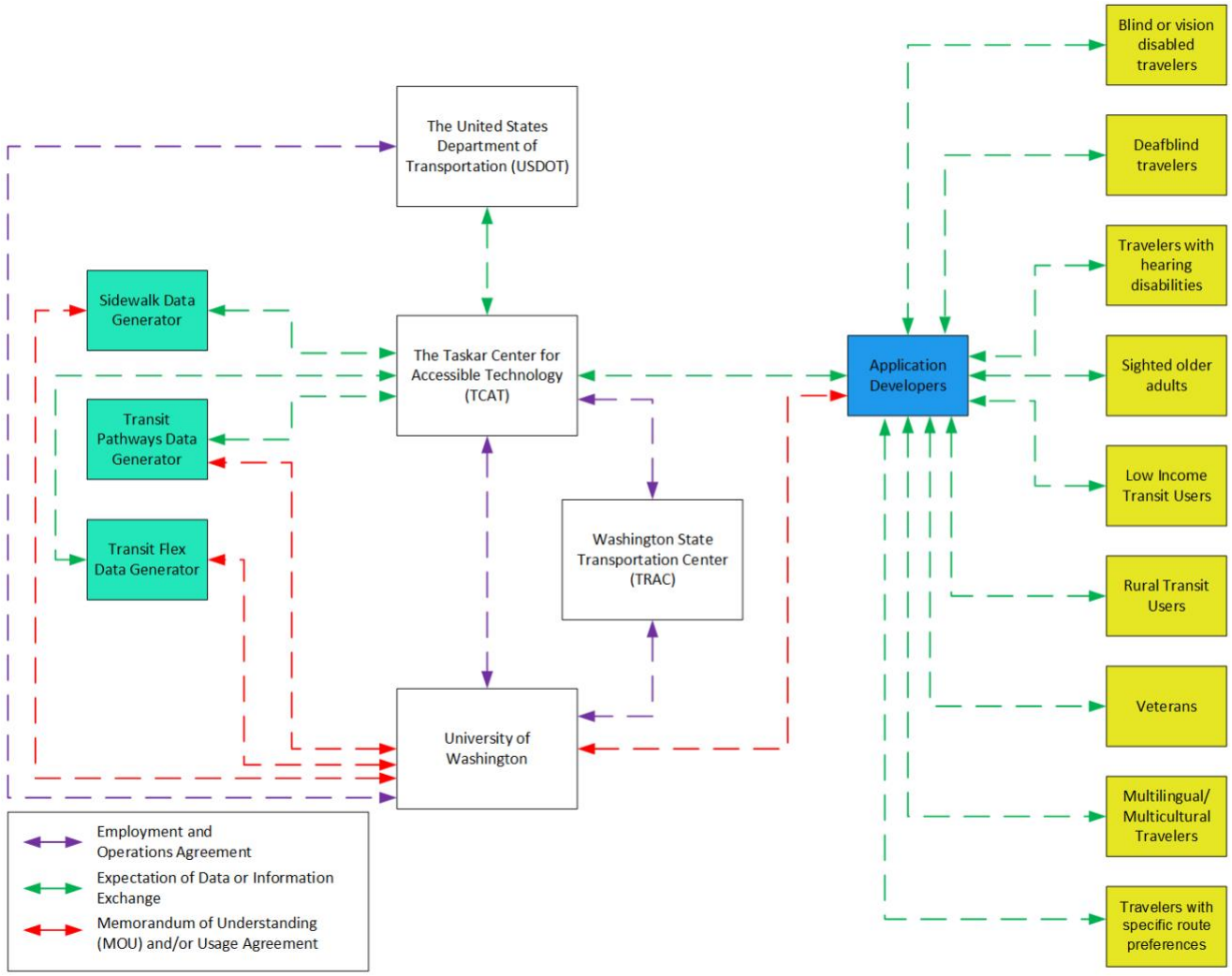

Figure 3 TDEI System Enterprise View: Relationships

4.2 Physical View

The physical architecture view shows the transportation system and associated information flows from the perspective of the physical objects that operate in the field, the center, and the back office. This section will provide a physical view of the applications within the proposed TDEI system, as well as a diagram of proposed service packages.

4.2.1 Physical View for all Applications

This subsection provides a level 1 and level 2 physical viewpoint of the TDEI system, following guidance provided by ARC-IT. Physical objects are defined in terms of the applications they support, the processing they include, and their interfaces with other physical objects. Five classes of objects can apply to most ITS projects. For the TDEI system, many of these classes still apply, but with a minor adjustment to definition. The following classes include:

- **Center**: These elements provide application, management, administrative, and support functions from a fixed location, termed to not be in proximity to the road network. In the context of the TDEI system, this aligns with the data processing, management, storage, and distribution elements of the project, which represent the primary portions of the project that are being developed as part of this effort.
- **Field**: These elements typically refer to infrastructure that are proximate to the transportation network that perform some type of action remotely. In the context of the TDEI system, no field infrastructure is being deployed, at least in the traditional sense for ITS projects. However, the agencies that have sidewalk and transit-related data (and may subsequently use the TDEI data translation tools to convert into the proper data standards) can be viewed as being a field entity, relative to the TDEI system itself. For purposes of this work, agencies with transportation data will be viewed as field elements.
- **Support**: These elements are termed to be a center that provides a non-transportation specific service. In the context of the TDEI system, this includes application developers who provide the software tools that facilitate movement of data to their digital device end users. These application developers are generally considered software services, and for purposes of this work, will be classified as support elements, even though they may process and provide services for transportation-related sidewalk or transit data. Note that the TDEI system is only providing data for these support elements to use, not operating or changing how each application runs.
- **Personal**: These elements include equipment used by travelers to access transportation services, either pre-trip or en-route. In the context of the TDEI system, these include the mobile devices used by digital device end users to receive sidewalk path and transit-related information. Note that the TDEI system is not developing any software or tools that are used on these devices, rather utilizing these devices via other applications to demonstrate the utility of the data.
- **Vehicle**: No vehicle elements are included in the TDEI system.

Figure 4 shows the level 1 physical viewpoint of the system. Since many of these physical objects reside among a variety of enterprise groups, many of the traditional communication methods on traditional ITS projects (i.e., center-to-center, center-to-field, etc.) are not applicable. A combination of wide area and local area networking is anticipated to facilitate the movement of information between objects. In most cases, physical objects will make use of the public internet to send data to other physical objects that may reside in different enterprise groups. In some limited instances, certain functional objects that are part of a larger physical object may exchange

information on a local network (shown in Figure 5); an example of this may be different software features that reside on one or more cloud servers. Figure 4 also shows a connection direct from Personal to Center over the public internet; this connection represents the case where an app on a personal device connects directly to the TDEI API without going through an application server. The type of connection used by an app on a personal device is determined by the application developer and is outside the control of the TDEI system. While some personal devices may connect directly to the TDEI, it is expected that connections through application servers (Support) will be more common. Language will be added to the data use agreement to specify allowed uses of API keys.

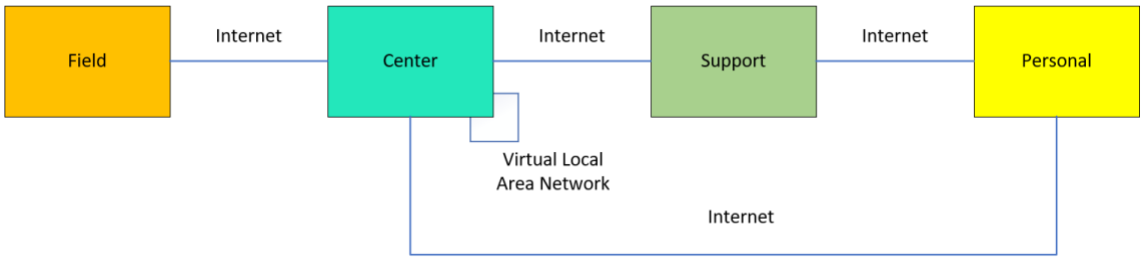

Figure 4 TDEI System Physical View: Level 1

Figure 5 shows the level 2 physical viewpoint of the system, which details more of the functional objects that are relevant to each physical object. The functional objects represent the building blocks that make up physical objects shown in the physical view and group similar processes into implementable packages. These functional objects will provide the functionality later discussed in the functional view. It is important to note that, in the context of the TDEI system, functional objects listed as part of “center” and the data translation tool used as part of “field” are being developed as part of this effort; all other functional objects are independently-created databases (such as those by sidewalk or transit agency owners), servers maintained by third-party application developers or transportation agencies, or personal devices maintained by digital device end users that all may support or demonstrate the TDEI system. In the context of other databases that have data to share that is already in the correct data schema that can be submitted to the TDEI system, these would be treated as support systems. The TDEI developer tools reside in the data translation computer, housed in the orange field box in this diagram.

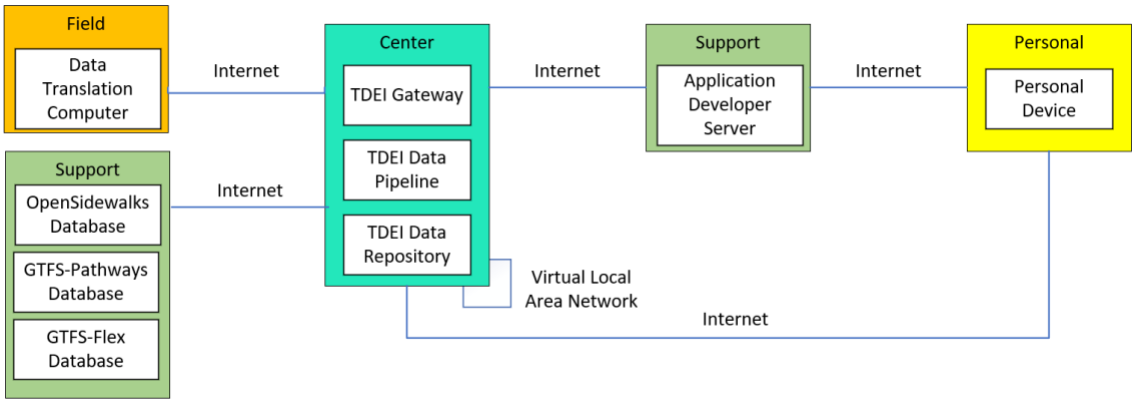

Figure 5 TDEI System Physical View: Level 2

4.2.2 Service Package Diagram

The service package diagram for the TDEI project is shown in Figure 6. This diagram assembles the physical and functional objects described in the previous subsection and illustrates the information flows that provide the desired level of service.

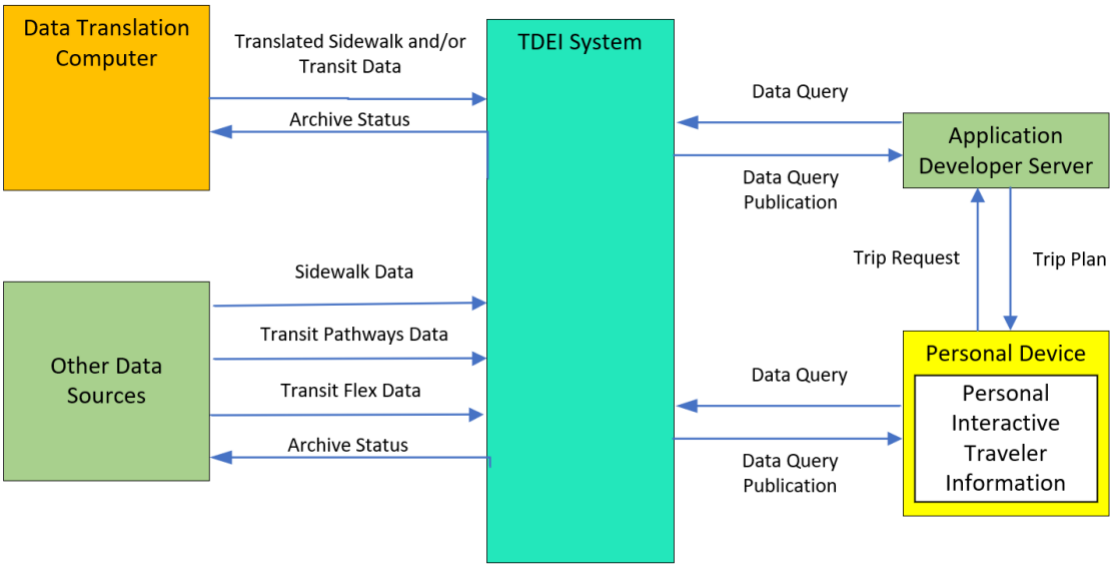

Figure 6 TDEI System Physical View: Service Package Diagram

Since the proposed system is of a unique design, it does not align exactly with the traditional ITS service packages offered as part of ARC-IT Version 9.1, although there are some similarities in a few of the offerings. Certain offerings in the traveler information service area, specifically Service package TI02: Personalized Traveler Information and TI04: Infrastructure-Provided Trip Planning and Route Guidance, as well as PT08: Transit Traveler Information in the public transportation service area, provide some of the building blocks that align with the proposed system here, although none are a perfect fit. Two service packages exist in the data management service area of ARC-IT Version 9.1, although neither the DM01: ITS Data Warehouse nor DM02: Performance

Monitoring align with the structure of the system since these service packages act more as support systems that store archive data across multiple transportation purposes.

For this proposed system, two custom service packages are most applicable:

- **Data submission, vetting, and incorporation:** Involves specific services involving the submission of sidewalk, transit pathways, or transit flex data from data producers to the TDEI system, and status verification from TDEI that the data was received and/or accepted.
- **Trip-specific data requests:** Involves specific services involving the request of trip-specific travel data for sidewalks, transit pathways, or transit flex service data, made by approved data consumers to the TDEI system, with the system providing the requested data to approved parties.

4.3 Functional View

This section provides the functional architecture view to describe the functions performed by the TDEI system. Specifically, it discusses processes associated with the TDEI system, processes associated with tools to transform the data, the associated data flows between processes and/or external objects, and any known terminators for information. This information is shown on a functional architecture in Figure 7, and is intended to show a high-level view of the architectures and functions discussed in the Phase 1 Enabling Technology Readiness Assessment.

Like the physical view, many of the processes offered by ARC-IT are more applicable to traditional ITS projects and have less relevance to the proposed system. Several processes under the Trip Planning (Level 6.1) and Provide Traveler Personal Services (Level 6.8) processes have similarities but are lacking the specifics associated with the functional processes offered by the TDEI system. As such, the processes proposed for this functional architecture are customized for this application.

4.3.1 Data Submission, Vetting and Incorporation

To support the proposed service package of data submission, vetting, and incorporation, the TDEI system will perform a total of 11 processes. The processes categorized by type of function are listed below.

Submission of data via the data translation tool, which is planned to be provided as web-based interface with source code available on the TDEI GitHub site:

1. Transform sidewalk data into OpenSidewalks data schema.
2. Transform transit pathway data into GTFS-Pathways data schema.
3. Transform transit flex data into GTFS-Flex data schema.
4. Submit data to TDEI system for validation and integration.
5. Confirm acceptance or rejection.

Submission of sidewalk data already in the OpenSidewalks data schema:

6. Submit OSW data to TDEI system for validation and integration.

7. Confirm acceptance or rejection.

Submission of transit pathways data already in the GTFS-Pathways data schema:

8. Submit GTFS-Pathways data to TDEI system for validation and integration.
9. Confirm acceptance or rejection.

Submission of transit flex data already in the GTFS-Flex data schema:

10. Submit GTFS-Flex data to TDEI system for validation and integration.
11. Confirm acceptance or rejection.

Figure 6 shows the confirmation of acceptance or rejection of data as Archive Status. The notification of acceptance or rejection is automatically sent to the user by the TDEI system without manual intervention. The notification may be a response to an API call or an email depending on the type of validation process used and the length of that validation process. Further, in the case where data is rejected, the data is not stored in the TDEI system, and the temporary copies of that data used for data validation are deleted from the system. Finally, when data is rejected, the user will be provided with information as to why the data was rejected.

All of these processes will use the TDEI authorization and authentication process described in the Interface Control Document (ICD).

4.3.2 Trip-Specific Data Requests

To support the proposed service package of trip-specific data requests, the TDEI system will perform a total of 4 processes. The processes categorized by type of function are listed below.

Data requests from application developers:

1. Request trip-specific travel data.
2. Send trip-specific OSW, GTFS-Pathways, and/or GTFS-Flex travel data.

Data requests from personal devices:

3. Request trip-specific travel data.
4. Send trip-specific OSW, GTFS-Pathways, and/or GTFS-Flex travel data.

4.3.3 TDEI Data Flows

The data flows associated with the TDEI system are shown in Table 8 on the next page.

Table 8 TDEI Data Flows

Flow Name	Source Element	Destination Element	Data Format
Sidewalk data	Data Generator	TDEI System	OpenSidewalks
Transit pathways data	Transportation Service Provider or Data Generator	TDEI System	GTFS-Pathways
Transit flex data	Transportation Service Provider or Data Generator	TDEI System	GTFS-Flex v2
Query for sidewalk data	Application Developer/System	TDEI System	API request
Query for transit pathways data	Application Developer/System	TDEI System	API request
Query for transit flex data	Application Developer/System	TDEI System	API request
Query-specific sidewalk data	TDEI System	Application Developer/System	API response, OpenSidewalks data format
Query-specific transit pathways data	TDEI System	Application Developer/System	API Response, GTFS-Pathways data format
Query-specific transit flex data	TDEI System	Application Developer/System	API Response, GTFS-Flex v2 data format
Query for sidewalk data	Personal Device	TDEI System	API request
Query for transit pathways data	Personal Device	TDEI System	API request
Query for transit flex data	Personal Device	TDEI System	API request
Query-specific sidewalk data	TDEI System	Personal Device	API response, OpenSidewalks data format
Query-specific transit pathways data	TDEI System	Personal Device	API Response, GTFS-Pathways data format
Query-specific transit flex data	TDEI System	Personal Device	API Response, GTFS-Flex v2 data format

4.3.4 System Terminators

Relevant terminators for the system include:

1. Sidewalk data in the OpenSidewalks data format, stored locally with a third-party (likely a transportation agency)

2. Transit pathway data in the GTFS-Pathways data format, stored locally with a third-party (likely a transportation agency)
3. Transit Flex data in the GTFS-Flex data format, stored locally with a third-party (likely a transportation agency)
4. Application developer systems that provide services to digital-device end users, utilizing their own means and methods to provide services, but may submit queries for sidewalk or transit-related data.
5. Personal device that serves as the interface for the digital device end user, which may submit queries for sidewalk and/or transit-related data from mobile applications located locally on the personal device. This instance is not expected to be common but would apply to mobile applications that do not use an intermediary application developer server and instead request data from the TDEI system.
6. USDOT ITS Data Hub, which is expected to pull data from the TDEI in accordance with the Data Management Plan. *(Service Package: Data Query Publication)*

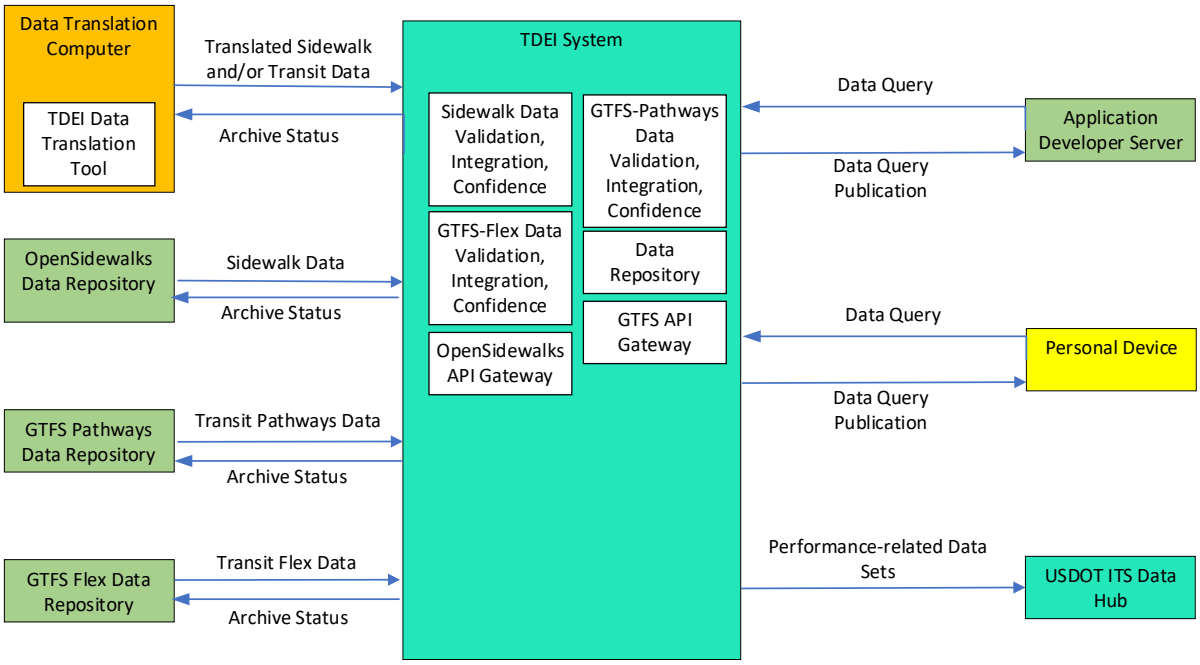

Figure 7 TDEI System Functional View

4.3.5 Data and Information Flow View

This subsection identifies key individual data flows, based on the functional viewpoint.

4.3.5.1 Sidewalk Data Submission

Figure 8 in a later section shows the comprehensive data flows involved with the submission of data to the TDEI system, including submission of sidewalk data. As outlined in the previous processes, data generators can either submit sidewalk data in the OpenSidewalks data format or utilize the TDEI data translation tool to convert into the OpenSidewalks data format. Once submitted over the public internet, the data goes through validation and quality assurance steps to make sure the data meets the OpenSidewalks schema and the data. The data generator is notified that the data is accepted or rejected along with information about why the data was rejected. If the data is accepted, the TDEI system undertakes additional steps to conduct graph analytics and augment the data to other applicable resources. It is then submitted to the Data Repository for storage.

4.3.5.2 Transit-Related Data Submission

Figure 8 in a later section shows the comprehensive data flows involved with the submission of data to the TDEI system, including submission of transit pathways and flex data. As outlined in the previous processes, data generators can either submit transit-related data in the GTFS-Pathways or GTFS-Flex (as applicable) data format or utilize the TDEI data translation tool to convert into the appropriate GTFS data format. Once submitted over the public internet, the data goes through validation and quality assurance steps to make sure the data meets the GTFS-Pathways or GTFS-Flex (as applicable) schema, and the data meets acceptance and quality criteria. The data generator is notified that the data is accepted or rejected along with information about why the data was rejected. If the data is accepted, the TDEI system submits the data to the Data Repository for storage.

4.3.5.3 Sidewalk or Transit Data Query

Figure 8 in a later section shows the comprehensive data flows involved with the distribution of data from the TDEI system to data consumers, which includes application developers and digital device end users. As outlined in previous processes, application developers may request this type of data to support the services they offer digital device end users. In the context of this system, the application developers put in a query through their server to the TDEI system's API, either for OpenSidewalks data requests or GTFS-Pathways/GTFS-Flex requests. The API will pass the necessary request information to pull data from the data repository. Data pulled from the repository would be sent back to the application developer server that made the request. All data exchanges between the TDEI system and the application developer server would be done over the public internet. Local data exchanges between the data repository and the APIs would occur over a virtual local area network.

4.4 Communications View

The communication view describes the communications protocols necessary to implement the information flow between physical objects, shown earlier in Section 4.2. These protocols are necessary to provide the necessary interoperability and communications between these objects, as well as meet the system requirements associated with function and performance.

This section outlines tables that illustrate the communications view for information flows between source and destination. Table 9 provides a review of the various flow names and applicable standards for flows associated with the TDEI system's physical objects.

The data exchanges between functional objects shown in Figure 7 occur over the public internet and will use the Hypertext Transfer Protocol Secure[8] (HTTPS) standard. HTTPS is an encrypted version of HTTP which uses Transport Layer Security[9] (TSL) over Transmission Control Protocol[10] TCP.

In terms of data standards, the ARC-IT Version 9.1 communication standards do not currently include the data standards which will be used by the TDEI: OpenSidewalks, GTFS-Pathways, and GTFS-Flex (although GTFS is defined). Table 9 shows both the communication standards and data standards which will be used for the information flows.

The TDEI will use Representational State Transfer (REST)ful API design[11] for a significant portion of its APIs. While REST is not a formal standard, REST is considered best practices in API design. In such cases, where RESTful functionality does not meet user needs, APIs may use alternate designs.

Finally, the TDEI will use the OAuth 2.0[12] and OpenID Connect (OIDC)[13] standards for security. Details on the TDEI registration, authentication and authorization processes are provided in the ICD.

Table 9 TDEI Information Triples and Standards

Flow Name	Source Element	Destination Element	Standards
Sidewalk data	Data Generator	TDEI System	OpenSidewalks
Transit pathways data	Transportation Service Provider or Data Generator	TDEI System	GTFS-Pathways
Transit flex data	Transportation Service Provider or Data Generator	TDEI System	GTFS-Flex v2

[8] “RFC 9110 HTTP Semantics.” June 2022. https://www.rfc-editor.org/rfc/rfc9110 (accessed Sept 6, 2022)

[9] “RFC 8446, The Transport Layer Security (TLS) Protocol Version 1.3”, August 2018. https://www.rfc-editor.org/info/rfc8446 (accessed Sept 6, 2022)

[10] “RFC 793, Transmission Control Protocol”, September 1981, https://www.rfc-editor.org/info/rfc793 (accessed Sept 6, 2022)

[11] Restful web API design. Microsoft. July 5, 2022. https://docs.microsoft.com/en-us/azure/architecture/best-practices/api-design (accessed Sept 7, 2022)

[12] OAuth 2.0. https://oauth.net/2/ (accessed Sept 7, 2022)

[13] OpenID Connect. https://openid.net/connect/ (accessed Sept 7, 2022)

Flow Name	Source Element	Destination Element	Standards
Query for sidewalk data	Application Developer/System	TDEI System	API request
Translated Sidewalk and/or Transit Data Submission	Data Translation Computer	TDEI System	Data: OpenSidewalks, GTFS-Pathways, GTFS-Flex Communication: HTTPS, REST Security: OAuth 2.0, OIDC
Archive Status	TDEI System	Data Translation Computer	Communication: HTTPS, REST Security: OAuth 2.0, OIDC
Sidewalk Data	Other Data Sources	TDEI System	Data: OpenSidewalks Communication: HTTPS, REST Security: OAuth 2.0, OIDC
Transit Pathways Data	Other Data Sources	TDEI System	Data: GTFS-Pathways Communication: HTTPS, REST Security: OAuth 2.0, OIDC
Transit Flex Data	Other Data Sources	TDEI System	Data: GTFS-Flex Communication: HTTPS, REST Security: OAuth 2.0, OIDC
Archive Status	TDEI System	Other Data Sources	Communication: HTTPS, REST Security: OAuth 2.0, OIDC
Data Query	Application Developer Server	TDEI System	Communication: HTTPS, REST Security: OAuth 2.0, OIDC
Data Query Publication	TDEI System	Application Developer Server	Data: OpenSidewalks, GTFS-Pathways, GTFS-Flex Communication: HTTPS, REST Security: OAuth 2.0, OIDC
Data Query	Personal Device	TDEI System	Communication: HTTPS, REST Security: OAuth 2.0, OIDC
Data Query Publication	TDEI System	Personal Device	Data: OpenSidewalks, GTFS-Pathways, GTFS-Flex Communication: HTTPS, REST Security: OAuth 2.0, OIDC

Table 10 provides a review of the various flow names and applicable standards for flows which are outside the scope of the TDEI system itself, but which are part of the demonstration effort showing the TDEI system in use. These flows occur between the application developers and the personal devices that are owned by digital device end users. Since the TDEI project is not developing these flows, the standards used are for the discretion of the application developers, although it is likely that they will utilize HTTPS or similar communications protocols to support transmission of data over the internet. It is also not known what format trip data will be sent as, since this is likely subject to the application developer's preference and design. These standards are left as Unspecified as they are not defined or implemented by the TDEI project.

Table 10 External Information Triples and Standards

Flow Name	Source Element	Destination Element	Standard
Trip Request	Personal Device	Application Developer Server	(Unspecified)
Trip Plan	Application Developer Server	Personal Device	(Unspecified)

4.5 Security Architecture View

The TDEI system will use security features to ensure that only registered and authorized users can consume (download) data from and produce (upload) data to the TDEI. The TDEI will use APIs to send and receive structured data; the system will only permit application developers with approved API tokens to query the system and will only permit data generators who have been approved by a transportation service provider to upload data.

Data Consumers: Users that wish to consume (download) data from the TDEI will be required to register and receive an API key which they then use to retrieve data. There will be no restrictions on who may register for an API key. the registration process ensures that data consumers accept a data use agreement, that the TDEI team is aware of who is using the data and can contact data consumers to tell them about any interface updates or improvements. If anomalous behavior is detected for an API key – for example, a very high level of API requests – the user's API key will be deactivated. Detection of the anomalous behavior will be done by the system, and deactivation of the API key will be done by TDEI staff through an administrative interface. Since the roles and permissions are an administrative security task that are setup as part of registration, the API key verification is not shown in the architecture views as a primary data flow, but are discussed in greater detail as part of the ICD.

Data Generators: Users that will generate (upload) data for the TDEI will be required to register and be approved by a transportation service provider (such as a transportation agency); approval will be required from the transportation service provider for which the data generator is generating data. The data generator will also sign a MOU. The data generator will then be provided an account which they can use to upload data to the TDEI. Since the roles and permissions are an administrative security task that are setup as part of registration, the API key verification is not shown in the architecture views as a primary data flow, but is discussed as part of the ICD.

Standards: The OAuth2.0[12] and OIDC[13] standards will be used for authentication and authorization for all TDEI information flows.

5 Functional Components Diagram

The TDEI system is a software-focused project, in contrast with traditional ITS projects that deploy and connect hardware in the field with central operations. As such, key details associated with the TDEI architecture are not captured in traditional ITS architecture diagrams, yet these details are still appropriate for a System Architecture Document. The architecture diagram in Figure 8 in this section has been created from a software development perspective and serves as a roadmap which will be used as part of the Agile development process to help track and report which parts of the system have been developed and which are currently under development. As such, this architecture diagram was included as part of this System Architecture Document, even though it differs from the diagrams and relationships found in ARC-IT.

Figure 8 shows the functional components that make up the TDEI software architecture. This diagram focuses on the TDEI system which is shown as 'Center; in the physical architecture shown in Figure 5 and 'TDEI System' in Figure 7. Thus Figure 8 encompasses all components identified within the TDEI system, including the TDEI gateway, the TDEI data pipeline, and the TDEI data repository. On the functional components diagram, data generators are shown on the far left, which represent the user groups listed as data generators and transportation service providers that submit sidewalk, transit pathways, or transit flex data. Data consumers are shown on the far right, which represent the application developers that query for data. API Gateways serve as the interface between both groups and the TDEI system itself. The boxes and flows between the API Gateways represent the TDEI data pipeline and data storage components.

The intent of the functional components diagram in Figure 8 is to provide a conceptual view of the TDEI system from a software development perspective. The TDEI is using a microservices architecture[14] which is an architectural approach in which a single application is composed of many loosely coupled and independent components called microservices. Each box on the functional components diagram is considered a microservice, which conducts individual tasks (e.g. processing data, storing data, etc.) separately from other microservices. The data repository is designed as a microservice (labeled data service) as well. Figure 8 shows a notional data flow from the data generators on the left to the data consumers on the right; this flow is notional only and does not encompass all details of the data flow. Additional details are provided in the System Design Document (SDD).

Figure 8 includes data validation, integration, and confidence metric calculation services on the left-hand side of the diagram as these services are performed on all data ingested into the system. Data validation includes schema and formatting checks. On the right-hand side of the diagram, services used for data being consumed from the system are included – including formatting the data to meet the data consumers needs and caching to improve performance.

[14] Microservice Architecture Style. Microsoft. https://docs.microsoft.com/en-us/azure/architecture/guide/architecture-styles/microservices (Accessed Sept 8, 2022)

Certain microservices are used across the system – these microservices are shown at the bottom of the diagram as common services and include monitoring, documentation, backup and notification. The authorization service is also used across the system; however, it is positioned by the API gateway as that is where it is most predominately used.

Further details on the design are provided in the Phase 2 System Design Document.

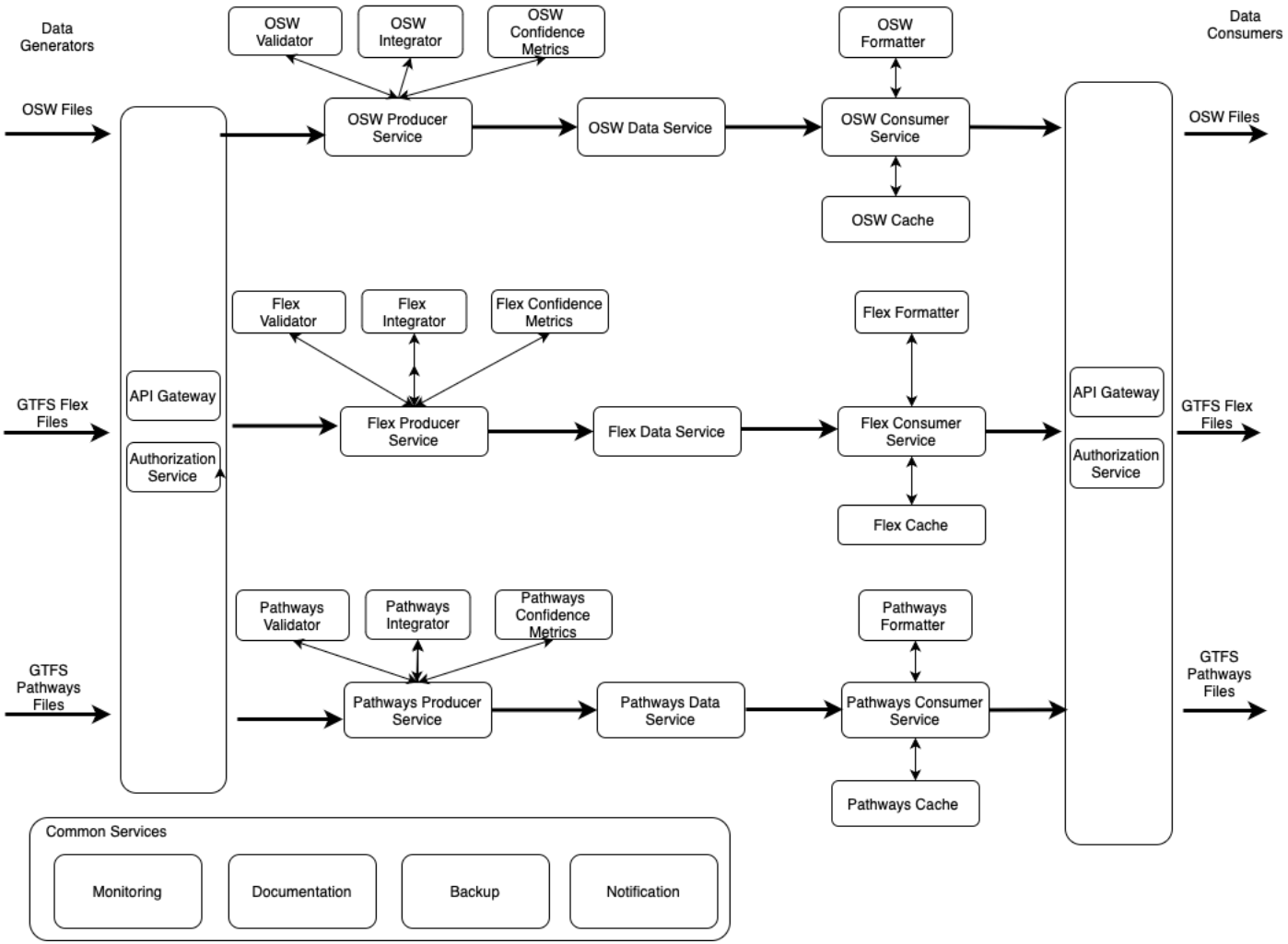

Figure 8 TDEI Functional Components Diagram

6 Appendix A Definitions, Acronyms, and Abbreviations

Acronym	Definition
AD	Application Developers
AOR	Agreement Officer's Representative
API	Application Programming Interface
ARC-IT	Architecture Reference for Cooperative and Intelligent Transportation
ATTRI	Accessible Transportation Technologies Research Initiative
ConOps	Concept of Operations
DOT	Department of Transportation
DS	Data Service Providers
DU	Digital Device End Users Experiencing Travel Barriers
GTFS	General Transit Feed Specification
GTFS-Flex	The Flex route extension to the General Transit Feed Specification, designed to describe demand-responsive or paratransit service
GTFS-Pathways	The Pathways extension to the General Transit Feed Specification which defines pathways linking together locations within stations
HTTP	Hypertext Transfer Protocol
HTTPS	Hypertext Transfer Protocol Secure
ICD	Interface Control Document
IEC	International Electrotechnical Commission
IEEE	Institute of Electrical & Electronics Engineers
IETF	Internet Engineering Task Force
ISO	International Organization for Standardization
ITS	Intelligent Transportation System
ITS JPO	Intelligent Transportation Systems Joint Programs Office
MOU	Memorandum of Understanding
OIDC	OpenID Connect
OIDF	OpenID Foundation
REST	Representational State Transfer
SAD	System Architecture Document
SDD	System Design Document
SOI	System of Interest
SyRS	System Requirements Specification
Taskar Center or TCAT	Taskar Center for Accessible Technology at the University of Washington
TCP	Transmission Control Protocol
TCRP	Transportation Cooperative Research Program
TDEI	Transportation Data Equity Initiative

Acronym	Definition
TLS	Transport Layer Security
TRAC	Washington State Transportation Center
UI	User Interface
UNCRPWD	United Nations Convention on the Rights of Persons with Disabilities
U.S.	United States
USDOT	United States Department of Transportation
UW	University of Washington
UX/UI	User Experience / User Interface

7 Appendix B Standards Plan

7.1 Introduction

This section covers the ITS Standards Plan for the TDEI system. Standards used by TDEI are described and traceability to system requirements is provided and finally standards gaps are identified.

7.2 Standards Used

The TDEI system is reliant on three standard types to facilitate the movement of data across the interfaces that are defined in the: communication networking standards, data schema standards and security standards.

7.2.1 Communication Networking Standards

Communication networking standards associated with the broadcast and transmission of data packets over the internet are used by the TDEI. The TDEI system both receives data from data generators and serves data to data consumers using the public internet, which allows greater flexibility for stakeholders and minimizes the chance of restricting access for a particular stakeholder that is not on the same private network. The TDEI system differs from most other traditional ITS projects in that it is a data service that interfaces with many third-party groups and is not dependent on connection to network-specific field devices, and thus the public internet is the best forum for providing access. The TDEI system uses HTTPS[8] over public internet in order to facilitate data exchange with other groups. HTTPS is a well adopted standard for this communication medium. In addition, the TDEI will use RESTful API design[11] for a significant portion of its APIs. RESTful APIs are considered best practice in API design and such design will be considered for all TDEI APIs. In such cases, where RESTful functionality does not meet user needs, APIs may use alternate designs.

7.2.2 Data Schema Standards

The second are data schema standards used to digitize the sidewalks, transit pathways, and transit flex data. The use of these standards is outlined below:

- The OpenSidewalks standard is used for describing the pedestrian-built environment including sidewalks. The OpenSidewalks standard is maintained by the Taskar Center for Accessible Technology[15] and is described by the following resources.
    - The OpenSidewalks website[4] describes the OpenSidewalks project.
    - The OpenSidewalks GitHub site[16] provides the Open Sidewalks schema.
- The GTFS-Pathways standard is used for describing transportation stations, particularly pathways through those stations. The GTFS-Pathways standard is maintained by Mobility Data[17] and is described by the following resources:
    - The GTFS-Pathways document[18] is a collaborative working tool for the GTFS-Pathways extension proposal and is a living document which evolves based on community feedback.
    - The current GTFS-Pathways standard specification can be found in the GTFS Reference[5].
- The GTFS-Flex-v2 standard is used for demand-responsive travel services (excluding real-time feeds). The GTFS-Flex-v2 standard is maintained by Mobility Data[17] and is described by the following resources:
    - The GTFS-Flex-v2 document[19] is the GTFS-Flex v2 extensions proposal working document and may evolve based on community feedback.
    - The GTFS-Flex-v2 GitHub site[20] provides information about GTFS-Flex-v2.
    - The current GTFS-Flex-v2 standard can be found on the GitHub site[21].

[15] Taskar Center for Accessible Technology. https://tcat.cs.washington.edu (accessed Sept 6, 2022)

[16] The Open Sidewalks Schema. https://github.com/OpenSidewalks/OpenSidewalks-Schema (accessed Sept 6, 2022)

[17] MobiityData. https://mobilitydata.org (accessed Sept 6, 2022)

[18] GTFS Pathways. http://bit.ly/gtfs-pathways (accessed Sept 6, 2022)

[19] GTFS Flex v2 extensions proposal. http://bit.ly/gtfs-flex-v2 (accessed Sept 6, 2022)

[20] GTFS Flex v2. https://github.com/MobilityData/gtfs-flex (accessed Sept 6, 2022)

[21] GTFS Flex v2 Specification. https://github.com/MobilityData/gtfs-flex/blob/master/spec/reference.md (accessed Sept 6, 2022)

7.2.3 Security Standards

The OAuth 2.0[12] standard is used for authentication and authorization in the TDEI. The OAuth 2.0 Authorization Framework specification[22] is maintained by the Internet Engineering Task Force (IETF) OAuth Working Group[23]. The OIDC[13] standard will also be used for authentication and authorization, OIDC is a layer on top of OAuth 2.0. OIDC is maintained by the OpenID Foundation (OIDF)[24].

7.2.4 Traceability

Communication networking standards, data schema standards are listed in the information flows shown in Table 9 Section 4.4 and the security standard is described in Section 4.5. Table 11 shows the traceability of the standards used for the information flows shown in Table 9 in Section 4.4 to TDEI system requirements from the Phase 1 ConOps. Note that some rows from Table 9 have been combined in Table 11 to reduce repetition and improve readability.

[22] OAuth 2.0 Authorization Framework specification. https://www.rfc-editor.org/rfc/rfc6749 (accessed Sept 7, 2022)

[23] IETF OAuth 2.0 Working Group https://www.ietf.org/mailman/listinfo/oauth (accessed Sept 7, 2022)

[24] OpenID Foundation. https://openid.net/foundation/ (accessed Sept 7, 2022)

Table 11 Interface Traceability Table

Information Flow Name(s)	Standard	System Requirement(s)
Translated Sidewalk and/or Transit Data Submission Data Query Publication	Data: OpenSidewalks, GTFS-Pathways, GTFS-Flex Communication: HTTPS, REST	F-DE-01 Data standards shall use attributes that support travel preferences of travelers. F-DE-01.01 Pedestrian built environment shall be described using the OpenSidewalks data standard. F-DE-01.02 Transportation stations and hubs shall be described using the GTFS-Pathways data standard. F-DE-01.03 Demand responsive travel services shall be described using the GTFS-Flex data standard, excluding real-time feeds. F-DE-02 The TDEI system shall use a common data model.
Sidewalk Data	Data: OpenSidewalks Communication: HTTPS, REST	F-DE-01 Data standards shall use attributes that support travel preferences of travelers. F-DE-01.01 Pedestrian built environment shall be described using the OpenSidewalks data standard. F-DE-02 The TDEI system shall use a common data model.
Transit Pathways Data	Data: GTFS-Pathways Communication: HTTPS, REST	F-DE-01 Data standards shall use attributes that support travel preferences of travelers. F-DE-01.02 Transportation stations and hubs shall be described using the GTFS-Pathways data standard. F-DE-02 The TDEI system shall use a common data model.
Transit Flex Data	Data: GTFS-Flex Communication: HTTPS, REST	F-DE-01 Data standards shall use attributes that support travel preferences of travelers. F-DE-01.03 Demand responsive travel services shall be described using the GTFS-Flex data standard, excluding real-time feeds. F-DE-02 The TDEI system shall use a common data model.

Archive Status Data Query	Communication: HTTPS, REST	F-SH-01 The TDEI system shall include data provisioning services that distribute data-on-demand for use in a variety of applications. F-SH-01.01 Data that is shared through the TDEI system shall be published on a Web service, either open to the public or through a requested API service. F-DI-01 The TDEI system shall use public-facing APIs to exchange data with application developers.
Authentication and Authorization for all information flows	Security: Oath2.0, OIDC	SEC-01 The TDEI system shall include user permissions that ensure the safe and secure transmission of data and metadata. SEC-02 The TDEI system shall include procedures that ensure the safe and secure transmission of data and metadata. SEC-05 The TDEI system shall ensure that the information technology (IT) policies and safeguards are consistently up to date to reduce unauthorized access to routing request data. MAN-02 The TDEI system shall contain different access levels (e.g., open and private), with defined user roles, to prevent unauthorized access of data and provide protection for sensitive private data.

7.2.5 Standards Gaps

The UW ITS4US project, the TDEI is developing a data repository which will be accessible to data generators and data consumers, including application developers via API over the public internet. As discussed above, the TDEI system differs from most other traditional ITS projects in that it not dependent on connection to network-specific field devices and uses public internet for communications. As such, traditional ITS standards are an imperfect fit for the TDEI. There are two types of standards gaps which are identified by this project – gaps in ITS standards and gaps in data standards.

For this SAD, the ARC-IT standard was loosely followed as can be seen in previous sections. However, the ITS service packages in ARC-IT Version 9.1 do not align exactly with the TDEI. Updates being made to ARC-IT will address some of these gaps. For this SAD, two custom service pages were added: Data submission, vetting, and incorporate and Trip-specific data requests. See Section 4.2.2 for details on these custom service packages.

In terms of data standards (OpenSidewalks, GTFS-Flex and GTFS-Pathways), a goal and output of this project is to identify updates to those standards to improve their usability for accessible transportation. Thus, the project is identifying gaps in those standards and will create proposed changes to those standards. The proposed changes will be published on the GitHub sites for the standards.

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