Phase 1 User Needs Identification and Requirements Planning

University of Washington ITS4US Deployment Project

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16. Abstract

This report is the User Needs Identification and Requirements Planning (UNIRP) document for the Transportation Data Equity Initiative project, an effort funded by the Federal Highway Administration's ITS4US program. The project, led by the University of Washington's Taskar Center for Accessible Technology and the Washington State Transportation Center, will develop a national pipeline of sidewalk data intended to help all people navigate more easily. The project will also help extend the national data standards for on-demand transit services (GTFS-Flex) and for mapping of multi-level transit stations (GTFS-Pathways).The project will demonstrate the use of those data and standards in three applications: a multi-modal, accessible travel planner (an extension of Access Map), an expansion of Microsoft's Soundscape application, which helps blind and low-vision people navigate and explore the environment, and a simulation tool to be built by Unity Technologies that allows travelers to explore the layout of transit stations prior to using those facilities.

The UNIRP describes the plan for identifying and prioritizing user needs, and the process by which those needs will be handled within the project. This includes recruiting and working with stakeholders.

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1. Introduction

This document defines the processes that will be used to generate, coordinate, approve, and support the configuration control of user needs and system requirements. This document also forms the foundation of the Systems Engineering Management Plan (SEMP) for the Transportation Data Equity Initiative (TDEI).

1.1. Project Background

Access to travel in the U.S. has significantly changed in the past 15 years. Traveler-focused tools, including mobility and wayfinding apps (such as MOOVEL, OneBusAway, Next Bus, Google's Directions, OpenTripPlanner), have given travelers an unprecedented ability to

a) search and discover transit services ("discoverability"),

b) be conveniently directed to transit services, including those for unplanned, serendipitous travel,

c) compare travel options,

d) filter those travel option by expressing personal travel preferences, and

e) streamline trip information in one application.

These mobility applications would not exist without the rapid diffusion of information and communication technology solutions into every field of mobility, along with the creation of novel data sharing approaches, such as those in Mobility-as-a-Service applications that are being tested as part of many Mobility-on-Demand projects. Combined, these changes enable and promote the use of a common infrastructure to collect, share, access, and search travel data in one application. This convenience should not be underestimated: it is transforming not only travelers' access to transit and other mobility services, but how people actually use and experience public transit overall, and it has even been linked with downstream impacts on determinants of health. Through the "new mobility ecosystem," more people are accessing more travel options, to more destinations, using more modes, including transit, than ever before.

However, many populations that have historically experienced travel disadvantages have yet to benefit from "new mobility" in the same way. Integration of data about many different travel modes is still largely lacking, and most significantly, it is completely absent in regard to sidewalks and pathways. These infrastructure feature provide the integral links that connect all modes in the "complete trip." Moreover, the established "new mobility" data infrastructure has focused chiefly on specific travel modes—personal vehicles and fixed route transit—yet travel-disadvantaged groups have typically required integration of some on-demand transit to complete their trip. Hence, the new mobility applications have marginalized some groups of people by excluding information about pedestrian environments and the on-demand transit services that some travelers use either exclusively or in conjunction with other modes.

The Transportation Data Equity Initiative will build a sustainable inclusive data infrastructure to enable and accelerate the future of equitable mobility and access to transportation. Our private/public partnership will achieve three goals towards this end:

1. **Coordinate Collaborative Releases of Data Standards**

Through community leadership, we will co-create, improve, and extend data formats that describe currently under- or un-represented detailed travel network information about:

(a) the pedestrian-built environment (sidewalks and footpaths)—**OpenSidewalks**

(b) transportation stations and hubs—**GTFS-Pathways**, and

(c) demand responsive travel services—**GTFS-Flex (excluding Realtime feeds)**.

2. **Publish and Maintain Interoperable Data Infrastructure**

By the end of Phase 2, our team will publish the collected data for the six U.S. counties that are part of this project. We will maintain them for five years after the conclusion of Phase 3 of this project, thereby supporting our own and any third-party applications interested in consuming the data. The six counties are King and Snohomish counties in Washington State, Multnomah and Columbia counties in Oregon, and Harford and Baltimore counties in Maryland. OpenSidewalks data is expected to be available in all six counties. While we hope to provide GTFS-Flex data for all six counties, data availability will depend on the cooperation of multiple agencies in those counties. This will be part of the outreach effort of the program, but the results of that outreach effort is unknown at this time. GTFS-Pathways data will be demonstrated at a set of transit centers in the three states. The exact number and location of transit centers will be a function of the comfort level of the transit agencies that will ultimately be responsible for the maintenance of that data, and the overall cost of the data collection process.

3. **Deploy and Sustain Three Accessible Mobility Applications**

These three standards are intended to allow a wide range of mobility application. As part of our three phase ITS4US project, we will demonstrate the use of these standards. Consequently, we will deploy three accessible mobility applications consuming standardized data that demonstrate the versatility and scalability of the data infrastructure: closing information gaps for three very **different populations** and addressing demonstrably different ***travel goals***:

(a) **Multimodal AccessMap (by Taskar Center for Accessible Technology)-** a comprehensive multi-modal personalized routing (A to B trip planning) web and mobile application addressing needs of people with **mobility limitations*,*** particularly supporting ***travel and exploration through new environments***. This application will use data from all three standards to allow multi-modal trip planning.

(b) **Soundscape (by Microsoft)**- a specialized orientation and ***exploration*** mobility iOS application enabling travelers who are **Blind and Visually Impaired** to perform ***spontaneous travel*** and ***explore new pedestrian environments*** without having to specify a destination. This application extension will take advantage of the OpenSidewalks data standard.

(c) **3-D Digital Twin (by Unity Technologies)-** a 3-D simulation tool that allows travelers (specifically addressing the needs of **sighted older adults and multilingual multicultural travelers**) to ***explore and visualize*** a trip path through a transit station that they need to take prior to taking that trip. This application will primarily take advantage of the GTFS-Pathways data standard, although it is expected to link to take advantage of the OpenSidewalks standard as part of the connecting the transit center to the built environment that surrounds the center.

At USDOT's direction, the Transportation Data Equity Initiative has been divided into three separate phases. These phases are:

1) Concept Development
2) Design, Build, and Test
3) Operate and Maintain.

1.2. Intended Audience

The intended audience for this document is the TDEI team, its direct partners (Cambridge Systematics, Inc., Studio Pacifica, Unity Technologies, the City of Bellevue), its cooperating partners (the Washington, Oregon, and Maryland Departments of Transportation, and the firms Google, Microsoft and Facebook), potential partners that will generate data on transportation services and infrastructure that will be provided to travelers (e.g., on-demand transit service providers or cities that own or are responsible for sidewalks), potential application developers that will use the data we generate, and the United States Department of Transportation (USDOT). This document is designed to inform the development of User Needs, which informs the Systems Requirements, which in turn inform the Systems Engineering Management

1.3. User Needs and Requirements Update Process

This project involves multiple different components,

- the data desired for various mobility applications for various target populations,
- the data collection techniques, strategies and partnerships needed to collect those data at scale,
- the alternative partnerships, relationships and software needed to collect, vet, store, and make available those data, and
- the software applications required to interact with end users, use the available data, and deliver desired travel information to those users.

Each aspect of the project activities requires different user needs and a different update process.

Considerable research has been conducted on the needs of end user's, particularly with respect to the travel needs of underserved populations.[1, 2, 3, 4, 5]. They are well documented in the literature. These needs are also directly incorporated into the work that informs the data standards efforts associated with the adoption of the three standards being supported in this project; OpenSidewalks,[6] GTFS extensions or GTFS-Flex and GTFS-Pathways.[7] That is, the data being incorporated in the standards are specifically identified because they can be used to resolve a specific user need. Vetting of the collected data, to ensure it accurately represents the actual infrastructure in place or transportation services being provided, is key to maintaining confidence in the output of user applications, and thus, the procedures for vetting of data prior to its release is a key part of the data import process being developed within this project.

When a specific mobility application is being developed, to support the conduct of a specific travel activity by a specific target population, details of those user needs are explored in more detail. While this project will be demonstrating three specific applications, the focus of this project is on the ability to collect data at scale in support of the three data standards. That is, the success of the project will be driven more by the project team's ability to deploy tools and systems that can be widely used to inexpensively generate and distribute the data that fill the information gaps that currently prevent people of all abilities to benefit from new mobility services. The widespread availability of data in these data formats will allow a wide variety of application developers to greatly expand the delivery of that information far beyond this project, meeting user needs which are not directly discussed in detail in this project. That is, the detailed user needs for those future projects are **not** part of this project. However, the success of our applications will provide an

[1] Pierce, Bob, E. Plapper, J. Rizek, and Battelle Memorial Institute, "Accessible Technologies Research Initiative (ATTRI) User Needs Assessment: Stakeholder Engagement Report, May 2016, Report No. FHWA-JPO-16-354

[2] Nicholas Bolten, Veronika Sipeeva, Sumit Mukherjee, Anissa Tanweer and Anat Caspi. A pedestrian-centered routing approach for equitable access to the built environment. 2017. IBM J. RES. & DEV. VOL. 61 NO. 6:10 [NOVEMBER/DECEMBER 2017] 10.1147/JRD.2017.2736279

[3] Nicholas Bolten, Amirhossein Amini, Yun Hao, Vaishnavi Ravichandran, Andre Stephens, and Anat Caspi. "Urban sidewalks: visualization and routing for individuals with limited mobility." First International Workshop on Smart Cities and Urban Analytics (UrbanGIS). Seattle, WA: 2015.

[4] Susan Shaheen, et. al., Travel Behavior: Shared Mobility and Transportation Equity, August 2017, Report No. PL-18-007,

[5] Jacquelyn Broader, et. al., ATTRI Policy Roadmap for Development Policies to Enable Widespread Deployment, March 2020, Report No. FHWA-JPO-20-783

[6] https://wiki.openstreetmap.org/wiki/Proposed_features/sidewalk_schema

[7] https://gtfs.org/changes

excellent set of examples of the benefits to be obtained from the data contained in these standards, as well as the technical details of how to build applications which use those data.

This project will demonstrate the use of the three standards through three specific applications. The three applications represent three very different uses of the data standards. That diversity is intentional, as the applications are meant to illustrate the wide range of uses of the data we will be developing, with the intent of sparking additional developer interest.

The first of our example applications is a practical multi-modal routing application. The other two applications are designed to help individuals more effectively explore their environment, but have different user focuses. AccessMap will be extended from a sidewalk and pathway routing system to include multi-modal connections to fixed route and on-demand transit services, to demonstrate how information on the paths to and from transit stops are crucial for the creation of routes needed to ensure the successful completion of trips. User needs for identifying the availability and usability of on-demand transit and for identifying paths through complex station environments will be identified for this extension of AccessMap.

Soundscape is designed for use by individuals with visual impairments to explore their surroundings. It currently uses data from OpenStreeMap as input. The planned improvements include the incorporation of detailed sidewalk and path data, to further improve the ability of users to move about and explore the travel environment.

Digital Twin is a new application which allows a sighted user, to use a 2D or 3D simulation tool to “walk through” a multi-level transit center facility, in order to 1) increase their comfort level with making a trip that involves traversing a major transit center, and 2) improve their ability to complete trips that require such movements, when they are unfamiliar with the transit center they need to use. Needs are associated with the ability of a user to explore and navigate centers virtually and the data required to allow that exploration and navigation.

The user needs to be addressed in this project focus on the following aspects:

1. the need for data about outdoor pedestrian paths
2. the need for data about pedestrian paths through transit facilities
3. the need for data about available on-demand transit services
4. the information needed for agencies, companies, or community groups interested in collecting the detailed data required to meet the above three types of data needs,
5. the information required by companies wishing to obtain, understand, vet, store, and make accessible to application developers the data collected in bullet #4
6. the information needed by application developers who wish to obtain data from the data generators referenced in bullet #5.

These user needs flow directly from the project design, which is a function of the work the project team has done for the past four years on the topic of new mobility options for people with disabilities, the data required to meet those needs, and the tasks required to collect, vet, store, and distribute those data. These needs are documented more completely in references included in Chapter 2 of this project’s Concept of Operations report.

Note that one agency/company may participate in any combination of the activities associated with bullets 4, 5, and 6 above. For example, with the initial implementation of GTFS (i.e., data that

describe what fixed route transit services are being provided) the typical data environment is for a transit agency to pay the software vendor that supplies their scheduling software to produce a GTFS data feed (a standard format similar to that identified in bullet #3.) The transit agency then publishes an API which makes that data available (bullet #5.) That feed can be used directly by a developer using the information provided in a process such as bullet #6. Alternatively, a company such as Google may obtain and aggregate the GTFS feeds from many transit agencies, aggregate those data, and make them available to developers, thus reducing the effort for developers to scale their software across the nation. Google also uses that data to provide their own mobility applications.

Our project's goal is to generate the data needed for three networked transportation layers (pedestrian pathways, transit center pathways, and on-demand transit), that can be incorporated into the transportation ecosystem that was created by the original GTFS specification and data delivery mechanism. Our User Needs are focused on the tasks required to generate that ecosystem.

This means that the user needs and requirements supported by this project are a function of both the standards adoption process[8] and the scalable data collection procedures the project is investigating and developing. That is, all changes in supported user needs and requirements will be vetted, discussed and agreed to as part of the formal data standard adoption process. They will then be promulgated to users of those standards through the output of the standards process. Data on the GTFS standards, their extension, and their use can be found at https://gtfs.org/. Similar information on OpenSidewalks is currently available from the OpenSidewalks GitHub site. (https://www.opensidewalks.com/.) The OpenSidewalk documentation will be expanded as part of this project.

This project will participate in the data standards improvement tasks, but does not control them. Adopted changes in the data standards will have downstream impacts on the software developed under this project as they will change what user needs can be successfully addressed, potential adding or deleting the ability to meet some desired functionality. Changes in the user needs and requirements which our applications can successfully address will be reflected in this project through changes in the ConOps and Systems Requirements documents. All changes required will be discussed by the developer team and those participating in the standards process as the standards process progresses, allowing the development team advanced notification of potential upcoming changes, so that those changes can be accounted for in the code. Note that changes in the data standards themselves does not change the user needs associated with the basic functionality of how data are obtained, stored, and distributed to the applications that serve digital device using end users. However, revisions to adopted standards do change what data are being

[8] Changes to the overall GTFS set of specifications follow the process described here: https://developers.google.com/transit/gtfs/guides/changes-overview.

Voting procedures for GTFS standards are described here:
https://github.com/google/transit/blob/master/gtfs/CHANGES.md
Open Sidewalks standards procedures will follow these same approaches.

imported to the data lake developed under this project. The import of those new data require updates to the data vetting procedures built into the data ingest process in order to ensure the validity and integrity of the data being stored and distributed to those applications.

The other major impact on user needs and requirements is the availability of data within those standards. That is, available data collection in some geographic areas may not include all data items defined and included in the adopted standards. The data services which provide access to those data will need to clearly identify when these data are missing, and the application developers will need to write their applications such that they account for times when data are not available.

It is incumbent on application developers (not this project) to understand the data needs of their own target user groups for the activity they are enabling. However, the developer must be able to learn from the outcomes of bullets 1 to 6 above, whether the data they require for their application are available for their desired geographic service area, and if so, how they can obtain them (bullet #6.) This is a user need that is part of this project.

1.4. Applicable Documents

This document identifies the processes that will be used in the creation of the following documents.

- Concept of Operations (ConOps) for the TDEI project, and
- System Requirements (SyRS) for the TDEI project.

2. User Needs Identification

2.1. Introduction to User Needs

Potential participants with the system being developed within this project can be divided into five separate categories. These categories are:

- End user travelers, which includes caretakers,
- Application developers
- Data service providers
- Transportation service providers, and
- Data generators.

Each of these groups has a unique series of needs. The needs of the end users drive the intent and design of the applications. Applications depend on the availability of data from providers of that data in order to produce solutions that meet end user needs. Transportation services are typically the source of the data that describe the services they provide. They may deliver those data to the data aggregators who then act as the data service provider for application developers, or the transportation service provider may also serve directly as the data service provider to application developers. However, some data items required by application developers for use in creating the end product to be delivered to end users are most effectively obtained and delivered by some agency or company other than a transportation service provider. Thus, additional data generators need to be incorporated into our project.

User needs for each of these groups will be present in this project's User Needs Summary. These needs will be incorporated into the project's Concept of Operations. For each need identified within each of our five categories of users, the project will

- **Assign a unique number and title**,
- **Describe a Major Desired Capability (MDC) that results from that user need, (the MDC** which will be associated with the activities associated with that category of users and their activities)
- **Express those MDCs and user needs in a way that is solution free**, and
- **Captures the Rationale** for why that capability is needed in the system.

The following is an example of an End User need. This specific need is based on published findings from previous ATTRI research, in this case, the ATTRI User Needs Assessment.

> ID: UN-EU1
>
> User Need: Those who cannot use or do not have regular access to either a private vehicle nor fixed route transit, need access to consolidated traveler information regarding on-demand transportation services or mode transfer options in order to streamline "discovery" of the available services that satisfy their travel needs.

Major Desired Capability: Allows a user to quickly identify the existence of on-demand travel services which allow them to reach desired activities.

Solution Free Rational: Service descriptions need to be created in a standard manner, aggregated, and displayed in a manner that allows the user to identify feasible travel options and compare alternative travel options when more than one feasible alternative exists.

The second example illustrate an application developer user need. This specific user need could be split into two needs, but we have chosen to present it in this case as a single user need statement. User needs similar to this are found in many published works describing modern coding techniques. This specific example was taken from a Georgia Tech Coding Boot Camp.

ID: UN-AD1

User Need: Application developers need access to standardized data available through a standardized procedure (e.g., an API)

Major Desired Capability: Application developers should be able to obtain available data from data service providers, and have the data supplied have a similar data structure and coding schema to similar data from other geographic locations/transportation service providers

Solution Free Rational: Consistent use of standards reduces the cost of application development, decreases the cost of data provisioning and data sharing, and helps create both cost-efficient scalability of applications and cost-efficient delivery of that data.

2.2. User Needs Identification Processes

This section of the document describes the various ways that the project team will identify user needs.

2.2.1. Previously Identified User Needs

As noted previously in this document, a very large number of our user needs have been identified by prior work. That work includes:

- Previously published research by USDOT's ATTRI program
- Previously published work by TCRP such as TCRP-210, Development of Transactional Data Specifications for Demand-Responsive Transportation
- Research performed by the University of Washington for the development of the OpenSidewalks data schema
- Research performed by the University of Washington for the development of the AccessMap software and the personalized routing process developed for that application to meet the needs of users with different abilities
- Research performed by Microsoft Corporation for the development of Soundscape

- Research performed by TriMet and Google for the development and deployment of the GTFS standard
- Documented changes to both the GTFS standard and GTFS deployment guidelines over the period of use for that data standard
- Documented activities for the acceptance review of the OpenSidewalks data standard within the OpenStreetMap community
- Documented activity in the development of formally adopted extensions to the original GTFS standard including GTFS-Flex and GTFS-Pathways and other associated standards such as GTFS-Stations, GTFS-Levels, GTFS-Vehicles, etc.)
- Documented activities working on implementation and production of sidewalk data standards with the largest national paratransit operator, MVTransit, and software consulting firm DXC.
- Various guides and standards published to define and support best practices in the development and deployment of software.

2.2.2. Stakeholder Engagements

The TDEI project has created six specific stakeholder involvement groups for review of the data standards we will be working with and providing insight into the use of those data. These six groups are:

- Local community GIS and mapper group to collect neighborhood or city data
- An accessibility and equity oversight advisory group
- A paratransit accessibility and equity oversight advisory group
- Participatory design, testing, evaluation, and validation groups (inclusive of people with lived experience and their support network)
- Pathways and sidewalk mapping data standards special interest group (inclusive of travelers, Application developers, Data service providers, Transportation service providers, and Data generators)
- OnDemand transit operational data standards (GTFS-flex) special interest group (inclusive of travelers, Application developers, Data service providers, Transportation service providers, and Data generators)

These groups are specifically aimed at ensuring that the TDEI understands the End User's need for data as it is delivered through applications, as well as ensuring that the data collected to meet those needs are gathered and used in ways that meet the team's equity goals and ethical standards.

The TDEI has an ongoing co-design group for AccessMap. We continue to recruit participants to that effort through our ongoing relationships with various community support groups for people with disabilities (e.g., Lighthouse for the Blind.) Through those contacts and various email messages sent via those organizations, we recruit participants with lived experience to participate in the co-design process. When they join, we then work with them in small groups (currently virtually) going over aspects of how they use data to make travel decisions. Those inputs are used to shape how data we can obtain are provided to them via AccessMap.

When individuals (or individuals that represent companies/agencies) are interested in the TDEI, they are directed to the project web site (https://transitequity.cs.washington.edu/). The web site allows each user to sign up for one or more of the six stakeholder groups. Each of these groups

will be engaged by 1) sending emails with attachments requesting comments on key project details, and 2) with periodic virtual meetings. The number and timing of these meetings will vary both between stakeholder groups and over the course of the project. For example, while specific data standards are being worked on, video meetings might occur once a week. In contrast, the ethics and equity stakeholder groups will meet roughly every two months, and specific members of the participatory design group may meet for 15 minutes daily while specific software development tasks are being performed.

The TDEI team is actively recruiting stakeholders through the TRB Pedestrian Committee (ACH10), the Bicycle and Pedestrian Data Subcommittee (ACP70(3)), and the Accessible Transportation and Mobility Committee (AME50). We are also recruiting project stakeholders from the various ongoing standards efforts (GTFS-Flex, GTFS-Pathways, OpenSidewalks.)

In addition to these groups, the TDEI will work with agency and company stakeholders on the technical side of data collection, storage and sharing. These later stakeholders include agencies and companies that provide both fixed routes and demand-responsive services, and companies that work in the transit information environment. This latter category includes large technology firms that currently act as data aggregators (e.g., Google for GTFS data), application developers (e.g., Transit, MOOVEL, CityMapper, Google, etc.), and software service providers to the transit agencies (e.g., INIT, GIRO, Optibus).

These groups will be recruited in three ways.

Transit service providers will be contacted directly and invited to participate. For example, we anticipate interacting with Washington's Sound Transit, Oregon's TriMet, and the Maryland Transit Administration when working on the approach to collecting data on fixed route transit centers. The UW Team already has direct contact with both Sound Transit and TriMet staff on these subjects. We will work with Maryland DOT to identify the correct Maryland Transit Administration staff to work with. Other transit agency personnel will be recruited and involved in the project on the basis of 1) their direct interest, and 2) the advice of the state departments of transportation that are supporting this project.

Similarly, the state DOTs will assist the TDEI in recruiting on-demand service providers as part of the GTFS-Flex portion of this project. The TDEI team is already working with King County Metro and their contractor MV Transit in this area. Similarly, we are working with the CALACT ITS4US team, which is also working with on-demand transit service provision. These agencies and the firms that support them will be engaged for both determining the data that should be incorporated into the extension of the GTFS-Flex standard, the coding of such an extension, and the work required to generate data in those standards given the current on-demand scheduling software.

Finally, the project team will work with the development community on the development and refinement of the steps required to perform the required data sharing. These stakeholders will be recruited from the current Data Standards community as well as from the TDEI team's direct knowledge of this community. These stakeholder engagements will take place within the context of the ongoing data standards work in which these stakeholders are already participating.

These engagements will operate much like the data standards efforts. Google Docs will be used to share requirements and proposed alternatives. Stakeholders will be able to comment on those requirements and alternatives within the documents. Periodic live video conferencing-based meetings will allow further discussion of those comments. Formal voting will be used to resolve outcomes where consensus is not possible.

The outcomes from these multiple stakeholder efforts result in insight into the required functionality of the entire system being developed. These insights will then be converted into any required changes in the ConOps and Systems Requirements for the project. These changes will then be documented in revisions to the ConOps and SyRS documents.

2.2.3. Use Case Decomposition

Development of use cases is based on the work the UW team has performed over the past four years. We developed the OpenStreetMap data standard specifically to respond to end user needs identified through both the personal lived experience of the UW team members, and through an extensive participatory design process performed throughout that four-year period. The participatory design effort was specifically designed to identify end user needs in ways that allow the collection of quantifiable statistics which could then be collected, stored, and presented to travelers in order for them to make personalized routing decisions.

This gives us considerable insight into the use cases that will drive the design of the TDEI. Those use cases cover the needs of all five user categories:

- End user travelers, which includes caretakers,
- Application developers
- Data service providers
- Transportation service providers, and
- Data generators.

Note that the TDEI is designed around the collection and provision of data required by individuals with disabilities that affect their mobility. The overall interaction of these user categories are shown in the figure below, with end users interacting with the applications on the right side of the figure. Application developers interact with the data service providers who are found in the blue box in the center of the figure (although application developers can also choose to interact directly with the data generators shown at the top and at the left of the figure.) Transportation service providers generate data about those services and are primarily found at the top of the image. (Local jurisdictions may generate sidewalk data. That option is not shown in this image.) Data generators other than the transit service providers are shown on the left side of the image.

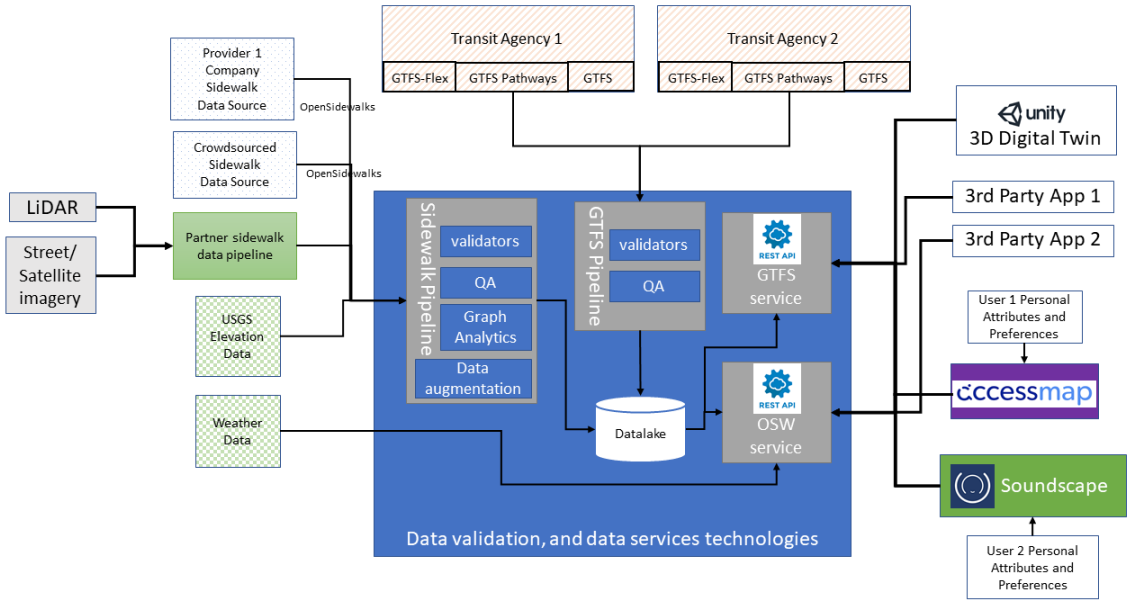

Figure 1: TDEI Data Flow Diagram

The TDEI project includes three example applications that will be directly used by end users. Use cases associated with End Users will be presented with those specific applications. AccessMap which will provide multi-modal trip planning assistance including both on-demand transit, and the first/last “50-foot” access paths needed to reach those transit services or reach the trip’s destination after being dropped off by those services. Soundscape allows for blind or low-vision users to explore geographic areas through which they are traveling. Digital Twin allows end users to preview paths through transit centers.

The other use cases to be examined in the ConOps describe the activities that are required by the participant groups in the TDEI that are not end users. For example, the ConOps will describe multiple potential mechanisms for how data are collected, vetted, and made available. Some use cases will examine the different mechanisms by which sidewalk data flow through this process, and others will examine how transit agencies can generate and make available data that describe the layout of transit centers and on-demand transit services. For all data use cases, the data standards will describe the data desired from the data generators, and the ConOps will explore how those data are generated, vetted, and made available.

Other use cases will examine how data service providers (e.g., data aggregators) will obtain data being produced by multiple data generators, vet those data (which may include different procedures than the initial data generation) and make them available to developers via easily used standard protocols.

2.3. Concept of Operations Development

The initial version of the Concept of Operations for the TDEI is being written as part of Task 2 for the project. The initial deliverable for that effort is the User Needs summary. The ConOps is based on the model of existing multi-agency, large data navigation systems, with an emphasis on

the approach successfully taken with GTFS. The ConOps assumes multiple data suppliers and applications, each of whom has a business reason to either

- generate, collect, and supply data on Pedestrian or transit facilities, or transit services,
- obtain, vet, aggregate, and serve those data, or
- use those data as input to an application that supplies information desired by an end user.

The ConOps will present the flow of information between the five categories of system participants. It will be developed in accordance with IEEE Standard 1362-1998.

2.3.1. ConOps Development Schedule

The ConOps development started in mid-February 2021. The initial user needs summary will be delivered to USDOT on April 19, 2021. The initial ConOps draft report will be delivered to USDOT on May 24, 2021. The Final user needs summary will be delivered on May 3, 2021. The Final ConOps report will be delivered on June 28, 2021.

2.3.2. ConOps Walkthrough

A walkthrough of the ConOps will be performed most likely during the week of June 14 - 18, 2021. A draft walkthrough briefing deck will be delivered to USDOT on May 24, 2021. After receiving comments from USDOT, a refined walkthrough briefing deck and project material will be sent to walkthrough participants at least one-week prior to the ConOps walkthrough.

Because much of the operational concept being proposed for this project follows procedures already in common use (e.g., the procedures used to create and deliver fixed route GTFS data, and the procedures used to create and deliver pathway data in OpenStreetMaps), the team expects the ConOps walkthrough to take no more than two days. The UW team will happily extend the planned ConOps walkthrough if the USDOT prefers a longer meeting after having reviewed the team's draft walkthrough briefing deck, although the UW team expects a number of our Walkthrough stakeholder participants to be available for only portions of even a two-day meeting. We will structure the Walkthrough so that they can attend those portions of the meeting that most apply to them and their organizations. This is particularly true for staff from some of the larger technology firms we are working with in order to help scale the data systems.

The walkthrough will consider the following aspects of the TDEI effort:

- Overview of the overall system design and data flow,
- User needs associated with each step of the data flow
- Example use cases,
- Descriptions of alternative data provision models (multiple models are expected to operate simultaneously),
- Description of, and role of, data standards,
- Description of the need for, and design of, data vetting procedures,
- Institutional relationships and roles,
- Outline of planned business processes (multiple models operate simultaneously),

- Initial specifications, and a variety of other technical documentation may also be walked through in order to bring participants in the walkthrough up to speed on the current status and content of the three data standards being used.

Given the COVID-19 pandemic, the UW team expects the walkthrough to take place via video conference, likely using Microsoft Teams. The walkthrough will consist of

- UW team members,
- demand responsive service providers (including, but not limited to public agencies that provide paratransit services),
- transit agencies that own and operate multi-level transit centers (e.g., subway stations),
- local jurisdictions that are responsible for sidewalks,
- national data service providers (e.g., major technology firms such as Google, Microsoft, and Facebook),
- transportation application developers (e.g., Transit, CALACT), and
- USDOT staff and USDOT's contractors.

2.4. Agile Development Considerations

It is expected that many aspects of Agile software development will be incorporated into the development of the TDEI. The core of the project is the scalable development of data sets that are currently not in existence, along with the storage and delivery of those data, in a sustainable manner, on what is designed to be a national scale. The scaled delivery of these outcomes are a function of the software delivered, the business models of the participating institutions, and how those institutions react to the changing business environment (e.g., new opportunities for interaction with developers and end users) that these data make available. Whether the project team can deliver the technology which allows the various parties (private companies, governments, and government agencies) that can collect and supply the data at a low enough cost that those firms/agencies are willing to collect and supply that data is a significant risk within this project. Our agile process is specifically designed to work with these potential data suppliers in the co-design process to maximize the probability that this occurs.

Consequently, as new data collection systems are developed and demonstrated along with multiple use cases, the institutional partners (transit agencies, technology firms, and government jurisdictions) which will help deploy those systems will have considerable input into how the design and operation of those systems are finalized, and thus, how the required data are collected, and sustainable business processes are put in place. Feedback to the team from these partners will result in agile changes to the systems being developed and deployed.

3. Requirements Planning

This chapter of the UNIRP discusses how the TDEI plans to transition from our user needs to the system requirements needed to direct the software engineering and programming required to deliver the TDEI.

3.1. Introduction to Requirements Planning

The TDEI systems requirements cover the collection, vetting, distribution/sharing, aggregation, and provision of routine access to data from external application developers. In addition, system requirements are needed for the applications being extended or deployed as examples of how to use the data the TDEI will be making available. These system requirements define the technical activities and constraints which need to be performed to deliver the TDEI's desired functionality. The well-formed system requirements developed in the project's System Requirements document will be:

- Necessary
- Concise
- Solution free
- Attainable
- Complete
- Consistent
- Traceable
- Unambiguous
- Verifiable

The initial system requirements are associated with collecting data such that the quality of those data are sufficient to meet End User needs when they are appropriately used by applications constructed to meet those end user needs. The collected data need to be produced using the data standard formats in order to allow their widespread distribution and use.

The second major set of requirements involves the tasks required to transfer those data from the organizations that collect them to both the organizations that aggregate similar data from different sources or that use them directly as one of many inputs to an application. In addition to the basic data transfer requirements, data vetting requirements will be defined, as will data access, security, and privacy requirements.

The third set of requirements are associated with the development of the Digital Twin application and the extension of the AccessMap and Soundscape applications. These last two sets of requirements will be restricted to those extensions to the current applications which are made possible by access to the new data made available in via the three refined data standards.

3.2. Requirement Decomposition

System requirements for the TDEI are primarily found in the functional, performance, interface, and security categories. The TDEI does not require physical specifications.

Many of the TDEI requirements are functional. They describe specific functions that need to occur within each of the subsystems that make up the TDEI. One of the more significant sets of functional specifications are those associated with the generation of data – the primary goal of the TDEI. The data collection functions will also include performance requirements that describe the quality of the data, its attributes. The Interface requirements specifications then describe the linkages that are needed to move data between various subsystems within the TDEI framework. The security requirements provide an overarching set of outcomes which govern the overall structure and architecture of the TDEI.

3.3. System Requirements Traceability

System requirements traceability will take advantage of the user needs identification tags. User needs for the TDEI are divided into each of the five major categories of users, which are:

- End user travelers, which includes caretakers,
- Application developers
- Data service providers
- Transportation service providers
- Data generators

Each of these categories is associated with a specific set of functional requirements. Each requires specific interfaces with other categories of users in order to be able to perform those functions. The data that transfer across those interfaces have definable performance and security requirements.

Each of those requirements can be traced back to the user needs associated with the specific type of user that has been outlined in the User Needs section of the Concept of Operations document. That document will maintain traceability of the user needs through the system requirements process and then to software development and testing. A Needs-to-Requirements Traceability Matrix (NRTM) will also be included in the appendix of the System Requirements Document to assist with this task. Such a table typically uses the structure shown below.

Table 1. Example NRTM

User Need ID	User Need	Req ID	Requirement

3.4. System Requirements Document Development

The initial version of the Systems Requirements document for the TDEI is being written as part of Task 6 for the project. The system requirements are expected to be very similar to those used to develop and deploy multi-agency, large data navigation software and database systems, with an emphasis on the approach successfully taken with GTFS. The SyRS assumes multiple data suppliers and applications, each of whom has a business reason to either

- generate, collect, and supply data on pedestrian or transit facilities, or transit services,
- obtain, vet, aggregate, and serve those data, or
- use those data as input to an application that supplies information desired by an end user.

The SyRS will present the requirements for the services performed by all categories of system participants and the interactions between those participants. Requirements will also be generated by the data management plan and the performance measurement and evaluation support plan and its anticipated needs and activities.

3.4.1. SyRS Development Schedule

Formal work on the Systems Requirement document (SyRS) is expected to start in mid-July of 2021, when the Concept of Operations is accepted by USDOT. The proposed SyRS stakeholder review panel will be submitted to USDOT on August 16, 2021 and finalized on August 30, 2021. A draft of the SyRS document will be submitted on September 20, 2021 along with a draft SyRS Walkthrough workbook. The system requirements will be developed in accordance with the IEEE Standard 1233-1998. A draft response to comments on the Walkthrough briefing document will then be submitted on October 4, 2021. The final SyRS document and Walkthrough Comment Resolutions Reports will be submitted to USDOT on October 25, 2021. The following table presents these dates.

Table 2: SyRS Schedule

Task	Date
Systems Requirements Work Starts	Mid-July, 2021
SyRS Stakeholder Review Panel Initial Submittal	August 16, 2021
SyRS Stakeholder Review Panel Finalized	August 30, 2021
Draft SyRS	September 20, 2021
Draft SyRS Walkthrough	September 20, 2021
Draft Response to SyRS Draft Walkthrough comments	October 4, 2021
Final SyRS	October 4, 2021
Walkthrough Comment Resolutions Reports	October 25, 2021

3.4.2. SyRS Walkthrough

A walkthrough of the SyRS will be scheduled early in October 2021, likely the week of October 11th. A draft walkthrough briefing deck will be delivered to USDOT on September 20, 2021. After receiving comments from USDOT, a refined walkthrough briefing deck and project material will be sent to walkthrough participants at least one-week prior to the ConOps walkthrough, but no later than October 4, 2021.

Because many of the system requirements being proposed for this project follow systems already in common use (e.g., the procedures used to create and deliver fixed route GTFS data, and the procedures used to create and deliver pathway data in OpenStreetMaps), the team expects the SyRS walkthrough to take two days. This estimate may be revised based on both the time required for the ConOps Walkthrough and the number and complexity of the system requirements to be discussed. As with the ConOps Walkthrough, we will structure the Walkthrough so that some of our stakeholders can attend just those portions of the meeting that most apply to them and their organizations, given their limited time availability.

The SyRS walkthrough will be structured around the requirements associated with the user needs of our five categories of participants:

- End user travelers, which includes caretakers,
- Application developers
- Data service providers
- Transportation service providers, and
- Data generators.

Given the COVID-19 pandemic, it is unclear whether the Walkthrough will occur in person, as requested in the USDOT Broad Area Announcement (BAA), or whether it will occur remotely. The UW team has budgeted for an in-person Walkthrough. However, if travel restrictions remain in place, the Walkthrough can take place via video conference, likely using Microsoft Teams. A hybrid approach to the walkthrough is also possible in order to increase the ability for stakeholders to attend.

The Walkthrough participants are expected to consist of UW project team members, and stakeholders who represent:

- demand responsive service providers (including, but not limited to public agencies that provide paratransit services),
- transit agencies that own and operate multi-level transit centers (e.g., subway stations),
- local jurisdictions that are responsible for sidewalks,
- national data service providers (e.g., major technology firms such as Google, Microsoft, and Facebook),
- transportation application developers (e.g., Transit, CALACT), and
- USDOT staff and USDOT's contractors.

3.5. Agile Development Considerations

It is expected that many aspects of Agile software development will be incorporated into the development of the TDEI. The core of the project is the scalable development of data sets that are currently not in existence, along with the storage and delivery of those data on what is designed to be a national scale in a sustainable manner. The scaled delivery of these outcomes are a function of the software delivered, the business models of the participating institutions, and how those institutions react to the changing business environment (e.g., new opportunities for interaction with developers and end users) that these data make available.

Consequently, as new data collection systems are developed and demonstrated along with multiple use cases, the institutional partners (transit agencies, technology firms, and government jurisdictions) which will help deploy those systems will have considerable input into how the systems requirements are finalized, and thus, how the software being written is developed, as well as how sustainable business processes are put in place. Feedback to the team from these partners will result in agile changes to the systems requirements being used for development of the various components of the TDEI.

The UW Team will use a combination of Google Docs, Slack channels, code, and code documentation within GitHub to ensure that the diverse members of the TDEI development effort are well informed of potential changes in system requirements and have substantial input into how and why those changes occur, and what additional changes in the SyRS and ConOps are needed as a result of any adopted changes in specific requirements.

4. Configuration Management

This chapter of the UNIRP discusses how the TDEI plans to maintain our user needs and requirements as the project progresses.

4.1. Configuration Management Processes

As part of the Configuration management for our key documents (e.g., the ConOps and SyRS documents), the UW team will maintain detailed documentation versions and document histories, and will use access controls for users to control documentation changes.

Document versioning and management will have a devoted GitHub document repository for our project. This repository will preserve a single source of truth for documents, cut down on accidental forking and keep a reversible audit trail. The following best practices will be enforced across the group:

- Documents will be saved directly to GitHub
- Once collaborative version will be defined per file, while forks and branches will be regularly merged and generally deprecated
- Realtime collaborative editing will be disabled
- Typical GitHub validation rules will apply to spreadsheet integrations, where needed.

To manage users and control their access and permissions to these key documents, we will

- Using Git member permissions, we will allow different users with varying levels of permissions
- Project members will be allowed to annotate documents. Authentication via GitHub
- Conflicts would be impossible for annotators
- Project core members (assigned by the UW Team leads - CDL, SDL, and PML) will have edit role
- Editors can modify documents and metadata and export the documents as needed
- Editor version control will allow tracking project and document process and maintain an audit trail for all project documentation, allowing editors to work unimpeded and efficiently, while retaining the ability track changes and return to earlier versions should that be required
- Project core members will meet regularly as part of the agile development process to ensure that the impact of changes across the project's multiple work efforts are appropriately understood before those changes are adopted
- All configuration changes via the user interface and the API are logged.

For the software we will be creating in Phases 2 and 3, the UW Team will put in place configuration management practices that work within the agile development process. These include

- ensuring that new versions of data standards are backward compatible with older versions,

- versioning code sets that are checked in,
- adding build automation for each project,
- deployment tests, and
- continuous integration.

Versioning of Data Standards: As new versions of data standards are adopted, the TDEI must make sure that older software that use the original versions remain functional.

Versioning Code: Developers will be encouraged to check in working code on a regular basis (at least once a day) in order to minimize code loss and to help incorporate continuous integration with other systems that are being developed simultaneously. Each check-in to GitHub will version the code being checked in. Additionally, versioning will also be placed on build scripts and test scripts. This will allow the team (if necessary) to roll back the code to a known good version.

Build automation: Automated build will be setup for each project within GitHub using a tool such as the Jenkins plugin or Docker. The exact tool will be determined and put in place prior to beginning development work

Deployment Tests: Deployments will involve tight integration, with automation of steps when possible, for all pushes to the test and production environments. This is done to reduce deployment mistakes from developers when deploying applications. Additionally, tests that are written for each application will be run after each build to ensure that all code is functioning as intended. Any tests that fail will be reported to the developers responsible as well as the project manager and technical lead.

Continuous Integration: Continuous integration encompasses versioning, proper code check in, and automating builds and deployments. This practice will encourage developers to check in working code that will not negatively affect the entire system. Code that does break the system is typically caught early in the process when incorporating continuous integration practices into the system.

We will closely follow the process described below for requirements development.

Requirements Initialization: We will gather, analyze and develop requirements from the Concept of Operations (CONOPS), stakeholder needs, objectives and external requirements identified by the Initial Capabilities Document (ICD). Once requirements are documented, they are prioritized, de-conflicted, and validated with the stakeholders.

Codifying Requirements: After Requirement Initialization, we will focus on listing the functional and performance requirements into a appropriate requirements documents; Initial Capabilities Document (ICD) and Capability Development Document (CDD). Requirements will be documented in order to establish a requirements baseline to start building a system and manage any changes.

Validating Completeness via Requirement Tracing: Next focus will be to check that a complete set of requirements have been developed and documented that defines all system functions that are needed to satisfy the stakeholder needs with their associated performance, environmental, and other non-functional requirements. We will complete a Requirements Traceability Matrix (RTM) in this step.

Analyze, Refine and Decompose Traceability Matrix: Our Systems Engineering process will include a requirements analysis step in which we will examine each requirement to see if it meets the characteristics of a good requirement (I'm sure Noblis will ask for criteria to be described). Each requirement is then decomposed into a more refined set of requirements that are allocated to sub-systems and documented in the SyRS. Newly derived requirements are expected to emerge from this process, which continues until all requirements are defined and analyzed.

Validate Requirements against System and Stakeholder needs: After decomposition of requirements, the resulting requirements will be verified and validated to ensure that these are meeting the overall objective of the system and all stakeholder needs.

Requirement Acceptance: Multiple Stakeholders are re-engaged to accept overall requirements and establish commonly accepted baseline.

Manage Requirements: Any changes to the requirements through the iterative development process will be controlled using the Document Configuration Management process described above.

4.1.1. Initial User Needs and Requirements Development

The initial user needs and requirements are based on a large amount of previous research, which we will document in our initial capabilities document. Previous research includes, but is not limited to, the following:

- Previously published research by USDOT's ATTRI program
- Previously published work by TCRP such as TCRP-210, Development of Transactional Data Specifications for Demand-Responsive Transportation
- Research performed by the University of Washington for the development of the OpenSidewalks data schema
- Research performed by the University of Washington for the development of the AccessMap software and the personalized routing process developed for that application to meet the needs of users with different abilities
- Research performed by Microsoft Corporation for the development of Soundscape
- Research performed by TriMet and Google for the development and deployment of the GTFS standard
- Documented changes to both the GTFS standard and GTFS deployment guidelines over the period of use for that data standard
- Documented activities for the acceptance review of the OpenSidewalks data standard within the OpenStreetMap community
- Documented activity in the development of formally adopted extensions to the original GTFS standard including GTFS-Flex and GTFS-Pathways and other associated standards such as GTFS-Stations, GTFS-Levels, GTFS-Vehicles, etc.)
- Documented activities working on implementation and production of sidewalk data standards with the largest national paratransit operator, MVTransit, and software consulting firm DXC.
- Various guides and standards published to define and support best practices in the development and deployment of software.

The project team will work within the current international data standards process for the development of those standards. This involves working on shared Google Docs and formal voting of proposed additions and changes. The data standards groups also typically meet via video-conferencing every one to two months.

For user needs tied to application development, in addition to documentation sharing, sharing of code and code documentation will be done via GitHub repositories. One-on-one and small group meetings will also be held with specific developers on an as needed basis.

4.1.2. Baselined User Needs and Requirements

As noted above in section 4.1.1, for standards development (OpenSidewalks, GTFS-Pathways, and GTFS-Flex), the existing formal voting process will be used to adopt changes to the standards and the associated user needs they support. All standards changes are posted in the GitHub and Google Docs associated with those standards.[9] These efforts do not need a formal control board.

For user need changes that require alteration of the code which allows sharing of data between applications/databases/organizations, these changes will be formalized as part of the ongoing stakeholder discussions for data transfers (e.g., vetting, API design, etc.) This email and slack channel notification of requested changes, Google Doc and Slack channel discussions about those potential changes, and formal voting on decisions to revise either user need and requirements, or the code implications of those user needs and requirements. Formal changes will then be made in the Github repository with tracking of those changes handled through Github version controls.

4.2. Authoritative Source of User Needs and Requirements

The authoritative source for the TDEI's User Needs and Requirements will be the project's ConOps document. The ConOps uses the data standards (OpenSidewalks, GTFS-Pathways, and GTFS-Flex) as an authoritative document. The user needs described in the ConOps will be the authoritative source for the System Requirements (SyRS), which will guide the refinement of the Software Engineering Management Process (SEMP.)

Note, however, that this project is not designing to a single formal user needs and requirements case for end users. We are primarily designing a series of flexible procedures that collect data to meet a set of formal data standards, vet that data to the extent possible, and then share those

[9] Changes to the overall GTFS set of specifications follow the process described here: https://developers.google.com/transit/gtfs/guides/changes-overview.

Voting procedures for GTFS standards are described here:
https://github.com/google/transit/blob/master/gtfs/CHANGES.md
Open Sidewalks standards procedures will follow these same approaches.

data via readily accessible, standardized procedures for use by a wide range of applications which can fulfill multiple uses, and where each of those applications can have a different set of end user needs and requirements.

For the data themselves, the data standards process defines the authoritative source of user needs and requirements which were used in the development of those standards. The user needs and requirements of those standards will be reflected in our project's ConOps, and consequently the System Requirements and Software Engineering.

The user needs and requirements associated with the transfer of data between the data collector, the data repository, the data aggregator/data service provider, and the application developer will also be reflected in the ConOps, leading to the Systems Requirements document and ultimately the Systems Engineering document. Note that during Phase 2 of this project, it is possible that one or more private partner (e.g., Google, Facebook, or Microsoft), will take over the lead of one or more of these data transfer activities. If that occurs, the private partner is likely to follow their own design process, which may diverge from the project team's ConOps, using slightly different user needs and requirements which fit their specific business approach. If this occurs, the TDEI project team will address these changes in consultation with the USDOT project management at the time this becomes a possibility.

Appendix A. Acronyms and Glossary

ACH10	the Transportation Research Board's Committee on Pedestrians
ACP70(3)	Transportation Research Board's Bicycle and Pedestrian Data Subcommittee
AME50	the Transportation Research Board Committee on Accessible Transportation and Mobility
API	Application Programming Interface
ATTRI	Accessible Transportation Technologies Research Initiative
BAA	Broad Area Announcement
CALACT	California Association for Coordinated Transportation
ConOps	Concept of Operations document
DRT	Demand Responsive Transit
DOTs	Departments of Transportation
FHWA	Federal Highway Administration
GOFS	General On-Demand Feed Specification
GTFS	General Transit Feed Specification
GTFS-Flex	General Transit Feed Specification for demand-responsive or paratransit service
GTFS-Pathways	General Transit Feed Specification for pathways linking together locations within stations
ID	Identification number
IEEE	Institute of Electrical & Electronics Engineers
INCOSE	International Council on Systems Engineering
LIDAR	Light Detection and Ranging (a detection system which works on the principle of radar, but uses light from a laser
MDC	Major Desired Capability
SEMP	Systems Engineering Management Plan
SyRS	System Requirements Specifications
TCRP	Transit Cooperative Research Program
TDEI	Transportation Data Equity Initiative
UNIRP	User Needs Identification and Requirements Planning Document
USDOT	United States Department of Transportation
UW	University of Washington

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