Phase 1 Integrated Complete Trip Deployment Plan

University of Washington ITS4US Deployment Project

www.its.dot.gov/index.htm

Final Report — March 4, 2022
FHWA-JPO-22-948

COMPLETE TRIP
ITS4US

U.S. Department of Transportation

Produced by University of Washington (UW) ITS4US Deployment Program, Phase 1
U.S. Department of Transportation
Intelligent Transportation Systems Joint Program Office
Federal Highway Administration
Office of the Assistant Secretary for Research and Technology
Federal Transit Administration

Notice

Technical Report Documentation Page

1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.
FHWA-JPO-22-948		

4. Title and Subtitle	5. Report Date
Phase 1 Integrated Complete Trip Deployment Plan – University of Washington ITS4US Deployment Project	March 4, 2022
	6. Performing Organization Code

7. Author(s)	8. Performing Organization Report No.
Anat Caspi, Mark Hallenbeck, Kristin Tufte, Erin Flanigan, Alice Marecek, Adam Danczyk, Guilherme Leao,	

9. Performing Organization Name and Address	10. Work Unit No. (TRAIS)
University of Washington 4333 Brooklyn Ave NE Box 359446 Seattle, WA 98195-9446	N/A
	11. Contract or Grant No. 693JJ321C000004

12. Sponsoring Agency Name and Address	13. Type of Report and Period Covered
U.S. Department of Transportation ITS Joint Program Office 1200 New Jersey Avenue, SE Washington, DC 20590	
	14. Sponsoring Agency Code HOIT-1

15. Supplementary Notes

Kate Hartman, COR

16. Abstract

This document presents the Integrated Complete Trip Deployment Plan (ICTDP) for the University of Washington (UW) ITS4US Deployment Project, which is developing and deploying the Transportation Data Equity Initiative (TDEI). This ITS4US Deployment Project currently is in Phase 1, planning and systems engineering development, in which the preliminary idea is developed into a structured concept that is suitable for further design, building, testing, and operation.

This ICTDP summarizes the refined deployment concept developed in Phase 1 and sets forth the high-level Phase 2 (Design/Build/Test) and Phase 3 (Operate/Maintain/Evaluate) Schedule. It provides a refined Phase 1 deployment concept and the technical approach the UW ITS4US team will use for phases 2 and 3. It also provides the current deployment schedule for phases 2 and 3, along with a cost estimate for those phases.

17. Keywords	18. Distribution Statement
ITS4US; Complete Trip; Deployment; ITS; Intelligent Transportation Systems; Deployment Plan, Open Sidewalks, General Transit Feed Specification (GTFS)-Flex, GTFS-Pathways	N/A

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of Pages	22. Price
Unclassified	Unclassified	73	

Revision History

Name	Date	Version	Summary of Changes	Approver
Mark Hallenbeck, University of Washington	31 January 2022	1	Initial Draft	
Mark Hallenbeck University of Washington	4 March 2022	2	Final Report	

Table of Contents

List of Tables

List of Tables

List of Figures

1 Refined Phase 1 Deployment Concept

1.1 Introduction

1.1.1 Document Purpose

The Integrated Complete Trip Deployment Plan (ICTDP) serves several purposes. First, it summarizes the Transportation Data Equity Initiative (TDEI) deployment concept developed in Phase 1. Next, it provides a high-level design / build / test plan for Phase 2, and an operate / maintain / evaluate plan for Phase 3. Further, it provides detailed budgets and schedules for both Phases 2 and 3. Included with the budgetary plans are the financial plans for both the project and the five-year period following the project for which the ITS4US project is guaranteed to operate.

This Plan describes the overall outcomes to be achieved, the challenges to be addressed to achieve those outcomes, and the overarching deployment concept that addresses those challenges. In addition, it describes the objectives, performance measures, applications, and general nature of the UW ITS4US team's project deployment.

Next, this Plan describes the organization of the UW ITS4US team and the various partnerships that are part of the project's deployment, whether those partners are subcontractors to the team, public agencies and cities that supply and use the data we publish, third-party application developers, or community and advocacy groups.

Finally, the plan summarizes the following:

- the data generated and shared by the system
- the key performance measures and methods to be used to assess the project's impacts
- steps being taken to ensure the safety and privacy of participants and system security and
- the open-source software being produced by the project.

1.1.2 Organization of This Document

This Plan is divided into four chapters. Chapter 1 presents the final system concept that has resulted from the work performed in Phase 1 and whose design will be finalized, built, and tested during Phase 2. Also presented in this chapter is the current organizational structure and how that structure will be modified to effectively perform Phases 2 and 3. Finally, the chapter concludes with a discussion of the financial and organizational models that will be used to support sustained operations of the project, along with a discussion of the organizational risks associated with that plan.

Chapter 2 presents the detailed technical approach to the performance of Phases 2 and 3. This includes a description of how both phases will be managed; system architecture will be refined and built; data management will be performed; all necessary hardware will be acquired and installed, and software will be developed, integrated, tested, and released. Also described are how staff and participant training and stakeholder outreach will be managed, how data standards will be incorporated into the project and data collected, and how performance measurement will be performed and evaluation activities supported. In addition to these activities, for Phase 3, this chapter also discusses the plan for system operations and maintenance and post-deployment transition planning.

Chapter 3 presents the refined schedule for both phases, as well as a description of the identified risks to that schedule.

Finally, Chapter 4 presents both the detailed cost estimates for both phases and a summary of those costs. This chapter also describes the risks associated with the project cost estimates.

1.2 Deployment Concept

1.2.1 Project Motivation

Millions of Americans, in particular those with disabilities, who are older adults, or living in rural or suburban locales, cannot use or do not have regular access to either a private vehicle or fixed-route transit. Like all travelers, this cohort needs reliable, consistent information about the travel modes they use and the travel environments that connect these modes, together making up their Complete Trip. These data are currently neither consistently collected nor shared (e.g., about a path that is too narrow for a wheelchair). Similarly, service descriptions for flex-route transit services are not commonly used, standardized, or electronically provided. Lack of these data means that they cannot be conveniently aggregated or displayed in a single mobile application. Therefore, individuals who use these transit modes do not have equitable access to streamlined “discovery” of the available services that satisfy their travel needs.

By comparison, the communication technologies that urban, non-disabled, English-speaking travelers can currently access provide reliable trip information conveniently aggregated and shared in one place. This gives them the unprecedented ability to discover, compare, and select among scheduled-route travel options and to learn about infrastructure and amenities along segments of the trip. This project is meant to provide functionality to people of all abilities, in ways that allow those capabilities to be scaled nationally.

1.2.2 Project Aims

This project addresses these travel data needs and inequities by making key data available to underserved populations. It provides mechanisms for data collection, maintenance, and publication, as well as services for consumption, validation, and analytics. The UW ITS4US project will deliver this functionality in six counties in three states. These counties, shown in Figure 1, include King and Snohomish counties in Washington state, Multnomah and Columbia counties in Oregon, and Harford and Baltimore counties in Maryland.

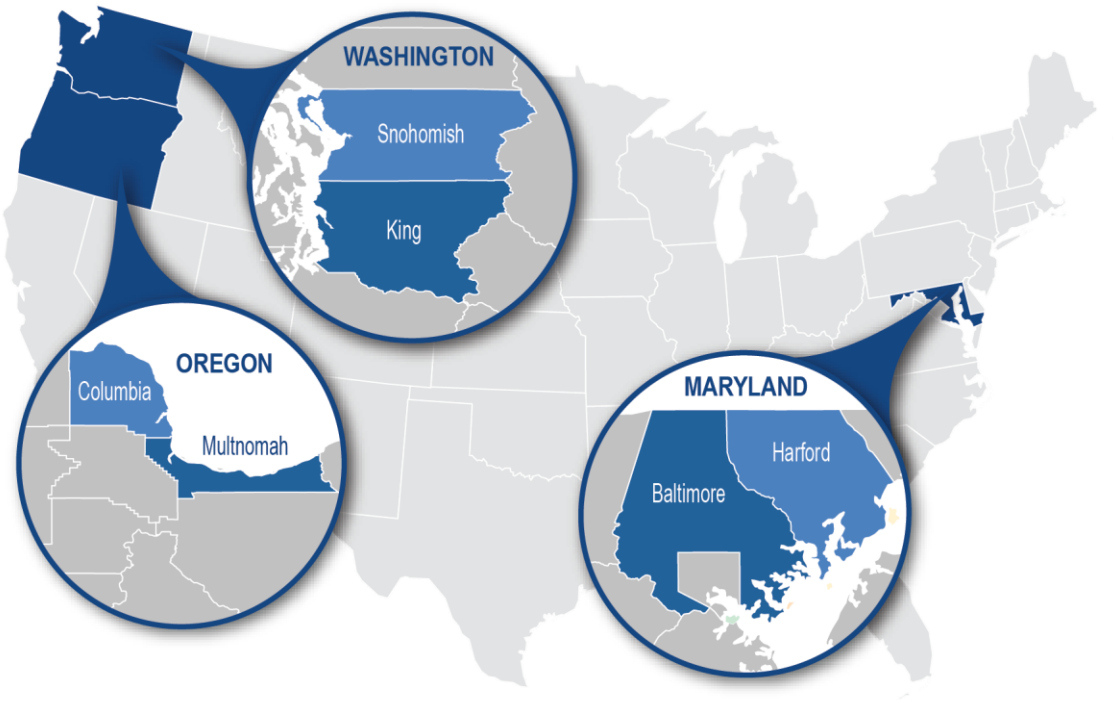

Figure 1. Map. Washington, Oregon, and Maryland counties

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

The UW ITS4US Deployment project consists of five major parts. The first part of the project includes working with existing standards committees to extend and update three existing, early-stage international data standards: OpenSidewalks, General Transit Feed Specification (GTFS)-Flex, and GTFS-Pathways. These three data standards enable the consistent collection and reporting of data that provide the underlying information needed by the currently underserved target populations—people with disabilities, older adults, and individuals with low income—to efficiently travel.

The second part of the project is the development of a series of tools that help agencies, jurisdictions, and other stakeholders collect the data that can be stored with these refined data standards. These tools are needed to lower the cost of those data collection efforts and improve their quality and consistency to increase the availability of the data. The tools developed will be open source and publicly available, allowing them to be used not just as part of this project but by any agency or jurisdiction that wishes to generate the types of data that are the subject of this project.

The third portion of the project is the development of tools, policies, and procedures that allow sharing and governance of the collected data. The tasks performed will enable effective and efficient vetting, aggregation, management, and fusion of the data that participating agencies, jurisdictions, and other stakeholders collect. This portion of the project also includes tasks required to enable and manage the sharing of those data with application developers that write software to deliver requested travel information. These tools will also be open source, and will be

accompanied by training and instructional material, allowing their widespread adoption and use both as part of the project and after the conclusion of the project, with the intent of further scaling the project's outcomes.

The fourth portion of this project is the development of a data repository to house the data shared within the six counties that represent the geographic boundaries for this ITS4US project. The data repository will be developed to allow these data to be collected, stored, governed, updated, and maintained over time and then served, upon request, to application developers. All data in the repository will be public data and will be publicly accessible via application programming interfaces (APIs). This project is a coauthor and signatory of the Mobility Data Interoperability Principles,[1] and all the data will be open, shared, and licensed in concert with those principles.

Finally, the fifth portion of this project is the development of three example applications that use the collected data. The three applications are intended to demonstrate three very different uses of the data that are collected, maintained, and made available to application developers as a result of the first four aspects of this project. Those data can be used to fulfill a variety of information needs, and those needs can be met through an almost infinite number of applications. The three applications deployed as part of this project are meant to test the TDEI and to demonstrate the TDEI's interoperability and value as a data endpoint. As the TDEI data will be publicly available, another goal is to use the demonstration applications to show other application developers how the newly available data can be obtained and delivered, enabling the development of applications beyond the three demonstration applications. Finally, the three demonstration applications will be available for use by the public.

The outcome of the project will be a complete data ecosystem that allows third-party providers to produce a variety of applications that deliver the information needed by people with mobility disabilities to identify and complete trips more effectively and efficiently, thereby improving their quality of life. The system being developed is specifically designed to scale nationally.

Figure 2 illustrates the overall "new mobility" ecosystem to which the UW ITS4US project is contributing. The outer circle consists of the variety of public transportation services that exist. Many of these services already generate data that can be readily obtained by applications via Internet connections—resulting in the discovery of "new mobility" options. These options include fixed-route transit services, micro-mobility services, and taxi services. The UW ITS4US project will help add the data sources that are particularly important to people with mobility disabilities, shown in purple at the bottom of the image. These are data that describe pedestrian pathways, transit station infrastructure, on-demand paratransit and community transit services, and other on-demand shared ride modes. The UW ITS4US project is also building the interoperable, integrated transportation data sharing layer and application programming interfaces (APIs) shown in the green inner circle. These create the functionality needed to collect, fuse, and aggregate the data from disparate transportation services. Finally, the UW ITS4US project will demonstrate a small number of applications to be used by the travelers shown in the center of the diagram. The applications will take requests for information from the travelers, extract the required data from the data sharing layer (green circle), perform any required tasks (such as computing navigation

[1] https://www.interoperablemobility.org

directions), and deliver information to users in formats (audio, text, tactile displays) designed to meet their needs.

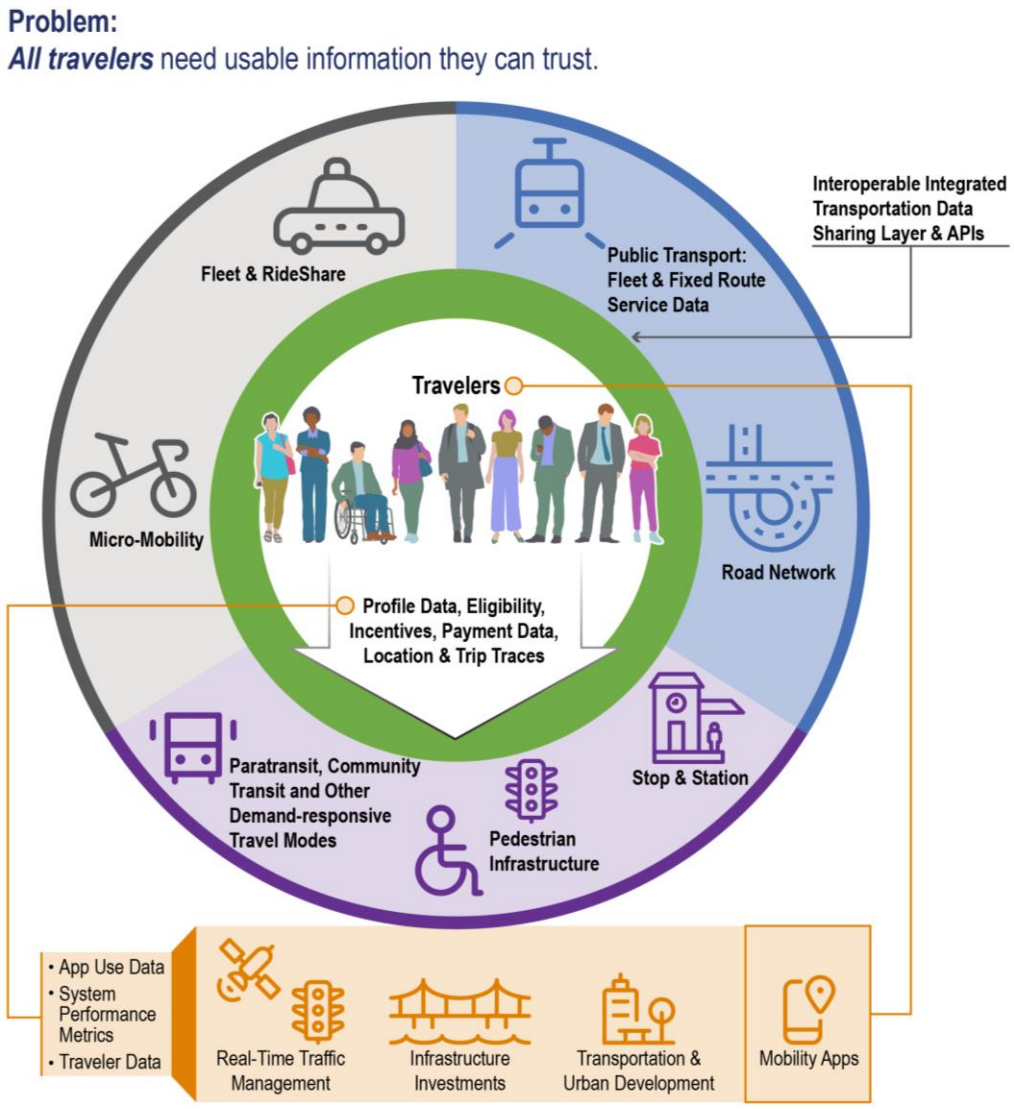

Figure 2. Diagram. UW ITS4US Deployment Project's ecosystem.

Source: University of Washington

Project stakeholders have been categorized into the following five groups:

- Data generators (e.g., municipal infrastructure owner/operator/regulators, private sector pedestrian-built-environment owner/operators, crowdsourced sidewalk reporters, elevation data providers),
- Transportation service providers (e.g., transit agencies and the companies that support the delivery of transit services operated by or for those transit agencies),
- Data service providers (e.g., providers of electronically accessible mapping services, weather data providers),

- Application developers (e.g., any organization that develops applications that use the mapping services data, including third-party application developers not obtaining funding from this project or contributing funds to this project), and
- Digital device end users (e.g., travelers with sidewalk preferences; blind, vision disabled, or deafblind travelers; sighted older adults; multilingual or multicultural travelers; low-income transit users; rural transit users).

These stakeholders will participate in a variety of ways, from providing or vetting data, to aggregating and publishing data, to using those data to deliver information needed by individuals and agencies. They will also include travelers who will use that information to identify and complete trips that improve their quality of life and agencies that use that information to prioritize and deliver transportation services to all members of the public. Specific needs within this wide range of stakeholders and roles are discussed in detail in the project's Concept of Operations.[2]

1.2.3 Project Evaluation

The project evaluation will focus on the ability of the project team to generate, store, and publish the data using sustainable and scalable software and procedures, with a modest amount of evaluation work conducted to determine the effects of the demonstration applications on travel behavior.

The most significant evaluation outcomes will be addressed by the availability of data within the six project counties, combined with the results of the data vetting efforts, which will describe the level of accuracy associated with those data. The next most significant outcomes will come from the number of data requests that originate from applications retrieving those data to provide them to end users. These results will describe the degree to which the data standards have been accepted and the level of use of the newly available data. Actual use of the data will directly demonstrate that end users find value in the data, in that they have gone to the trouble of looking up and using them. The amount of data available for use (by type of data) describes both the types of travel navigation and discovery benefits that are currently available and the geographic areas where those benefits are available.

These primary project outcomes will then be supported by an analysis of the travel benefits obtained by 40 individuals who use the demonstration applications, with the primary analysis based on the benefits obtained from the Multimodal AccessMap demonstration. The detailed evaluation will determine the value perceived by the user population, measured in terms of both how often they use the application and their responses to survey questions about the benefits they experience. It will also determine the degree to which those users are able to perform the trips they plan with the application, and measures describing any navigation errors they experience while using the software will describe the specific unexpected costs of data errors and limitations in the application's user interface.

Detailed data describing the travel activities of individuals will not be collected or stored, except for a very limited data sample associated with the evaluation of the Multimodal AccessMap application. This will limit the potential for loss of participant privacy in the event of a data breach. Similarly, while the security of pedestrian infrastructure and transit service data is an extremely

[2] ITS4US project documents available at: https://www.its.dot.gov/its4us/htm/publications.htm

important aspect of the project, participant privacy, safety, or security from the handling of those data will be a low risk to the project.

Finally, all software paid for with funds from the project will be Open Source. The project will follow USDOT's guidance to post source code to the USDOT identified platform.

1.3 At-Scale Deployment Summary

While the project is specifically intended to deliver data within six counties, the TDEI is being designed to scale nationally. The project team is taking advantage of the international standards process, international data repositories (such as OpenStreetMaps), and cloud computing resources to deliver a system design that can be scaled nationally. The UW team is in active discussions with major technology firms to refine and implement sustainable business models that support the long-term operation of the system.

One goal of the project is to examine imagery covering all roads in the six counties to provide routable sidewalk line work and street crossing information. The level of feature detail available for that sidewalk line work will vary depending on the quality of the imagery available, the availability of data from the participating jurisdictions, and the availability of community vetting. Similarly, another project goal is to include GTFS-Pathways data for all Sound Transit Link stations, and a minimum of three subway and light rail stations in each of Oregon and Maryland. Data on additional stations will be collected given the availability of resources from Tri-Met in Portland and the Maryland Transit Authority (MTA). It is currently uncertain how many on-demand transit service providers will be incorporated into the data set by the end of Phase 3. Current expectations are for data from a minimum of eight providers in Washington and Oregon and three providers in Maryland by the end of Phase 3. Additional providers will be added as they are recruited through our state department of transportation partners.

While the ITS4US project specifically addresses the needs of residents in the project's six counties, a driving goal of the TDEI is to provide national access. Therefore, potential users of the system during the ITS4US project should number in the hundreds to thousands, whereas ultimately, the concepts first deployed and demonstrated by the TDEI should reach millions if the business plans developed in this project encourage scaling of the system as desired.

1.4 Team Organizational Structure

Organizations working with the project team fall into one of the following five categories:

- Group 1: Direct team members, helping to construct the software systems that generate, vet, store, and publish the three data sets at the core of the TDEI.
- Group 2: Third party software application developers that build software that utilizes the data being collected and published as part of the TDEI.
- Group 3: Supporting organizations that own or regulate infrastructure used by pedestrians (sidewalks, pathways, and transit centers) or operate public transit services that can supply or vet infrastructure data. Also included in this group are private organizations that supply the software functionality used by the team.

- Group 4: Community organizations that advocate for improved transportation opportunities for communities and that assist in both the collection and vetting of the data.
- Group 5: Supporting universities that instruct students in the principles of the complete trip and equity in transportation planning, and that also assist in both the vetting of data and the development of new uses for those data.

1.4.1 Team Organization

The UW ITS4US project organization is shown in Figure 3. The figure shows which of the five groups an organization belongs to, as well as the basic role it will serve within the project, with the roles divided into project management, software development, and data collection and vetting.

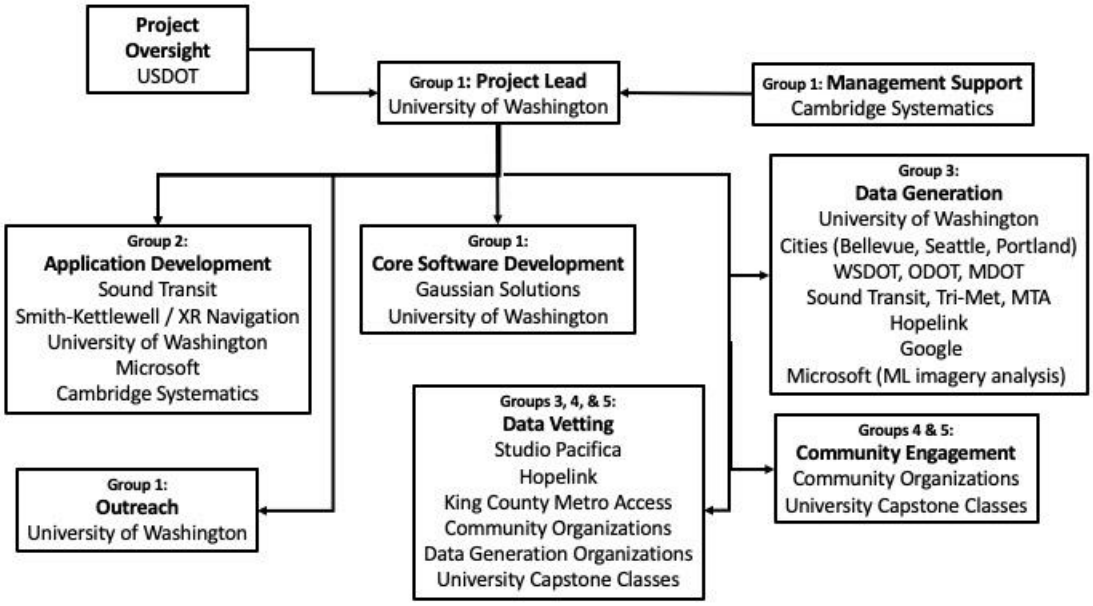

Figure 3. UW ITS4US team organization

Source: University of Washington

The University of Washington will lead most technical design aspects of the project, although the subcontractors will supply considerable expertise that will be incorporated into those technical design decisions. Project management support will be provided by Cambridge Systematics (CS). Software development will be done by a combination of firms, including the University of Washington (the Technical Applications Lead and supporting staff and students), Gaussian Solutions, and XR Navigation (working with the Smith-Kettlewell Eye Research Institute), as well as a number of specialty software development firms that work in the area of transportation navigation and streaming event data. The software development will be coordinated at the University of Washington by the Program and Business Lead and the Data Management Architect and Lead. Training material will be developed and delivered by the UW in support of the data collection, data vetting, and application development activities. Training will be performed as part of the on-boarding process, with the UW staff available to provide oversight of, and assistance with, those activities as they move forward with the participating agencies and groups.

The list of public agencies (Figure 3) that support the project through the provision of data is expected to grow during Phase 2 as additional jurisdictions are contacted through the project's Outreach plan. The role of these agencies will be to provide data that are collected as part of their regular business processes. The work of the community groups shown in Figure 3 will be refined during the first year of the Phase 2 project; however, this work is expected to include at least data vetting and outreach. Phases 2 and 3 of this project will continue work that the UW Team has done with these organizations for several years – including and prior to Phase 1 of this project. This list may also expand during Phase 2 as more definitive working arrangements are made with jurisdictions and the community groups active in those jurisdictions. Formal agreements will be signed as part of Phase 2 once the software tools for ingesting the data from jurisdictions, agencies, and community groups have been developed and tested.

1.4.2 Key Personnel

The NOFO requests that three lead roles be defined for Phase 2: the Deployment Lead (DL), Systems Engineering Lead (SEL), and Project Management Lead (PML). Unfortunately, those leadership positions do not match up well with the actual skill requirements associated with the UW ITS4US's project, which is specifically intended to create a live data repository, data analytics, and data warehousing for a number of enhanced transportation data schemas. The UW project does not include a major hardware infrastructure deployment such as found in connected-vehicle pilot projects, for which this type of requirement is very appropriate.

In place of the three positions in the NOFO, the UW team proposes four major lead roles for managing the TDEI work streams. These four roles and their associated responsibilities are described below. The four roles are mapped to the three roles required by the NOFO at the bottom of this subsection. The ultimate decision-making authority lies with the Deployment and Development Lead (DDL).

1.4.2.1 Program and Business Lead (PBL)

The Program and Business Lead will be Mark Hallenbeck, the Phase 1 Project Management Lead (PML). This position will be responsible for program management. Mr. Hallenbeck will also be responsible for working with the transportation sector as data producers and sometimes consumers. The program manager has experience in systems development efforts within the transportation sector, and he also understands the issues that will confront the transportation agencies and DOTs. For this reason, he will have co-managerial authority over some of the tech team members. The role of PBL will ultimately be responsible (with the Deployment Development Lead) for platform delivery to outside stakeholders (such as project partners and project sponsors). The PBL will be the "owner" of the transportation data stored in the data warehouse for transportation agencies. This business sponsorship role will include the funding responsibility for the inclusion of the Phase 2 data into the TDEI infrastructure, particularly transportation agency data (i.e., data from transit stations and on-demand transit services). In addition, the PBL will champion the effort, help communicate the value of data interoperability to the community, and serve as project owner for transit agencies.

1.4.2.2 Deployment Development Lead (DDL)

The Deployment Development Lead will be Dr. Anat Caspi, the Concept Development Lead (CDL) for Phase 1 and Principal Investigator for the University of Washington. Most of the

development of the platform and data infrastructure will be performed by teams. The DDL will enable the group to properly structure and conduct platform development, ensuring the focus is there to achieve the goals of the project and coordinating internal deadlines to meet deliverable objectives across teams and to outside stakeholders. The role of the DDL will be ultimately responsible for platform delivery to outside stakeholders (such as project partners and project sponsors). The DDL will be responsible for strategically setting the timeline and development progression as a new area is incorporated into the infrastructure. In addition, the DDL, along with the Program and Business Lead, will champion the effort, help communicate the value of data warehousing to the community, and serve as technical project owner for funding agencies and external stakeholders.

1.4.2.3 Data Management Architect and Lead (DMAL)

The Data Management Architect and Lead will be Dr. Kristin Tufte. The DMAL will be ultimately responsible for all data lifecycle activities, such as those listed in the Enabling Technologies Readiness Assessment (ETRA), and will have managerial authority over the data system and models. The DMAL will share responsibility for the interoperable data sharing infrastructure with the DDL and the Technical Applications Lead. The DMAL will own and control the operational aspects of the data lifecycle, such as data consumption, ingestion, and storage. A goal of the DMAL will be to minimize redundant operational data and to structure data to serve the organization's overall purpose in capturing those data. These functions will be essential for successfully creating and maintaining an interoperable data sharing architecture.

The Data Management Architect and Lead will have primary administrative responsibility for the actual physical design of the data infrastructure environment. She will participate in the modeling activities as the representative of the physical implementation of the model's entities. She will oversee the creation of the database infrastructure and the maintenance of the data's physical environment and will monitor the changes made to the environment. The database architect's strength will lie in her ability to develop the vision of the physical view of the warehouse.

1.4.2.4 Technical Applications Lead (TAL)

The Technical Applications Lead will be Dr. Nick Bolton. The TAL will be ultimately responsible for the technical applications internal to the interoperable data infrastructure. The actual creation of the TDEI infrastructure will entail the extraction of specific data elements from various systems and raw data files into a database. Before being loaded into this database, some form of data transformation or integration will be required. This will involve changing the formats of certain elements to conform to a standard, making all iterations of an element have the same data type and size, or altering the algorithm that summarizes certain elements. These programs for transforming and extracting data can be developed in-house with instruction by the TAL, or they can be purchased from vendors and customized for the TDEI environment. Additionally, the TAL will be responsible for the underlying application data tools provided to consumers and producers, specifically where analysis is required for the creation of data or in responding to complex queries against the database. The person in this role will also be responsible for all the technical tools to ensure that TDEI data are available for storing, reuse, and modification.

This is how the four positions relate to the positions named in the NOFO:

- The Deployment Development Lead (Caspi) will perform the role of the Deployment Lead.
- The Data Management Architect and Lead (Tufte) and the Technical Applications Lead (Bolton) will perform the role of the Systems Engineering Lead.
- The Program and Business Lead (Hallenbeck) will perform the roles of the Project Management Lead and the Point of Contact.

1.4.2.5 Cambridge Systematics Support

The Cambridge Systematics (CS) team project manager will be Ms. Erin Flanigan. Ms. Alice Marecek will provide day-to-day project management support for Phase 2 and Phase 3. Mr. Adam Danczyk will lead the CS work documenting the system architecture, data management plan, and system test planning.

1.4.3 Changes in Organizational Form from Phase 1

Phase 2 will involve three primary changes in the UW ITS4US project team from Phase 1. One team member, Unity Technologies, has been dropped from the team. The application Unity was developing (the Digital Twin) will be replaced by an application for individuals with visual disabilities, with development work done by XR Navigation. The Digital Twin was intended to provide a virtual model of a physical object to allow users to interact digitally with a "digital twin" of the physical object. The original intent of the Digital Twin application in our project would have been to represent a transit station and allow travelers to virtually foreshadow a trip through that environment. Unity Technologies has been replaced primarily because of two concerns that the organization was unable to resolve. First, it was unclear how the large volumes of 3-D imagery data were going to be stored and consumed in real time. Second, the Unity organization was not willing to sufficiently invest in the development of small pilot demonstration projects to show technical feasibility. The replacement application, called Audiom, is an inclusive digital map viewer that uses the web and auditory virtual reality, combined with large, high-contrast visuals, to convey map data through headphones or a screen. Audiom is compararable with the Digital Twin for travelers in that it will provide a simulated trip experience through a transit station. Audiom further enhances the traveler experience by providing audio virtual guidance through the built environment in addition to transit stations and facilities. However, unlike Digital Twin, Audiom will not provide purely visual experiences for travelers with limited English proficiency. Audiom is an existing application that will be refined to help blind and low-vision individuals navigate transit centers. Audiom has been chosen as a replacement because it is an existing, functional application that can be directly used by project stakeholders.

Another addition to the team will be Sound Transit. Sound Transit will provide both data (GTFS-Pathways) and third-party applications that use data in all three project data standards. Sound Transit (ST) will have a large Passenger Experience Improvement program funded during Phase 2 of this project. It will coordinate that program with the UW ITS4US project. The UW team will provide technical oversight to the ST projects that generate data and provide applications that improve the ability of travelers to navigate their facilities.

Most other changes will involve an increase in the number of organizations actively participating in the project. The project will rely on the collection of large amounts of data from multiple sources. One of the sources for these data will be public agencies (e.g., transit agencies) and jurisdictions (e.g., cities and counties). The project team is talking with a significant number of

these organizations and expects to work with many of them. In Phase 1, data were made available by several of these organizations without a formal agreement. For example, the team was able to obtain traffic control data (traffic signal locations and details that are important for pedestrian navigation across streets) without signing a formal agreement. The team expects to obtain a large amount of data from other jurisdictions in Phase 2. This may or may not require formal agreements, as often the data to be received are public data.

Similarly, the UW team has been working with both transit service providers and state DOTs to develop the working relationships that will allow the team to obtain GTFS-Flex data from agencies operating in the three participating states. The team is working to determine whether formal agreements will be needed with these organizations. This work will also be finalized in Phase 2.

The next group of potential participants comprises community and advocacy groups that have an interest in collecting and vetting sidewalk and path data. These community groups vary from community to community. The project's outreach plan describes the approach for reaching out to these groups to gain the labor required to vet large amounts of sidewalk and path data.

Finally, with internal resources, the UW is currently developing course material that it will share with collaborators in other universities in the three participating states. College courses provide the opportunity to contribute to three desired project outcomes: vetting of data, development of insights into the use of those data for improved jurisdiction planning, and training of both new graduates and jurisdictions in the uses and benefits of those data. This type of outreach will contribute to a sustainability vision in which use of the data persists past project completion. The course material will also be designed to teach students about the importance of universal design and the need for the appropriate transportation infrastructure and services for people of all abilities. The course will include a significant capstone project in which students will 1) vet the data needed for their analyses, 2) develop and refine approaches for identifying and prioritizing infrastructure and service improvements, and then 3) propose specific improvements to the controlling jurisdictions. The specific project outcomes will be vetted data, new applications that use those data, and better direct involvement from the jurisdictions for whom the capstone projects are developed.

1.4.4 Summary of Financial and Organizational Models for Sustained Operations

The financial model for the TDEI relies on a combination of funding sources. This is true for Phases 2 and 3, as well as for the five-year period after Phase 3 ends and on into the future. As with the budget submitted for Phases 2 and 3, funds will come from multiple private and public sources. It is expected that the actual amounts, and even the specific companies and public agencies involved in supporting the TDEI, will change over time. The TDEI is a shared data system expected to grow and change over time, and consequently the costs and responsibilities will change as data users, uses, and priorities change.

Note that funds for data generation/collection/vetting will be different for each of the three different data types (pedestrian, on-demand, and transit center), and the funding of the ongoing operation of the data aggregation/storage/publication system can be separate from the data generation/vetting process.

In all cases, the business model for the system needs to make sense to the organizations performing the required tasks. For public agencies, this means the data must be routinely used so that their collection can compete for scarce resources. The use of the data must continue to meet important agency outcomes and policies. Similarly with private sector funds—whether as a business activity or as a foundation activity—the value of the outcomes from use of the data must exceed the cost of the financial contribution. In the case of a business, this is best measured by a positive revenue to cost relationship, but it can also result from meeting related corporate policy goals.

For Phases 1 through 3 of the UW ITS4US project, the team is using federal funds to lower the local costs associated with the development, set-up, and testing of the system. However, local resources will be needed into the future to operate and maintain the system. The lower the cost of these activities, the more likely that funds will be available to perform them; therefore, a portion of the UW ITS4US project is developing tools that will lower the cost of ongoing activities such as data collection and data vetting. The UW ITS4US team is also encouraging third-party applications to use the data being generated because when public agencies/jurisdictions and private companies experience those benefits, it will become easier to compete for available funds and thus generate sufficient revenue to maintain and grow the system.

During Phase 2, the UW team will actively market the data, the services that can be created with those data, and the analytical transportation performance measures (e.g., equity measure of access) that become possible by using the data to generate future support for the system. The UW team has identified sufficient resources to maintain the system for five years after the end of Phase 3, but new resources will be needed to further expand the system and operate it beyond the ITS4US program. Identification of those funds will be a key task during Phases 2 and 3.

Financial plans—both those expected to occur and alternatives that are under consideration for post-Phase 3—are described below. In all scenarios, financial participation in the cost of operating the TDEI is expected from both public and private entities.

1.1.1.1 Data Collection and Vetting

The source of funds for data collection and vetting is expected to vary with the type of data being generated, collected, and vetted.

1.1.1.1.1 GTFS-Pathways

The transit agencies that own and operate transit centers are expected to lead the expansion, vetting, and maintenance of their respective GTFS-Pathways data; the precedent for this has been set with existing GTFS data for transit services. All three major agencies have expressed interest in having GTFS-Pathways data feeds. The ITS4US project has an objective of reducing the cost of producing these data, and we expect that once those costs have been lowered, agencies will generate these data as part of making their systems accessible. Similarly, transit agencies will vet and maintain these feeds, just as they do their existing GTFS feeds that improve accessibility (through easier-to-access digital information) to transit service.

1.1.1.1.2 GTFS-Flex

For GTFS-Flex, the larger, more sophisticated transit service providers are expected to generate, vet, and maintain GTFS-Flex data feeds and APIs. However, smaller, on-demand service

providers will be unlikely to have the resources or technical ability to perform these tasks. The model the UW team expects is currently seen on the West Coast, in which state DOTs traditionally provide funding and technical support for small, rural transit agencies; similarly, they are expected to provide financial support for the development and maintenance of GTFS-Flex at smaller agencies. In the case of on-demand medical or veteran's transportation services, funding is likely to come from the medical services sector (e.g., hospitals and insurance companies) that financially supports these services and veteran's agencies. Again, the easier the ITS4US project can make the generation of GTFS-Flex data streams and the more beneficial the services that use those data, the more likely this support will be made available.

1.1.1.1.3 Sidewalk and Path Data

Unlike the two GTFS data systems, there is not always a clear connection between a specific agency and sidewalk data. For example, in many cases, cities regulate but do not own sidewalks. In other cases, the city owns the sidewalk but has maintained relatively sparse records about that infrastructure. The result is that many cities do not have good sidewalk data, and the cost of collecting those data can be intimidating. However, routable sidewalk data have enormous potential for improving the quality and completeness of planning analyses related to equitable access to services and users' ability to safely achieve active transportation.

Already several private firms offer to provide basic routable sidewalk data as part of independent efforts. Thus, where public interest in accessibility—especially equitable Americans with Disabilities Act (ADA) access—is high, public funding for data collection will be possible. However, there are strong private sector motivations for collecting these data in many locations. For example, the same data needed to route a wheelchair are needed to route a freight delivery robot. Therefore, a market for these data exists not just in the pedestrian navigation space and the public transportation and equity space, but also in a number of emerging private sector business markets. The UW team expects that expansion of the TDEI routable sidewalk network beyond this project will be dependent on a combination of public and private sector activities, and the decision to generate these data will be made differently in different parts of the country.

However, once the data exist, maintenance and continued vetting of the data will depend on a combination of community involvement and self-interest from both public agencies that wish to use the data for planning purposes and private companies that need high quality data. Again, the exact mix of these funds will vary from region to region.

1.1.1.2 Operations and Maintenance Costs

The other major expense for the TDEI will be the ongoing operation and maintenance of the system. During the ITS4US project, these funds are being provided by a combination of federal project funds and local matching funds. Local funds will be used to operate and maintain the system for the five-year period at the end of the project.

The financial framework for operation and maintenance of the TDEI has not been finalized at this time. There are three potential business models, as well as a fourth model that is a combination of those three. The UW team will explore each of these models as part of Phases 2 and 3, working with interested and involved public and private sector partners. The four possible financial models are Public Operation, Private Operation, Non-Profit Operation, and a Combination Model. Each of these is briefly outlined below.

1.1.1.2.1 Public Operation

In the public operation model, one or more regional, state, or local entities operates the TDEI (or a regional version of the TDEI). For example, in the Puget Sound region, the value of the combined transit and sidewalk data might be so high to the public sector that the Seattle metropolitan planning organization (MPO) would fund the continued operation of the system. Because the initial costs have already been paid for by the project, the MPO would be responsible only for operating and maintaining the system. This could be done by MPO staff or under contract. This business model exists in many parts of the country for regional traffic operations centers, which public agencies pay private contractors to staff and operate.

Under this model, it is also possible for multiple regions or states to jointly fund the TDEI, or a regional/state-level TDEI. This model exists on the East Coast in the form of the Eastern Transportation Coalition (formerly the I-95 Corridor Coalition), which allows states to jointly fund a program that helps operate much of the freeway system on the eastern seaboard.

The key to this model is that the public agencies that provide the funding to operate the system see sufficient benefit from the system to allocate scarce public funds. These benefits would be a combination of improved disability mobility for residents, improved planning for active transportation modes, and a more competitive economic environment that derives from providing better access to the built environment.

1.1.1.2.2 Private Operation

A second model is private sector operation. In this model, one or more technology firms take over operation of the TDEI. That firm then generates sufficient revenue from the use of those data to pay for the operation and maintenance of the system. An excellent example of this model is Google Maps. Google supplies a large amount of data through Google Maps. It generates funds from advertising on the maps and from fees paid by users of the data (limited use of the data is free, but large data requests require payment).

The exact business model would be up to the private firm. Any firm operating the TDEI would then work with the groups collecting and vetting data to continue to expand and improve the base data. An excellent example of this type of business model is the operation of WAZE, which often signs data sharing agreements with public agencies.

1.1.1.2.3 Non-Profit Operation

A third model is for a non-profit organization to operate the TDEI. For example, this could be the OpenStreetMap Foundation or another non-profit with a specific interest in either active transportation or disability mobility. As with the private firms, a foundation might generate revenue from the sale of access to the data when the use of those data was for commercial purposes.

1.1.1.2.4 Combination Operation

Finally, these three models can be used in combination. That is, the public sector could work with a major technology firm to collect and vet data in return for reduced or no cost data access. It might work with a non-profit in much the same way.

It is also possible that the business model will change over time, as occurred with the evolution of the business models that support traveler information services. Early in the intelligent

transportation systems (ITS) era, the public sector dominated traveler information. Now, while almost all public agencies maintain a basic level of traveler information delivery, much information delivery to travelers occurs via private sector companies, which both collect their own data and absorb the public data feeds. They then provide that combined information to travelers as part of their business model. It is entirely possible that such a combination model could eventually support the functions of the TDEI.

1.1.1.3 Organizational Risks

This section documents the UW project team's plan for identifying and managing organizational risks in a timely and efficient manner. Routine meetings aligned with project tasks and a Risk Register will be the key mechanisms for identifying, tracking, and managing risks as described in the Project Management Plan (PMP).

The key methodology for risk management in this project is to use multiple approaches; this methodology will be applied to organizational risk as well as risks related to data collection and data standards. By using multiple approaches, the UW team can pivot to an alternative approach if needed. This multi-pronged approach will be used for the institutional, financial, and partnership roles that will shape the ultimate design of the data storage and sharing services.

First, the roles required to successfully deliver the ITS4US project do not need to be those that are best suited for national operation of the proposed data system. The project team will explore many different institutional, partnership and financial relationships and the business models that underlie them.

The project team has used a combination of expert judgment, project experience (having developed initial versions of many of the data formats and applications being extended and scaled in this project before the start of this project), and the outcome of pre-award meetings to develop the initial Risk Register.

Our initial list of risks relevant to organization and partnerships includes the following:

- Inability to agree on standards releases
- Inability to address privacy concerns at this stage of standard releases
- Inability to get standards adopted by service providers
- Lack of a successful business model to build, operate, and maintain the system of data and mobility applications
- Loss of key staff or lack of available time for key staff due to accident or unexpected demand for those individuals from other projects.

The co-design and multi-technique approaches described above are key to mitigation of these risks. The co-design approach, which started in Phase 1, brings together the stakeholders involved in the larger eco-system in which we are working. This means that groups that control transportation services, application developers, and travelers with lived experience are all part of early review of the ongoing design of the system. By working with these groups directly, continuously, and from an early stage in the process, we are likely to identify specific risks early and to be able to plan for and address those risks. Finally, working with this wide range of

stakeholders will allow the UW team to identify contingency plans if the preferred alternative is not feasible.

2 Phase 2 and Phase 3 Technical Approach

2.1 Introduction

The UW ITS4US Deployment project aims to greatly increase the availability of pedestrian and transit pathway data and flexible transit information to all travelers. This will be done by creating the foundational data tools necessary for both public and private entities to collect, share, manage, and use transportation data that provide equitable outcomes to all travelers. At its core, the project is about creating the foundational requirements for interoperable transportation data sharing that fulfills the informational needs of all travelers. This requires a specific focus on the unmet needs of people with mobility disabilities and other historically travel-disadvantaged communities, the focus of this project. Without implementing this type of project, the mobility data informational needs of these communities will continue to be unmet or underserved, limiting the ability of citizens in these communities to access destinations, explore opportunities, and be aware of all services available to them.

To operationalize the data sharing infrastructure, the project will build a sustainable framework to enable and accelerate the future of equitable mobility and access to transportation. Specifically, it will implement and demonstrate data collection and data standards that allow a variety of mobility applications to access the information they need to support a wide range of mobility services for travelers of all abilities. The project will do so by addressing three primary goals:

1. Coordinate Collaborative Releases of Data Standards – During Phase 2, via community leadership, this project will continue to co-create, improve, and extend data formats that describe currently under- or un-represented, detailed travel network information.

2. Publish and Maintain an Interoperable Data Infrastructure – During Phase 2, the UW team will build, refine, and use data collection and data vetting techniques to generate data for three data standards, along with the development of data provisioning services that distribute those data for use in a variety of applications. Much of the Integrated Complete Trip Deployment Plan (ICTDP) will be devoted to the needs associated with these tasks. By the end of Phase 2, the UW team will publish collected data for the six U.S. counties that are part of this project. Those data will be published via an API made available on a website managed by the UW Team. Registration will be required for access to the API for purposes of understanding who is using the data and for communicating with data users (such as when data schema updates occur), but access will not be restricted. Any person could obtain an API key in order to request and consume the published data, much like Translink provides API keys to requestors offering access to their GTFS-real-time data. Those data will be maintained for five years after the conclusion of Phase 3 of this project, thereby supporting the team's and any third-party applications' interests 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.

3. Deploy and Sustain Three Accessible Mobility Applications – This project will deploy three accessible mobility applications in the evaluation and testing of the usability and efficacy of the data standards developed in Phase 2 and the supporting infrastructure developed in Phase 2.

2.1.1 Motivating Factors

The UW Team has categorized the factors that motivated and shaped the development of this project into three categories:

1) Transportation and mobility are undergoing transformational changes that take advantage of data.

2) Accessible and inclusive design in data systems cannot be retrofitted without great cost and complexity.

3) Civic technologies must be integrally driven by equitable, interoperable data-sharing infrastructure.

These topic areas are discussed briefly below.

2.1.1.1 Transportation and Mobility Undergoing Transformation

Transportation and mobility are areas undergoing enormous transformation. Throughout most of the 20th century, transportation in the United States (U.S.) remained focused on ownership of a private vehicle, with additional modes offered as a collection of disconnected systems of separately financed public transit, influenced by political decision-making processes and supported through a variety of private providers. Importantly, this fragmentation of public transit systems in the U.S., combined with the projected growth in transport demand, is widely recognized as unsustainable, and it has generated a major shift toward innovative services that can support seamless mobility and away from car ownership. Specifically, three transformational trends are taking place in transportation:

- Transportation agencies are adopting integrated data platforms to make mobility systems more seamless, sustainable, accessible, affordable, and safe. Experts say this is underlying the development of "integrated solutions that elevate collaboration and productivity among transit agencies, ultimately improving the quality-of-service agencies provide to their communities."[3]
- To address first- and last-mile challenges, transit agencies and municipalities are introducing new mobility hubs, with a range of travel options tuned to local demand.
- Transportation planning is looking toward a future in which flexible fleets of on-demand, shared, and electric vehicles may connect to transit within a mobility hub, where the goal is to increase capacity, speed, and frequency of the transit network by including new modes of transit and improvements to existing services.

[3] Trapeze Group. "Esri and Trapeze collaborating on integrated data platform." *PRNewswire, April 12, 2021*, Esri and Trapeze Group Join Forces to Transform the Customer Experience with Powerful Technology Integrations (prnewswire.com). Accessed 2/27/2022.

All three of these trends are expected to be heavily supported by the digitization of transportation made possible by mass access to smartphones and Internet connectivity, the proliferation of big data, and emergence of innovative and intelligent approaches to coordinating fleets and travelers using static and real-time data about the entire transport sector.

2.1.1.2 Accessible and Inclusive Design in Data Systems Cannot Be Retrofitted

For decades, transportation agencies have dealt with the significant expenses involved in retrofitting physical structures and fleets to address accessibility. For example, within the London subway system, while newer stations are designed with accessibility in mind, older stations that were not so designed are not yet accessible because of the technical difficulties and costs involved. Another example is the Singapore metro system, for which a report in 2004[4] noted that the cost of incorporating accessibility into new construction was minimal in comparison to the astronomical costs associated with retrofitting the system years later. This has led to a worldwide best practice of designing accessibility features into the construction of new transportation systems.

For information technology, the pattern is similar. Ample examples exist of the extreme challenges and significant expenses involved in the process of retrofitting an existing information technology (like a website) for accessibility. By comparison, if a project starts with universal access in mind, the design can be achieved with less coding. Here again, the cost of accessibility retrofitting can be enormous, whereas the cost of accessibility when deliberately and intentionally planned is minimal.

The design of data pipelines and data schema involved in the creation of transportation databases (containing both static and real-time data) exhibit the same pattern. If data pipelines and their recipient databases contain data schemas that are not designed with accessibility and inclusivity in mind, then retrofitting those data schemas can be difficult, resource-intensive, and costly in comparison to the cost involved in creating accessible designs from the outset. Accessibility and usability have also been shown to add other value to products—as much as a hundred-fold return on investment, according to early research.[5]

2.1.1.3 Civic Technologies Are Integrally Driven by Equitable, Interoperable Data-Sharing Infrastructure

Data-sharing infrastructures that are both open-source and interoperable represent a significant opportunity for all participants in technology that supports civic engagement, not just the mobility ecosystem. Social and demographic trends, as well as the popularity of various integrated mobile apps, suggest that civic consumers want access to public services, public assets, and information via citizen-centered, data-driven applications. Behind every such application lies a complicated data pipeline, potentially fed by multiple public data producers such as municipalities, utility companies, transportation agencies, and more. Moreover, federal guidelines and the public

[4] RICS (2004) Land value and public transport, Stage two - testing the methodology on the Corydon Tramlink, RICS, ODPM and DfT, 52.

[5] R.G. Bias and D.J. Mayhew (editors), 1994. Cost–justifying usability. Boston, Mass.: Academic Press.

expect the data to be current, reliable, trustworthy, and accessible. The shared interest in foundational data infrastructure motivates public and private sector organizations to co-invest in trustworthy, equity-first data pipelines, interoperable standards, and shared repositories. Data infrastructure suppliers benefit from interoperable data sharing by using it to identify new civic market opportunities and hone their service offerings. Governments also benefit. The data platforms can be leveraged to plan the future of cities, help civic services operate more efficiently, and avoid building expensive, unnecessary infrastructure for each civic sector by improving utilization of shared data infrastructures. The same infrastructure may also widen the potential for governments to participate in the delivery of new services.

For purposes of this project, data interoperability is defined as the ability to join and merge data without losing meaning. In practice, data are said to be interoperable when they can be easily reused and processed in different applications, allowing different information systems to work together. In today's world, people's expectations are for greater interconnectivity and seamless interoperability, so different systems can deliver data to those who need them and in the forms they need. Data interoperability and integration are therefore crucial to data management strategies in every organization. However, teams and organizations are often overloaded with day-to-day operations and have little time left to introduce and adopt standards, technologies, tools, and practices for greater data interoperability. This is termed the "interoperability gap."

The following four contextual backdrops will peripherally inform the needs assessment for this project, as they are influencing factors within the entities engaged in transportation data production and consumption.

- There is significant pressure on the transportation industry to identify mechanisms for interoperable data sharing, underlying many efforts to systematize mobility data, whether called "mobility on demand," "mobility-as-a-service," or something else.
- Where data creation and consumption happen in both public and private spaces, an equity-and-accessibility-first evaluation must take place during the design phase to conserve considerable retrofitting costs later.
- Other civic and government players will be watching, and possibly consulting, this mobility data infrastructure development because it will likely inform data infrastructure in other civic domains.
- There is an "interoperability gap" between the data sharing needs of organizations and their capacity for building standards, technologies, and tools to support the creation, use, and sharing of those data. This project aims to follow and document a clear process for devising interoperable data strategies for transportation data, to help devise sustainable practices, organize quality data for accessibility, and set the scene for the development of more tailored, detailed, and interoperable approaches to data management.

In conclusion, the backdrop and focus of this project is the production of not just any transportation data, but the building of a transportation data sharing infrastructure that takes an intentional and directed approach to assuring inclusivity and accessibility.

2.2 Phase 2 Technical Approach

2.2.1 Task 2-A: Project Management

To continue delivering high quality products, the UW team will follow consistent processes and procedures based on guidance documented in the Project Management Body of Knowledge (PMBOK). These processes and procedures will be documented in a Phase 2 Project Management Plan (PMP), which will define how the project will be executed, monitored, and controlled in terms of scope management, schedule management, communications management, cost management, quality management, configuration (or change) management, and risk management. The Phase 2 PMP will incorporate knowledge, skills, tools, and techniques that the UW team will use to enhance the chance of success of this project, with a focus on continued improvement throughout the project. The Program and Business Lead (Mark Hallenbeck) will work with the PMP-certified Cambridge Systematics Project Manager (Alice Marecek) to develop the draft and revised Phase 2 PMP. The Phase 2 PMP will build from the Phase 1 PMP, with the Phase 1 Systems Engineering Management Plan (SEMP) serving as a supplemental document focusing on technical plans and Agile systems engineering processes that will be used to carry the project to its end. Anat Caspi, the Deployment Development Lead, will be supported by Kristin Tufte, the Data Management Architect and Lead, to organize and lead the deployment team partnership. Four key representatives from the UW team will participate in the Phase 2 Kickoff Meeting (in-person or virtual) within four weeks after the effective date of the award with the USDOT and its representatives to ensure that all parties have a common understanding of the award requirements and expectations.

Traditional systems engineering processes for ITS projects utilize the V-model approach, in which a project's development, deployment, and transition to operations are accomplished through careful step-by-step documentation, prescribed sequential steps, and established project management. While this process is extremely useful for deployment of traditional ITS assets such as roadside CCTV cameras, the prescribed development activities can limit flexibility with systems that have a less straightforward design, particularly those that involve development of software. As an alternative, the Agile approach, described in more detail under Task 2-B, reframes the rollout of the project to be progress-oriented, demonstration-focused at various milestones, and receptive to ongoing feedback from stakeholders.

The team envisions that—from a project management perspective—Agile will be utilized for all design and development tasks that are directly within the team's purview, specifically the components that represent the data repository, the tools to help data generators create useful data, and updates to AccessMap. Other third-party applications, such as the Microsoft Soundscape demonstration application, will be created by independent participants that will follow their own processes for development, but with a goal of achieving milestones that work collaboratively with the rest of the system.

The PMP will be accompanied by a detailed Deployment Project Schedule that will delineate the work tasks and schedules for this project, with specific emphasis on the key outcomes required both to successfully develop the work to be performed in Phase 2 and to prepare for the operations and evaluation efforts in Phase 3. The Work Breakdown Structure will be closely aligned with the USDOT-defined Phase 2 tasks but will be further broken down into separate streams of work based on Sidewalk Data Collection Testing and Analysis, Standards

Development Activities (including standards testing), and Systems Engineering for Application Development/Refinement.

Utilizing Agile processes will allow the project team to establish key milestones while also maintaining some degree of flexibility to adjust delivery and solicit feedback from stakeholders. By completing sprints and releases, the project team anticipates being able to deliver a product that will more closely align with the project's user needs. The detailed Deployment Project Schedule will reflect this Agile methodology by showing the timeline for the planned number of releases. However, because of the nature of constant, planned change in Agile iterations, the scope of work to be completed within each release will not be communicated through the Deployment Project Schedule but rather through pre-release memorandums and release reports to be developed for each release. Progress made during sprints and releases will also be communicated through monthly progress reports, as well as through regular coordination teleconferences (i.e., bi-weekly deployment teleconferences, monthly all-site coordination teleconferences, and roundtable participation). The role of the Program and Business Lead will be to make sure that work planned for each sprint falls within the UW ITS4US Deployment Project scope of work. In addition, the number of releases may change as the development progresses, and these changes will be reflected in the monthly Deployment Project Schedule updates.

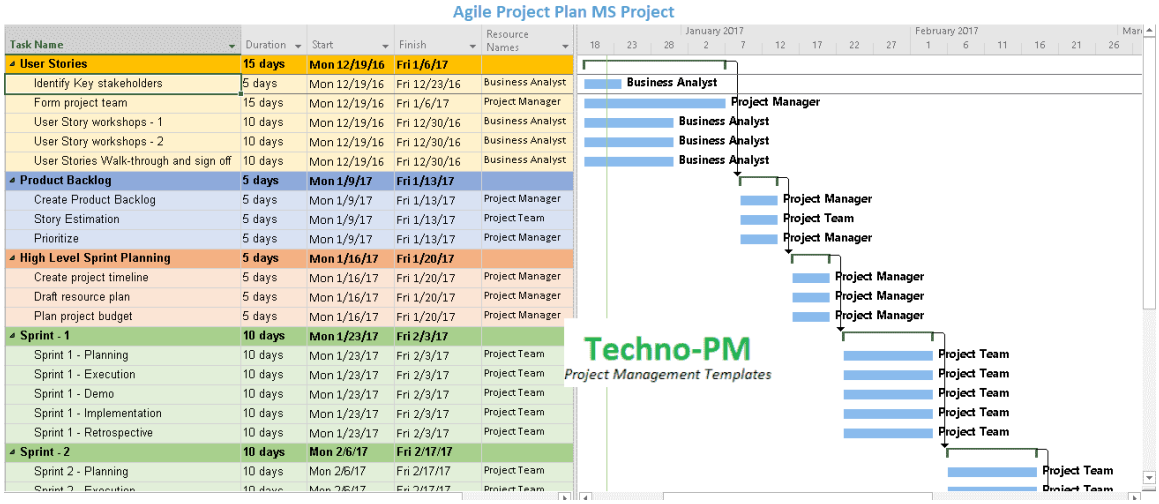

Figure 4. Agile project plan example

Source: www.techno-pm.com

The Program Management Lead will also maintain a Lessons Learned Logbook with ongoing input from the project team. The logbook will capture issues identified with specific Phase 2 tasks and will provide details regarding the realized/potential impacts, mitigating action(s) taken, and results identified to date. A summary of its contents will be included in the monthly progress reports.

One challenge anticipated during Phase 2 will be the multiple parallel communication efforts with external project technology business partners and project agency partners, all of which are critical to ensuring the successful development of all UW ITS4US Deployment Project components. The project management team plans to leverage relationships built with these partners before Phase 1 of this project through continued regular coordination meetings. Milestones for involvement will

be established as part of the Release Plan—one of the first Agile processes in Phase 2—to help document the roles requested of project partners. Further details are provided in Task 2-B.

The UW plans to address the challenge of coordination of the various software development teams by having clearly defined integration points between teams and by minimizing the number of critical integration points. The three demonstration applications will interface with the TDEI by ingesting data produced by the TDEI. The data format for this exchange will be based on the existing data standards in use by this project. Any refinements necessary to those standards for this project will be defined early in Phase 2 so that the development teams for the three demonstration applications can work in parallel with the UW development team. The development of the TDEI itself and the related tools will be done by Gaussian Solutions and the UW development team. These two teams will interact closely through this process, and that integration will be managed by the UW team through regular checkpoints and through the use of software engineering techniques (namely the use of a microservices architecture).

2.2.1.1 Deliverables

- Kick-off Meeting
- Draft Project Management Plan (PMP)
- Revised PMP (as required)
- Monthly Progress Report Part I: Technical Progress and Status Summary
    - Includes: Project Milestone Schedule, Updated Task Schedules, and Project and Task Detailed Risk Register.
- Monthly Progress Report Part II: Detailed Financial Summary
- Lessons Learned Logbook (LLL), updated monthly
- Participation in site-specific bi-weekly coordination teleconferences
- Participation monthly all-site coordination teleconferences
- Participation in periodic roundtable teleconferences.

2.2.2 Task 2-B: System Architecture and Design

2.2.2.1 Architecture and Interface Development Processes

The UW team will develop a System Architecture that reflects the comprehensive TDEI system by utilizing concept diagrams composed for the Concept of Operations document in Phase 1 and the core functional view diagram (Figure 5) composed for the Enabling Technologies Readiness Assessment (ETRA) report from Phase 1. This system architecture is envisioned to be a conceptualization of the system requirements, informed by the specific requirements that were approved as part of the Phase 1 System Requirements Specification and any associated updates made in collaboration with the USDOT. This document will serve as the foundation from which subsystems can be separately developed through the Agile process, with their own respective milestones for confirming integration with the larger TDEI system.

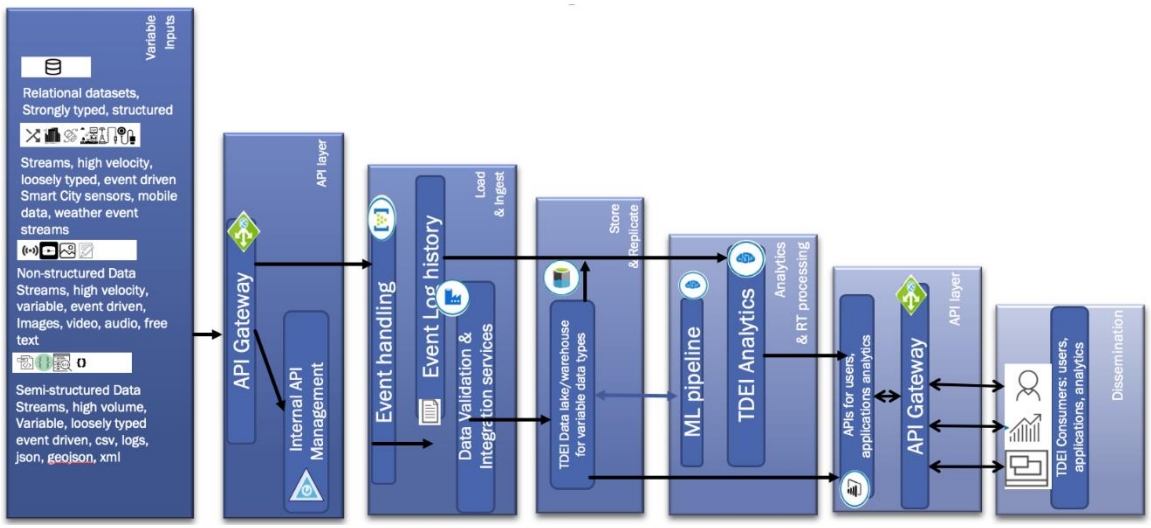

Figure 5. Functional view of core components in the TDEI.

Source: University of Washington

The project team will develop the system architecture in Microsoft Visio or an equivalent software product, and the team will store this document electronically and update it whenever a high-level design change takes place. In particular, if updates occur as part of the Agile development process, an updated version will be included as part of that release memorandum to document the changes that were made to the diagram. Any versions of this architecture submitted as part of a deliverable will be made available in PDF format. Additionally, a change log will track architecture decision records when updates are made to the overall architecture.

The project team will work in coordination with the USDOT to utilize IEEE Standard 42010-2011 or an approved alternative for developing a system architecture. The system architecture will touch on the following:

- Enterprise Architecture – showing relationships between organizations required to support the overall system architecture.
- Functional Architecture – showing functional elements and their logical interactions that satisfy the system requirements.
- Physical Architecture – showing physical objects and their application objects, as well as the high-level interfaces between those physical objects.
- Communications Architecture – showing the communications protocols between application objects.

The project team will utilize the National ITS Architecture and will consider any applicable ITS standards as part of site efforts to design interoperable, extensible capabilities. Because the TDEI system will be a predominantly stand-alone system, its data flows as part of the ITS architecture may be fairly limited in comparison to a traditional ITS project; the project team anticipates linkages tied to data produced by the transit agencies (e.g., GTFS data feeds) as one of the elements that may align with the National ITS Architecture initially. Areas where the ITS Architecture does not represent the TDEI, but where the UW team believes the ITS Architecture could represent the TDEI with additions, will be noted and provided to the USDOT.

The System Architecture Document (SAD) will also include a Standards Plan and an Interface Control Document. These will be part of the SAD deliverable.

Interface Control Document: This document will describe the nature of required interfaces to other systems. Because the TDEI system will interface with many external systems as part of its design, this document will be important to record the direction of data flow (e.g., one way or bi-directional) and the extent of data that are exchanged through these interfaces.

Standards Plan: The relevant standards that will be used by this project are OpenStreetMap (OSM), OpenSidewalks (OSW), GTFS-Flex v2, and GTFS-Pathways. These standards are governed by standards managing bodies and are utilized for real-world applications.

The TDEI project strongly supports the use of standards, and existing standards will be used wherever possible in this project, with extensions proposed to those standards as needed (see Task 2-L). Traditional ITS standards that are more customary for other USDOT-funded projects—such as National Transportation Communications for ITS (NTCIP), SAE International standards (such as for connected vehicle applications), or National Electrical Manufacturers Association (NEMA) standards (such as for traffic signal controllers and cabinets)—have very limited applicability to this project, as the TDEI is not anticipated to deploy physical devices into ITS environments within which those standards apply. In the event that the UW team identifies areas where some of the more traditional ITS standards could better meet the needs of underserved communities, those observations will be noted for the USDOT.

Finally, the TDEI is expected to be integrated into the Puget Sound Regional Council ITS Architecture as applicable.

2.2.2.2 Design Processes

As mentioned earlier, Phase 2 will utilize an Agile approach that develops the system incrementally, as opposed to the traditional V-model approach that decomposes a high-level and detailed design before development begins. Informed by various predecessor documents both in Phase 1 and Phase 2, the UW team will compose user stories and a development roadmap to serve as the design.

For this project, the UW project team anticipates using the Scrum framework, which is one of the key types of the Agile methodology. The Scrum framework utilizes a defined product backlog and levels of planning to orient a project team toward an overall project completion. The product backlog and delivery planning are discussed in greater detail in the following subsections.

The TDEI team anticipates that Agile is the best method for delivering tasks identified as part of Phase 2 of the UW ITS4US project as described in the SEMP. As detailed in the SEMP, the Agile process will use a Product Backlog consisting of Themes, Epics, User Stories, and Tasks. It is worth noting that a Product Backlog is never complete, so the expectation is that it will be updated frequently. The earliest development of the Product Backlog only lays out the initially known and best-understood requirements. The Product Backlog evolves as the product and the environment in which it will be used evolves. The Product Backlog constantly changes to identify what the product needs to be appropriate, competitive, and useful.

The initial Product Backlog will be developed based on the user needs developed in the Phase 1 Concept of Operations (ConOps) and the system requirements developed in the Phase 1 System Requirements (SyRS). The team will do a detailed review of these user needs and system requirements to translate those user needs and system requirements into specific items to be included in the Product Backlog. The items in the Product Backlog will be prioritized based on user need and system requirements priorities. As Phase 2 continues, and as user needs and system requirements are further understood and refined (and/or the ConOps and SyRS are revised to include additional needs identified in Phase 2), the Product Backlog will be updated to reflect these refinements.

2.2.2.2.1 Delivery Planning

The UW team will utilize the traditionally defined five levels of planning often used in an Agile product. These five, as laid out in Section 2.3.4.2 of the SEMP, include Product Vision, Product Roadmap, Release Plan, Sprint Plan, and Daily Commitment. Figure 6 shows the different levels of this planning in the Agile Planning "Onion."

Figure 6. Diagram. Agile planning "onion": five layers of planning

Source: LA Metro. DrayFLEX Agile Systems Engineering Management plan (A-SEMP). Final Report. April 2019.

During an Agile project, there will be updates to all levels of plans, but the updates will occur with different cadence. The Product Vision might be defined early in the project and never change. The Product Roadmap might need only a slight update every quarter. The Release Plan will likely be updated every few weeks or once a month. A Sprint Plan lives only during the sprint. In Agile, it is acceptable to create detailed, near-term activities but keep long-term activities broader, which is why these updates vary.

2.2.2.2.2 System Design Document

The UW project team will prepare a System Design Document (SDD) that is based on the Phase 1 System Requirement Specification and the Phase 2 SAD; however, with the above-described Agile methodology, the approach to this document will differ slightly in comparison to traditional specification development. Rather than specifying all hardware and software components, this design document will identify what is known (often foundational elements that will not change) and what will be developed. Items scheduled for development will be framed in the context of a release schedule that utilizes the user stories to chart a path to completion. The design document will focus on conveying why the proposed release schedule is advantageous for the design, rather than prescribing exactly how the design will be. Details that are known at the start of Phase 2 will be provided as part of this design document; however, focusing on the development process through Agile approach will allow the system to be flexible with its design while remaining oriented in a direction that is agreeable to the USDOT and project stakeholders.

The SDD will primarily address the necessary processes for the Agile approach, outlining user stories, release schedules, and timelines. It will highlight the processes for reporting status with each release; the project team proposes to publish pre-release and release report memorandums (discussed in Task 2-E) to meet these status reporting requirements. At a high level, the pre-release memorandum will describe key features proposed for the release, a schedule, and architecture impacts, and the release report memorandum will describe and document the work done during the release.

The SDD will also discuss the process to be followed for the Scrum development methodology. In particular, it will document the approach to backlog grooming, sprint planning, and review, as well as the approach to daily Scrum meetings to serve as interim control points for the project.

2.2.2.3 Walkthroughs and Other Deliverables

In addition to the SAD and SDD, which will be created and managed through the Agile processes described above, the team will provide a Systems Architecture Walkthrough and Workbook based on the initial SAD and also a Walkthrough and Workbook based on the SDD. The SAD walkthrough will be with the Agreement Officer Representative (AOR) and federal team and is expected to be in the Washington, DC, area. The SDD walkthrough will include the AOR, federal team, and other key stakeholders. The purpose of the walkthroughs will be to demonstrate the completeness and technical soundness of the system architecture and design. Finally, the team will provide updated versions of the Phase 1 deliverables: Revised Concept of Operations, Revised System Requirements, and Revised Integrated Complete Trip Deployment Plan.

2.2.2.4 Deliverables

This design process will produce a Systems Design Document (SDD), which will include a Product Backlog Report, a Sprint Backlog, and Proposed Release Report. (See Section 2.3.4.3 of the SEMP for details on these and related deliverables.)

These documents will be submitted in Phase 2 as part of the initial design processes. A draft and final version will be submitted. Because they will be living documents, the UW team will notify the USDOT when an update to these documents has been made in response to a design deviation, often triggered later in the development process. These updates will likely occur as part of documentation submitted as part of development, discussed in the next section.

Full list of deliverables:

- Draft Systems Architecture Document (SAD)
- Systems Architecture Walkthrough and Workbook (DC metro area)
- Revised SAD with Comment Resolution Report
- Final Systems Architecture Document
- Draft Systems Design Document (SDD)
- Systems Design Walkthrough and Workbook (deployment site)
- Revised SDD with Comment Resolution Report
- Final Systems Design Document
- Updated Phase 1 Deliverables, at a minimum
  - Revised Concept of Operations
  - Revised Systems Requirements
  - Revised Integrated Complete Trip Deployment Plan.

2.2.3 Task 2-C: Data Management Planning

Under Task 2-C, the UW team will develop a Data Privacy Plan (DPP), a Privacy Management Plan, and will develop a Phase 2 Data Management Plan (DMP) based on updates to the Phase 1 Data Management Plan (DMP). These plans will build upon the Phase 1 Concept of Operations, DMP, and Human Use Approval Summary and will describe how data being collected from the project will be stored and shared while maintaining the privacy of the individuals participating in the project during Phase 2 and Phase 3. These plans will cover data for the three data standards that are published by the TDEI system, as well as the demonstration applications that will demonstrate the mobility enhancements that result from those data sources.

The DPP will document sufficient data privacy controls to mitigate the risk of harm to individuals that could result from the improper handing or disclosure of personally identifiable information (PII) and sensitive PII (SPII) collected from individuals. A specific concern documented in the Phase 1 DMP is the presence of PII, which includes potential PII, actual PII, locational PII, and SPII, as well as other potential information that threatens the privacy of an individual or group. The proposed system will not capture confidential business information. However, the data collected by the proposed system may contain locational PII, which is captured by routing and pathway requests. These data are considered research private data, meaning they are available for research, but users of the data must meet Institutional Review Board (IRB) requirements before gaining access. As part of this task, the UW team will examine whether locational PII is indeed being collected as part of the design now that further design-related details are known, and they will be cognizant of and note any other changes to data needs that involve some type of PII and how privacy will be maintained with those changes. The UW team will develop draft, revised, and final versions of the DPP in coordination with the USDOT, with accompanying Comment Resolution Reports as applicable. If directed by the USDOT, the UW team will provide the DPP to the IRB for review.

The Privacy Management Plan will be prepared in accordance with relevant state and local laws within the six deployment counties (Harford and Baltimore counties, Maryland; Multnomah and Columbia counties, Oregon; and King and Snohomish counties, Washington). It is anticipated that

the Privacy Management Plan will follow the most restrictive requirements among the six counties, although some variation may exist among each county that may need to be documented and accommodated as part of the design. A Notice of Privacy Management Consistency will be submitted to USDOT indicating that the Privacy Management Plan has been completed.

In addition to specifying the data available to enable transparent system performance measurement and to support independent evaluation, the Phase 2 DMP will serve as an operational guide for managing data collectively as a strategic asset. This plan will document decisions regarding data storage, licensing, management, standards, schema, and descriptions based on preliminary recommendations presented in the Phase 1 DMP but finalized in Phase 2. The Phase 2 DMP will cover data that are sent to, stored in, or transmitted from the proposed data repository through the processes developed by the UW team within the central system. This DMP will not deal with data that the data contributors have not submitted to the system, nor data collected by demonstration applications that are not submitted to the data repository in the form of a query, as these are data sets considered outside the scope of the project because they do not directly interact with the proposed system. This document will also present a Data Sharing Framework and discuss the difference between infrastructure data (maintained independently of the applications) and user data (maintained as part of the applications). This is particularly critical with regard to data sharing to the USDOT as well as potential opportunities to extend the life of the TDEI system, particularly through discussions to encourage commercialized data service providers to adopt the TDEI system as part of their offerings on a wide scale. The UW team will develop draft, revised, and final versions of the Phase 2 DMP in coordination with the USDOT, with accompanying Comment Resolution Reports as applicable. The Phase 2 DMP may need to be updated multiple times, incorporating changes from testing and sample data schema, with a final update at the end of the project in Phase 3.

2.2.3.1 Deliverables

- Draft Data Privacy Plan (DPP)
- Revised DPP with Comment Resolution Report
- Final Data Privacy Plan (DPP)
- Notice of Privacy Management Consistency
- Draft Phase 2 Data Management Plan (DMP)
- Revised Phase 2 DMP with Comment Resolution Report
- Final Phase 2 Data Management Plan (DMP).

2.2.4 Task 2-D: Acquisition and Installation Planning

As part of the Phase 2 effort, the UW team will develop a Comprehensive Acquisition Plan (CAP) and a Comprehensive Installation Plan (CIP). The CAP will identify the types and numbers of devices, equipment, and software-based capabilities to be acquired. The CIP will identify the types and numbers of equipment required to be configured and installed. The goal of this task is to plan for acquisition, configuration, and installation of all physical devices, software, and supporting capabilities required for the TDEI system, which specifically include any commercial off-the-shelf (COTS) and modifiable off-the-shelf (MOTS) software obtained from vendors.

The TDEI project is primarily a software and data system project. The hardware acquisition and installation will include hardware, such as cell phones, tablets, and the computer infrastructure necessary to operate and test the TDEI and affiliated cloud services. A list of items expected to be acquired and installed by the TDEI project is below. This list is a draft for now and will be refined in the CAP and CIP. All equipment purchased with federal funds will be dealt with in accordance with the contract with USDOT and will be returned to USDOT according to the contract specifications. Any server hardware necessary for running the TDEI will stay at the UW for the five-year post-deployment period and will be returned to USDOT after that period.

2.2.4.1 TDEI Acquisitions

2.2.4.1.1 Mobile Devices

- Approximately 40 cell phones for testing the AccessMap Application. AccessMap will demonstrate how the TDEI system can provide accessible routes.
- Approximately 40 GPS units, one for each cell phone, to increase the GPS accuracy of the cell phones.
- Approximately 20 tablet devices to be used for sidewalk inventory data collection.

These mobile devices are all commonly available, COTS products. The mobile devices will be selected on the basis of project requirements, device availability, and cost, and they can be acquired from a number of commercial vendors.

2.2.4.1.2 Equipment and Supporting Capabilities

- Three servers are proposed for data processing and analysis. These servers will reside at the University of Washington.
- One server will be used as a test data client. This server will reside at UW but will be installed outside the TDEI ecosystem to provide the team the ability to test a data client.
- At least one network attached storage (NAS) device will be acquired and used to store TDEI data. This device will be used to store both raw data acquired and being processed, as well as derived data products.
- The TDEI will require data backup and is likely to use cloud backup storage that will have a periodic (e.g., monthly) fee.
- The TDEI will acquire cloud services. In addition to using some on-premises (at UW) data storage and processing capabilities, the TDEI project will rely heavily on cloud storage and processing services for data storage and analysis. See Section 2.2.4.2 for details on potential cloud tools to be used for TDEI.

The servers and NAS are commonly available products and can be purchased from a number of commercial vendors. The TDEI servers may be purchased from a computer vendor with which the UW has a previous purchasing relationship. The servers and NAS will be selected on the basis of project need, technology, and cost.

Cloud services are commonly available from a number of commercial vendors. The TDEI project is considering the use of Microsoft Azure cloud services for this project, which is the platform currently used by the UW for OpenSidewalks and AccessMap. However, the final decision of which platform to use will be determined on the basis of project need.

2.2.4.1.3 Other

No vehicles, in-vehicle equipment, roadside equipment, or operations/management center equipment/capabilities will be acquired by the TDEI project.

2.2.4.2 Cloud Procurement – Potential Options

This section describes potential procurement options using the Microsoft Azure cloud platform, which is the cloud platform that the TDEI currently uses for all OpenSidewalks and AccessMap development. The use of the cloud platform is not free, but TDEI code is and will be both open-source and free to use. The TDEI software is not currently cloud-platform dependent; the team will attempt to avoid tying the TDEI software to a specific cloud platform vendor as much as possible during development, possibly by doing a first implementation on Azure and then progressively moving parts of the system to non-platform-dependent code. This type of change is enabled by the microservices architecture chosen for the TDEI, described in the Enabling Technologies Readiness Assessment (ETRA) and briefly described in Task 2-E.

The following Microsoft Azure components could be used to implement the TDEI architecture; see the ETRA for details on all these components and their potential implementations:

- TCAT's Computer Vision Pipeline for street-level imagery can be implemented with Azure Virtual Machines.
- The TDEI Event Hub can be implemented with the Azure IoT Hub.
- The TDEI Data Storage and TDEI Raw Media Storage can both be implemented via Microsoft Dataverse.
- The TDEI Application Registry, as well as the TDEI Container Registry, can both be implemented with the Azure Container Registry.
- The TDEI Data Lake/warehouse can be implemented with Azure Data Lake Storage Gen 2.
- The TDEI Integration Server can use Azure Logic Apps.
- TDEI Analytics can be implemented via Azure Monitor.
- The TDEI Data Orchestration module can be implemented via the Azure Data Factory.
- A CI/CD (continuous integration/continuous deployment) pipeline will be used to enable applications and services to be updated without affecting TDEI data producers and consumers. Azure DevOps can provide this service functionality.
- Model orchestration can be done by using Azure DevOps or Azure DataFactory.

The cloud cost estimates are based on the team's experience processing similar data for cities outside of this project. From that experience, the team has learned that the processing of the data scales nicely once the infrastructure is in place and has estimated the volume of sidewalk data expected to be collected for the project area as 1GB; therefore, the team is relatively confident in the cloud cost estimates. Cloud usage will be regularly monitored using the tools provided by the selected cloud service providers. Should the cloud costs turn out to be significantly higher, the team has budgeted for servers that are intended for testing and data analysis but that could run the TDEI if needed. For longer-term sustainability, part of the Phase 2 and Phase 3 activities will be to discuss sustainability with private and public sector data service providers.

2.2.4.3 Process and Deliverables

The UW Team will produce a CAP and a CIP. The CAP will include, for each item to be acquired, at least the following: a description, reference to relevant requirements from the SDD, all certification requirements (certification requirements are not expected to be heavily applicable to the TDEI project), and the method of acquisition and potential vendors and suppliers. All procurement will be done by the UW using existing UW procurement processes. Initial thoughts on potential vendors/suppliers are included above.

The CIP will provide an overview of procurement methods, a high-level plan for inventory management, and a high-level installation schedule and plan. The USDOT requires that the CIP will identify, for each piece of equipment, the following: suppliers, inventory control methods, required configuration or pre-installation modifications, pre- and post-installation inspection procedures, detailed installation procedures, QA/QC and maintenance processes (with identified responsible parties), a preliminary, high-level installation schedule, hardware/software configuration control processes, and spare parts/warranty contingency plans. The UW team will, to the best of our ability, provide this information for all pieces of equipment and capabilities procured, but we acknowledge that some information is not applicable to the type of equipment and capabilities that the project will procure. For example, there is no need for spare parts for cloud services, but warranties will be purchased for the servers that the project purchases. Additionally, spare cell phones, tablets, and GPS units will also be procured.

The CAP and CIP will be provided to the USDOT for review and will be revised on the basis of DOT comments. Subsequently, the UW team will deliver final CAP and CIPs to the DOT.

2.2.4.4 Deliverables

- Draft Comprehensive Acquisition Plan (CAP)
- Revised CAP with Comment Resolution Report
- Final Comprehensive Acquisition Plan
- Draft Comprehensive Installation Plan (CIP)
- Revised CIP with Comment Resolution Report
- Final Comprehensive Installation Plan.

2.2.5 Task 2-E: Software Development and Integration

The primary deliverables for this task are the Software Development Schedule (SDS) and progress and risk summaries; the Technical Progress and Status Summary section of the monthly report; and the Open-Source Software and Supporting Documentation. The SDS and progress and risk summaries will be produced in accordance with the Agile software development process that has been chosen by the UW team. Utilizing Agile will allow the project team to establish key milestones but also maintain some degree of flexibility to adjust delivery and solicit feedback from stakeholders. By completing sprints and releases that satisfy well-defined needs—as discussed earlier in this document—the project team anticipates being able to deliver a product that more closely aligns with the project's user needs while more adaptively handling risks that come with software design of this type.

In this section, we describe the Agile software development process, the Implementation and Integration processes, and the team's initial ideas for the TDEI architecture and implementation.

2.2.5.1 Agile Software Development Processes

The use of Agile in the design process was introduced in Task 2-B System Architecture and Design of this document and is more fully described in Sections 2.3.4, 2.3.5, and Section 3 of the SEMP. Figure 7 shows an illustration of the Agile Sprint process.

Figure 7. Diagram. Illustration of Agile sprints

Source: Cambridge Systematics.

The UW project team will develop the TDEI system in an Agile fashion using the Product Roadmap and Release Plan that was created and approved as part of the design process (as described in Task 2-B). Before each release, the UW project team will submit a draft and final planning memorandum (Pre-Release Planning Memorandum) that documents forecasted activities that will occur as part of that release, as well as the current relevance of those activities relative to other releases and the overall project. The Pre-Release Planning Memorandum will discuss key features, proposed release schedule and sprints, product backlog, project architecture impacts, and proposed stakeholder involvement.

After each release, the UW project team will submit a draft and final release report memorandum (Release Report Memorandum) that discusses the outcomes of that release, progress made, and updates to the proposed release schedule (including greater detail on upcoming backlog work that has transitioned from long term to near term). The Release Report Memorandum will highlight outcomes from the release, including key features implemented, product backlog addressed and traceability to system requirements, deviations from the release plan, illustration of architecture elements addressed, screenshots of features implemented, verification/validation testing, and stakeholder involvement.

A Pre-Release Memorandum and Release Report Memorandum will be developed for each release of the overall project. The length may vary, will include illustrations or screenshots, and will focus strictly on providing the necessary facts to stakeholders for documentation purposes, keeping the focus on development over documentation.

All systems and subsystems in the project will utilize the Agile approach, as the vast majority will be new software. This includes the Multimodal AccessMap demonstration application, which is existing software that will be augmented with new features and functionalities as part of this project; because it is owned by stakeholders on the UW project team, it will follow the same Agile approach as the rest of the TDEI system.

An exception will occur with the Microsoft Soundscape demonstration application, which is an existing application that is being modified to work with data produced by the TDEI system. This application is privately owned by Microsoft and will be developed in accordance with its own software development processes, over which the UW project team has little influence. The interface between Soundscape and TDEI is that Soundscape will ingest and use TDEI data. To allow both TDEI and Soundscape development to proceed in parallel, the interface that Soundscape will use to obtain TDEI data will be based on the OpenSidewalks data format, with any refinements being defined early in Phase 2. Both teams will develop their software based on that defined interface. Once TDEI data are available in that interface later in Phase 2, the TDEI and Soundscape teams will work together to verify that Soundscape can ingest and use TDEI data as planned.

The UW project team will make the TDEI system an open-source development to allow this system to be shared broadly with the development community. Exceptions will include the third-party independent demonstration applications used to test the TDEI system to digital device end users. During development of the TDEI system, all open-source code will be posted on a resource server that can be shared with the USDOT and its stakeholders at the end of each release. As of Phase 1, the UW team anticipates that GitHub may be a working repository for this open-source code, but this will be refined as part of Phase 2.

At the completion of the project, all open-source code will be submitted to the USDOT. The UW team will prepare a source code management plan before the start of the first release that documents this proposed approach.

As part of development using the Scrum development methodology, the UW team will conduct a full cycle of tasks during each sprint development: Backlog Grooming, Sprint Planning Meeting, Scrum Meeting, Sprint Review, and Sprint Retrospective.

2.2.5.2 Deliverable Descriptions

The deliverables for this task are a Software Development Schedule (SDS), an Open-Source Software/Source Code Management Plan, and Monthly Progress Reporting. The SDS will be delivered through the Agile process described above by using the Product Backlog, sprints, and releases. A high-level schedule will be created in the System Architecture and System Design process. The details of the software development schedule will be developed as the project progresses and based on the team's assessments of user needs and the team's capabilities. The Pre-Release Planning Memorandum and Release Report Memorandum for the applications developed by the UW team will provide the schedule details.

This development process will additionally produce an Open-Source Software/Source Code Management Plan. The open-source software and supporting documentation to be provided in this task will be identified as deliverables/milestones within the SDS. The public posting of all identified open-source code and supporting documentation as specified by the DOT-identified public software distribution platform will be a deliverable under this task. This updates and expands upon the information provided in Appendix B of the SEMP that discusses open-source software.

Finally, development progress will be reported in the Monthly Progress Report—to include an activity narrative, an updated Lessons Learned Logbook, updated monthly project and task

schedules, and an updated risk register—utilizing DOT templates that will be provided at the Phase 2 kick-off.

2.2.5.3 Implementation and Integration Processes

Most effort associated with implementation and integration will be captured as part of the releases discussed in the development process section above. With the establishment of release goals and tracking dependencies, the TDEI system will be implemented and integrated by virtue of demonstrating successful user stories (tied to the system requirements). At the end of each release (and documented in the release report), acceptance testing will be conducted to demonstrate that the feature is performing as expected. This will occur for all releases.

The TDEI system will be deployed in the three types of environments listed below. It is anticipated that at the end of a completed release, the TDEI system will operate in the production environment to maximize exposure to relevant stakeholders as the system develops. Implementation and integration details will be documented in each Pre-Release Planning Memorandum in accordance with the Agile development process being used by the TDEI and described above.

- **Development/Integration environment** – Used to run unit tests and Integration tests, often correlating to a release schedule.
- **Testing/Staging environment** – A complete environment in which complete system tests can be executed and system verification can be performed.
- **Production environment** – The environment in which users interact with the system to validate that original user needs are being met.

2.2.5.4 Implementation Strategy and Architecture

This section provides the team's initial ideas for the implementation strategy and architecture for the TDEI system. These initial ideas will be further developed and modified throughout the project and are provided here to give the reader a concept of the planned TDEI system. Further details on the implementation strategy can be found in the SEMP.

The TDEI system will have three main system components:

- A microservices architecture for data collection, aggregation, transformations, and other lifecycle activities.
- A data sharing architecture enabled by event streams.
- Application programming interfaces (APIs) to enable data provision and consumption.

The TDEI system is expected to be built with a microservices architecture. Microservices architecture is a modern, cloud-native architectural approach in which a single application is composed of many loosely coupled and independently deployable smaller components or services. These services typically have their own technology stack, communicate with one another over a combination of APIs and event streaming, and are organized by a specific function. Microservices are different from the traditional monolithic architecture in that microservices compose a single application from many smaller, loosely coupled services in contrast to the monolithic approach of a large, tightly coupled application. The benefits of a microservices-based architecture for the TDEI are clear. New features and functionality are faster

to develop, test, and deploy. Services can be deployed independent of each other, and no single point of failure exists. Using microservices will allow the team to increase developer productivity and agility, as well as to meet the demands of different project partners head on.

Architecting the TDEI microservices and how they interact will be the heaviest lift and present the highest uncertainty for the TDEI system. The UW team believes there is ample experience and use cases from our experience with OpenSidewalks that these use cases will serve as the starting point for outlining the microservices breakdown for the uses that the TDEI may prioritize and address. The additional use cases will keep us abreast of potential future issues, risks, and points of failure and will provide the backdrop to curate our approach and give us a deeper understanding of the tools and modularization that will provide the best, most decoupled approach.

The TDEI microservices arrangement should accomplish the following:

- Avoid requiring real-time, consistent access to functionality or data managed by another service.
- Use clean lines of segregation between microservices and pass data around asynchronously.
- Clearly define the event stream topics that services use to communicate.
- Ensure microservices can connect into one or more topics, publish new events, and/or consume the events sequentially. These events could be simple notifications of actions, or they could carry state changes, allowing each microservice to maintain its own data set.

The TDEI will use event streams, also called topics, to connect microservices. The event streams will be carefully designed to be decoupled from how they access data and to aim for “no sharing” data allowed among microservices. Event streams are often described as “distributed commit logs,” and they can be conceptualized as a list of chronological events broken up into multiple streams known as “topics.” Topics will define the interactions among the microservices used by the TDEI.

Finally, all data providers and data consumers will access the TDEI by using APIs, fed through an API Gateway that will manage permissions and security. The TDEI APIs need to be sustainable and extensible, and therefore the team will design the API calls in a way that matches the use cases selected to be addressed by the project and to ensure that the API calls are sufficiently decoupled and separated.

Ultimately, APIs are the most visible mechanism by which stakeholders will interact with the TDEI, so there are high stakes in the decisions made with respect to safeguarding the TDEI data and providing the services that stakeholders require. The team plans to reach beyond our development team and engage our partners and stakeholders in the evaluation of the API creation and governance.

As noted above, there are multiple options for open-source API Gateway solutions, and we will need to ensure that our solution offers the right kind of support not only for our data schemas and data ingest protocols, but also for caching and traffic management, for monitoring API and service usage, providing adequate content vetting and filtering, and importantly, ensuring the security needed in authenticating users and understanding their roles with respect to the data.

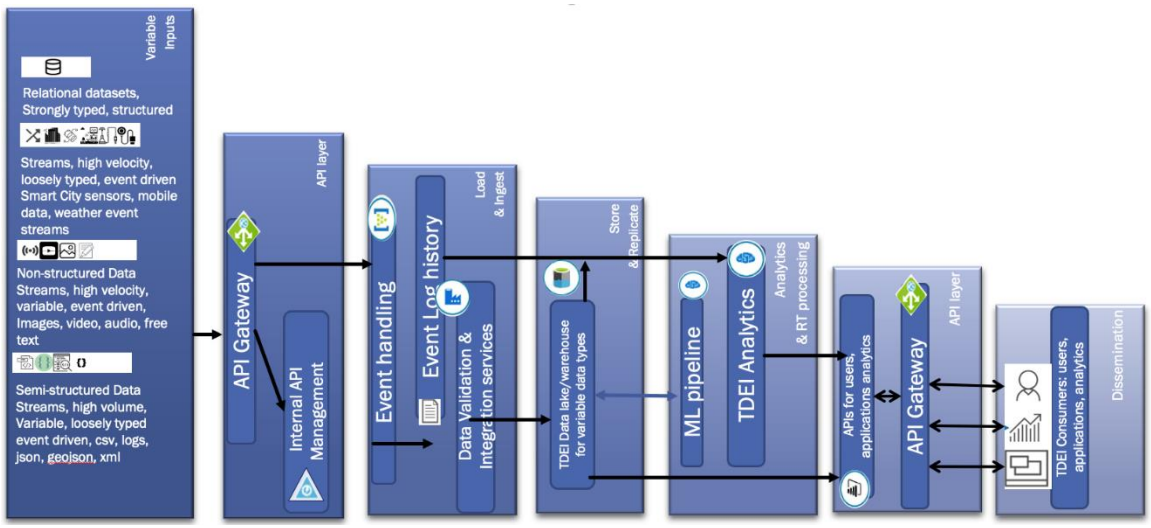

Figure 8. (repeated): Functional view of core components in the TDEI. This figure also shows how microservices, APIs, and event buses interact in the TDEI.

Source: University of Washington and Cambridge Systematics.

Figure 8 provides a high-level view of component integration—a functional view of the microservices architecture, APIs, and event buses and how they might interact in the context of the TDEI. The overall composition lends agility and scale to the architecture. The image is subdivided into functional panels, indicating in white vertical text the function of each panel.

The first panel indicates that the TDEI anticipates handling a large variety of inputs. Within each additional panel are text-labeled elements. The elements represent a group of microservices that, when grouped together, lend the TDEI the functionality described in the element's text. So, for instance, the element labeled "API Gateway" embedded within the panel labeled "API Layer" is a group of different, smaller applications that together function as an API Gateway.

2.2.5.5 Deliverables

- Initial Software Development Schedule (SDS)
- SDS Update with Progress/Risk Summary
  - Element of Monthly Progress Report Part I: Technical Progress and Status Summary, see Monthly Progress Report Section
- Open-Source Software and Supporting Documentation (per the SDS).

2.2.6 Task 2-F: Staff and Participant Training

2.2.6.1 Staff Training

As with all complex technologies, educating users and systems staff members is essential to a successful implementation of an interoperable data sharing infrastructure. Educators should have a deep understanding of the TDEI data infrastructure concepts and technological solutions. Strong interpersonal and communication talents are also important. Project leads will develop

materials for use in staff training. The areas for education of project staff will include general understanding of accessibility in the built environment; sample case studies of complete trip failures and travel disadvantage in the current system; the business case for an interoperable data sharing infrastructure and the tensions among developing operational systems/ infrastructure; the need for strong data integrity; and the needs for data provenance and transparency at every step of building and maintaining mobility data.

There will be several layers of training during the Phase 2 development process. The initial training will be for those assigned to integrate the various infrastructure tools within the pilot deployment. This training will be oriented primarily to systems staff and members of the development team. Later, training in the use of the deployment infrastructure, in analytic skills, and in the tools provided to the TDEI data tenant community (both producers and consumers) will involve both systems and engagement staff. Skilled trainers will conduct initial training, with later user training possibly taught by experienced data tenant users from the respective organizations.

For our systems staff members, training and educational material will be made available in the following manner.

1 **Repository Motivation and Administration**. The purpose of the data sharing repository will be to provide a single point of access, consistency, and interoperability for mobility data and their associated metadata. Metadata indicate where the data come from, how they should be translated or transformed, their form, and their functions. Repository training will allow trainees to effectively serve as the liaisons between the technical and user communities for the operations of the TDEI. The training will explain data management approaches, integration of producer data, and the logical models of the system, as well as the background for staff to participate and facilitate discussions in the standards development teams.

2 **Data Consumer Requirements Training**. The goal of this portion of the training will be to provide staff an understanding of the analytical processes and data needs that TDEI consumers might have. The training may include representatives from the community to explain and identify their informational requirements. These training exchanges may prompt the next requirements gathering phase for the TDEI. The training facilitator will ensure that questions about data consumers' needs have been identified and answered satisfactorily.

3 **Training on Data Integrity, Provenance and Data Modeling**. Staff will be trained on a summary representation of consumers' informational requirements and a detailed representation of the TDEI data schemas, including the informational data model, and how they support the consumers’ informational requirements. Both are necessary for the proper, cohesive development of the system and will be conducted as part of systems development and enhancement efforts. Operationally, a team of data tenants will guide the build of models, and then TDEI will validate them by mapping data from producers to the TDEI infrastructure. Staff should be aware of both the operational and informational processes that answer travelers' informational queries; map producers' processes to consumers' data needs; match via similarity and differences in data stored across mapped regional systems; and extract only pertinent data as requested. These trainings will be led by trainers with some data modeling expertise and who are part of the data administration staff.

2.2.6.2 Participant Training

Participant training courses will be delivered in multiple formats with different time options. The specific choice of modules will depend on settings, previous knowledge, and desired outcomes. The modules will be adopted heavily from an initiative from the Center for Participatory Research at the University of New Mexico, in collaboration with the Health Promotion Unit of the Pan American Health Organization (PAHO).

The goal is for participants to engage in interdisciplinary and cross-sectoral learning through self-reflection about their own life experiences and power relations, in-depth dialogue involving new ways of listening to and with others, and translation of reflection into opportunities for collective action, with the aim of reconstructing new realities for improved community active transportation, access to mobility, and well-being.

There will be four main participant training components:

1 **Community Empowerment**. This module will discuss community empowerment through data and data science. Discussions will include topics related to data, privilege, and social determinants of health. Social and community participation leading to empowerment has been a key strategy of health promotion to encourage community mobilization, with supportive environments and healthy public policy as key pillars for a healthy society. The concept of this training is that community empowerment—specifically encouraging people to gain control over their lives through collective action—can improve social justice and equity outcomes. In particular, this training is related to the TDEI in that a part of the sustainability and maintenance of the data will be through community data stewardship. For this reason, we need to engage participants in long-term support for the project, data collection, and use the data to engage public discourse.

2 **Tools for Community Empowerment**. Community empowerment tools will be structured around the TDEI's data schemas and deployment demonstrations. Participants will learn by practicing with and experiencing the traveler-centered deployment tools as well as participatory mapping and codifying tools, identification of mobility themes, and case studies. Communities and their partners will use these to trigger and facilitate effective dialogue, engage in action planning, and create strategies for data-driven change, along with data-driven evaluations (as outlined in 4 below)

3 **Community-Based Participatory Action as a Roadmap for Data Stewardship**. This training will use processes borrowed from community-based participatory research (CBPR, a collaborative approach of research-in-action that incorporates data and the creation of knowledge by equitably involving all partners in the process). Starting from community priorities, CBPR, known alternatively as community engaged research (CEnR), integrates evidence-based and local community knowledge to support data stewardship and collaborative creation of effective data-driven programs to achieve social change. The CBPR model provides participants with a framework for both planning and evaluation of community-engaged practice. This module will create the engagement plan and data stewardship for each locale.

4 **Data-Driven Evaluation**. In these modules, participants will choose specific travel, mobility, and transit issues addressed through the deployment demonstration tools to create a roadmap for both measuring success and making mid-course design iterations with TDEI partners. In planning for these outcomes, participants will understand how to organize a project or program using results-based accountability; establish indicators to measure community participation, access to mobility, and health impact; and evaluate projects with community stakeholders.

2.2.6.3 Training Materials

Our technical staff will work closely with the design and editorial teams within the team to ensure that training materials are clear, concise, and cohesive, and that relevant graphics, figures, and other visualization strategies are used effectively and generously to appropriately enhance the writing. The UW team will develop polished data standard user guides, as well as concise and informative stakeholder education materials for the three demonstration applications. Training materials will be tailored to specific audiences, providing them the information they seek in a self-contained, easy-to-digest format.

2.2.6.4 Deliverables

- Initial Training Implementation Schedule (TIS)
- TIS Update with Progress/Risk Summary
    - Element of Monthly Progress Report Part I: Technical Progress and Status Summary, see Monthly Progress Report Section
- Training Materials (Initial and Updates, as specified in the Participant Training and Stakeholder Education Plan (PTSEP) and TIS)
- Human Use Approval Confirmation Materials (per the Human Use Approval Summary (HUAS).

2.2.7 Task 2-G: System Test Planning

This task will document the necessary tests and demonstrations that establish operational readiness. An Operational Readiness Plan (ORP) will be developed to describe the tests and demonstrations that will need to be completed to a satisfactory and successful level to consider the TDEI system ready to move to an operational phase. The Draft ORP will be part of an Operational Readiness Plan Walkthrough that will be conducted.

2.2.7.1 Testing

Testing will be conducted to verify that the system performs according to the documented system requirements established in the Phase 1 System Requirements Document. A System Test Plan (STP) will be developed to outline how the TDEI system will be verified and validated against the needs and requirements set forth by the stakeholders of the project.

The STP will factor in the defined Agile User Stories and Release Plan to document the “when” and “where” that a particular element will be tested and demonstrated. This schedule will set expectations about when certain elements are tested, as well as support the release schedule by calling out interdependencies and other critical-path needs. The STP will discuss the overall test

processes and how failures will be handled, how regression testing will be accomplished, how deficiencies/defects will be handled and reported (likely through an update in sprint or release planning), and how the test results and progress against schedule will be reported. A Requirements Traceability Matrix (RTM) will outline the traceability between the test case and the system requirements it addresses, as well as its test verification method (e.g., inspection, demonstration, analysis, or test).

This effort will further reiterate that the defined user stories truly encompass all the necessary elements that need to be demonstrated. Most effort associated with implementation, integration, and testing will be captured as part of the releases. By establishing release goals and tracking dependencies, the TDEI system will be tested by virtue of demonstrating successful user stories (tied to the system requirements). At the end of each release (and documented in the release report), acceptance testing will be done to demonstrate that the feature is performing as expected. This will occur for all releases.

The three environments in which the TDEI system will be tested are Development / Integration, Testing / Staging, and Production, as discussed in Task 2-E.

It is anticipated that at the end of a completed release, the TDEI system will operate in the production environment to maximize exposure to relevant stakeholders as the system develops. Releases will undergo system verification in the test environment. Sprints will undergo their tests in either the development or the testing environment, as appropriate. All these details will be documented in each Pre-Release Planning Memorandum. Demonstrated outcomes of these tests—occurring as part of Task 2-H, discussed later—will occur with each release and will have covered the necessary elements by the final release. Additionally, the STP will highlight how unincorporated system requirements will be identified as part of testing and how those will be dealt with. The project team will provide an opportunity for USDOT to review untraced system requirements as part of the Backlog Item planning (early in Phase 2), throughout the release schedule as things change, and as part of the System Verification efforts.

The TDEI system is anticipated to have three main system components built with the three core enabling technologies. These components and the enabling technologies are described in detail in the Phase 1 ETRA. Testing for these components is described below.

1. **A microservices architecture for data collection, aggregation, transformations, and other lifecycle activities.** Two key pieces of testing are envisioned: 1) testing each microservice individually to ensure that the microservice itself functions as described by the microservice definition, which is driven by user needs and system requirements; 2) testing the microservice's integration into the architecture and the microservice's interactions with other microservices—ensuring that microservices can connect to topics and publish and consume events. The ability to break testing down into these two pieces—functionality testing and integration testing—will make testing easier and will help ensure a more stable system.

2. **A data sharing architecture enabled by event streams.** Event streaming is a modern mechanism for connecting microservices, allowing the asynchronous exchange of information, which provides for improved system efficiency, scalability, and extensibility. Event streams are also often referred to as "topics." Microservices can connect to these topics to publish and consume events. The team envisions a multi-step test process to

successfully test and demonstrate the event streams, which are envisioned to be tied to real use cases of the TDEI infrastructure.

3. **Application programming interfaces to enable data provision and consumption.** The team envisions doing automated and limited manual API testing using a number of open-source tools. In alignment with the Agile software development process, testing will be performed at each development step and before each release.

Additional tests may be needed to support the assessment of operational readiness, which will be documented in the Operational Readiness Test Plan (ORTP). Generally, these may include, but will not be limited to, the following: 1) untested or retested user stories that did not get resolved as part of an earlier release test; 2) previously accepted user stories that stakeholders wish to see again or the project team and/or the USDOT deem valuable enough to test again when the system is fully complete; and/or 3) user stories that are at a higher level than those defined in release planning that encompass end-to-end capabilities. The ORTP, at a minimum, will incorporate the following elements for each proposed test as part of the documentation: descriptions, inputs, procedures, data, results, failure remediation, and schedule.

In the Agile process followed by the team, the System Development and Acceptance Testing System Engineering deliverable will be delivered as followed:

- The System Development source code with comments will be stored in a version control system and updated with each release.
- Unit tests will be written as automated tests and will be stored together with source code for the product in a source version control system. An executed and passing Unit test will be part of the “Done” criteria for each user story and release.

2.2.7.2 Demonstration

An Operational Readiness Demonstration Plan (ORDP) will be developed to show how the system will be demonstrated to perform as expected in key use cases or scenarios. The ORTP will conduct use case demonstrations that are at a higher level than those in the STP or demonstrated as part of the releases because the purpose here will be to show that the system operates with end-to-end capabilities that are central to the deployment Concept of Operations. This will serve as a key step in system validation efforts, which demonstrate that the project’s user needs (defined in the Phase 1 Concept of Operations and User Needs Identification and Requirements Planning (UNIRP)) are being met as part of this proposed system. Demonstrations will be conducted in a manner that is observable to the USDOT, allowing for review of whether the intended result was accomplished. The ORDP, at a minimum, will incorporate the following elements for each proposed demonstration as part of the documentation: descriptions, procedures, data, and results.

In some cases, opportunities may exist to demonstrate some key use case scenarios before the completion of all releases. Since the release plan will not be developed until Phase 2, it is not known whether these opportunities are feasible. It is likely that most of these high-level demonstrations will be after the last release in order to show those end-to-end capabilities.

A preliminary list of proposed demonstrations will be documented as part of the Operational Readiness Concept Briefing. The demonstrations will include, but not be limited to, the following:

- The use cases that help validate the system against the user needs, as outlined in the UNIRP and the Phase 1 Concept of Operations document.
- Safety-focused demonstration elements to address key scenarios identified in the Phase 1 Safety Management Plan.
- Privacy-focused demonstration elements illustrating key privacy aspects contained in the Phase 1 Concept of Operations, the Phase 1 Data Management Plan, and the Phase 2 Privacy Management Plan.
- Performance measurement and evaluation support demonstration elements (e.g., a dry run) illustrating key aspects of the Phase 1 Performance Measurement and Evaluation Support Plan, including data collection and processing (see Task 2-K).
- Institutional coordination and successful execution of governance frameworks, management processes, and financial arrangements, illustrating key aspects of the Phase 1 Institutional, Partnership, and Financial Plan.
- Maintenance-oriented demonstration elements (see Task 2-I).

2.2.7.3 Deliverables

- Draft System Test Plan
- Revised System Test Plan with Comment Resolution Report
- Final System Test Plan
- Operational Readiness Concept Briefing (DC metro area)
- Draft Operational Readiness Plan (ORP)
- ORP Walkthrough and Workbook (DC metro area)
- Revised ORP with Comment Resolution Report
- Final Operational Readiness Plan (ORP).

2.2.8 Task 2-H: Installation and Operational Readiness Testing

2.2.8.1 System Test Results Summary:

Before the start of the Operational Readiness Testing, as outlined in the ORTP, the team will deliver the System Test Results Summary (STRS). The STRS will document the test results that were produced per the STP from Task 2-G. In addition to providing a pass-fail status of the tests conducted in the unit, subsystem, integration, and system acceptance test phases, the STRS will provide additional guidance about which Agile release tested a particular item, whether it had failed but subsequently passed in a later release, and whether corrective actions were taken between releases to bring a particular test to a passing metric. Additional details and insights that were part of the release—such as stakeholder feedback or key changes in design—will be documented as part of this summary. The goal will be to provide a chronological summary to help show the evolution, as applicable, of a particular testing element or component as it moved through the Agile development process. This will provide a historical ledger of defects that occurred in the past, with some details available to discuss their impact on the system and their severity based on information at that point in time. Ideally, this will help reduce the number of

open defects that remain at the last Agile release, as well as provide a greater document trail of previous development challenges.

Any open defects that remain will be documented, along with their impact on the system, severity, and anticipated timeframe for resolution.

Specifically, the STRS will address the following:

- **System Verification Results**: A summary that documents the necessary user stories to be demonstrated by the proposed system to verify that the necessary system requirements have been met.
- **System Validation Results**: A summary that documents the necessary testing scenarios that will be examined with stakeholders to validate that the necessary user needs in the ConOps have been addressed. Sprint reviews with stakeholders will be held for each increment. The working product will be tested by a smaller group of real users (beta testing) or a specific user group. This user testing can be performed for every increment or when the larger set of features is ready. Some validation of the project for achieving goals can be done in the performance measurement plan.

2.2.8.2 Operational Readiness Test Results Summary Documentation and Operational Readiness Demonstrations

After the completion of the Operational Readiness Tests, the test results will be documented in accordance with processes identified in the ORTP. This will likely include the tests identified specifically in the ORTP, as well as any additional tests that were added from the STP because of not being complete for reasons such as a defect. Results will be published in a manner that aligns with what was provided in the ORTP.

Operational demonstrations will be scheduled in conjunction with the USDOT, and they will be conducted and documented per the processes identified in the ORP. The project team will explore and propose opportunities to demonstrate the TDEI system in accordance with the ORDP based on stated preferences of key participants, subject to USDOT approval.

2.2.8.3 Installation and Operational Readiness Testing Schedule (IORS)

The team will produce an Installation and Operational Readiness Testing Schedule (IORS), a work breakdown structure of activities (and dependencies) required to implement the CIP and ORP. The tasks defined in the CIP and ORP will be analyzed to determine the best schedule for implementing those tasks. Technical risks and issues will be documented and will be included in an IORS updated with a progress and risk summary, which will be included in the Monthly Progress Report. In addition, all tests will be documented with test results. and results will also be included in the updated IORS progress and risk summary as part of the Monthly Progress Report.

2.2.8.4 Deliverables

- Installation and Operational Readiness Testing Schedule (IORS)
- IORS Updated with Progress/Risk Summary
    - Element of Monthly Progress Report Part I: Technical Progress and Status Summary, see Monthly Progress Report Section

- System Test Results Summary (STRS)
- Test Results Summary Documentation (per the ORP)
- Operational Readiness Demonstrations (per the ORP).

2.2.9 Task 2-I: Maintenance and Operations Planning

The operations and maintenance process will begin when the first release of the TDEI system is deployed into the production environment, even though all system features may not be available yet. This means that operations and maintenance will commence in Phase 2, even though the demonstration and evaluation may occur more in Phase 3. As part of release planning, the team will identify the capabilities that define a functioning release in the production environment that would initiate operations and maintenance processes. When the system enters production, it will be monitored for compliance with the necessary service levels, such as up-time performance and response times of system components. This will also provide an opportunity to collect user-reported issues as stakeholders begin to interact with the system beyond the demonstrations that occur as part of system verification and validation, likely through a problem ticket submission system. Note that even though the system undergoes operations and maintenance processes as a partial system, the UW team will still follow the Phase 2, Phase 3, and post-deployment schedule requirements that are initiated by other project milestones; initiation of operations and maintenance in Phase 2 will put the processes in place to keep the system running in a production environment during development.

Each new release will be added to the production environment in accordance with the project schedule. The UW ITS4US project team will aim to send new releases into production during the overnight hours when potential stakeholder use is low, even though this is not yet considered a full system. Once the full system has been deployed, an established maintenance time will be published to help inform users of potential downtimes. It is unknown how frequently this patching schedule will occur.

Members of the UW team who are tasked with operating and maintaining the system will need some training to maintain critical operation features, troubleshoot minor issues, restore the system when necessary, and complete other tasks.

2.2.9.1 Deliverables

The team will produce a Comprehensive Maintenance and Operations Plan (CMOP), which will address operations and maintenance for all hardware and software acquired for this project. Given that limited hardware will be acquired for this project, the primary focus of the CMOP will be on maintenance and operations of the TDEI software, with a secondary focus on the relevant hardware. The categories for the CMOP will include mobile devices for which limited maintenance and operations are expected. The CMOP will also address the category of equipment and supporting capabilities, namely the servers, network attached storage, and cloud services. The servers and network storage are expected to be maintained by UW Information Technology staff according to the hardware provider’s specifications. Cloud systems, especially cloud hardware, will be maintained in large part by the cloud provider as part of the service agreement with the cloud provider. It is expected that UW Information Technology staff or TDEI subcontractors will be responsible for maintaining any software deployed on the cloud, such as frameworks, event streaming services, or other software that is being used, but not developed, by the TDEI team.

The UW team and development sub-contractors will maintain the TDEI software, likely in a GitHub repository, following software maintenance best practices. A draft CMOP will be provided to the USDOT for review, and a final CMOP incorporating comments from the USDOT will be provided to the USDOT.

- Draft Comprehensive Maintenance and Operations Plan (CMOP)
- Revised CMOP with Comment Resolution Report
- Final CMOP.

2.2.10 Task 2-J: Stakeholder Outreach

The Transportation Data Equity development project is designed to improve mobility data infrastructure so that all travelers can discover mobility options, make informed mobility decisions, and avoid friction caused by a lack of data about their trips. The initiative will also make data handling simpler for mobility service providers by enabling all providers to use public data about other services and travel environments and by consolidating mobility data and making them consistent. In developing outreach approaches, the TDEI plans to reach out to stakeholders (data producers, consumers, app developers, and information consumers at the application level) through global and local communication mechanisms, engagement tools, and feedback opportunities.

2.2.10.1 Outreach Goals of the Transportation Data Equity Initiative

The Transportation Data Equity Initiative is a well-scoped, focused data infrastructure project that creates value through fundamental data capacity building. However, its potential impact and benefits to different stakeholder groups addresses a number of complex issues and concepts. The unifying theme for the TDEI outreach goals is that many potential stakeholders (people and organizations alike) are oriented to staying ahead of the current issues that they face. Therefore, the project's outreach activities will include marketing and communicating both the direct and indirect benefits of the project. The project's outreach goals will include the following:

- Explain the TDEI project and expected benefits to wide audiences.
- Explain the TDEI project and project outcomes to targeted audiences, including but not limited to transportation conferences, panels, webinars, demonstrations, journals, and convenings of accessibility-focused public gatherings.
- Communicate, particularly with data producers and transportation service providers, that building capacity through growth in data infrastructures enhances transportation delivery.
- Convey to larger audiences how building an open, shared, interoperable data repository about sidewalks and other travel environments promotes current agendas related to
    - Pedestrian safety
    - Safe Routes to Schools
    - Community resilience, particularly for first responders
    - Protecting and prioritizing infrastructure investments
    - Facilitating performance measures for street environments, commensurate with Smart Growth America and Complete Street standards
    - Mitigating transportation impacts on climate change via increased capacity for multi-modal trip planning and active transportation

- Public involvement and equity metrics for community health

- Building sustained enthusiasm for the TDEI data, promoting sustainable community efforts and data stewardship past the end of the project
- Enhancing project visibility within the industry.

2.2.10.2 Target Community Engagement Groups

In Phase 1, the TDEI project conceptually categorized its stakeholder pool into several characteristic needs categories having to do with their relationship to the data collected, stored, shared, and disseminated by the TDEI data infrastructure (see the Phase 1 Needs Summary for the UW project). We will continue to refer to these categories of stakeholders as a useful tool for framing and targeting our marketing and communications collateral.

Many of the individuals who engaged with us in Phase I are also leaders nationally in their fields. Thus, they serve as an excellent resource for both disseminating the outreach messaging as well as identifying new recipients for outreach information. The following are the five targeted categories of interested parties in the TDEI data project:

1. **Data Generators (DG)** – Entities in this group include ***data producers*** from private-sector data companies, governmental bodies, or transportation agencies. Governmental bodies and transportation agencies that own and operate sidewalk infrastructure or transportation hubs typically produce data about these assets.

2. **Transportation Service Providers (TS)** – Entities in this group include ***data contributors*** from public- or private-sector transit agencies or transportation operators that offer fixed-route or on-demand transit service, or that may own, operate, and maintain transit station facilities.

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 ***data aggregators*** that obtain data from multiple sources (e.g., mobility data foundation).

4. **Application Developers (AD)** – Entities in this group include ***data consumers*** that create digitally based, user-facing applications that use data from public- or private-sector organizations that disseminate data for mapping or travel.

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 travel disadvantage who utilize digital cartography and information to make informed travel decisions.

The five groups have been chosen to ensure that targeted messaging of the TDEI matches the audience's experience with data infrastructure and technology. Throughout Phases 2 and 3, we will continue to recruit participants for user needs identification, to participate in the co-design process, and to evaluate the technology outcomes of this project. When stakeholders engage, we will use outreach tools designed for outcome messaging and sustained enthusiasm for the TDEI. Separate outreach activities will take place with would-be data producers (regional transit

operators, transit facility operators, community organizations, and municipalities) to build regional data collection interest and gather support for data stewardship after the project ends.

2.2.10.3 Outreach Implementation Strategies

A key emphasis of the TDEI has been the incorporation of meaningful engagement of people with disabilities and stakeholder partners throughout all Phase 1 activities across the three topic areas of project activities: data schemas, data governance, and technical operations. In accordance with the TDEI's outreach goals, we will produce inclusive, consistent messaging about the project itself (capacity building for data infrastructure) as well as how TDEI benefits and enhances other efforts to improve community well-being and equitable travel outcomes. These messages will be conveyed with targeted, sub-segmented audiences as outlined in the previous section, through the following mechanisms:

- The TDEI website
- Quarterly emailed project updates, with specific targeted messaging for each needs stakeholder group
- Public video
- Project brochures
- Annual Project Impact Reports
- Project fact sheet and infographics
- Social media
- Press releases
- Local press
- National press
- Public meetings and hackathons/mapathons
- Trade journal articles
- Trade shows, webinars, workshops, and conferences.

2.2.10.4 Communications and Recruitment Strategies

The UW team will employ the following communications and recruitment strategies:

- TCAT's marketing and outreach services (including both the UW teams and the CS communications teams).
- Working with regional leaders, nonprofits, and partnerships built throughout Phase 1.
- TCAT's social media, email project updates, and slack channels, with the hashtags #map4dataequity, #transitequity, #moveequity, and @OpenSidewalks.
- Storytelling in TCAT's email updates and website, for example, descriptions of product capabilities from the perspective of users and their travel stories.
- Ongoing outreach at events and through transportation organizations and statewide campaigns.

2.2.10.5 Deliverables

- Draft Phase 2 Outreach Plan
- Revised Phase 2 Outreach Plan with Comment Resolution Report
- Final Phase 2 Outreach Plan
- Initial Outreach Implementation Schedule (OIS)
- OIS Updated with Progress/Risk Summary
    - Element of Monthly Progress Report Part I: Technical Progress and Status Summary, see Monthly Progress Report Section
- Outreach Materials (as specified in the Phase 2 Outreach Plan and OIS).

2.2.11 Task 2-K: Performance Measurement and Independent Evaluation Support

In this task, the UW team will collect, process, and distribute data and performance reports according to our Phase 1 Performance Measurement and Evaluation Support Plan (PMESP). The UW team will also support the USDOT's independent evaluation effort. The details of these efforts are described in the PMESP report and the Data Management Plan (DMP).

The design of the evaluation can be divided into five major reporting efforts:

- The effectiveness and acceptance level of the three data standards that are part of this project.
- The amount and quality of the data developed as part of the project.
- The performance of data vetting systems implemented to further increase the quality and reliability of data shared with the public.
- The performance of the data sharing system that makes the data accessible to third-party applications via APIs.
- The performance of the three demonstration applications, in terms of both their ability to access, download, and deliver the data being collected in this project and, in the case of Multimodal AccessMap, the travel outcomes achieved by delivering those data to users.

The project will also examine the level of satisfaction stakeholders have with the data, systems, tools, and applications with which they interact to determine whether the needs they have expressed as project stakeholders are being met.

As part of this task, the UW team will prepare a Performance Measurement and Evaluation Support Schedule (PMESS) that includes a work breakdown structure for the project activities that are required to implement the PMESP and DMP. The work breakdown will also describe all dependencies that support the work required for performance measurement and to support the independent evaluation effort. The PMESS will identify milestones, performance summary reports, and pre-deployment ("BEFORE") data for coordination with DOT.

The UW team will deliver an initial draft PMESS to the AOR for review and will prepare monthly updates to the PMESS in response to DOT comments, as well as documenting progress against

plan. These monthly updates will also track known risks and issues and their resolution. The updated PMESS will include a concise summary of activities under way, progress made since the last update, and a data impact log that records any changes that affect data needed for the performance measurement effort. Monthly schedule and risk updates will be delivered to the USDOT from the time that this task is initiated until the end of Phase 2.

Periodically (but no less than once), the UW team will update the PMESP in Phase 2. The team will document within the updated PMESP all analytical models and algorithmic methodologies utilized in performance measurement calculation. The team will also update the DMP, as noted in Task 2-C, according to the PMESP update and as required by feedback obtained as part of the Human Use Approval.

The UW team will deliver the products identified in the PMESP and other supporting information on or before the delivery dates identified in the PMESS.

2.2.11.1 Deliverables

As part of this task, the UW team will deliver the following documents:

- An initial PMESS.
- Monthly updates to the PMESS that will be included as an element of the monthly progress report within the Part I: Technical Progress and Status Summary. Updates will describe and summarize project progress and changes to known risks.
- At least one update to the PMESP during Phase 2, with additional updates provided if changes to the PMESP are required.
- Revised performance measurement materials that differ from those previously identified in the PMESP and PMESS if they are required. For example, these could include changes to pre-deployment performance data, system performance reports, or other supporting information.
- A revised Human Use Approval Summary that reflects any necessary revisions requested by the UW's IRB.

2.2.12 Task 2-L: Participation in Standards Development

The TDEI team has and will be heavily engaged with standards development organizations (SDOs). Use of data standards and engagement in and improvement of those standards is a core principle of the TDEI.

2.2.12.1 Need for Standards

Without standardization, systems cannot be scaled. Data input must be standardized, or every new deployment requires re-engineering of that input. Once data standards exist, economies of scale allow the development of far more cost-efficient approaches to data collection, storage, and access, and that access allows the scalability in application development required for widespread adoption of those applications.

There are two difficulties with the adoption of standards. The first is making sure that the standards being adopted have the right features. Without those features, the standards will not

meet the needs of users. The second problem is obtaining widespread adoption of the standards. This project will deal with these two issues as described below.

As mentioned above, if the UW team identifies opportunities where traditional ITS standards development could benefit from lessons learned in this project, the team will note those opportunities for the USDOT.

2.2.12.2 Standards Applicable to the TDEI

The standards and associated SDOs that the TDEI team will engage with are listed below.

OpenStreetMap (OSM) (https://www.openstreetmap.org/about) is a community-built map and map standard managed by the OpenStreetMap Foundation (https://wiki.osmfoundation.org/wiki/Main_Page). OSM is a "free, editable map of the whole world" that "includes data about roads, buildings, addresses, shops and businesses, points of interest, railways, trails, transit, land use and natural features." (https://welcome.openstreetmap.org/what-is-openstreetmap/) OSM is a widely accepted and used map and standard.

OpenSidewalks (OSW) (https://www.opensidewalks.com) is an extension to OSM that supports standardized data for information such as sidewalks, curb cuts, and street furniture to help fill a longstanding gap in data about sidewalks, especially as that information pertains to people with mobility limitations. OSW has been accepted by the OSM community and is managed by the OpenStreetMap Foundation, the same foundation that manages OSM.

GTFS-Flex v2 (https://github.com/MobilityData/gtfs-flex) is a proposed extension to the General Transit Feed Specification (GTFS) (https://gtfs.org) that adds the capability to model demand-responsive transit. (GTFS models only fixed-route public transit.) GTFS-Flex v2 data are produced by Trillium (https://trilliumtransit.com/) and OpenTripPlanner v2 (https://www.opentripplanner.org/).

GTFS-Pathways (https://gtfs.org/reference/static#pathwaystxt) is an extension to GTFS that is used to describe "pathways" through subway or train stations.

GTFS-Flex v2 and GTFS Pathways are managed by MobilityData (https://mobilitydata.org).

Note that because of the nature of the TDEI project, the TDEI will focus on standards relevant to transportation data, as listed above, more than traditional ITS standards.

2.2.12.3 Standards Development Organization (SDO) Involvement

The UW team will engage with the OpenStreetMap Foundation and the Mobility Data Standards Development organizations. The project team will attend regular meetings of these SDOs and will interact with the SDOs by using the SDOs' standard communication mechanisms, which may include electronic communication via GitHub repositories for the standards. The UW team will provide feedback to the SDOs and will, as appropriate, propose extensions to the standards based on lessons learned from the TDEI project. The UW team will create one SDO memorandum for each standard with which the team engages to describe the project team's engagement with the appropriate SDO for that standard and any proposed changes to the

standard. The USDOT will be kept apprised of all SDO engagement through the Monthly Progress Report.

2.2.12.4 Standards Philosophy

The UW team has been engaged with the SDOs referenced above—OpenStreetMap Foundation and Mobility Data—long before even Phase 1 of the TDEI project began. This section summarizes the project team's approach to standards. To develop and obtain adoption of standards, the first requirement is that the standards meet the needs of the broader stakeholder community. One of the key findings of our work with the disability community is that no two travelers are the same. Personal differences result in different individuals choosing or requiring different paths from a common origin to a common destination, where the "best" path is a function of each individual's mobility attributes. One individual may be able to step on and off curbs, whereas a companion may use a manual wheelchair that requires curb ramps. The third member of their party may use an electric wheelchair, which is wider than the manual wheelchair and requires a wider path than the second traveler. This simple example shows that pathway data must include a variety of physical attributes.

Our experience working with different communities has shown that users of the navigation system must provide input into what those attributes are. We have also discovered that the attributes must be collected and described in objective ways, as subjective descriptors (e.g., "accessible") are not universally applicable to all travelers. For example, a description such as "concrete ramp access, 2 percent slope, 5 feet wide" can be used by anyone to determine whether that entrance is accessible to them.

Having a standard is not the end point. Many standards have been adopted but are rarely used. The only truly useful standards are those that actually solve the business problems they were intended to address. They must not only exist but allow applications that use those data to solve actual business problems. In addition, they must provide enough benefit to users that users will adopt them. One of the best ways to ensure adoption is for groups with national or global reach to deliver data using those standards. Two excellent examples of this approach are the Traffic Messaging Channel (TMC) network model used for the delivery of the National Performance Management Research Data Set (NPMRDS) and many vehicle navigation directions. An even more applicable standard is the GTFS.

Our project seeks to duplicate this process by working directly with Google, Microsoft, and Mapillary, as well as with the user stakeholder community. The three large technology firms all have very strong corporate interests in providing data useful to the population as a whole, and they operate significant transportation data APIs and navigation systems. As a result, they are currently working as active stakeholders in the project to ensure they understand the potential improvements being developed so that they can absorb those improvements in their systems. Thus, these working relationships ensure not only that the standards meet the needs of the users but also the adoption of those standards—and potentially an expansion of the market for their use from our pilot deployment sites to the national stage and even the world. This in turn will lead to the last motivating factor, sustainability.

2.2.12.5 Sustainability

Our project team has learned from painful experience that the best technical advances change the world only if those developments are sustainable in the long term.

To achieve sustainability, the project will work with major data service providers (Microsoft, Mapillary, Google) to create replicable and scalable data pipelines that can be leveraged by end-user applications for accessibility (such as Soundscape and Multimodal AccessMap). Importantly, we believe those same data pipelines will also be useful for multiple commercial applications, such as sidewalk-navigating wheelchairs or delivery robots (e.g., Scout, FedEx SameDay Bot, etc.) and even software applications designed to help cities manage their sidewalk networks and prioritize improvements to those networks.

We strongly believe that once the sidewalk data standard has been constructed, business plans exist that will allow it to be indefinitely sustainable. Similarly, the benefits of GTFS-Flex and GTFS-Pathways to all three primary stakeholder groups (users, transit agencies, and map-navigation companies) will be sufficiently impactful that not only will these standards become quickly adopted, but they will be sustained indefinitely because of the economies of scale they encourage. Like GTFS, they will allow consulting/engineering/planning/software firms to leverage those data by providing services that lower the cost and improve the performance of transit operations, while at the same time allowing application developers to write one application that can be quickly rolled out to serve the entire nation, providing mapping-navigation companies with customers.

2.2.12.6 Deliverables

- SDO-specific Technical Memoranda (as defined in the Standards Plan within the SAD)
- Participation in SDO working group or committee meetings/activities (as required).

2.3 Phase 3 Technical Approach

2.3.1 Task 3-A: Project Management

The UW team will continue to provide the same project management oversight in Phase 3 as in the previous two project phases in order to deliver high quality products. Four key representatives from the UW team will participate in the Phase 3 Kickoff Meeting (in-person or virtual) within four weeks after the effective date of the award with the USDOT and its representatives to ensure that all parties have a common understanding of the award requirements and expectations. The Program and Business Lead will be responsible for monthly progress reports covering technical progress, a status summary, and a detailed financial summary. Key representatives from the UW team will continue to participate in bi-weekly coordination teleconferences, monthly all-site coordination teleconferences, and period roundtable teleconferences.

The Program and Business Lead and Cambridge Systematics Project Manager will develop draft and revised versions of the Phase 3 PMP that will build upon the Phase 2 PMP, but with an added focus on system operations, maintenance, and evaluation. The latest version of the SEMP (several versions of the SEMP are typically released during the life of a project) will serve as a supplemental document with defined operations and maintenance processes. By the start of Phase 3, the UW ITS4US team will have a viable TDEI system for demonstration of operations. The Program and Business Lead, with support from the UW team, will be responsible for confirming that the operational TDEI system functions as per the documented requirements outlined in Phase 1 and Phase 2. In addition to maintaining working relationships with external

project partners, the UW team will ensure that any new releases or patches added to the production TDEI environment adhere to the project schedule with minimal disruption to system users.

2.3.1.1 Deliverables

- Phase 3 Kick-off Meeting
- Project Management Plan (PMP)
- Revised PMP (as required)
- Monthly Progress Report Part I: Technical Progress and Status Summary
    - Includes: Project Milestone Schedule, Updated Task Schedules, and Project and Task Detailed Risk Register.
- Monthly Progress Report Part II: Detailed Financial Summary
- Lessons Learned Logbook (LLL), updated monthly
- Participation in site-specific bi-weekly coordination teleconferences
- Participation in monthly all-site coordination teleconferences
- Participation in periodic roundtable teleconferences.

2.3.2 Task 3-B: System Operations and Maintenance

The team will produce a Systems Operations and Maintenance Schedule (SOMS), with monthly progress and risk updates provided as part of the Monthly Progress Report. The SOMS will address operations and maintenance for all hardware and software acquired for this project. The TDEI system is expected to be deployed in the cloud; therefore, the categories of maintenance applicable to Phase 3 will include maintenance of any software deployed on the cloud, such as frameworks or event streaming services, that is being used but not developed by the TDEI team. It will also include maintenance of the software developed by the TDEI team. Note that cloud hardware is maintained in large part by the cloud provider as part of the service agreement with the cloud provider. The hardware—specifically the mobile devices, servers, and network storage—to be purchased as part of Phase 2 will be primarily for Phase 2 testing but will be included in the SOMS to the extent that those components are necessary for Phase 3 verification and evaluation. All TDEI-developed software will be maintained in a GitHub repository where maintenance issues (e.g., bugs and fixes) can be tracked, implemented, and managed.

The operations and maintenance process will begin when the first release of the TDEI system has been deployed into the production environment, even though all system features may not be available yet. This means that operations and maintenance will commence in Phase 2, even though the demonstration and evaluation may occur more in Phase 3 and post-Phase 3.

As with Phase 2, the system will be monitored for compliance with the necessary service levels, such as up-time performance and response times of system components. The team will also collect user-reported issues from stakeholders, likely through a problem ticket submission system. The ticket system will be used to prioritize and track issues and completion of fixes for those issues.

Each new release, with fixes, will be added to the production environment in accordance with the project schedule. The UW team will aim to send new releases into production during the overnight hours when potential stakeholder use is low. In Phase 3, once the full system has been deployed, an established maintenance time will be published to help inform users of potential downtimes. It is unknown how frequently this patching schedule will occur.

Members of the UW team who are tasked with operating and maintaining the system will need some training to maintain critical operation features, troubleshoot minor issues, restore the system when necessary, and perform other tasks.

2.3.2.1 Deliverables

- Initial System Operations and Maintenance Schedule (SOMS)
- Updated SOMS with Progress/Risk Summary (monthly)
    - Element of Monthly Progress Report Part I: Technical Progress and Status Summary, see Monthly Progress Report Section.

2.3.3 Task 3-C: Stakeholder Outreach

The Transportation Data Equity development project is designed to improve mobility data infrastructure so all travelers can discover mobility options, make informed mobility decisions, and avoid friction caused by a lack of data about their trips. The goals of the TDEI outreach will remain the same as in Phase 2 (see Task 2-J for detail). However, as Phase 3 is the maintenance phase of the project, the Phase 3 outreach will be constrained to assessments, in-field assessments, analytics on our own data usage, and dissemination of results. In Phase 3 interactions with standards organizations and stakeholders will focus on providing lessons learned from our implementation and testing that these organizations may leverage.

The stakeholder groups identified for Phase 2 will also be identified as stakeholders for Phase 3.

2.3.3.1 Outreach Implementation Strategies

A key emphasis of the TDEI has been the incorporation of meaningful engagement of people with disabilities and stakeholder partners throughout all Phase 1 and 2 activities. Phase 3 will continue TDEI's community-based participatory ethos, specifically introducing the test deployment projects in the field and enhancing the user base for the applications developed by the TDEI. The inclusion of diverse perspectives in responses to and feedback to the TDEI implementations is a key feature of the TDEI community outreach plan. In particular, in Phase 3 we will continue pursuing many of the engagement models identified for Phase 2, including gamification, working with data collaboratives such as MobilityData and the Mobility Data Interoperability Principles consortium, and prototype and in-field testing. Again, the focus of Phase 3 will be structured around feedback, assessments, incorporation of feedback, analytics, and data and knowledge dissemination.

2.3.3.2 Stakeholder Outreach Materials and Dissemination

Stakeholder outreach materials will be tailored for two different audiences: technical audiences and the general public. Materials developed for these may include awareness campaigns,

web/social media content, trade show and conference materials, and other supporting materials intended to inform and engage stakeholders and the public. For technical audiences, technical publications will be paired with presentations made at conferences, in committees, and through webinars to raise the profile of the work being done and provide opportunities for the project team to connect with professionals and agencies working in related areas. Once the GTFS-Flex and GTFS-Pathways standards have been finalized and adopted, specific marketing materials will be produced to discuss the implementation of those standards. Materials will be developed for our private partners, focusing on newly available data sources that can be added to Google and Microsoft's existing trip planning and navigation software, as well as their specialized applications (e.g., Soundscape).

The second major outreach effort will be aimed at the public. Once applications have become available for use, additional outreach materials, such as concise and graphically intensive fact sheets, will be developed to convey knowledge of these new services to disability communities. We will leverage our team's experience in storytelling and graphics to develop materials that clearly demonstrate the added value that these applications bring to achieving complete trips. All public-facing engagement materials will undergo a thorough 508 compliance check to ensure that the materials are accessible by all members of the public.

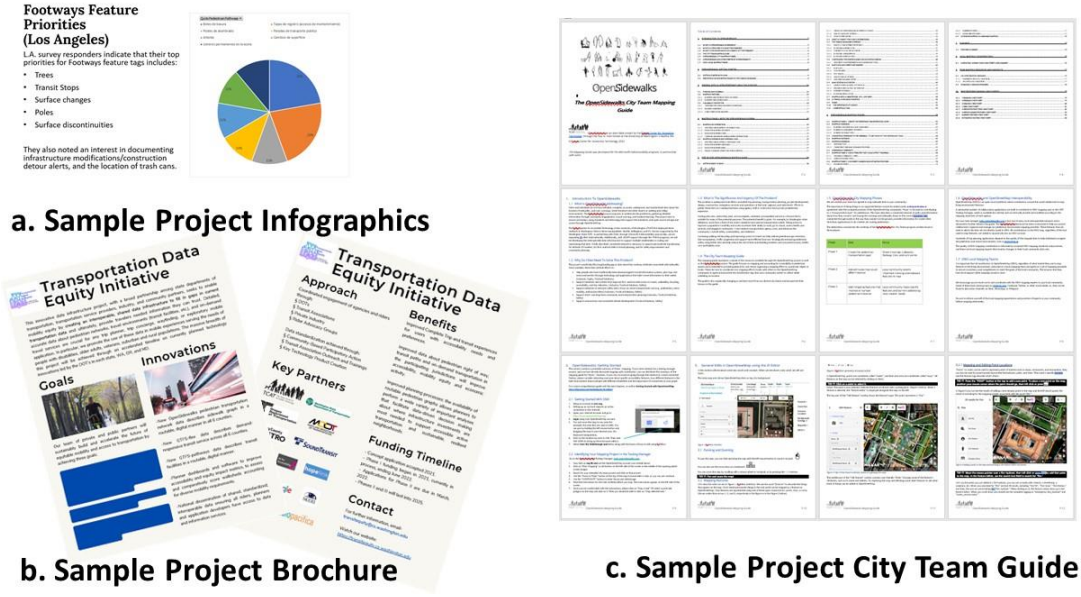

Figure 9. TDEI outreach material examples

Source: University of Washington.

2.3.3.3 Deliverables

- Initial Outreach Implementation Schedule (OIS)
- Outreach Materials (as specified in the OP and OIS)
- Updated OIS with Progress/Risk Summary (monthly)

    - Element of Monthly Progress Report Part I: Technical Progress and Status Summary, see Section Monthly Progress Report Section

- Draft Operational Capability Showcase Plan (OCSP)
- Revised OCSP with Comment Resolution Summary
- Final Operational Capability Showcase Plan (OCSP)
- Operational Capability Showcase
- Draft Operational Capability Showcase Summary (OCSS)
- Revised OCSS with Comment Resolution Report
- Final Operational Capability Showcase Summary.

2.3.4 Task 3-D: Performance Measurement and Independent Evaluation Support

In this task, the UW team will collect, process, and distribute data according to the updated PMESP. These data will measure the performance of the project, including the five areas of analysis described in the PMESP:

- The effectiveness and acceptance level of the three data standards that are part of this project.
- The amount and quality of the data developed as part of the project.
- The performance of data vetting systems implemented to further increase the quality and reliability of data shared with the public.
- The performance of the data sharing system that makes the data accessible to third-party applications via APIs.
- The performance of the three demonstration applications in terms of both their ability to access, download, and deliver the data being collected in this project and, in the case of Multimodal AccessMap, the travel outcomes achieved by delivering those data to users.

The Phase 2 software development effort will include the creation of software tools that routinely generate a variety of performance reports that will be used for project management. For example, these tools will report on the amount of data (e.g., geographic extent of sidewalk data, number of agencies reporting on-demand transit data, number of stations for which GTFS-Pathways data are available) available in the TDEI, the status and quality of data being developed as measured by the vetting processes (e.g., the number and locations of vetting checks made and the number of errors reported as a result of those checks), the activity levels for each of the applications using those APIs (number of API requests), and the performance of those APIs (e.g., response times).

These performance statistics will be used to manage the system, as they will indicate when specific parts of the system (e.g., a data generation tool, or an API) is not working as well as intended and needs improvement. For example, when artificial intelligence/machine learning software is used to identify routable sidewalk paths and path attributes from imagery, confidence intervals associated with those data will be generated. These statistics will indicate whether the imagery is robust enough to allow the AI software to be confident of the sidewalk's presence, location, and other attributes. From the "business management" perspective, these statistics will

be used to determine the level of vetting required before these data can be published. Statistics that describe the outcome of the vetting activities will then describe both which data meet data quality requirements, and where improvements in the data generation software are needed.

These data will also support the independent evaluation effort. The collection, processing, and transfer of these data will be discussed in detail within the DMP and the PMESP. These documents will also describe the coordination required with the independent evaluator. As part of the coordinated performance measurement and evaluation activities, the UW team will facilitate any access to project staff and stakeholders required by the independent evaluation team.

In this task, the work breakdown structure of activities and dependencies (PMESS) initially developed in Phase 2 will be maintained, updated as appropriate, and submitted monthly. As in Phase 2, the monthly progress report submitted to USDOT will contain summary descriptions of progress made, activities under way, required changes to the schedule, and changes to identified risks, including any changes that affect data needed for the performance measurement effort. The PMESP and DMP will also be updated when appropriate. The PMESS will identify milestones, performance summary reports, and the delivery of post-deployment ("AFTER") data for coordination with USDOT.

During Phase 3, the UW team will update the PMESP and DMP at least once. Other updates will be performed as needed. As part of these updates, the UW team will document in the PMESP all analytical models and algorithmic methodologies utilized in performance measurement calculation.

2.3.4.1 Deliverables

Specific products to be delivered during Task 3-D are listed below.

- A monthly update to the PMESS, including a technical progress report and a status summary, descriptions of activities under way, required changes to the schedule and reasons for those changes, and changes to identified risks.
- At least one updated PMESP, with additional updates if required.
- At least one updated DMP, with additional updates if required.
- All performance measurement materials identified in the PMESP and PMESS (e.g., post-deployment performance data, system performance reports, performance measurement results, and other supporting information).
- A site performance measurement dashboard.
- Public-facing performance data as documented in the DMP and PMESP.

2.3.5 Task 3-E: Post-Deployment Transition Planning.

In this task the UW team will complete planning for the transition of the system from operation under the aegis of the Complete Trip-ITS4US Deployment Program to routine operational practice. As part of this effort, the team will start with and update both the Institutional, Partnership, and Financial Plan and the Integrated Complete Trip Deployment Plan initially written in Phase 1.

The resulting Comprehensive Transition Plan (CTP) will include a description of the basic concept of operation for the final system, the applications required within that system, the organizational responsibilities for participants in the system, the equipment required to operate the system, and the maintenance required for that equipment. If any of these attributes are different than those of the system being operated in Phase 3, then the CTP will describe those difference and explain why they exist.

In addition, the CTP will describe the governance of the system, along with agreements from the participating organizations and their responsibilities (financial, operational, and cooperative) within that structure. The CTP will also describe the performance measures and targets for the system.

The final deployment transition plan will require agreement among each of these major components. This includes a clear vision of how the institutional, financial, and operational arrangements will be performed, as well as how these must be altered or adapted from Phase 3 to the post-deployment period to ensure a smooth transition to permanent operational practice.

Finally, the CTP will have one section for concepts and applications found to be successful and included in continuing operations, and one section for concepts and applications found to be unsuccessful and to be removed from continuing operations. The CTP will provide the rationale for deeming each element successful or unsuccessful. The CTP will describe the organizational responsibilities to be taken in the post-deployment period and how those compare to organizational responsibilities performed in Phase 3. The CTP will include documentation of the financial resources and agreements required to ensure financial sustainability in the post-deployment period for all continuing elements. Public and private sources of funds will be identified, and if one or more new businesses are proposed to be a source of funds, a business plan containing standard elements will be part of the documentation. The CTP will also describe dependencies on external organizations. The CTP will explicitly identify contingency plans with respect to identified uncertainties and other potential post-deployment issues that pose a risk to successful post-deployment operations.

The UW team will deliver a draft CTP to the USDOT for review. The UW team will prepare a revised CTP in response to USDOT comments with an accompanying Comment Resolution Report. Based on USDOT review of the revised CTP, the UW team will deliver a final CTP.

2.3.5.1 Deliverables

- Draft Comprehensive Transition Plan (CTP)
- Revised CTP with Comment Resolution Report
- Final Comprehensive Transition Plan (CTP).

2.3.6 Task 3-F: Participation in Standards Development

In Phase 3, as in previous phases, the UW team will be heavily engaged with standards development organizations (SDO). Use of data standards and engagement with and improvement of those standards is a core principle of the TDEI.

2.3.6.1 Standards Applicable to the TDEI

As discussed previously, the standards and associated SDOs with which the UW team will engage are Open OpenStreetMap (OSM), OpenSidewalks (OSW), GTFS-Flex v2, and GTFS-Pathways. Brief descriptions of these standards are provided in Task 2-L.

Note that because of the nature of the TDEI project, the TDEI will focus on standards relevant to transportation data more than traditional ITS standards.

2.3.6.2 Standards Development Organization (SDO) Involvement

The UW team will engage with the OpenStreetMap Foundation and the Mobility Data Standards Development organizations. The TDEI team will attend regular meetings of these SDOs and will interact with the SDOs by using the SDOs' standard communication mechanisms, which may include electronic communication via GitHub repositories for the standards. In Phase 3, the focus of the TDEI's involvement will be to provide feedback to the SDOs based on lessons learned from the TDEI project. The TDEI team will create one SDO memorandum for each standard with which the team engages to describe the project team's engagement with the appropriate SDO for that standard and any proposed changes to the standard. The USDOT will be kept apprised of all SDO engagement through the Monthly Progress Report, as desired.

2.3.6.3 Deliverables

- SDO-specific Technical Memoranda (as defined in the Standards Plan within the SAD)
- Participation in SDO working group or committee meetings/activities (as required).

3. Phase 2 and 3 Deployment Schedule

3.1 Schedule Summary

3.1.1. Phase 2 Schedule

This section describes the Phase 2 schedule for this project. Phase 2 is proposed to be 24 months long. The proposed schedule for all required deliverables is provided in Table 1.

All systems engineering deliverables identified in the Phase 1 SEMP (Table 3) are included in this schedule. The schedule aligns with the USDOT's proposed deliverable schedule.

In the schedule, the letter 'X' indicates a planned activity, and the letter 'T' indicates potential timing of activities that will be defined by processes during Phase 2. For example, we assume participation in a Roundtable Teleconference every two months, and we assume that the Systems Test Result Summary will occur in months 20-23. However, the actual teleconference times and frequency will be determined by USDOT, and the timing of the Systems Test Result Summary will be determined by the Installation and Operational Readiness Schedule. Therefore, the T's indicate potential timings that we expect will be updated throughout the course of the project.

This project is primarily about software development, and as described in the Phase 1 SEMP it will use the Agile software development methodology. Agile is a software development process that breaks software development into small tasks typically completed in two-week sprints so that those tasks can be accurately estimated, and task completion can be verified. The Agile process is specifically being used to mitigate the cost and schedule risks inherent in software development. Although Agile breaks software development down into small tasks, Agile also needs higher-level goals and milestones that can be used to monitor and ensure progress toward those project goals. The Systems Engineering documents can help provide the high-level framework within which the Agile process can proceed. The Phase 1 SEMP described how the Agile software process will be integrated with the Systems Engineering Process and deliverables required of this project. As appropriate, the UW Team will provide previews of deliverables such as the System Architecture Document, System Design Document, and System Test Plan to ensure that the USDOT is apprised of progress in development of those deliverables.

Stakeholder Outreach is expected to begin as initial software development occurs so that the stakeholders can be engaged in the Agile process. Note that Phase 1 stakeholder engagement has been used to develop user stories and user needs that will guide the software development.

Table 1. Phase 2 Schedule

Task	Deliverable	Proposed Due Date (time after award)	M 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
Task 2-A:	Project Management																									
	Phase 2 Kick-off Meeting	4 weeks			X																					
	Draft Project Management Plan (PMP)	4 weeks	X																							
	Revised PMP	as needed										T	T	T												
	Monthly Progress Report Part I	monthly	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
	Monthly Progress Report Part II	monthly	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
	Lessons Learned Logbook	monthly*	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
	Project Milestone Schedule	monthly*	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
	Updated Task Schedules	monthly*	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
	Project and Task Detailed Risk Register	monthly*	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
	Bi-Weekly Coordination Teleconference Participation	bi-weekly	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
	Participation in Monthly All-Site Coordination Teleconferences	monthly	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
	Participation in Roundtable Teleconferences	as needed		T		T		T		T		T		T		T		T		T		T		T		T
Task 2-B:	System Architecture and Design																									
	Draft Systems Architecture Document (SAD)	3 months			X	X	X																			
	Systems Architecture Walkthrough and Workbook	3.5 months			X	X																				
	Revised SAD with Comment Resolution Report	4 months				X																				
	Final Systems Architecture Document	6 months					X	X																		
	Draft Systems Design Document (SDD)	9 months							X	X	X															
	Systems Design Walkthrough and Workbook	9.5 months									X	X														
	Revised SDD with Comment Resolution Report	10 months										X														
	Final Systems Design Document	12 months											X	X												
	Updated Phase 1 Deliverables	12 months											X	X												
Task 2-C:	Data Management & Planning																									
	Draft Data Privacy Plan (DPP)	2.5 months				X	X																			
	Revised DPP with Comment Resolution Report	3.5 months			X	X																				
	Final Data Privacy Plan	4 months				X																				
	Notice of Privacy Management Consistency	4 months				X																				
	Draft Phase 2 Data Management Plan (DMP)	5 months			X	X	X																			
	Revised Phase 2 DMP with Comment Resolution Report	6 months					X	X																		
	Final Phase 2 Data Management Plan	7 months							X																	
Task 2-D:	Acquisition and Installation Planning																									
	Draft Comprehensive Acquisition Plan (CAP)	8 months					X	X	X	X	X	X														

Task	Deliverable	Proposed Due Date (time after award)	M 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
	Revised CAP with Comment Resolution Report	9 months								X	X															
	Final Comprehensive Acquisition Plan	10 months										X														
	Draft Comprehensive Installation Plan (CIP)	11 months						X	X	X	X	X	X													
	Revised CIP with Comment Resolution Report	12 months											X	X												
	Final Comprehensive Installation Plan	13 months													X											
Task 2-E:	Software Development and Integration																									
	Initial Software Development Schedule (SDS)	4 months			X	X	X	X																		
	SDS Update with Progress/Risk Summary	monthly*					X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
	Open Source Software and Supporting Documentation	per the SDS					T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T
Task 2-F:	Participant and Staff Training																									
	Initial Training Implementation Schedule (TIS)	per PTSEP							T	T	T															
	TIS Update with Progress/Risk Summary	monthly*			X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
	Training Materials	per PTSEP, TIS							T	T	T															
	Human Use Approval Confirmation Materials	per the HUAS									T	T	T													
Task 2-G:	System Test Planning																									
	Draft System Test Plan	10 months				X	X	X	X	X	X	X	X													
	Revised System Test Plan with Comment Resolution Report	12.5 months						X	X				X	X												
	Final System Test Plan	13 months								X	X				X											
	Operational Readiness Concept Briefing	6 months			X	X	X	X																		
	Draft Operational Readiness Plan (ORP)	11 months							X	X	X	X	X													
	ORP Walkthrough and Workbook	11.5 months											X	X												
	Revised ORP with Comment Resolution Report	12 months												X												
	Final Operational Readiness Plan	13 months													X											
Task 2-H:	Installation and Operational Readiness Testing																									
	Initial Installation and Operational Readiness Schedule (IORS)	13 months										X	X	X	X											
	IORS Updated with Progress/Risk Summary	monthly*														X	X	X	X	X	X	X	X	X	X	X
	System Test Results Summary	per the IORS																				T	T	T	T	T
	Test Results Summary Documentation	per the ORP																					T	T	T	T
	Operational Readiness Demonstrations	per the ORP																					T	T	T	T
Task 2-I: Maintenance and Operations Planning																										
	Draft Comprehensive Maintenance and Operations Plan (CMOP)	15 months													X	X	X									
	Revised CMOP with Comment Resolution Report	16 months																X								
	Final CMOP	17 months																	X							
Task 2-J:	Stakeholder Outreach																									

Task	Deliverable	Proposed Due Date (time after award)	M 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
	Draft Phase 2 Outreach Plan	2 months			X	X																				
	Revised Phase 2 Outreach Plan w Comment Resolution Report	3 months			X																					
	Final Phase 2 Outreach Plan	4 months				X																				
	Initial Outreach Implementation Schedule (OIS)	4.5 months					X																			
	OIS Updated with Progress/Risk Summary	monthly						X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
	Outreach Materials	per Outreach Plan, OIS						T	T	T																
Task 2-K:	Performance Measurement and Independent Evaluation Support																									
	Initial Performance Measurement and Evaluation Support Schedule (PMESS)	6 months						X	X	X																
	PMESS Updated with Progress/Risk Summary	monthly*							X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
	Updated Performance Measurement and Evaluation Support Plan (PMESP)	minimum one update											T	T												
	Revised Human Use Approval Summary	As needed, per IRB approval											T	T												
	Performance Measurement Materials identified in the PMESP and PMESS	per the PMEPS and PMESS													T	T	T	T								
Task 2-L:	Participation in Standards Development																									
	Standards Development Organization (SDO)-specific Technical Memoranda	per SAD									T	T														
	Participation in SDO Meetings/Activities	as required	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X

Two deliverables described in the SEMP that are required for the Agile software development process are the Pre-Release Planning Memorandum and the Release Report Memorandum. The Agile software development will be organized in releases. Releases will be defined in the System Design Document and are expected to be approximately two months long (thus each release will comprise approximately four sprints). In addition to information on development progress to be provided in monthly reports, the team will provide, for each release, 1) a Pre-Release Planning Memorandum describing what will be done in the release and how to verify / test that the work has been done; and 2) once the Release has been completed, a Release Report Memorandum describing the work completed in the release, any issues encountered, and verification that the release was completed successfully.

The content of the releases, that is the software that will be developed in each release, will be determined in Phase 2 by using the System Design Document and the Agile software development process. Examples of some potential software development milestones are listed below. These milestones are listed solely to give the reader a concept of what such milestones may be; the milestones are likely to change during the design process:

- The API for sidewalk data in the OpenSidewalks format is implemented, tested, and documented.
- OSW data validation service is implemented, integrated, tested, and documented.
- GTFS-Pathways data ingestion and egress are implemented, tested, and documented.
- GTFS-Flex data ingestion and egress are implemented, tested, and documented.
- Ingestion and egress of data from an agency are tested.

All milestones above will include testing and documentation according to Agile software best practices, and testing and documentation will occur as the software is developed. Testing in this context means testing of the software components that have been developed and testing of the integration of those components into the system. Testing will be incremental to ease the integration process and to ensure that the components function both independently and together in an integrated system. Final end-to-end tests will occur in the last few months of the project.

The testing for approval to move to Phase 3 is expected to occur in the last four months of the project. The exact timing of the Operational Readiness Testing will be determined by the Installation and Operational Readiness Schedule (IORS), but it is expected to occur in the last four months of the project.

3.1.2. Phase 3 Schedule

This section describes the Phase 3 schedule for this project. Phase 3 is proposed to be 18 months long. The proposed schedule for all required deliverables is provided in

Table 2. The Phase 3 schedule follows the USDOT proposed schedule. As with the Phase 2 schedule, ‘X’ indicates time periods in which the team will work on scheduled deliverables, and ‘T’ indicates potential time periods in which the team will work on deliverables whose schedule depends on other deliverables. The boxes labeled ‘T’ are simply to give an idea of when the team may be working on those deliverables.

Table 2. Phase 3 Schedule

Task	Deliverable	Proposed Due Date (time after award)	M 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
Task 3-A:	Project Management																			
	Phase 3 Kick-off Meeting	4 weeks						X												
	Project Management Plan (PMP)	4 weeks	X																	
	Revised PMP	as required																		
	Monthly Progress Report Part I	monthly		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
	Monthly Progress Report Part II	monthly		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
	Lessons Learned Logbook	monthly*		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
	Project Milestone Schedule	monthly*		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
	Updated Task Schedules	monthly*		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
	Project and Task Detailed Risk Register	monthly*		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
	Participation in Site-Specific Bi-Weekly Coordination Teleconferences	bi-weekly		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
	Participation in Monthly All-Site Coordination Teleconferences	monthly		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
	Participation in Periodic Roundtable Teleconferences	as needed																		
Task 3-B:	System Operations and Maintenance																			
	Initial System Operations and Maintenance Schedule (SOMS)	1 month						X												
	Updated SOMS with Progress/Risk Summary	monthly*																		
	Initial Outreach Implementation Schedule (OIS)	1 month	X																	
Task 3-C:	Stakeholder Outreach																			
	Outreach Materials	per Outreach Plan, OIS																		
	Updated OIS with Progress/Risk Summary	monthly*																		
	Draft Operational Capability Showcase Plan (OCSP)	1.5 months		X																
	Revised OCSP with Comment Resolution Report	2.5 months			X															
	Final Operational Capability Showcase Plan (OCSP)	3 months			X															
	Operational Capability Showcase	12 months				X	X	X	X	X	X	X	X	X						
	Draft Operational Capability Showcase Summary (OCSS)	13 months												X	X					
	Revised OCSS with Comment Resolution Report	14 months														X				
	Final Operational Capability Showcase Summary	14.5 months														X				
Task 3-D:	Performance Measurement and Independent Evaluation Support																			

	Updated PMESS with Progress/Risk Summary	monthly*						X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
	Performance Measurement Materials identified in the PMESP and PMESS	per the PMESS																								
	Site Performance Measurement Dashboard	per the PMESS																								
	Updated PMESP	minimum one update																								
	Updated DMP	minimum one update																								
	Public-facing Data	per the DMP, PMESS																								
Task 3-E:	Post-Deployment Transition Planning																									
	Draft Comprehensive Transition Plan (CTP)	12 months																	X	X	X						
	Revised CTP with Comment Resolution Report	13 months																		X						
	Final Comprehensive Transition Plan	14 months																			X					
Task 3-F:	Participation in Standards Development																									
	SDO-specific Technical Memoranda	per SAD																								
	Participation in SDO meetings/activities	as required	X	X	X	X	X	X	X	X		X		X		X		X	X	X	X	X	X	X	X	

3.2 Schedule Risks

A key schedule risk for this project is the difficulty of estimating software development times. Software development tasks are known to be difficult to estimate accurately. This project is addressing this risk by, first, using the Agile software development methodology, which is specifically intended to help mitigate the risks inherent in software development by breaking that development into small pieces that can be independently implemented and tested. In this way, any major estimation errors or issues can be discovered early and mitigated. Second, the team has recruited individuals and subcontractors with significant experience in software development (see the Staffing and Team Experience Sections) who have the capability to manage and deliver on software implementation projects.

4. Phases 2 and 3 Deployment Cost Estimate

4.1 Cost Summary

Costs for Phases 2 and 3 comprise 1) labor (salaries + benefits); 2) other direct costs, which include research participant expense, cloud computing services, specialized departmental research computing facilities, travel, supplies and equipment, and student aid or tuition; 3) subcontractors; and 4) facilities and administration (F&A) expenses. Facilities and administration costs are 55.5 percent, charged on all items except tuition and equipment, and only on the first $25,000 of each subcontract. A summary of project costs is provided in Table 3 in Section 4.3

4.2 Cost Risks

Three major cost risks are associated with this project. These risks are the cost of software development, the loss of local funding, and the potential for operations and maintenance costs being far larger than anticipated.

The biggest cost risk is that the effort required to build the core software system has been significantly under-estimated. The team is aware of this risk, and the software cost risk is being addressed and mitigated by using Agile software development as described in the SEMP, progressively finer granularities of software estimation, and prioritization. As described in Aquisition in the Digital Age – Cost Estimation[6] and in the Agile Manifesto[7], Agile is a software development methodology whereby tasks and estimates are created in short increments (e.g., two-week sprints), and progress on those tasks is closely monitored and regularly evaluated (e.g., every two weeks). Research has shown that implementation of smaller software increments is much more effective at delivering software on cost and on schedule than larger programs[8]. Thus, by breaking tasks into small increments and regularly evaluating the progress of tasks and project progress versus larger goals specified as releases and epics, software progress can be closely monitored, and unexpected software cost issues can be identified early and addressed. In accordance with Agile principles and general software practices, initial estimates will be higher-level and lower fidelity; as development progresses and more information is known about the system, these estimates are refined so that detailed cost estimates will be created for each sprint.

[6] Mitre. Acquisition in the Digital Age. Cost Estimation. https://aida.mitre.org/agile/agile-cost-estimation/

[7] Manifesto for Agile Software Development. https://agilemanifesto.org

[8] Mitre. Acquisition in the Digital Age. Agile Fundamentals Overview. https://aida.mitre.org/agile/agile-fundamentals/

The Product Backlog and Agile Epics and Sprints will be created, refined, and prioritized on the basis of user needs and system requirements. The combination of initial high-level estimates and detailed sprint estimates and monitoring of the sprint estimates versus sprint execution costs will allow the team and USDOT (through the Pre-Release and Release Report Memos) to monitor progress. As development progresses and cost estimates are refined, work will be prioritized on the basis of user needs and system requirements priorities. In this way, the highest priority features will be implemented early in the project and lower priority features implemented later in the project. In addition, we will document our processes and work so that if we should need to replace key software developers during the project, that documentation will make it easier to integrate a new person into the project with limited lost time or cost.

The second major risk is the loss of local funding. Phase 3 funding is somewhat at risk in that most of our funding partners do not budget three years out. They are therefore reluctant to commit funds three and four years out. To mitigate this risk, the team is working during both Phase 1 and Phase 2 to line up additional local match partners so that match exceeds the minimum 20 percent value, ensuring that the minimum match requirement is met. If additional local funds are available as a result of these efforts, the team will be able to add additional on-demand transit service providers, additional transit center GTFS-Pathways data sets, and additional sidewalk features.

The final major cost risk is that operational costs for the system far exceeds expected values. To mitigate this risk, the architecture design is specifically being designed such that the system can be maintained both on the cloud and locally. The cloud has considerable operational advantages but carries more risk. If cloud services prove too expensive, the team will consider moving some or all of the services to university provided systems where costs can be better controlled. The team will also explore operating agreements with technology firms that could reduce the operational costs of the system. These decisions will be made based on the early operational experiences provided through the Agile development process.

4.3 Estimated Phases 2-3 Costs

Table 3. Summary of costs by task

		Cost Share			Federal Share			Total		
Task ID	Task	Budget	Cost to Date	Remaining	Budget	Cost to Date	Remaining	Budget	Cost to Date	Remaining
2-A	Program Management	$ 73,000			$ 433,951			$ 506,951		
2-B	System Architecture and Design	$ 100,000			$ 502,331			$ 602,331		
2-C	Data Management Planning	$ -			$ 301,019			$ 301,019		
2-D	Acquisition and Installation Planning	$ 100,000			$ 193,030			$ 293,030		
2-E	Software Development and Integration	$ 1,013,680			$ 2,820,885			$ 3,834,565		
2-F	Participant and Staff Training	$ -			$ 521,360			$ 521,360		
2-G	System Test Planning	$ 200,000			$ 878,352			$ 1,078,352		
2-H	Installation and Operational Readiness Testing	$ 163,320			$ 777,965			$ 941,285		
2-I	Maintenance and Operations Planning	$ 200,000			$ 291,353			$ 491,353		
2-J	Stakeholder Outreach	$ 50,000			$ 388,825			$ 433,825		
2-K	Performance Measurement and Independent Evaluation Support	$ 50,000			$ 277,464			$ 327,464		
2-L	Participation in Standards Development	$ 50,000			$277,464			$ 327,464		
	Phase 2 Subtotal	$ 2,000,000			$ 7,659,000			$ 9,659,000		
3-A	Program Management	$ 27,000			$ 363,514			$ 390,514		
3-B	System Operations and Maintenance	$ 473,000			$ 424,078			$ 897,078		
3-C	Stakeholder Outreach	$ -			$ 324,768			$324,768		
3-D	Performance Measurement and Independent Evaluation Support	$ -			$ 297,782			$ 297,782		
3-E	Post-Deployment Transition Planning	$ -			$ 295,016			$ 295,016		
3-F	Participation in Standards Development	$ -			$ 294,842			$ 294,842		
	Phase 3 Subtotal	$ 500,000			$ 2,000,000			$ 2,500,000		
	Total	**$ 2,500,000**			**$ 9,659,000**			**$12,159,000**		

Appendix A. Acronyms

Table 3. Acronyms

Acronym	Meaning
AOR	Agreement Officer Representative
API	Application programming interface
ATC	Advanced Transportation Controller Standard
CAP	Comprehensive Acquisition Plan
CBPR	Community-based participatory research
CEnR	Community engaged research
CI/CD	Continuous integration/continuous deployment
CIP	Comprehensive Installation Plan
CMOP	Comprehensive Maintenance and Operations Plan
ConOps	Concept of Operations
COTS	Commercial off-the-shelf
CS	Cambridge Systematics, Inc.
CTP	Comprehensive Transition Plan
CV/AV	Connected Vehicles/Automated Vehicles Standard
DDL	Deployment Development Lead
DL	Deployment Lead
DMAL	Data Management Architect and Lead
DMP	Data Management Plan
DPP	Data Privacy Plan
DOT	Department of transportation
ETRA	Enabling Technology Readiness Assessment
GS	Gaussian Solutions
GTFS	General Transit Feed Specification
HUAS	Human Use Approval Summary
ICTDP	Integrated Complete Trip Deployment Plan
IORS	Installation and Operational Readiness Testing Schedule
IoT	Internet of things
IRB	Institutional Review Board
ITS	Intelligent transportation systems
KCM	King County Metro Transit
MOTS	Modifiable off-the-shelf
MV	MV Transportation
NAS	Network attached storage
NPMRDS	National Performance Management Research Data Set
NTCIP	National Transportation Communications for ITS Protocol
ORP	Operational Readiness Plan
ORTP	Operational Readiness Test Plan
ORDP	Operational Readiness Demonstration Plan
OSM	OpenStreetMap
OSW	OpenSidewalks
PBL	Program and Business Lead
PII	Personally identifiable information
PMBOK	Project Management Body of Knowledge

PMESP	Performance Measurement and Evaluation Support Plan
PMESS	Performance Measurement and Evaluation Support Schedule
PML	Project Management Lead
PMP	Project Management Plan
PTSEP	Participant Training and Stakeholder Education Plan
QA/QC	Quality assurance/quality control
RTM	Requirements Traceability Matrix
SAD	System Architecture Document
SDD	System Design Document
SDO	Standards development organization
SDS	Software Development Schedule
SEL	Systems Engineering Lead
SEMP	Systems Engineering Management Plan
SK	The Smith-Kettlewell Eye Research institute
SOMS	Systems Operations and Maintenance Schedule
SP	Studio Pacifica
SPII	Sensitive personally identifiable information
ST	Sound Transit
STP	System Test Plan
STRS	System Test Results Summary
TAL	Technical Applications Lead
TCAT	Taskar Center for Accessible Technology
TDEI	Transportation Data Equity Initiative
TIS	Training Implementation Schedule
TMC	Traffic Messaging Channel
TRAC	Washington State Transportation Center
UNIRP	User Needs Identification and Requirements Planning
USDOT	United States Department of Transportation
UW	University of Washington
WSDOT	Washington State Department of Transportation

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

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

FHWA-JPO-22-948

U.S. Department of Transportation