Phase 2 Comprehensive Acquisition Plan (CAP)

University of Washington ITS4US Deployment Project

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ITS4US
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16. Abstract

This Comprehensive Acquisition Plan (CAP) provides an overview of the proposed acquisition approach for the University of Washington (UW) ITS4US project, the Transportation Data Equity Initiative (TDEI). The TDEI project is a software-focused project which will primarily deployed on the cloud. The TDEI project will acquire mobile phones that will be used to run applications that demonstrate the value of the TDEI, computers and storage to be used by TDEI staff for data processing and cloud resources for the development, deployment, and operation of the TDEI system. This document identifies the acquisition needs and requirements for the mobile phones, computers, storage, and cloud resources that will be acquired by the project.

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1 Introduction

This Comprehensive Acquisition Plan (CAP) provides an overview of the proposed acquisition approach for the University of Washington (UW) ITS4US project, the Transportation Data Equity Initiative (TDEI). The TDEI aims to improve travel accessibility for people with mobility disabilities by improving the data available to these underserved populations. The TDEI project includes the development of a data repository for these data and an evaluation of the value of the system through the use of a set of demonstration applications. The TDEI is a software-focused project which will primarily be deployed on the cloud. The TDEI project will acquire cloud resources for the development, deployment, and operation of the TDEI system, mobile phones that will be used to run the applications to demonstrate the value of the TDEI, and computers and storage to be used by TDEI staff for data processing. This document identifies the acquisition needs and requirements for these devices which have been drawn from the Concept of Operations (ConOps[1]), System Requirements (SyRS[2]) for the UW project. Installation for the items described in this CAP are described in this project's Comprehensive Installation Plan (CIP).

1.1 Intended Audience

This document is intended for use by the UW ITS4US project team, its partners, and peer agencies and the US Department of Transportation (USDOT). In addition, entities, such as public agencies, may refer to this document for a better understanding of the acquisition needs and processes for a project such as the TDEI.

1.2 Project Background

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

[1] UW ITS4US Phase I Concept of Operations https://rosap.ntl.bts.gov/view/dot/58675

[2] UW ITS4US Phase I System Requirements https://rosap.ntl.bts.gov/view/dot/60129

With this in place, previously underrepresented individuals will have tools available to make informed, customized travel decisions under multiple situations.

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

1. **Develop a Centralized Data Repository**. The UW Team will develop a centralized data repository that services many functions, including receipt/validation of data (including sidewalk, transit station pathways, and on-demand transit), storage of data, and distribution of data through an Application Programming Interface (API) in response to requests for geographically focused data for trip making. This centralized data repository represents the focal point of the project for moving data from those who produce it to those who want to use it.
2. **Create tools to support data collection**. The UW Team will develop tools for sidewalk infrastructure owner-operators and transit agencies to collect data, translate it into the data standards supported by TDEI, and submit data to the data repository. The goal of the tools is to simplify the level of effort required to collect data, thus, encouraging agencies to undertake this data collection initiative.
3. **Demonstrate use of the data by under-represented communities through three accessibility-focused mobility applications.** This project will utilize accessible mobility applications in the evaluation and testing of the usability and efficacy of the data standards and the supporting infrastructure.

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

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

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

2 Acquisition Overview

The TDEI will acquire four categories of items: mobile phones, computers, storage, and cloud resources. The mobile phones will be used to run demonstration applications, particularly AccessMap Multimodal, to demonstrate use of the TDEI data by under-represented communities. The computers and storage will be used by TDEI staff for processing, analysis, and storage. Finally, the cloud resources will be used for the development, deployment, and operation of the TDEI system.

2.1 Acquisition Approach

The mobile phones, related accessories, computers, and storage will be purchased through vendors with whom the UW has existing contracts. The phones, related accessories, computers, and storage needed for this project are Commercial-Off-the-Shelf (COTS) and are readily available from these vendors. The cloud computing resources will be purchased through Microsoft Azure which is the cloud platform which was selected for the project. Request for Proposals (RFP)s are not necessary due to the use of vendors with whom UW has existing contracts.

The UW Team will meet Federal Acquisition Regulation (FAR) (52.204-25) for Contracts and the Code of Federal Regulations (CFR) (200.216 & 200.471) for Grants and Cooperative Agreements for the acquisitions and 2 CFR 200.317-2 CFR 200.327 (Procurement Standards) for the requirements regarding procurements. In addition, prior to acquiring an item or service from a vendor, the UW Team will complete due diligence to ensure that the vendor will not charge any costs that include covered equipment and services from restricted companies. To ensure that the item or service is not covered equipment or services from a restricted company, the System Award Management (SAM)[3] website will be reviewed prior to initiating a purchase. The team will also review the procurement plans with UW's post-award fiscal compliance team who specializes in federal fiscal compliance questions.

2.2 Acquisition Schedule

The acquisition of the mobile phones, computers, and storage will primarily occur during the second half of Phase II of the project. The mobile phones are needed for the demonstration application testing in Phase III and will be purchased near the end of Phase II so they are ready for use in Phase III. Mobile phones and related accessories are expected to be available within a few days or weeks of purchase; thus, an April 2024 purchase date for the mobile phones provides

[3] Federal Contractor Registry. System Award Management. https://federalcontractorregistry.com

time for delivery, inspection, installation, and preliminary testing prior to Phase III. The computers and storage will be purchased during the second half of Phase II and will be used during the second half of Phase II and into Phase III. The computers are expected to be available within weeks to up to one to two months after purchase. The team will begin the acquisition process in September 2023 to verify and adapt to the delivery time frame and accommodate any delivery delays so that the computers and storage can be in use by late 2023 or early 2024.

The acquisition of the cloud resources will be acquired throughout Phase II and Phase III. The acquisition of the cloud resources began in August 2022 after the cloud provider was selected and at the time that the TDEI system software development began. The acquisition will continue throughout Phase II and Phase III. It is expected that the cloud acquisition will ramp up throughout Phase II as the TDEI system development progresses and then remain relatively stable in Phase III during operation of the system. Cloud acquisition changes in Phase III would primarily be for adapting the system to changes to the number of users of and data in the system. Table 1 shows the TDEI acquisition schedule.

Table 1 TDEI Acquisition Schedule

Item	Action	Time Frame
Mobile Phones	Acquisition	Phase II – March 2024
Mobile Phones	Installation and Preliminary Testing	Phase II – March-May 2024
Computers & Storage	Acquisition	Phase II – September 2023 - Jan 2024
Computers & Storage	Installation and Begin Usage	Phase II – November 2023 – Feb 2024
Cloud Resources	Identify Cloud Provider	Phase II – August 2022
Cloud Resources	Begin acquisition	Phase II – September 2022
Cloud Resources	Acquire cloud resources needed for system development	Phase II – May 2024
Cloud Resources	Finalize cloud resources needed for system operation	Phase II – May 2024
Cloud Resources	Acquire cloud resources needed for TDEI system operation	Throughout Phase III – June 2024 – December 2025

2.3 Vendor Outreach Plan

The UW Team will be purchasing hardware – mobile phones, computers, and storage – and cloud resources. In terms of hardware, to identify the devices to be purchased, the UW Team will

research the availability of the devices to be acquired through UW's internal purchasing web site, which lists items available from vendors with which UW has purchasing agreement. This process will identify potential vendors, product specifications, and prices. Items that meet the requirements with the lowest identified prices will be preferred. For mobile phones and related accessories, potential vendors include CDW, Office Depot, and Best Buy. For computers and storage, potential vendors include Dell, HP, and NewEgg.

The Microsoft Azure platform was selected as the cloud computing platform for the project. The UW Team assessed the Microsoft Azure and Amazon AWS platforms based on cost of expected services and UW and software development team skills and experience. Microsoft Azure was selected because it provided the best value overall – the costs were comparable to other options investigated and it will reduce staff acclimatation cost as the UW Team has significant experience with Microsoft Azure. Cloud resources will be purchased through the Microsoft Azure system.

All items will be purchased in accordance with the TDEI design as documented in the UW ITS4US Concept of Operations (ConOps), System Requirements Specification (SyRS), Emerging Technology Readiness Assessment (ETRA)[4], and the System Design Document (SDD).

[4] UW ITS4US Phase I Emerging Technology Readiness Assessment
https://rosap.ntl.bts.gov/view/dot/62479

3 Mobile Devices

The UW Team will acquire mobile phones to be used to run the AccessMap Multimodal[5] demonstration application to demonstrate and evaluate the value of the TDEI and its data. The mobile phones may also be used for the demonstration application evaluation using the Audiom[6] software. The use of the phones in the evaluation studies is described in the ConOps, the Performance Measurement and Evaluation Support Plan (PMESP)[7], and the Human Use Approval Summary (HUAS)[8].

3.1 Mobile Phones

The UW Team will acquire mobile phones and ancillary equipment, including Subscriber Identity Module (SIM)[9] cards, to provide a data connection for the phones and Global Positioning System (GPS) [10] units to improve the accuracy of the location collection.

3.1.1 Technical Description

The primary requirement for the mobile phones is that they can run the AccessMap Multimodal application and the e-mission[11] application, e-mission will be used as part of the AccessMap Multimodal application to collect users' travel plans as described in the PMESP and HUAS. The phones will be Android[12] phones to meet the requirements of as the e-mission, AccessMap Multimodal, and Audiom applications.

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[5] AccessMap Multimodal https://tcat.cs.washington.edu/2021/12/03/accessmap/

[6] Audiom https://www.audiom.net

[7] UW ITS4US Performance Measurement and Evaluation Support Plan https://rosap.ntl.bts.gov/view/dot/60781

[8] UW ITS4US Human Use Approval Summary https://rosap.ntl.bts.gov/view/dot/62488

[9] Subscriber Identity Module (SIM) https://csrc.nist.gov/glossary/term/subscriber_identity_module

[10] GPS: The Global Positioning System. U.S. Government. https://www.gps.gov

[11] e-mission software https://github.com/e-mission

[12] Android https://www.android.com

3.1.2 Ancillary Equipment

Two types of ancillary equipment are required for the use of the phones: SIM cards for data connections for the phones and a GPS unit to improve location accuracy. Forty (40) of each item will be acquired.

3.1.3 Requirements and Specifications

The primary requirements of the mobile phones to be acquired for the TDEI is the ability to run AccessMap Multimodal, e-mission, and Audiom software. In addition, the phones need to have an Inertial Measurement Unit (IMU)[13], which uses a phone's gyroscope, accelerometer, and sometimes magnetometers to determine the phones' location and movement in space. IMUs are available on most phones in the market currently. Finally, the phones must be Bluetooth-enabled and have a minimum of 128GB of internal memory.

The SIM card purchase includes a SIM Kit which contains the SIM card itself and a prepaid refill code to add funds to the phone's account. The SIM cards in the SIM Kit must be compatible with the phones, specifically the size of the SIM card must be the size used by the phone, and the phone must be compatible with the network of the SIM card.

The GPS units are required to be a multi-purpose universal Bluetooth GPS receiver with a position update rate of 1/second or greater. The GPS units need to be compatible with two Global Navigation Satellite Systems (GNSS)[14]. GNSS is a general term for what is commonly called GPS. The phones must be compatible with GPS, which is the U.S. GNSS maintained by the U.S. Department of Defense[15] and the European GNSS (Galileo). For this project, the positional accuracy requirement is the ability to determine if travelers are off-route; a 10-foot error radius 70% of the time which is provided by this GPS receiver is sufficient for that purpose.

3.1.4 Quantities and Exemplar Devices

Table 2 provides quantities and exemplar devices for the phones, SIM cards, and GPS units to be acquired. The specific devices may change at the time of purchase due to product updates and product availability; however, the purchases will remain materially the same. Forty (40) of each item will be purchased, as there are forty (40) participants in the studies for which the mobile phones will be used.

[13] Inertial Sensors. Parker. Microstrain. https://www.microstrain.com/inertial/IMU

[14] Global Navigation Satellite Systems. U.S. Government. https://www.gps.gov/systems/gnss/

[15] Satellite Navigation – Global Positioning System (GPS). FAA. https://www.faa.gov/about/office_org/headquarters_offices/ato/service_units/techops/navservices/gnss/gps

Table 2 Quantities and Exemplar Devices for Mobile Phones and Ancillary Equipment

Item	Exemplar Device	Quantity	Notes
Mobile Phone	Samsung Galaxy S22[16]	40	Samsung Galaxy S22; 5G wireless; 128GB internal memory. Model: SM-S901UZKAXAA
SIM Cards	AT&T – SIM Kit[17] AT&T Prepaid $50 Refill[18]	40	The exemplar phone uses a Nano-SIM and is compatible with AT&T, Sprint, T-Mobile, Google Fi, Verizon, Cricket, Mint Mobile, Simple Mobile, H2O Wireless, Ting Mobile, Ultra Mobile, MetroPCS, US Cellular, Boost Mobile. Model: ATT PREPAID SIM KIT Model: AT&T $50 DIGITAL .COM
GPS Unit	Garmin - Instinct GPS Smartwatch[19]	40	Model 010-02064-00

3.1.5 Associated Software

The AccessMap Multimodal, e-mission and potentially Audiom software will be used with the phones. In addition, the Garmin Connect app will be installed on the phones to connect the GPS device to the phones. AccessMap Multimodal, e-mission and Audiom are open-source and are available for free. Garmin Connect is also available for free. No software will be purchased.

[16] Samsung Galaxy S22. Best Buy. https://www.bestbuy.com/site/samsung-galaxy-s22-128gb-unlocked-phantom-black/6494419.p?skuId=6494419

[17] AT&T – SIM Kit. Best Buy. https://www.bestbuy.com/site/at-t-sim-kit/6377453.p?skuId=6377453

[18] AT&T Prepaid $50 Refill. Best Buy. https://www.bestbuy.com/site/at-t-prepaid-50-refill-code-digital/6358075.p?skuId=6358075

[19] Garmin - Instinct GPS Smartwatch. Best Buy. https://www.bestbuy.com/site/garmin-instinct-gps-smartwatch-45mm-fiber-reinforced-polymer-graphite/6315353.p?skuId=6315353

4 Data Management & Analysis Equipment

The UW Team will acquire computers to process and analyze data collected as part of the TDEI project and to generate sidewalk network data. This data analysis will be done outside of the cloud environment to reduce the amount of cloud resources needed and for convenience for the data analyst. Network Attached Storage will be acquired to store the inputs and outputs of this data analysis.

4.1 Computers

The UW Team will purchase computers to support the data analysis associated with the TDEI project. In addition, these computers provide an alternative option for operating the TDEI system should cloud costs become excessive.

4.1.1 Technical Description

The computers to be acquired will be modern off-the-shelf personal computers.

4.1.2 Requirements and Specifications

The primary requirement for the computers is that they be powerful enough to handle the project data analysis tasks. Requirements include an AMD Ryzen™ 5000 series processor or newer, with a minimum 12 cores and 70MB cache. In addition, a minimum 32GB Double Data Rate 4 (DDR4) memory and 1TB of Solid State Drive (SSD) storage is required.

4.1.3 Quantities and Exemplar Devices

Table 3Table 2 provides quantities and exemplar devices for the computers. The specific devices may change at the time of purchase due to product updates and product availability; however, the purchases will remain materially the same. Two computers will be purchased.

Table 3 Quantities and Exemplar Devices for Computers

Item	Example Device	Quantity	Notes
Computer	Alienware Aurora Ryzen™ Edition R14 Gaming Desktop[20]	2	Manufactured by Dell; AMD Ryzen™ 9 5900 processor (70MB cache, 12-cores, 24-threads); 32GB DDR4 memory; 1TB SSD

4.1.4 Associated Software

The computers will run open-source software, including the GNU/Linux Operating System[21,22]. Additional software will include standard data processing software including languages such as Python[23]and JavaScript[24], and databases such as PostgreSQL[25].

4.2 Network Attached Storage (NAS)

The UW Team will purchase Network Attached Storage (NAS)[26] devices to store data that is used and generated by the offline data analysis (outside of the cloud system). In addition, along with the computers, the NAS can provide an alternative option for operating the TDEI system should cloud costs become excessive. In addition, the NAS can be used to create an offline backup of data in the TDEI system. Finally, this NAS will be backed up to a second NAS currently owned by the Taskar Center for Accessible Technology (TCAT) at UW.

[20] Alienware Aurora Ryzen™ Edition R14 Gaming Desktop. Dell. https://www.dell.com/en-us/shop/gaming-and-games/alienware-aurora-ryzen-edition-r14-gaming-desktop/spd/alienware-aurora-r14-desktop/wdr14aurdod1h

[21] GNU Operating System. https://www.gnu.org

[22] The Linux Kernel Archives. https://www.kernel.org

[23] python https://www.python.org

[24] JavaScript. Mozilla Developer Network. https://developer.mozilla.org/en-US/docs/Web/JavaScript

[25] PostgreSQL https://www.postgresql.org

[26] What is NAS? Seagate. https://www.seagate.com/blog/what-is-nas-master-ti/

4.2.1 Technical Description

Network Attached Storage (NAS) consists of storage devices (disk drives) and a minicomputer to house those disk drives. This minicomputer houses the disk drives and connects them to the network so the storage can be accessed by other computers.

4.2.2 Requirements and Specifications

The key requirement for the storage devices is the amount of storage to be provided and a requirement that the minicomputer supports that storage, specifically that the data transfer speed matches that of the analysis computer so the data transfer does not become a bottleneck. The project storage requirement is six (6) 12TB drives with 256MB cache. These drives will be configured in a RAID format to protect against drive failure.

4.2.3 Quantities and Exemplar Devices

Table 4Table 2 provides quantities and exemplar devices for the storage devices. The specific devices may change at the time of purchase due to product updates and product availability; however, the purchases will remain materially the same. One storage box and six (6) storage drives will be purchased. The NAS is external to the storage box and does not use the internal drive connections within the storage box.

Table 4 Quantities and Exemplar Devices for Network Attached Storage

Item	Example Device	Quantity	Notes
Storage Devices (Disk Drives)	WD Red Pro NAS Hard Drive. Part#: WD121KFBX[27]	6	From Western Digital; 12TB; 256 MB cache.
Storage Box (Computer)	Intel® NUC 11 Pro Mini PC; NUC11TNKv7[28]	1	11th Gen Quad-Core; 16GB DDR4 RAM; 512GB SSD

4.2.4 Associated Software

The storage box will run the latest version of the GNU/Linux Operating System, which is open source and freely available.

[27] WD Red Pro NAS Hard Drive. Western Digital. https://www.westerndigital.com/products/internal-drives/wd-red-pro-sata-hdd#WD121KFBX

[28] Intel® NUC 11 Pro Mini PC. Intel. https://www.intel.com/content/www/us/en/products/sku/205608/intel-nuc-11-pro-mini-pc-nuc11tnkv7/specifications.html

5 Cloud Infrastructure

This section describes the cloud resources that are being acquired for the TDEI system, which is being developed and operated on the Microsoft Azure Cloud. The acquisition of the cloud resources began in August 2022 and continues in line with the schedule in Section 2.2.

The cloud resources to be acquired have been divided into six categories: compute, databases, integration, storage, containers, and DevOps. DevOps is a term derived from the terms development and operations, it is a practice of integration and collaboration between software development teams (Dev) and information technology teams (Ops)[29]. For each of these categories, we describe the services in that category, their purpose in the TDEI system, and the specific Azure service that will be used for that category of cloud resources. These descriptions are followed by a section that connects the cloud resources to components in the Functional Components diagram from the Phase II System Architecture Document (SAD) and provides general specifications and quantities of the resources to be acquired. Detailed specifications are provided in the Bill of Materials in Section 6. Full details of the cloud architecture of the system are provided in the Phase II System Design Document (SDD).

The resources described in this section are the planned acquisition for the TDEI production environment. The TDEI will have three environments: production, staging and development. The production environment will run the operational TDEI, the development environment will be used for software development, and the staging environment will be used for internal testing prior to deployment to the production environment. The resources acquired for the development and staging environment will have the same types and quantities of resources, but with less powerful specifications to reduce costs. Resource specifications may be modified to meet operational and development needs; such modifications are a natural part of and a benefit of developing and operating in a cloud computing environment. The categories and types of cloud resources needed are not expected to change.

5.1 Compute

The TDEI system will use compute services to run microservices in the system. A compute service is the virtual equivalent of a computer, in other words, a virtual machine. There will be one compute service allocated for each component microservice in the system. Microservices, such as the General Transit Feed Specification (GTFS)-Flex[30] data validator, will run in a compute service, the Authorization Service will run in a compute service, and so on. In general, services

[29] What is DevOps? Microsoft. https://learn.microsoft.com/en-us/devops/what-is-devops

[30] GTFS-Flex. https://github.com/MobilityData/gtfs-flex

for the three data types the TDEI is collecting – GTFS-Flex, GTFS-Pathways[31], and OpenSidewalks (OSW)[32] – will run as separate microservices. That is, there will be a GTFS-Flex data validator microservice, a GTFS-Pathways data validator microservice, and an OSW data validator microservice. There are expected to be approximately twenty (20) compute services in the TDEI system. These compute services are described in the SDD.

The majority of the compute services will run software developed by the TDEI team, which runs on the open-source GNU/Linux operating system and uses languages such as Python and JavaScript. One compute service will run Keycloak[33], which is part of the authorization service.

The specific Microsoft Azure service used to provide the compute services is AppService[34].

5.2 Databases

Two types of databases will be used in the TDEI system: PostgreSQL, a relational database, and Cosmos DB a distributed database. The specific Azure components used are Azure Database for PostgreSQL[35] and Azure Cosmos DB[36].

The PostgreSQL database is a relational database which stores structured data including file meta-data as described in the Phase II Data Management Plan (DMP). There is one PostgreSQL database for each of the three data types (OSW, GTFS-Flex and GTFS-Pathways). In addition, there is a PostgreSQL database which stores user registration data. The user registration data is isolated in the Authorization Service for security reasons as described in the Phase II Data Privacy Plan (DPP).

The Cosmos DB is a distributed database that manages data stored in different physical locations. Cosmos DB will be used to store the system audit logs.

[31] GTFS-Pathways. https://developers.google.com/transit/gtfs/reference

[32] OpenSidewalks. https://tcat.cs.washington.edu/opensidewalks-2/

[33] Keycloak. https://www.keycloak.org

[34] AppService. Microsoft. https://azure.microsoft.com/en-us/products/app-service/#overview

[35] Azure Database for PostgreSQL. Microsoft. https://azure.microsoft.com/en-us/products/postgresql/

[36] Azure Cosmos DB. Microsoft. https://azure.microsoft.com/en-us/products/cosmos-db/

5.3 Integration

The TDEI system will run Azure Service Bus[37], which provides cloud messaging, specifically cloud messaging as a service. The microservices in the TDEI system will communicate over the Azure Service Bus.

5.4 Storage

Azure Blob Storage[38] is a Simple Storage Service (S3)[39]-compatible scalable object storage system. The distinguishing feature of object storage is that it stores objects such as files, documents, images, and videos as 'blobs', which stands for Binary Large Object (BLOB). When using 'blobs', the system stores the objects, the system is not aware of any structure inside the 'blobs', and users cannot retrieve portions of the blob. This is in contrast to a relational database, wherein data is stored in a tabular format and the system is aware of the rows and columns in the database and users can issue complex queries over the data.

In the context of the TDEI system, the blob storage will be used to store GTFS-Pathways, GTFS-Flex, and OSW data files, while the file-meta data and other meta-data is stored in the PostgreSQL database.

5.5 Containers

The Azure Container Registry[40] will be used to store Docker[41] images of the TDEI system components. As described in Section 5.1, the TDEI system will run a set of microservices, with each in its own compute service (AppService). The code for each of these microservices will be bundled in Docker images; using Docker images improves deployment consistency, testing, and automatic deployment / start-up of the microservices. That is, the microservices can be started up by the system using the Docker images without human intervention, improving the efficiency and correctness of system start up.

[37] Azure Service Bus. Microsoft. https://azure.microsoft.com/en-us/products/service-bus

[38] Azure Blob Storage. Microsoft. https://azure.microsoft.com/en-us/products/storage/blobs

[39] Amazon Simple Storage Service. https://aws.amazon.com/s3/

[40] Azure Container Registry. Microsoft. https://azure.microsoft.com/en-us/products/container-registry/

[41] Docker. https://www.docker.com

5.6 DevOps

Azure Monitor[42] is a monitoring solution for cloud resources and will be used to monitor the TDEI system. The TDEI System will use the Azure AppInsights[43] extension to Azure Monitor to collect metrics for monitoring system health and for producing performance metrics. Metrics to be collected include number of API calls, number of API calls for data ingest and data requests, response time of API calls, and system uptime and downtime. Details on the performance metrics are provided in the PMESP.

5.7 Specifications and Mapping to Functional Components

Table 5 provides a list of the types of cloud service categories that will be acquired for the TDEI system and, for each category, lists the Azure service to be used, a Description and General Specifications, Functional Components that will use or access that service type, and the Quantity to be acquired. This table is intended to provide a high-level summary of the cloud resources that will be acquired.

Selected components in the functional components diagram in Figure 2 TDEI Functional Components Diagram are not currently associated with cloud resources. The Functional Components Diagram is intended to be a conceptual rendering of the system and it is expected that not all components will be implemented as microservices. Full architectural details are provided in the Phase II System Design Document (SDD).

With respect to the Functional Components Diagram, the caches will not be separate microservices, rather the caches will be enabled as part of the data services. The Flex and Pathways integrators are implemented as part of the Flex and Pathways Consumer Services, respectively. The Flex and Pathways formatters will be libraries, which will be integrated into the respective data services. Formatting for OSW data is more complex; thus, there is a microservice for formatting OSW data.

[42] Azure Monitory. Microsoft. https://learn.microsoft.com/en-us/azure/azure-monitor/overview

[43] Azure AppInsights. Microsoft.https://learn.microsoft.com/en-us/azure/azure-monitor/app/app-insights-overview

Table 5 Description of TDEI Cloud Services and Mapping to Functional Components

Category	Azure Service	Description	General Specification	Related Functional Components	Quantity
Compute	App Service	Virtualized systems to run system components.	Basic Tier; 1 B3 (4 Core(s), 7 GB RAM, 10 GB Storage)	OSW, Flex, Pathways – Validator, Confidence Metrics, Integrator, Data Service, Consumer Service, Producer Service Authorization Service, Gateway,	One for most components in Figure 2. See Section 6 for details.
Databases	Azure Database for PostgreSQL Azure Cosmos DB	PostgreSQL relational database stores structured data including file meta-data and user registration data. Cosmos DB stores audit logs.	Small: PostgreSQL Flexible Server Deployment, General Purpose Tier, 1; 32 GB Storage, 100 GB Additional Backup storage Large: PostgreSQL Flexible Server Deployment, General Purpose Tier, 1; 3,000 GB Storage, 6,000 GB Additional Backup storage Cosmos: Standard provisioned throughput; 100 GB transactional storage	Accessed by the OSW, Flex, and Pathways Data Services Authorization Service Monitoring	3 PostgreSQL – small 1 PostgreSQL - large 1 Cosmos DB
Integration	Azure Service Bus	Service Bus for facilitating communication.	Standard tier	All microservices.	1

Category	Azure Service	Description	General Specification	Related Functional Components	Quantity
Storage	Azure Blob Storage	Blob storage – provides file storage. Stores OSW, Flex and Pathways data files.	Block Blob Storage, General Purpose V2, 3,000 GB Capacity	Accessed by OSW, Flex, Pathways Data Service.	3
Containers	Azure Container Registry	Stores docker container images for the components.	Basic Tier, 1	All microservices.	1
DevOps	Azure Monitor	Used for monitoring the system to collect performance metrics and system health metrics.	Log analytics; Managed Prometheus; Application Insights	All components.	1

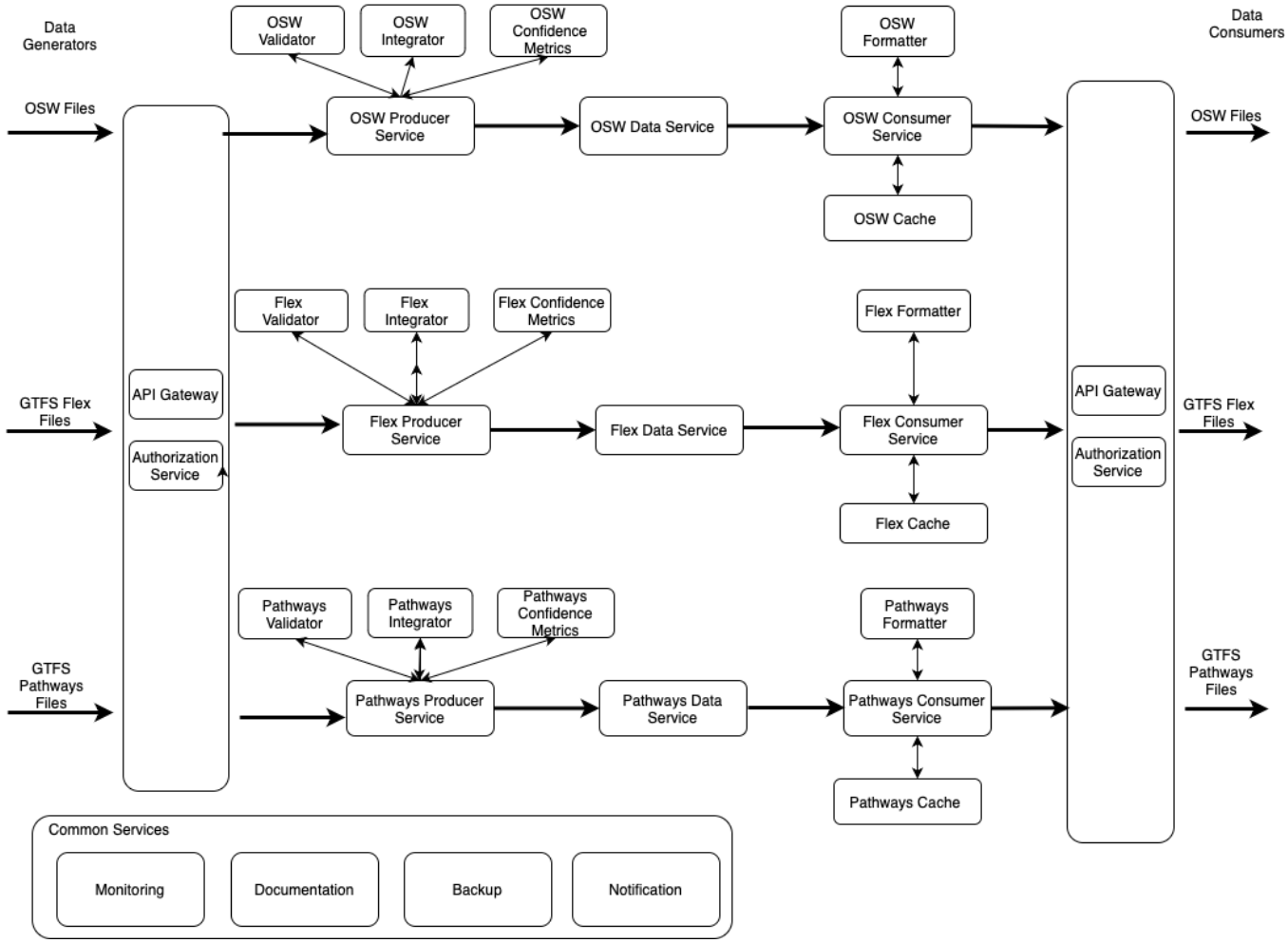

Figure 2 TDEI Functional Components Diagram

6 Bill of Materials

This section provides the Bill of Materials for the items to be acquired for the TDEI project.

6.1 Mobile Devices

Repeated from Table 2 Quantities and Exemplar Devices for Mobile Phones and Ancillary Equipment from Section 3.1.4.

Table 6 Bill of Materials – TDEI Mobile Phones and Ancillary Equipment

Item	Exemplar Device	Quantity	Notes
Mobile Phone	Samsung Galaxy S22[44]	40	Samsung Galaxy S22; 5G wireless; 128GB internal memory. Model:SM-S901UZKAXAA
SIM Cards	AT&T – SIM Kit[45] AT&T Prepaid $50 Refill[46]	40	The exemplar phone uses a Nano-SIM and is compatible with AT&T, Sprint, T-Mobile, Google Fi, Verizon, Cricket, Mint Mobile, Simple Mobile, H2O Wireless, Ting Mobile, Ultra Mobile, MetroPCS, US Cellular, Boost Mobile. Model: ATT PREPAID SIM KIT Model: AT&T $50 DIGITAL .COM
GPS Unit	Garmin - Instinct GPS Smartwatch[47]	40	Model 010-02064-00

[44] https://www.bestbuy.com/site/samsung-galaxy-s22-128gb-unlocked-phantom-black/6494419.p?skuId=6494419

[45] https://www.bestbuy.com/site/at-t-sim-kit/6377453.p?skuId=6377453

[46] https://www.bestbuy.com/site/at-t-prepaid-50-refill-code-digital/6358075.p?skuId=6358075

[47] https://www.bestbuy.com/site/garmin-instinct-gps-smartwatch-45mm-fiber-reinforced-polymer-graphite/6315353.p?skuId=6315353

6.2 Computers

Repeated from Table 3 Quantities and Exemplar Devices for Computers from Section 4.1.3.

Table 7 Bill of Materials – TDEI Computers

Item	Example Device	Quantity	Notes
Computer	Alienware Aurora Ryzen™ Edition R14 Gaming Desktop	2	Manufactured by Dell; AMD Ryzen™ 9 5900 processor (70MB cache, 12-cores, 24-threads); 32GB DDR4 memory; 1TB SSD

6.3 Storage Devices

Repeated from Table 4 Quantities and Exemplar Devices for Network Attached Storage from 4.2.3.

Table 8 Bill of Materials – TDEI Storage Devices

Item	Example Device	Quantity	Notes
Storage Devices (Disk Drives)	WD Red Pro NAS Hard Drive. Part#: WD121KFBX	6	From Western Digital; 12TB; 256 MB cache.
Computer	Intel® NUC 11 Pro Mini PC; NUC11TNKv7	1	11th Gen Quad-Core; 16GB DDR4 RAM; 512GB SSD

6.4 Cloud Services

Table 9 provides details of the acquisition of Microsoft Azure Services. Links to the Azure pricing information for each Service type are included in the first entry for that Service type in the table below. The information at those links explains the information in the Description column of Table 9. Note that 730 hours is the average number of hours in a month and represents one month of service.

Table 9 Bill of Materials – TDEI Microsoft Azure Services

Service category	Service type	Service Description	Description
Compute	App Service[48]	App Service – Authorization Service	Basic Tier; 1 B3 (4 Core(s), 7 GB RAM, 10 GB Storage) x 730 Hours; Linux OS; 0 SNI SSL Connections; 0 IP SSL Connections
Compute	App Service	App Service – File Service	Basic Tier; 1 B3 (4 Core(s), 7 GB RAM, 10 GB Storage) x 730 Hours; Linux OS; 0 SNI SSL Connections; 0 IP SSL Connections
Compute	App Service	App Service – Gateway	Basic Tier; 1 B3 (4 Core(s), 7 GB RAM, 10 GB Storage) x 730 Hours; Linux OS; 0 SNI SSL Connections; 0 IP SSL Connections
Compute	App Service	App Service – GTFS Flex Validation	Basic Tier; 1 B3 (4 Core(s), 7 GB RAM, 10 GB Storage) x 730 Hours; Linux OS; 0 SNI SSL Connections; 0 IP SSL Connections

[48] App Service Pricing. Microsoft. https://azure.microsoft.com/en-us/pricing/details/app-service/linux/

Service category	Service type	Service Description	Description
Compute	App Service	App Service – Keycloak (Used for use authorization and authentication.)	Basic Tier; 1 B3 (4 Core(s), 7 GB RAM, 10 GB Storage) x 730 Hours; Linux OS; 0 SNI SSL Connections; 0 IP SSL Connections
Compute	App Service	App Service – OSW Validation	Basic Tier; 1 B3 (4 Core(s), 7 GB RAM, 10 GB Storage) x 730 Hours; Linux OS; 0 SNI SSL Connections; 0 IP SSL Connections
Compute	App Service	App Service – GTFS-Pathways validation	Basic Tier; 1 B3 (4 Core(s), 7 GB RAM, 10 GB Storage) x 730 Hours; Linux OS; 0 SNI SSL Connections; 0 IP SSL Connections
Compute	App Service	App Service: OSW Formatter	Basic Tier; 1 B1 (1 Core(s), 1.75 GB RAM, 10 GB Storage) x 730 Hours; Linux OS; 0 SNI SSL Connections; 0 IP SSL Connections
Compute	App Service	App Service – Pathways Data Service	Basic Tier; 1 B3 (4 Core(s), 7 GB RAM, 10 GB Storage) x 730 Hours; Linux OS; 0 SNI SSL Connections; 0 IP SSL Connections
Compute	App Service	App Service – Flex Data Service	Basic Tier; 1 B3 (4 Core(s), 7 GB RAM, 10 GB Storage) x 730 Hours; Linux OS; 0 SNI SSL Connections; 0 IP SSL Connections
Compute	App Service	App Service – OSW Data Service	Basic Tier; 1 B3 (4 Core(s), 7 GB RAM, 10 GB Storage) x 730 Hours; Linux OS; 0 SNI SSL Connections; 0 IP SSL Connections
Compute	App Service	App Service – Pathways Confidence Metric Service	Basic Tier; 1 B3 (4 Core(s), 7 GB RAM, 10 GB Storage) x 730 Hours; Linux OS; 0 SNI SSL Connections; 0 IP SSL Connections
Compute	App Service	App Service – Flex Confidence Metric Service	Basic Tier; 1 B3 (4 Core(s), 7 GB RAM, 10 GB Storage) x 730 Hours; Linux OS; 0 SNI SSL Connections; 0 IP SSL Connections
Compute	App Service	App Service – OSW Confidence Metric Service	Basic Tier; 1 B3 (4 Core(s), 7 GB RAM, 10 GB Storage) x 730 Hours; Linux OS; 0 SNI SSL Connections; 0 IP SSL Connections

Service category	Service type	Service Description	Description
Compute	App Service	App Service – OSW Integrator Service	Basic Tier; 1 B3 (4 Core(s), 7 GB RAM, 10 GB Storage) x 730 Hours; Linux OS; 0 SNI SSL Connections; 0 IP SSL Connections
Compute	App Service	App Service – OSW Producer Service	Basic Tier; 1 B3 (4 Core(s), 7 GB RAM, 10 GB Storage) x 730 Hours; Linux OS; 0 SNI SSL Connections; 0 IP SSL Connections
Compute	App Service	App Service – OSW Consumer Service	Basic Tier; 1 B3 (4 Core(s), 7 GB RAM, 10 GB Storage) x 730 Hours; Linux OS; 0 SNI SSL Connections; 0 IP SSL Connections
Compute	App Service	App Service – Flex Consumer Service	Basic Tier; 1 B3 (4 Core(s), 7 GB RAM, 10 GB Storage) x 730 Hours; Linux OS; 0 SNI SSL Connections; 0 IP SSL Connections
Compute	App Service	App Service – Flex Producer Service	Basic Tier; 1 B3 (4 Core(s), 7 GB RAM, 10 GB Storage) x 730 Hours; Linux OS; 0 SNI SSL Connections; 0 IP SSL Connections
Compute	App Service	App Service – Pathways Consumer Service	Basic Tier; 1 B3 (4 Core(s), 7 GB RAM, 10 GB Storage) x 730 Hours; Linux OS; 0 SNI SSL Connections; 0 IP SSL Connections
Compute	App Service	App Service – Pathways Producer Service	Basic Tier; 1 B3 (4 Core(s), 7 GB RAM, 10 GB Storage) x 730 Hours; Linux OS; 0 SNI SSL Connections; 0 IP SSL Connections
Compute	App Service	App Service – User Management Front End	Basic Tier; 1 B3 (4 Core(s), 7 GB RAM, 10 GB Storage) x 730 Hours; Linux OS; 0 SNI SSL Connections; 0 IP SSL Connections

Service category	Service type	Service Description	Description
Databases	Azure Database for PostgreSQL[49]	Database: Stores file meta-data for GTFS-Flex.	Flexible Server Deployment, General Purpose Tier, 1 D2ds v4 (2 vCores) x 730 Hours (Pay as you go), 32 GiB Storage, 100 GiB Additional Backup storage - LRS redundancy, without High Availability
Databases	Azure Database for PostgreSQL	Database: Stores file meta-data for GTFS-Pathways.	Flexible Server Deployment, General Purpose Tier, 1 D2ds v4 (2 vCores) x 730 Hours (Pay as you go), 32 GiB Storage, 100 GiB Additional Backup storage - LRS redundancy, without High Availability
Databases	Azure Database for PostgreSQL	Database: Stores file meta-data for OSW.	Flexible Server Deployment, General Purpose Tier, 1 D2ds v4 (2 vCores) x 730 Hours (Pay as you go), 32 GiB Storage, 100 GiB Additional Backup storage - LRS redundancy, without High Availability
Databases	Azure Database for PostgreSQL	Database: Stores user registration information.	Flexible Server Deployment, General Purpose Tier, 1 D2ds v4 (2 vCores) x 730 Hours (Pay as you go), 32 GiB Storage, 100 GiB Additional Backup storage - LRS redundancy, without High Availability
Databases	Azure Cosmos DB[50]	Database: Stores audit log.	Standard provisioned throughput (manual), Always-free quantity disabled, Single Region Write (Single-Master) - West US 2 (Write Region); 400 RU/s x 730 Hours; 100 GB transactional storage; Dedicated Gateway not enabled

[49] Azure Database for PostgreSQL Pricing. Microsoft. https://azure.microsoft.com/en-us/pricing/details/postgresql/flexible-server/

[50] Azure Cosmos DB Pricing. Microsoft. https://azure.microsoft.com/en-us/pricing/details/cosmos-db/autoscale-provisioned/

Service category	Service type	Service Description	Description
Integration	Service Bus[51]	Service Bus: Facilitates communication between microservices	Standard tier: Messaging Operations: 730 Hours of base charge, 0 x 1 million operations; 0 brokered connection(s); Hybrid Connections: 0 listener(s), 0 overage GB; WFC Relays: 0 x 100 relay hours, 0 x 10,000 message(s)
Storage	Storage Accounts[52]	Blob Storage for storing GTFS-Flex, GTFS-Pathways and OSW data files	Block Blob Storage, General Purpose V2, Flat Namespace, LRS Redundancy, Hot Access Tier, 1,000 GB Capacity - Pay as you go, 10 x 10,000 Write operations, 10 x 10,000 List and Create Container Operations, 10 x 10,000 Read operations, 1 x 10,000 Other operations. 1,000 GB Data Retrieval, 1,000 GB Data Write
Containers	Azure Container Registry[53]	Docker Containers	Basic Tier, 1 registries x 30 days, 0 GB Extra Storage, Container Build - 1 CPUs x 1 Seconds - Inter Region transfer type, 5 GB outbound data transfer from West US 2 to East Asia

[51] Service Bus Pricing. Microsoft. https://azure.microsoft.com/en-us/pricing/details/service-bus/

[52] Storage Accounts Pricing. Microsoft. https://azure.microsoft.com/en-us/pricing/details/storage/blobs/

[53] Azure Container Registry Pricing. Microsoft. https://azure.microsoft.com/en-us/pricing/details/container-registry/

Service category	Service type	Service Description	Description
DevOps	Azure Monitor	Monitoring service. Uses Azure AppInsights extension.	Log analytics: Log Data Ingestion: 0 GB Daily Analytics logs ingested, 0 GB Daily Basic logs ingested, 1 months of Interactive Data Retention, 0 months of data archived, 0 Basic Log Search Queries per day with 0 GB data scanned per query, 0 Search job Queries per day with 0 GB data scanned per query; Managed Prometheus: 0 AKS nodes in cluster, 10000 Prometheus metrics per node, 30 seconds of Metric collection interval, 0 Average daily Dashboards users, 7 Dashboards, 50000 Data samples queried per dashboard, 25 promql alerting rules, 25 promql recording rules; Application Insights: 3 months Data retention, 0 Multi-step Web Tests; 0 resources monitored X 1 metric time-series monitored per resource, 0 Log Alerts at 5 Minutes Frequency, 0 Additional events (in thousands), 0 Additional emails (in 100 thousands), 0 Additional push notifications (in 100 thousands), 0 Additional web hooks (in millions)
Licensing			Microsoft Customer Agreement (MCA)

Appendix A. Acronyms

Acronym	Definition
API	Application Programming Interface
BLOB	Binary Large Object
CAP	Comprehensive Acquisition Plan
CFR	Code of Federal Regulations
CIP	Comprehensive Installation Plan
ConOps	Concept of Operations
COTS	Commercial Off the Shelf
DDR4	Double Data Rate 4
DMP	Data Management Plan
DPP	Data Privacy Plan
DOT	Department of Transportation
ETRA	Emerging Technology Readiness Assessment
FAR	Federal Acquisition Regulation
GNSS	Global Navigation Satellite System
GPS	Global Positioning System
GTFS	General Transit Feed Specification
HUAS	Human Use Approval Summary
IMU	Inertial Measurement Unit
ITS	Intelligent Transportation System
ITS JPO	Intelligent Transportation System Joint Program Office
NAS	Network Attached Storage
OSW	Open Sidewalks
PMESP	Performance Measurement and Evaluation Support Plan
RFP	Request for Proposal
SAD	System Architecture Document
SDD	System Design Document
SAM	System Award Management
SIM	Subscriber Identity Module
SSD	Solid State Drive
SyRS	System Requirements
Taskar Center or TCAT	Taskar Center for Accessible Technology
TDEI	Transportation Data Equity Initiative
TRAC	Washington State Transportation Center
U.S.	United States
USDOT	United States Department of Transportation
UW	University of Washington

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