MAT Standards Coordination Plan

Multimodal and Accessible Travel Standards and Vulnerable Road User Cybersecurity Support Project

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This document is produced by the MAT and Cybersecurity Subject Matter Experts (SMEs).

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1 Introduction

1.1 Scope

The MAT Standards Coordination Plan provides a plan for coordinating participation in MAT Standards activities that occur both within and outside of the traditional ITS standards development organizations. The document will identify the organizations developing standards or specifications for the following key areas:

- Reservations/Scheduling/Dispatching (RSD) application programming interface (APIs),
- Vulnerable road users (VRUs) in the vehicle-to-everything (V2X) environment
- Public Right of Way (PROW)

In addition, the coordination plan covers how cross-cutting areas including cybersecurity and privacy will be addressed. The Task 2 Cybersecurity and Privacy White Paper addressed many of the gaps, standards and best practices, and organizations spearheading development activities. Results from the Task 2 white paper are addressed. The document will develop a plan for addressing the gaps identified in the current set of standards and specification relative to these three areas.

Although the project identified a gap in standards to include eligibility for services and payment, the area is not yet mature enough for standardization. To that end, it is not explicitly discussed as a coordination element for this plan.

1.2 Background

USDOT, ITE, and their standards development partners have worked on ITS standards since the inception of the ITS Standards Program more than 20 years ago. In recent years, traditional ITS technologies have started to integrate with multimodal travel and support vulnerable road users (VRUs). Working with the multimodal community to survey existing standards and how they can support/augment ITS implementations is a necessary step. Additionally, ensuring that the security needs of VRUs are addressed in both standards and ITS deployments is critical to the safety and security of those VRUs. USDOT previously had a MAT Standards project that produced a MAT Standards Assessment and Roadmap that this project is expected to build on.

The MATSA project (see https://www.its.dot.gov/research_archives/mod/mod_resources.htm) reviewed emerging trends and challenges related to MAT that would benefit from standard development. The MAT activities cover the convergence of ITS technologies, multimodal and accessible travel, and VRUs. With this convergence, the standards cut across domains, modes, and standard / specification development organizations. This Multimodal and Accessible objective of this project is to continue the work started under the Multimodal and Accessible Travel Standards project to address gaps in standards for MAT and VRU technologies when integrating with ITS environments and technologies, including connected vehicle (CV) technologies. Identifying the unique security and privacy risks associated with VRUs participating in ITS environments is a key activity that will be used to inform future cybersecurity guidance and standards development efforts. A key consideration in addressing the gaps is that MAT interfaces are addressed by numerous specification efforts that occur outside of the traditional Standards Development Organization (SDO) arena.

1.3 Plan Organization

This document is organized into eight sections with several appendices.

Section 1 – Introduction: provides a high-level overview of the Plan scope and background.

Section 2 – MAT Standards Coordination Strategy: discusses the reasons for developing this coordination strategy and the goals and outcomes for MAT coordination. It also discusses the organization and project coordination efforts for three domain projects and the cybersecurity / privacy cross-cutting project (referred to as the four project areas). Sections 3 through 6 describe projects that fall under the MAT coordination efforts.

Section 3 – Project Coordination for VRUs using V2X: describes the goals, issues/gaps, standards, and stakeholders that are associated with Vulnerable Road Users using Vehicle-to-Everything (V2X) standards.

Section 4 – Project Coordination for PROW and Independence Accessibility: describes the goals, issues/gaps, standards, and stakeholders that are associated with public right of way user needs.

Section 5 – Project Coordination for RSD Standards: describes the goals, issues/gaps, standards, and stakeholders that are working on RSD standards and implementations.

Section 6 – Role of Cybersecurity and Privacy Standards with MAT: describes the goals, issues/gaps, standards, and stakeholders related to cross-cutting issues associated with how cybersecurity and PII standards are applied to MAT projects.

Section 7 – Engaging Community-Based Specifications Development Organizations: provides insight into how the USDOT may engage CBDOs to become active in MAT standards coordination.

Section 8 – Next Steps for Coordination: provides guidance on steps that should be taken to implement this plan.

Section 9 – Recommendations for MAT Standard Priorities: provides recommendations for the priority standards or activities to address first in each coordination project.

Several appendices are included in this document. They include the following:

Appendix A: s

Appendix B: MAT Deliverables - five white papers that were developed to delve into details summarized in this document. The white papers include the four project areas and a fifth paper on gaps in MAT Eligibility standards. Although one of the largest gaps in standards relates to the resource and manual processes applied to looking up eligibility for MAT services, the topic was deemed too immature until more pilots and methods are implemented.

References / References and End Notes**:** The final section is a list of the references throughout the document.

2 MAT Standards Coordination Strategy

2.1 Why MAT Standards Coordination

The MAT Standards Coordination Plan describes the strategy for how USDOT can support the development and deployment of standards and specifications that target multimodal and accessible travel standards. Developing a standard may not be enough in a market such as MAT. Experience learned from both successful and failed standard development activities shows that four elements should be embraced during the development and early deployment of standards. These include the following:

1. Develop specifications that meets user needs;
2. Pilot and test specifications in deployment to improve the specifications based on lessons learned;
3. Build open source software (OSS) or free tools to deploy and test implemented specifications (e.g., data file, transaction exerciser);
4. Develop guidelines and deliver training for deploying and using specification instances.

USDOT funds Standard Development Organizations (SDO) to develop standards. USDOT grants and awards favor using open interfaces and architectures. Guidelines and training opportunities are available. There are critical elements that are missing from the USDOT programs that this coordination plan tries to address.

Issue #1: Limited focus by SDOs on MAT related standards. The MAT white papers (see **Appendix B: MAT Deliverables**) that describe the organizations and specifications related to the major gaps in MAT standards show that SDOs heretofore have not been focused on MAT related standards, rather Community-based Development Organizations (CBDO) have been the most active. These CBDOs rely on volunteer resources to make significant progress. To that end, the specifications generated may be limited in scope, deployment experience, and training opportunities. Few of these specifications become widespread without tools to help generate and consume the data or transaction sets. The RSD-related specifications which are broad and emerging, are a prime example of the limited deployment scope and the great industry need (see Section 5.2 for more information).

Issue #2: With no central program by the USDOT, all MAT specification development efforts have been de-centralized piecemeal work. Most USDOT awards are not connected to testing and improving standards. Among the exceptions is the USDOT CV Pilots program that shows how multiple projects were used to influence and improve consistent implementation of the connected vehicle (CV) standards. The Work Zone Data Exchange (WZDx) Working Group and the work zone microgrants are programs supported by the USDOT for building consistency, improvement, and guidance around a specification. The CV pilots started out with existing standards. They were able to focus on consistent implementation. The WZDx did not have a standard, and so the USDOT initiated an open, community-based approach to develop the standard with microgrants for states and regions to spearhead the deployment of the specification. The WZDx working groups include efforts to develop guidelines and improve the specification. Although there have been informal efforts to further MAT specifications, USDOT MAT-related programs do not have a program that focuses on addressing standard gap areas; specifically, RSD, PROW, and VRU.

Issue #3: MAT standards and specification efforts have no centralized forum for the broad-based stakeholders to communicate and collaborate. MAT standard gap areas leverage and depend on other modal information and communication standards. The USDOT-sponsored Connected Intersection Project built a coordination task force composed of stakeholders, SDOs, and consultants that address several core areas. The coordination group focused on the core needs and use cases that cut across the various disciplines. They built consensus on a multi-disciplined operational concept and requirement to update standards, conformity testing, and guidelines. Unlike the loose relationships associated with SDOs working on the CI project, MAT standard and specification development organizations do not have the forum to collaborate.

The MAT Standards Coordination Plan is an attempt to highlight four projects that could be addressed by a MAT Standards Coordination Steering Committee. The coordination goals and outcomes are described in the following sections.

2.2 Coordination Goals

The goal of the coordination effort is to speed up the adoption of standards or specifications that address gaps identified in the key areas of MAT covered by this project. In addition, the coordination effort should address where standards and specifications are complementary but not consistent, seeking to synchronize the multiple efforts addressing aspects of MAT data interfaces.

2.3 Coordination Outcomes

There are three primary outcomes of this Coordination Plan:

1. Definition of the approach to coordinating with the various SDOs and other stakeholder groups that should be included in coordination effort. In the early stages of coordination, three areas of coordination were selected; they include VRU, RSD, and PROW. Although Eligibility is a gap in standards development, it was deemed in Task 3 Gap Analysis and Use Case Development reports that the topic was not yet mature enough for which to develop standards.
2. Engage stakeholders for a MAT Steering Committee that will consider some of the overarching or cross cutting topics for MAT standardization, such as cybersecurity.
3. Under the MAT Steering Committee, organize three working groups for the three key areas defined above. The working groups will serve as a point of coordination between different standards and specification groups to address gaps and overlaps relating to MAT data interfaces.

2.4 Coordination Organization

It is envisioned that a coordination committee structure be established to manage and bring together the various stakeholder groups working on, using, or advocating for MAT standards. Although the organizational principles, goals, and outcomes for the overall committee will be directed by USDOT and stakeholders involved in the activities, this plan anticipates a Steering Committee provides support for projects that coordinate key MAT standards. The MAT steering committee will coordinate the efforts of vertical working groups – addressing specific topics related to standards, as well as cross cutting areas that extend to each domain – like cybersecurity and privacy. This structure is shown in Figure 1.

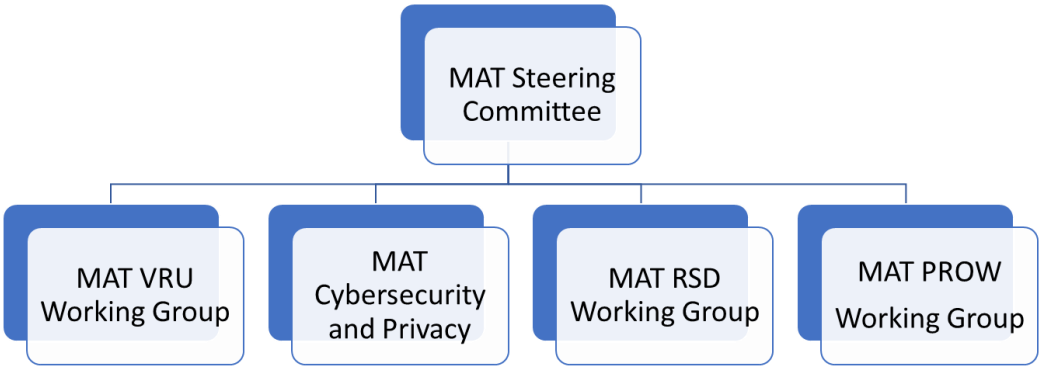

Figure 1. MAT Coordination Group. *Source: ITE.*

Working groups will be composed of SDOs and CBDOs working on standards and specifications, as well as stakeholders with an interest in furthering standardization. Sections 3 through 6 describe the four projects. Each of these chapters include a section on the following:

- Project Goals and Outcomes
- Issues and Standard Gaps
- Standards (and emerging standards)
- Stakeholders

These sections provide some initial goals and a list of interested parties for initiating a working group. The issues and gaps sections provide background information for the working group to get started on a problem statement.

3 Project Coordination for Vulnerable Road Users using V2X

This section summarizes the information provided in the Task 6 VRU white paper.

3.1 Project Goals and Outcomes

Gaps in the standards for VRUs in the V2X environment have been identified in the Task 6 VRU white paper. The goal of this project is to coordinate the standards development effort around the VRUs in the V2X environment topics that are ready for standardization by identifying stakeholders to include in the MAT Steering Committee. The next section describes these topics: VRU classification/taxonomy, incident data reporting, personal safety message (PSM) confidence intervals, and on-board units (OBUs) for bicycles.

3.2 Issues and Standard Gaps

This section discusses standard gaps that the MAT Steering Committee may consider for development.

3.2.1 VRU Classification/Taxonomy

Existing VRU taxonomy standards require harmonization of classification. In addition, standardized VRU profiles that are limited in inclusivity and encompass every type of VRU needs to be created. Harmonization of VRU types and the creation of profiles is the foundation of further standardization efforts; creating a complete VRU taxonomy with granular profiles is necessary for ensuring that future standards minimize gaps in coverage of VRUs. The version of the **ISO Working Draft 24317 Intelligent Transportation Systems— Mobility Integration – C-ITS for light mode conveyances and accessibility travel standards gap assessment** used for the Task 6 VRU white paper analysis includes a work plan that addresses their identified gaps. Before starting work on VRU classification/taxonomy, the MAT Steering Committee should coordinate with the relevant ISO working groups to avoid duplication of efforts. Currently, ISO Technical Committee 204 Working Group 19 Mobility Integration whose domain this is in, has only developed a gap analysis. No significant work has been initiated in any of the working groups.

3.2.2 Incident Data Reporting

A detailed VRU incident data reporting standard is needed. In order to make transportation and policy decisions, including those related to V2X, incident data is needed. However, current incident reporting standards lack sufficient detail or differ greatly between data collectors. For example, motorized wheelchair users and e-scooters both fall under the category of “Person on Motorized Personal Conveyance.” MMV advocacy groups such as PeopleForBikes and advocacy groups for people with disabilities such as the Disability Rights Education and Defense Fund may also have input on information to include in reporting. The MAT Steering Committee may determine whether this topic is in scope.

3.2.3 Personal Safety Message Confidence Intervals

The standard for the PSM for VRUs needs to be extended to include elements that describe confidence levels for items such as object detection, classification, and existence. The PSM is essential for VRUs in the V2X environment. Proxy PSMs may be generated by the infrastructure or vehicle sensors, and confidence in the VRU detection information is valuable for the intersection actors’ decision making.

This gap was mentioned in a USDOT Request for Information: Enhancing the Safety of Vulnerable Road Users at Intersections comment; the MAT Steering Committee may determine whether there is consensus on the desire for this PSM feature.

3.2.4 On-Board Units for Bicycles

Multiple companies are developing OBUs for bicycles. OBUs for bicycles allow cyclists to connect to the V2X environment. This technology may be mature enough to consider standardization. The MAT Steering Committee may determine which areas of this topic can be standardized.

3.2.5 Other Possible Topics

The following topics were determined in the Task 6 VRU white paper to not yet be ready for standardization: sensing and perception of VRUs, VRU path prediction, and alerting. However, the MAT Steering Committee may determine that certain areas of these topics may be mature enough for standardization. The MAT Steering Committee may also determine that a topic is out of scope. For example, some V2X technologies in work zones are proprietary and may not need standardization.

3.3 Standards

This section provides a list of standards and other documents related to VRUs in the V2X environment that the MAT Steering Committee may reference. Descriptions for each standard is available in the VRU white paper. Standards are hosted by the following SDOs:

- ETSI: European Telecommunications Standards Institute
- SAE: Society of Automotive Engineers
- ISO: International Organization for Standardization
- CEN: European Committee for Standardization
- IEEE: Institute of Electrical and Electronics Engineers

Standards still in progress are indicated as work-in-progress (WIP).

3.3.1 Taxonomy

This section lists standards related to VRU taxonomy. Subsections include general standards about VRUs, standards specifically about VRU taxonomy, other standards for micromobility vehicles (MMVs), and architecture standards that include VRUs.

General

- ETSI TR 103 300-1 V2.3.1, Vulnerable Road Users (VRU) awareness; Part 1: Use Cases definition; Release 2. (2022-11)
- ETSI TS 103 300-2 V2.2.1, Vulnerable Road Users (VRU) awareness; Part 2: Functional Architecture and Requirements definition; Release 2. (2021-04)
- ETSI TS 103 300-3 V2.1.2, Vulnerable Road Users (VRU) awareness; Part 3: Specification of VRU awareness basic service. Release 2. (2021-04)
- SAE J2945/9 Vulnerable Road User Safety Message Minimum Performance Requirements
- ISO 13111-1:2017, Intelligent transport systems (ITS) — The use of personal ITS station to support ITS service provision for travellers — Part 1: General information and use case definitions

- ISO 13111-2:2022 Intelligent transport systems (ITS) — The use of personal ITS stations to support ITS service provision for travellers — Part 2: General requirements for data exchange between ITS stations

Taxonomy

- SAE J3194 Taxonomy and Classification of Powered Micromobility Vehicles
- SAE J3272 Powered Micromobility Vehicle Identification [Work-In-Progress]
- ISO 7176-5:2008 Wheelchairs - Part 5: Determination of Dimensions, Mass, and Maneuvering Space
- ISO 7176-26:2007 Wheelchairs - Part 26: Vocabulary
- CEN 17128:2020 Light motorized vehicles for the transportation of persons and goods and related facilities and not subject to type-approval for on-road use - Personal light electric vehicles (PLEV) - Requirements and test methods (withdrawn standard)

Other standards for MMVs

- SAE J3274 (WIP) Minimum Sound Requirements for Powered Standing and Seated Scooters
- SAE J3230/1 Kinematic Performance Metrics for Powered Standing Scooters
- SAE JA3163_202106 Taxonomy of On-Demand and Shared Mobility: Ground, Aviation, and Marine

Architecture Standards

- ISO TR 22085-1:2019, Intelligent transport systems (ITS) — Nomadic device service platform for micromobility — Part 1: General information and use case definitions
- ISO 22085-2:2021 Intelligent transport systems (ITS) — Nomadic device service platform for micro mobility — Part 2: Functional requirements and dataset definitions
- ISO 22085-3:2022 Intelligent transport systems (ITS) — Nomadic device service platform for micro mobility — Part 3: Data structure and data exchange procedures
- ISO 17427-1:2018 Intelligent transport systems — Cooperative ITS — Part 1: Roles and responsibilities in the context of co-operative ITS architecture(s)
- ISO 24102 Series -- Intelligent transport systems —Communications access for land mobiles (CALM) — ITS station management a. Part 1: Local management b. Part 2: Remote management of ITS-SCUs c. Part 3: Service access points d. Part 4: Station-internal management communications e. Part 6: Path and flow management
- ISO 21217:2020 Intelligent transport systems — Station and communication architecture

3.3.2 Incident Data Reporting

This section lists incident reporting systems.

- Crash Report Sampling System (CRSS)
- Fatality Analysis Reporting System (FARS)

3.3.3 Sensors/Perception

The following are standards related to sensing and perception of VRUs:

- ISO 18682:2016 Intelligent transport systems — External hazard detection and notification systems — Basic requirements
- ISO 19237:2017 Intelligent transport systems — Pedestrian detection and collision mitigation systems (PDCMS) — Performance requirements and test procedures
- ISO 22078:2020 Intelligent transport systems — Bicyclist detection and collision mitigation systems (BDCMS) — Performance requirements and test procedures
- SAE J3116-202301 Active Safety Pedestrian Test Mannequin Recommendations
- SAE J3157201902 Active Safety Bicycle Test Target Recommendations
- SAE J2945/3 Requirements for Road Weather Applications

3.3.4 V2X

The following are standards related to the V2X environment:

- SAE J2735 V2X Communications Message Set Dictionary
- SAE J3224 V2X Sensor-Sharing for Cooperative and Automated Driving

3.3.5 Work Zones

The following are documents related to work zone VRU safety:

- Work Zone Data Exchange (WZDx) Specification
- Connected Work Zones Standard Implementation) [Work-In-Progress]

3.3.6 Path Prediction

The following are examples of documents related to path prediction:

- IEEE 2846-2022 Standard for Assumptions in Safety-Related Models for Automated Driving Systems
- IEEE 2846 White Paper - Literature Review on Kinematic Properties of Road Users for Use on Safety-Related Models for Automated Driving Systems

3.3.7 Alerting

The following is an example of a document that partly deals with driver alerting:

- ISO/TR 10992-2:2017 Intelligent transport systems — Use of nomadic and portable devices to support ITS service and multimedia provision in vehicles — Part 2: Definition and use cases for mobile service convergence

3.4 Stakeholders – Lead/participating/cooperating organizations

This section lists stakeholders to include in further development of standards related to VRU safety in the V2X environment. Some examples of each group are provided.

3.4.1 Standards Development Organizations

- ISO
- CEN
- SAE and other SDOs involved in V2X standards

3.4.2 Private Sector Companies

- Spoke Safety and its partners
- Autotalks
- Other vendors of V2X/safety technologies and services

3.4.3 Government

- National Highway Traffic Safety Administration (responsible for incident data reporting systems)
- Federal Lands / Department of the Interior – National Park Service
- FHWA
- FTA
- NTSB
- State, local, territorial and tribal governments

3.4.4 Advocacy Groups

- PeopleForBikes
- Disability Rights Education and Defense Fund
- Micro-mobility for Europe (MMfE)
- Safety associations
- Other advocacy groups

3.4.5 Other

- Research institutions

4 Project Coordination for Public Right-of- Way and Impendence Accessibility

4.1 Project Goals and Outcomes

The term Public Right-of-Way (PROW) currently has no universal definition in the literature, but can be simply described as routes, paths, "or right-of-way upon which the public has a right to travel or any person's safe and efficient access to the entryway of any building, where such entryway abuts a sidewalk, walkway, or right-of-way upon which the public has a right to travel."[1]

Many PROW standards provide a digital twin or graph of the infrastructure that includes modeling the sidewalk or bike path. There are several standards and specifications that exist or are under development related to PROW. In organizing a coordination plan to develop comprehensive and interoperable PROW standards, the PROW Project goals include the following:

- Establish a forum of organizations working on PROW standards
- Recommend actions to develop standards that address gaps for MAT-related applications, including coordination activities to enable interoperability among PROW-related standards and specifications
- Recommend guidelines for data feature quality conformance for profiles for specific downstream applications
- Recommend guidelines for encoding PROW standards that meet the quality and implementation of PROW standards

The project should produce a set of standards and specifications that are interoperable and address gaps as described in Section 4.2.

4.2 Issues and Gaps

For the most part, sidewalks and bike paths (lanes, cycle tracks, etc.) are defined as attributes of street networks (centerline) or faces of plot boundaries. Some accessibility features such as curb cuts and ramps are rendered as a point that may or may not be associated with a curb, intersection, or even a road network. Many "informal" pathways are not represented or have no object models in navigation maps. In addition, three-dimensional models may have multiple ways to transform the solid/surface model to a navigable model that can be used to generate trip plans. Although some standards or methods are under development for describing accessible pathways and integrating pedestrian/active mode networks with vehicle mode networks, there is no consistent approach nor one that is recognized across the transportation industry.

In addition, the mapping standard provides a variety of semantic, syntax, referencing, and encoding methods to refer to PROW feature and attribute sets. The network representation including associated features and attributes will drive the efficacy of the downstream application that uses the network.

Among the most prevalent uses include the following:

- **Accessibility**– to support universal design recommendations and compliance with Americans with Disability Act (ADA). The Americans with Disabilities Act, the Accessibility Guidelines for

Buildings and Facilities (ADA Appendix A, 2004) provide feature design elements for accessibility features for walking paths, including location and design of curb cuts or ramps where pedestrian activity is expected. Documentation of these features are typically documented in hard-coded paper maps, some are provided as point information on a map.

- **Curb Management** – to manage the traffic and usage of the curb including sidewalks used for commercial and personal usage. The types of information may be described as an attribute of road networks (e.g., on-street parking, loading zones, pick up/drop off locations, curb cuts, curb ramps, driveway aprons, cross walks) and may require a linear referencing system to locate positions along the road.
- **Wayfinding and Routing** – to provide multimodal trip planning to, from, and transitioning among different modal services including active mobility services. In order to personalize the trip for vulnerable travelers, a network that represents a graphic for multimodal travel is needed. Sometimes, a PROW cannot be associated with a road (e.g., pedestrian bridge). These paths require their own, interoperable network that provides paths through accessible features such as ramps, curb cuts, and around obstacles such as poles and benches, as well as across the road network (e.g., cross walks). These networks are used to provide navigable trip plans based on personal capabilities and accessibility needs.

Although there are some existing standards, there is no comprehensive standard that provides the following set of standards:

- **Network modeling** – this includes how the PROW is related to other transportation networks. This includes the graph and linear referencing models that describe paths through accessible features (e.g., edges and nodes).

- **Attributes / semantic ontologies (i.e., classifications)** – that describe the meaning of similar PROW attributes across different domains.

- **Metadata** – information about the data (in a feed), its content (coverage and attributes), source, lineage, processing, quality, and other information that describes how to discover, access, and use the data. This includes the minimum set of attributes and their quality to support accessibility for different VRU communities.

- **Compliance tests** -- to measure the quality. Quality factors might include accuracy, precision, resolution, consistency, and currency. Completeness is based on a different set of criteria based on the usage and end-users of the data. For example, the minimum set of attribute information needed to generate cost functions for travel for people using manual vs. motorized wheelchairs differs, as does the set minimum set of requirements for transition plans versus curb management versus trip planning (point vs. linear vs. topologically connected graphs models).

- **Performance descriptions and tests** – to measure the metrics (enumerated values) assigned to an attribute. For example, a measure for the surface may include values from rough to smooth. A major challenge for any standard is to provide guidelines or rules to quantify these values. The performance description and test provide a rubric or algorithm for each qualitative value. Performance tests are one approach for building consistency.

Other standards and protocols are used to access, transmit, or describe the information. For access and transmitting the models, key protocols related to data transfer include the following:

- Encoding standards such as Geographic Markup Language (GML), JSON/GeoJSON, REST, and Delimited files
- Application protocols such as HTTP or OpenAPI
- Feed or exchange specifications that describe the semantics and their structure of information including shapefiles (ESRI format), map and feature services (Open Geospatial Consortium - OGC), General Transit Feed Specification (GTFS), and more.

4.3 Standards

This section describes standards, specifications, and policy documents that describe PROW models and requirements used for the three downstream uses described above (accessibility compliance, curb management, wayfinding and routing).

4.3.1 Accessibility Specifications

There are several policy guidelines that provide requirements to meet accessibility needs for people with disabilities. The most significant guideline is the following:

ADAAG -- part of the Americans with Disabilities Act, the Accessibility Guidelines for Buildings and Facilities (ADA Appendix A, 2004) describes sets of requirements related to the following:

- Accessibility routes
- General site and building elements
- Recreational facilities
- And more

The specification does not provide the capability to encode the infrastructure into a digital twin that can be represented, visualized, or processed (e.g., generate routes). Many standards and specifications (developed in the US) use these guidelines to assess compliance with ADA requirements.

Linked Data for Accessibility Group[2] — Linked Data for Accessibility Group is a coordinated effort by the World Wide Web Consortium (W3C) to standardize accessibility information about buildings, services, and routes by *"(1) by creating an open standard vocabulary for accessibility and (2) by providing a central place for the web community to discuss issues around physical accessibility data."*[3]

4.3.2 Curb Management

There are several standards that represent curbs and their attributes in the public domain. They include the following:

Curb Data Specification: The Curb Data Specification (CDS), governed by the Open Mobility Foundation (OMF), "covers the supply component of the curb but incorporates a demand component by having both an events and metrics API."[4] The CDS focuses on managing the road to the curb including loading zones, parking and bike lanes. It also covers features of the intersection. It does not cover the full range of public right of ways.

CurbLR: "A specification developed by SharedStreets…It was designed to capture the complex structure of curb regulations in a robust, priority driven design with locations based off of the SharedStreets [linear] referencing system."[5] The CurbLR is used in conjunction with CDS to measure the relative location along a road edge. It can be used to for any pathway, though it is currently not supported or managed by any CBDO.

CityGML – Open Geodata Consortium (OGC)'s CityGML defines "a conceptual model and exchange format for the representation, storage, and exchange of virtual 3D city models. It facilitates the integration of urban geodata for a variety of applications for Smart Cities and Urban Digital Twins, including urban and landscape planning, Building Information Modeling (BIM), mobile telecommunication, disaster management, 3D cadastre, tourism, vehicle and pedestrian navigation, autonomous driving and driving assistance, facility management, and energy, traffic, and environmental simulations."[6]

4.3.3 Wayfinding and Routing

OpenSidewalks[7] – OpenSidewalks is a coordinated effort by the University of Washington Tasker Center for Accessible Technology. OpenSidewalks was designed for creating an open-source pedestrian map layer that standardizes "transportation network-focused methods for gathering detailed information such as sidewalks, curb cuts, crossings, and street furniture."[8]

GTFS-Pathways – A proposed extension to the General Transit Feed Specification (GTFS) that describes transit stations pathways including entrances and interiors including elevator, escalator, and stairs, platforms, bus bays, and fare gates. [9]

CityGML – As described above (Section 4.3.2), the CityGML is a conceptual, cadestre model of the virtual city. CityGML includes tools to transform the digital twin into a network that can be used for managing the curb edge. With all network transformation tools, the algorithm used changes the image and may require quality control procedures to generate a network suitable for managing accessibility along public right of way networks. In addition, CityGML does not contain a rich set of attributes needed to describe the PROW features and conditions.

OSM – OpenStreetMap, open specifications, visualizations, and interfaces that represent geographic data including "physical features on the ground (e.g., roads or buildings) using tags attached to its basic data structures (its nodes, ways, and relations). Each tag describes a geographic attribute of the feature being shown by that specific node, way, or relation."[10] Features include the following:

- Public transportation modes (ariel way, railway, and transit)
- Barriers
- Boundaries
- Buildings
- Places of interest
- Highways (all roads)
- Land use
- Routes including bicycle, public transportation, detours, foot, hiking

- Natural features and landmarks
- Waterways

4.4 Stakeholders – Lead/participating/cooperating organizations

The type of stakeholder groups who participate in developing, collecting, and using PROW standards include the following:

- Standard or specification development organizations
- Data collectors and repository managers
- Users of PROW data

Specific organizations developing standards that generate data and use the standards are listed in the sections that follow:

4.4.1 Standards Development Organizations

SDOs and grassroot organizations that develop standards and specification include the following:

- Open Mobility Foundation
- MobilityData
- Open Geospatial Consortium / ISO Technical Committee 211 and 204
- SharedStreets (not currently managed by a CBDO)
- OpenStreetMap
- University of Washington Tasker Center
- SDOs involved in Smart Intersection and Work Zones standards including ITE, SAE, and AASHTO

4.4.2 PROW Data Collection and Repository Managers

The stakeholders who collect, store, and distribute PROW data sets include the following:

- Public jurisdictions including cities, counties, local planning organizations, and states
- USDOT Federal Geographic Data Committee (FGDC)
- OpenStreetMap

4.4.3 Users of PROW data

Stakeholders who develop applications or stakeholders who use these applications include the following:

Application Developers who use PROW

- Curb management tools
- Trip planning/511 tools
- Transportation planning models
- Transportation management tools

Users Who Use Applications or Data

- ADA transition planners

- Crowdsourcing using data collection tools
- VRU communities including organizations advocated for People with Disabilities, Older Adults, Vision Zero, and other communities advocated for accessibility and safety for vulnerable road users.

5 Project Coordination for Reservations, Scheduling, and Dispatching (RSD) Standards

5.1 Project Goals and Outcomes

Making a reservation to use a specific mobility service consists of trip booking, management of standing orders or subscription trips, and modifying or cancelling a trip. Another term that is often used as a substitute for *reservation* is *booking*, which refers to reserving a specific asset on a certain date and time at a designated location.

Scheduling mobility service trips consists of using multiple criteria or parameters to deliver the service using specific vehicles (with specific drivers if it is a public transit trip) taking specific routes for public transit service. Scheduling must set priority levels on all ADA complementary paratransit trips, which require higher service standards. Scheduling for paratransit or demand-response transit trips includes the generation of daily manifests for each run, indicating pull-in and pull-out times, the projected arrival time of a vehicle at each pickup and drop-off location, and listing the trip events in chronological order. When creating a daily manifest, scheduling must take into account any vehicle assignment restrictions. For example, certain vehicles can provide only a specific type of trip (e.g., buses with wheelchair ramps).

Dispatching is an operational function that can include assigning vehicles to trips/routes, monitoring vehicle location, managing schedule adherence, managing trip manifests and other operational functions. Every transit agency does not dispatch service in the same way.

The gaps in standards for reservations, scheduling, and dispatching exist primarily because the transit software industry is inundated with proprietary systems. Further, funding is significantly lacking to complete the development and demonstration of standards that are in process, such as those described in this section. USDOT has the opportunity to support standards development and deployment in this area through convening the stakeholders to agree to the specific elements needed for full-featured standards in reservations, scheduling and dispatching (RSD), providing funding to complete and demonstrate the use of these standards, and supporting the development and use of open-sourced RSD software.

In organizing a coordination plan to develop standards for RSD, the project goals include the following:

- Establish a forum of organizations working on RSD standards. Proposed organizations may include those listed in Section 5.4
- Recommend actions to develop standards that address gaps for MAT-related applications including coordination activities to enable interoperability among RSD related standards and specifications.
- Recommend guidelines for encoding RSD standards that meet the quality of standards developed by traditional standards development organizations (SDOs)

The project should produce a set of standards and specifications that are interoperable and address gaps as described in Section 5.2.

5.2 Issues and Standards Gaps

The primary reason for gaps in RSD standards and specifications is that this system functionality is provided mostly in proprietary software. While there are several open software products that include this functionality (e.g., RideSheet, Ride Pilot described below) they have been deployed in a very limited number of agencies. Further, standardizing this functionality has not been a priority in the transit industry in general. While many agencies claim that they take reservations, prepare schedules, and facilitate dispatching in unique ways, the basic functionality is the same across transit agencies that provide fixed-route, paratransit and microtransit services. Finally, there are several efforts to standardize these processes, but they are being conducted by non-traditional standards development organizations such as MobilityData and California Integrated Travel Project (Cal-ITP). Funding is critical for these non-traditional SDOs to spearhead development. As of March 2023, several standards development efforts mentioned in this section have been halted because of a lack of funding including the General On-demand Feed Specification (GOFS) and several extensions of the General Transit Feed Specification (GTFS).

In terms of specific standards gaps, there is a lack of standards or specifications that govern the processes associated with reservations, scheduling, and dispatching which are essential to transit operations. For example, while the Cal-ITP Operational Data Specification (ODS) is a start to standardize this functionality, the industry needs to support adopting it. Regarding ODS development, representatives of several North American scheduling and computer-aided dispatch (CAD)/automatic vehicle location (AVL) companies were consulted. These private sector companies realize the current trend of moving away from proprietary formats. In addition, they recognize that if the ODS is included as a requirement in a request for proposals (RFP), they will ensure that their products comply with ODS in the future. Cal-ITP intends to seek funding for projects that test the use of ODS in transit agencies that procure RSD software.

“For agencies who are frustrated with a lack of seamless integration between their scheduling and CAD/AVL systems and want to help speed the roll-out of ODS support along, agencies should definitely be asking [their vendors], ‘When is this rolling out? When is this coming? Is it on your roadmap?’ Having the agencies build that pressure will only help us get the vendors on the path to doing this development work.”[11]

As of the date of this report, Swiftly, a company that assists transit agencies in determining how to operate more efficiently and improve service reliability and passenger information, is reported to be the first consumer of ODS data. They are working with the Water Emergency Transportation Authority (WETA), a San Francisco Bay ferry system, on this effort.

5.3 RSD Standards and Specifications

5.3.1 Operational Data Specification (ODS)

Developer: California Integrated Travel Project (Cal-ITP)

Description: ODS is an open specification for describing scheduled transit operations. It is based on the existing General Transit Feed Specification (GTFS) and extends it to include information about staff (e.g., vehicle operators) and their working schedules, non-revenue service (e.g., deadheading) and other data

such as the locations of bus garages, which is needed to plan and operate transit service. ODS v1.0.0 was adopted by the ODS Working Group on May 3, 2022.

"When planning tools produce both the GTFS and ODS data sets according to the specifications, [computer-aided dispatch/automatic vehicle location] CAD/AVL tools designed to accept those same formats will be able to import the data with minimal error or need for staff to tweak it manually."[12]

5.3.2 Transactional Data Specifications (TDS)

Developer: National Academies of Sciences, Engineering, and Medicine's Transportation Research Board (TRB)

Description: The Transactional Data Specification (TDS) was developed through a Transportation Research Board (TRB) Transit Cooperative Research Program (TCRP) project for demand-responsive transportation (DRT) "to facilitate interactions among the software systems that manage these services. The specification accomplishes two objectives. First, it establishes a common language for software systems to communicate transactional data—all pertinent DRT trip details, such as origin and destination of the traveler and time of the requested pickup or delivery—with each other to accomplish DRT trips from the beginning to the end of the trip lifecycle. Second, it provides a recommended technical approach for how data communication will occur among the interoperating computer systems. Public transportation agencies, DRT service providers, and technology providers can use the products of this report to improve DRT services. Cities, planning agencies, and health-care organizations will benefit from the adoption of transactional data specifications as a means of fostering the cost-effective evolution and growth of DRT services."[13]

5.3.3 General Transit Feed Specification (GTFS)- Flex

Developer: MobilityData maintains this extension of the specification

Description: GTFS-Flex, which is an extension to GTFS, provides specific information about demand-response transportation services including traditional paratransit, deviated fixed routes and on-demand transportation (e.g., microtransit) services so that these services can be discovered in trip planning. As of the date of this report, GTFS-Flex is produced for over 100 transit services and allows discovery of these types of demand-response services when using Google Maps and OpenTripPlanner. The most current version of this extension is GTFS-Flex v2 and it is maintained by MobilityData.

As of March 2023, GTFS-Flex is considered provisional and has not been adopted formally.

5.3.4 GTFS-Eligibilities and GTFS-Capabilities

Developer: MobilityData

Description: Two other applicable GTFS extensions that relate to accessing specific transit services are under development:

- GTFS-Eligibilities describes an individual's characteristics such as age, disability status, residence location, employment and registration in one or more programs (e.g., ADA-eligible); and
- GTFS-Capabilities describe a transportation provider's ability to meet a rider's needs (e.g., whether the provider offers services such as door-to-door service, door-through-door service, stretcher service, mobility device accommodation, and bariatric capability)."

5.3.5 General On-demand Feed Specification (GOFS)[14]

Developer: MobilityData

Description: The General On-demand Feed Specification describes on-demand transportation services and is intended to establish guidelines to manage rider-facing transactional data. While GTFS-Flex allows demand-response services to be discovered, GOFS will allow travelers to actually reserve these services when planning a trip.Initially, four main features are being prioritized: service discoverability, service description, real-time service description, and booking (via deep linking) along with pricing. The existing GTFS extension proposals will be used to develop use cases of GOFS:

- GTFS-Flex v2
- GTFS-FareData
- GTFS-VehicleCategories
- GTFS-RiderCategories
- GTFS-Capabilities
- GTFS-Eligibilities project

As of May 2021, the GOFS working group decided that GTFS-Flex and GOFS will consolidate into a single extension for GTFS. However, as of March 2023, there is no funding for the GOFS project, so the specification development is not moving forward.

5.3.6 GOFS-lite[15]

Developer: Transit App

Description: The General On-Demand Format Specification lite (GOFS-lite) allows on-demand service providers to define their service in a lightweight format that can be consumed by transport applications in an interoperable way.

GOFS-lite is a version of GOFS that has less functionality – it provides limited information about demand-response services.

GOFS-lite supports the following on-demand services:

- Without fixed routes
- Operated from zone to zone
- Available to anyone
- That can be ordered in real time

Examples of supported services include ridehailing (for transportation network companies [TNCs] like Uber or Lyft), microtransit, and paratransit.

Future GOFS-lite extensions may support on-demand services:

- Operated from curb-to-curb, stop-to-stop, or door-to-door
- Providing private and/or shared trips
- Can be booked in advance

GOFS-lite is a work in progress, and there are currently important missing functionalities like pricing, travel time estimations, etc.

5.3.7 General Bikeshare Feed Specification (GBFS)[16]

Developer: MobilityData

Description: The General Bikeshare Feed Specification (GBFS) is an open data specification for shared mobility. GBFS makes real-time data feeds in a uniform format publicly available online (read-only). Information that is personally identifiable is not currently and will not become part of **GBFS**.

GBFS was created in 2014 with collaboration from public, private sector, and nonprofit shared mobility system owners and operators, application developers, and technology vendors. The North American Bikeshare Association's endorsement, support, and hosting led to its success starting in 2015. In 2019, NABSA chose MobilityData to govern and facilitate the improvement of GBFS. MobilityData hosts a GBFS Resource Center[17].

An example of using GBFS data in trip planning in the Commuter Connect trip planner in the Detroit, MI area – the real-time status of the MoGO Bikeshare is identified.

5.3.8 Applications Using Specifications for Open APIs

5.3.8.1 Rural Lake County, OR (TDS and RideSheet)[18]

Lake County, Oregon is in a rural area larger than Massachusetts and does not have taxi, Uber, or Lyft service. The only demand-response transportation is provided by two local nonprofits—Inner Court Family Center (ICFC) and Lake County Senior Center Association. These two agencies have overlapping territories and many of the same clients. In 2020, they became the first two providers anywhere in the United States to commit to a collaboration that relies on the TDS.

RideSheet is a scheduling platform that these two nonprofit organizations use to coordinate their services. RideSheet uses the TDS to format trip data, then exchanges it online using Google Sheets (a free cloud-based spreadsheet) to maximize the number and convenience of the rides that the two agencies can offer. The use of RideSheet allows these agencies to schedule and coordinate rides with the use of emails or phone calls.

5.3.8.2 Applications using GTFS-Flex

The Vermont Agency of Transportation (VTrans), along with several partners, developed the data and software tools that enable rural and demand-response transportation to be discovered in trip planners. Three key technology innovations were developed and implemented within the Go! Vermont trip planner:

- GTFS-Flex data was specified and developed for public transit providers in Vermont. A database containing the descriptions of all possible trips that could be served by Vermont public transit, including flexible services, was developed.
- OpenTripPlanner (OTP) was adapted to search and visualize flexible trip plans based on the aforementioned GTFS-Flex data. This included the discovery of any possible future demand-

responsive trips. Once the trip is discovered, the traveler needs to reserve the requested trip in coordination with the agency(ies) providing the trip.[19]

- After the initial definition of GTFS-Flex, VTrans et al. worked with MobilityData, constituting the GTFS-Flex v2 specification that is now being used in the industry. Further, OTP code enhancements were merged into OTP 1.4.

The Go! Vermont trip planner shows both a GTFS-Flex option with Green Mountain Transit's Dial-A-Ride service, as well as microtransit options with MyRide by GMT (the white-labeled microtransit service in Montpelier, VT).

After this groundbreaking work in VT, MaineDOT's GO MAINE contractor demonstrated the use of GTFS-Flex for Western Maine Transportation Services in Farmington, ME. For a particular route/option on the trip planner in this area, there are more detailed directions and instructions for booking a ride. Another enhancement for this area is that individuals can download and purchase passes in an app if desired.

RidePilot is an open-source web-based transportation scheduling and reporting system for scheduling door-to-door demand-response service. It was designed for small and medium-sized agencies. RidePilot can be integrated with web-based trip planning tools through an API. This seamless integration allows customers to review itinerary options before selecting and requesting a service.[20]

5.3.8.3 Transport Operator Mobility-as-a-service Provider (TOMP) API

The Ministry of Infrastructure and Water Management in the Netherlands developed an Application Programming Interface (API) that provides Transport Operators (TO) to communicate with Mobility as a Service (MaaS) Providers (MP) about trip planning, booking, execution, support, general information, and payments of multimodal trips. "Using the TOMP API enhances the interoperability between parties in the MaaS ecosystem."Since 2020 the TOMP-[working group] WG has become an open source foundation with an international scope."[21]

5.4 Stakeholders – Lead/participating/cooperating organizations

The following stakeholder groups could play a role in addressing standards and specifications gaps in the reservations, scheduling, and dispatching area.

5.4.1 Advocacy groups

The following end-use stakeholder groups would be most helpful in addressing the gaps in reservations, scheduling, and dispatching standards and specifications. Because of each of these organizations' missions, the role of these advocacy groups would be to assist in addressing these gaps that cover an invidual's access to healthcare using transportation services.

- **American Public Health Association:** their mission is to improve the health of the public and achieve equity in health status.
- **Center for Health Progress:** their mission is to build power for the recognition, rights, and resources of health equity.
- **Center for Neighborhood Technology:** they provide analysis and solutions that support community-based organizations and local governments to create neighborhoods that are equitable, sustainable, and resilient.

- **National Aging and Disability Transportation Center:** they promote the availability and accessibility of transportation options that meet the needs of older adults, people with disabilities, and caregivers.

5.4.2 Transportation Organizations and Trade Associations

The following transportation organizations and trade associations would be most helpful in addressing the gaps in RSD standards and specifications. Their roles would be to identify those standards and specifications gaps that impact their constituents in conducting RSD functions, and to help come to consensus on prioritizing the resolution of the gaps.

- **AARP Public Policy Institute:** their focus is on developing creative policy solutions to address the common need for financial security, health care, and quality of life for older Americans.
- **American Association of State Highway and Transportation Officials (AASHTO) Shared Mobility/Mobility on Demand/Mobility as a Service Inter-Committee Working Group:** this WG helps to facilitate the safe, sustainable, efficient, and equitable deployment of Mobility on Demand and MaaS technology and practices.
- **American Public Transportation Association (APTA):** provides advocacy for federal funding and policies, research, technical expertise and consulting services, workforce development programs, educational conferences and seminars, and subject-matter working committees.
- **Association of Commuter Transportation (ACT):** provides advocacy for commuter transportation and transportation demand management (TDM) professionals.
- **Community Transportation Association of America (CTAA):** empowers transportation agencies to provide equitable transportation to all by providing impactful advocacy; expert technical assistance, high-quality training, and responsive communications.
- **National Association of City Transportation Officials (NACTO):** assist in building cities as places for people, with safe, sustainable, accessible, and equitable transportation choices that support a strong economy and vibrant quality of life.
- **North American Bikeshare and Scootershare Association (NABSA):** provides resources, education, and advocacy for the shared micromobility industry, and creates spaces for the industry's public, private, and nonprofit sectors.
- **National Rural Transit Assistance Program (RTAP):** addresses the training and technical assistance needs of rural and tribal transit operators across the nation, and to support the state RTAP programs.
- **Shared-Use Mobility Center (SUMC):** connects the public and private sectors, piloting programs, conducting new research, and providing policy and technical expertise to cities and regions to extend the benefits of shared mobility for all.
- **Transportation Research Board (TRB):** provides leadership in transportation improvements and innovation through trusted, timely, impartial, and evidence-based information exchange, research, and advice regarding all modes of transportation.
- N**ational Alliance of Public Transportation Advocates (NAPTA):** supports increasing investment in public transportation through representing grassroots transit coalitions, grassroots transit rider organizations and advocates.
- **Transportation for America (T4A):** local, regional, and state leaders envisioning a transportation system that safely, affordably and conveniently connects people of all means and ability to jobs, services, and opportunity through multiple modes of travel.

5.4.3 Community, Consortium, Nonprofit, and Trade Associations

The following community-based organizations and trade associations would be most helpful in addressing the gaps in RSD standards and specifications. Their roles would be to identify those standards and specifications gaps that impact their constituents' technology-enabled mobility services, and to help come to consensus on prioritizing the resolution of the gaps.

- **Assistive Technology Industry Association (ATIA):** serves as the collective voice of the assistive technology industry to help ensure that the best products and services are delivered to persons with disabilities.
- **California Integrated Travel Project (Cal-ITP):** is bringing industry standards to California's transit providers to make travel simpler and cost-effective for everyone.
- **ITS America / Mobility on Demand (MOD) Committee:** identifies legislative and regulatory barriers and opportunities to advance Mobility on Demand, monitors national trends and related research, and promote best practices and private and public sector partnerships.
- **Mobility as a Service (MaaS) Alliance:** facilitates a single and open market for MaaS and full deployment of MaaS services through a shared work programme and by engaging transport operators, service providers, public authorities and users.
- **Mobility Data Collaborative (SAE Industry Technologies Consortia):** convenes mobility partners to establish a framework for mobility data sharing and leveraging to promote safe, equitable, and livable streets for all.

5.4.4 Standards Organizations

The following standards organizations would be most helpful in addressing the gaps in RSD standards and specifications. Their roles would be to guide and lead the development of standards and specifications that address these gaps.

- International SDOs:
  - **International Organization for Standardization (ISO) Technical Committee 204 Working Group 8:** develops standards for intelligent transportation systems, Working Group 8 focuses its standards development activities on public transport and emergency services.
  - **European Committee for Standardisation (CEN) Technical Committee 278 Working Group 3:** manages the preparation of standards in the field of Intelligent Transport Systems (ITS) in Europe. WG 3 specifically addresses standards related to public transport.
  - **SAE International**: advances mobility knowledge and solutions for the benefit of humanity and provides voluntary consensus standards development.

- National SDOs:
  - **Institute of Transportation Engineers (ITE):** works to improve mobility and safety for all transportation system users and help build smart and livable communities.
  - **National Electrical Manufacturers Association (NEMA):** convenes a neutral forum to discuss industry-wide concerns and objectives under a legal umbrella.
  - **Rehabilitation Engineering and Assistive Technology Society of North America (RESNA):** promotes the health and well-being of people with disabilities through increasing access technology solutions.

- Consensus-based SDOs:
  - **MobilityData:** nonprofit that facilitates development and stakeholder engagement on several mobility data standards
  - **Open Mobility Foundation:** creates a governance structure around open-source mobility tools

5.4.5 USDOT Programs

The following USDOT offices would be most helpful in addressing the gaps in RSD standards and specifications by providing guidance and funding to develop standards and specifications that address these gaps.

- Federal Transit Administration (FTA):
  - Office of Research, Demonstration, and Innovation
  - Office of Transit Safety and Oversight
  - Office of Planning and Environment
- USDOT ITS Joint Program Office
- Federal Highway Administration (FHWA):
  - Office of Operations
  - Office of Safety
  - Office of Planning, Environment and Realty

5.4.6 Commercial Product Developers/Vendors

The following RSD software vendors would be most helpful in addressing the gaps in RSD standards and specifications by participating in forums to address these gaps and ensuring that their products comply with the standards and specifications.

- AlphaRoute
- Cambridge Systematics (software is Ride Pilot)
- Clever Devices (scheduling software is MAIOR)
- CTS Software (Tripmaster)
- DDS Wireless (Stratagen software)
- DemandTrans
- Downtowner
- Ecolane
- Enghouse
- Engraph Software (ParaPlan software)
- Full Path (RideSheet software)
- GIRO
- Innovations in Transportation (INIT)
- IT Curves
- Kevadiya
- Kinetik
- Liftango
- MediTrans
- MJM (EzTransport®)
- Mobility Route
- Moovit
- MTM
- NEMT Cloud Dispatch
- NEMT Platform
- NEMT Pulse
- Passio Technologies
- QRyde (by HBSS)
- RideCo
- Route Genie
- Routing Box
- SAFR Care
- Schedule Viewer
- Shah Software
- Spare Labs
- Spedsta
- Syncromatics
- TaxiMobility
- The Routing Company

- TransitExec
- Transloc
- Trapeze / TripSpark
- TSS Paratransit
- Urban Mobility
- Via

6 Role of Cybersecurity and Privacy Standards with MAT

6.1 Review of Best Practices, Standards, and Frameworks from the Task 2 White Paper

Completed in September 2022 under Task 2 for this project, a white paper was created with an objective to research and document critical risks for privacy and security of individual transportation system users, particularly VRUs in connected/automated vehicle environments and integrated mobility systems. It built upon the previous MAT Standards efforts, and in conjunction with this project's Use Cases obtained from the ITS4US and other relevant projects, an evaluation of where cybersecurity and privacy risks exist was determined while evaluating the convergence of ITS technologies with multimodal and accessible transportation for VRUs.

After conducting a review of more than twenty cybersecurity and privacy standards along with six ITS4US projects, the Task 2 white paper revealed gaps in cybersecurity and/or privacy in the following areas:

- Wayfinding/navigation
- Eligibility processes
- Payment processing / mobility payment integration
- Reservation systems
- Data storage
- Data backup and recovery

As an example of some of the differences in the application of cybersecurity in the ITS4US projects' data plans, all but three had different methods for backing-up and recovery plans for information stored. Two projects specifically classified data as containing "PII" or as having a "cybersecurity concern" and whether encryption was required for that data, and one project identified and declared that cybersecurity and privacy protection will be managed by 3rd parties. One aspect that had not been identified in the projects included a resource or role description for collection of vulnerabilities and/or disclosure of exploits. There also was not much mention about malware defenses and general vulnerability management, incident response, or penetration testing, but those might have been referenced in later phases of the NYC/THEA CV Pilot.

Similarly, a threat that has become more prevalent since these projects' data management plans were created is ransomware. This is a topic that reveals a gap in the current projects and should be added as the projects progress towards later phases. After reviewing these projects in conjunction with industry standards and Use Cases, some "best practices" were created.

Following the "best practices" and industry standards recommended in the Task 2 white paper (some of which are reiterated herein), would be a place to start integrating the programs and filling in the cybersecurity and privacy standards gaps. Until a cybersecurity framework specific to the transportation sector or standards for VRUs exist, following general cybersecurity and privacy industry standards is recommended. White papers associated with this project also detailed some of the concerns about sharing both threat intelligence data and data generated by micro mobility companies.

As is referenced in a later section of this Coordination Plan and in the Task 6 Cybersecurity and Privacy white paper, efforts should be made to coordinate with the private sector and "community based" organizations to share data; those coordination efforts will be easier if VRU projects can show that they are implementing cybersecurity and privacy best practices and industry standards. This recommendation results from interviews conducted; more useful data might be shared with the VRU projects if cybersecurity and privacy standards were implemented uniformly and transparently.

A logical place to start is by applying the CIS (Center for Internet Security) Controls Model (current version 8) and the NIST Cybersecurity and Privacy Frameworks. The following list includes recommendations from CIS and NIST (National Institute for Standards and Technology) for addressing the privacy and security gaps, including existing standards, guidance, and best practices:

- Inventory and control of assets
- Data destruction plans
- Security for payment processing/mobility payment integration
    - Payment Card Industry Data Security Standard (PCI-DSS)
    - Blockchain technology for pseudonymity to authorize payments.
        - Pivot App
- Disaster response plans and event recovery
    - NIST Special Publication 800-184 "Guide for Cybersecurity Event Recovery"
- Encryption standards defined for data at rest and data in transit.
- Signals (DSRC, cellular, Bluetooth, etc.) security and privacy policies and standards
- Detail and standardized protection of metadata
    - ASTM 2468-05
- Log management
- Access Management
- Security and privacy awareness and training
- Testing of security systems, such as vulnerability scanning and penetration testing
    - MITRE ATT&CK or Microsoft STRIDE
- Security design frameworks
    - MITRE ATT&CK or Microsoft STRIDE
- Engineering of secure and cyber resilient systems
    - NIST SP800-160 vol 1 & 2
- Security for communications between the user's app and traffic field systems
    - National Electrical Manufacturers Association (NEMA) Standards Publication TS 8-2018
- Security for how management station interfaces with a field device to control and monitor traffic signal controllers and are relevant to Personal Safety Messages (PSM)
    - NTCIP 1202 v03
- Privacy protection of Personal Identifiable Information (PII)
    - NIST Cybersecurity Privacy Framework
    - NIST SP800-122 and SP800-53 controls for Sensitive PII
    - NIST SP800- 122, Section 4.2.4 for Anonymization Methods
- Security and Privacy for health care information

- Health Insurance Portability and Accountability Act (HIPAA)

6.2 Research Material

NEMA Standards Publication TS 8-2018 Cyber and Physical Security for Intelligent Transportation Systems (ITS)

These standards address distinct aspects of security including those associated with field systems, communications, and central systems. The projects included apps such as PedX that interact with traffic management field systems.

NIST SP800-160 vol 1, Rev. 1 (draft), "Engineering Trustworthy Secure Systems"

This NIST guidance attempts to "infuse systems security" into the existing systems engineering processes, making Systems Security Engineering (SSE) as a sub-discipline of Systems Engineering (SE). Considering that most of these projects are at Phase One of their development plans, this could be incorporated into future system designs.

The following points are applicable:

- The systems security engineering tasks to be undertaken, as outlined in Section 2.1.
- System security is a holistic property; all system elements must meet security requirements.
- A system needs only to be "as secure as reasonably practicable" (ASARP). Stakeholder asset-protection needs, and security objectives are the starting point.
- Part of security is the concept of intent, which has two parts that must be satisfied: design intent and user intent. Security achieves only the authorized and intended system behaviors and outcomes.
- Assets and their protection needs must be identified. Protection needs come from stakeholder perspective, system perspective and engineering perspective. The consequences and type of asset loss must be evaluated.
- Asset protection needs are satisfied via security requirements and security policies.
- Protective measures may include any aspects of the system: machine part, human portion, and physical environment.
- Trustworthiness (demonstrating security) is achieved via the building of "assurance cases" for acceptable security and showing that that case is satisfied.

NIST SP800-160 vol 2 Rev.1 (draft) "Developing Cyber Resilient Systems: A Systems Security Engineering Approach

The NIST guidance focuses on cyber resiliency engineering which is a specialty systems engineering discipline to be applied in conjunction with resilience engineering and systems security engineering to develop more survivable, trustworthy systems.

- The cyber resiliency design model (Section 4.2.2) incorporates a similar resilience framework as is referenced in Volume 1 and utilizes risk management techniques by incorporating a multitude of

facets including assets, threats, vulnerability, and controls which are to be jointly evaluated with the variables of probability and impact. These take into account the cyber resiliency design model.

- MITRE ATT&CK™ Threat Framework (Section 4.2.2) incorporates a similar resiliency framework as is referenced in Volume 2 and utilizes risk management techniques by incorporating a multitude of facets including assets, threats, vulnerabilities, and controls which are to be jointly evaluated with the variables of probability and impact.

CTI 4501 v01.01 Connected Intersection Implementation Guide

This project leveraged the experience of Connected Vehicles (CV) technology deployments and produced a Connected Intersections (CI) Implementation Guide that addresses the gaps, ambiguities, and incongruous practices discovered. This document provides guidance to help achieve consistent infrastructure-vehicle interoperability across the United States.

Ransomware Risk Management: A Cybersecurity Framework Profile

This Ransomware Profile identifies the Cybersecurity Framework Version 1.1 security objectives that support identification of, protection against, detection of, response to, and recovery from ransomware events. The profile can be used as a guide to manage the risk of ransomware events. That includes helping to gauge an organization's level of readiness to counter ransomware threats and to deal with the potential consequences of these events.

NIST Special Publication 800-184: Guide for Cybersecurity Event Recovery

This publication provides tactical and strategic guidance regarding the planning, playbook development, testing, and improvement of recovery planning. It also provides an example scenario that demonstrates guidance and informative metrics that may be helpful for improving resilience of information systems.

6.3 Cybersecurity, Communication, and Mobility Standards and Specifications

The following list of standards, specifications, and guides are referenced in the included ITS4US projects. They range from communication standards to NIST guidelines for "respond and recover" procedures.

6.3.1 NIST Publications

- NIST Special Publication 800-184 "Guide for Cybersecurity Event Recovery" https://www.iso.org/standard/44404.html
- NIST's publication 800-53, "Security and Privacy Controls for Information Systems and Organizations," https://csrc.nist.gov/publications/detail/sp/800-53/rev-5/final : This is a key reference for security controls. The document is divided into topics for security and privacy. An organization can select those which best fit its service or product. There are 20 families in the document. The following Security and Privacy Control Families are a minimum recommendation of what to include. They are the following:

    - IA: Identification and Authentication
    - IR: Incident Response

- PT: PII Processing and Transparency
- SC: Systems and Communication Protection
- AU: Audit and Accountability
- AC: Access Control
- AT: Awareness and Training

6.3.2 SAE Standards

SAE J2735: J2735SET_202007 -- https://www.sae.org/standards/content/j27 35set_202007/ open XML

This standard includes definition of relevant messages: PSM (including path prediction, heading, and animal type), SPaT, MAP, and SSM

SAE J2945 parts 1 and 9: SAE J2945_201712 -- https://www.sae.org/standards/content/j29 45_201712/ open XML

6.3.3 IEEE Standards

- IEEE 1609.2 IEEE Trial-Use Standard for Wireless Access in Vehicular Environments—Security Services for Applications and Management Messages: DSRC communications standard

6.3.4 NTCIP Standard

- NTCIP 1202: Object Definitions for Actuated Traffic Signal Controller (ASC) – Version 03; identifies and defines how a management station may wish to interface with a field device to control and monitor traffic signal controllers and are relevant to Personal Safety Messages (PSM).

6.3.5 Internet Standard

- SNMPv3 data performed over TLS 1.2 (over wireless IP connection or fiber)

6.3.6 ISO Standard

- ISO/DTR 24317: Mobility Integration Needs for Vulnerable Users and Light Transportation

6.4 Privacy Standards and Policies

This section references prominent privacy standards, project-specific privacy policies, and the relatively new "NIST Privacy Framework." Some of these were referenced in the projects herein and others are recommended for guidance with future phases of the project.

1.1.1 NIST Specifications and Documentation

- NIST SP800-122 and SP800-53 controls for Sensitive PII
- NIST SP800- 122, Section 4.2.4 for Anonymization Methods
- NIST Privacy Framework, v. 1.0: https://www.nist.gov/privacy-framework

6.4.1 ASTM Standard

- ASTM 2468-05 (https://www.astm.org/Standards/E2468.htm) standard format for metadata and data documentation

6.4.2 Misc.

- NYC Citywide Encryption Policy (http://www1.nyc.gov/assets/doitt/downloads/pdf/encryption.pdf)
- The Privacy Act of 1974 5 U.S.C. § 552a (2012) for definition of PII: https://www.justice.gov/archives/opcl/page/file/844481/download
- HIPAA: https://www.hhs.gov/hipaa/index.html

6.5 Other Standards and Projects Referenced

The following standards, publications, and project references were collected from the projects reviewed and are provided for completeness. These were referenced to a lesser degree in the projects, but important to mention.

- National Transportation Communications for ITS Protocol Object Definitions for Signal Control and Prioritization (SCP). NTCIP 1211 version v02. Microsoft Word - NTCIP 1211v024 e02 20140929 to Publication JPO
- Reference for SharedStreets Project: https://www.sharedstreets.io/taxi-tnc-activity/
- PCI-DSS (ver. 8): https://www.pcisecuritystandards.org/

7 Engaging Community-Based Specification Development Organizations

Many popular MAT standards are being developed by community-based or grass-root organizations like MobilityData, Open Mobility Foundation, Shared Streets, and more. In some cases, these community-based development organizations (CBDO) collaborate informally with SDOs. Similar to SDOs, these organizations rely on donations and membership fees to develop and test specifications and develop implementation methods and tools to deploy the specifications. However, due to the smaller marketplace and predominance of public agencies involved, the donations and fees are limited.

Moreover, much of the success for generating ITS standards is driven by USDOT contracts to SDOs. This is still true today. In contrast, the CBDOs have not participated in these activities, rather, much of their success has been achieved either through a state government or corporate sponsorship of their development and deployment activities. As noted in the sections on standards for PROW (Section) and RSD (Section), most of the specifications have been developed by vendors such as Google (for example, General Transit Feed Specification), or ad hoc groups such as OMF and MobilityData (e.g., GTFS family of standards).

In some cases, MAT-related specifications have been tested through limited funded pilots and short-term projects such as a MOD Sandbox grant such as GTFS-flex through the GO Vermont project. If one of these projects deployed a specification, the lessons learned may not have been recycled to improve the specification. Although there are several programs developed by USDOT to speed up the development and adoption of ITS standards as well as to ensure consistency across the standards, these programs are not the norm. For example, the WZDx specification development had major support from the USDOT with USDOT mini-grants available for public agency deployment.

Models to accelerate MAT standards development and adoption that may be supported by the USDOT include the following:

SDO Annual Business Plan. Establish a mechanism for SDOs to engage CBDOs to develop MAT standards. The business plan would include a comprehensive approach to Federal programming including work related to policy, technical and program innovation, as well as collaborative standards/specification development. Potential collaborative environments may be modeled on the *Work Zone Data Exchange* with the CBDO leading the effort. Another model is to develop working groups in the *Smart Intersection Project* that deals specifically with VRU traffic and pathways. Both models would require support for ITS standard extensions, MAT specification conformance testing and developing OSS tools to generate and consume the implemented specification.

MAT Grant/Award Program. Develop a USDOT Grant/Award for multiple recipients to participate in a pilot project to deploy the same CBDO-developed specification. The award may include a pre-award to enhance a specification that is limited in scope (like GOFS-lite or Transaction Data Specification see Sections 5.3.5 and 5.3.2, respectively) or is missing the system engineering framework. The pilot approach is used widely by the European Committee for Standardization (CEN). The CV Pilots morphed into this model when it was determined that the pilot sites were

applying CV standards inconsistently. This model would utilize the CBDOs to oversee the deployment, support developing conformance specifications and tools, as well as incorporate lessons learned back into the specification. The benefit of having multiple grants working on the same specification is that potentially several vendors are involved, and multiple environments deployed.

8 Next Steps for Coordination

Moving forward, this Coordination Plan recommends the following:

- Organize a Multimodal Accessible Travel Steering Committee to establish a charter including the following:
    - Organization Structure
    - Committee Roles and Responsibility
- Establish a business plan to develop standards and specifications for VRU, PROW, and RSD, and cross cutting recommendations for cybersecurity and privacy.

The goal of the Steering Committee is to speed the development and adoption of MAT standards. Yet, USDOT is the driver of whether the Steering Committee serves as a promoter, coordinator of existing standards, or active sponsor of standard development activities. Regardless, recommendations for establishing the MAT Coordination Committee are described below.

8.1 Committee Organization

It is recommended that a Multimodal Accessible Travel Steering Committee be created. The following are a set of suggestions for the organization of the Steering Committee.

The Steering Committee shall consist of at least nine members but no more than 18 voting members.

The Steering Committee should include voting members with experience relevant to MAT, either with specification development or specification and standard application with a MAT deployment. At a minimum, this would include the following:

- Public agency stakeholders (state and local transportation agencies, including transit agencies)
- Device industry representatives and suppliers
- Private service providers of MAT
- Traveler information providers
- Representatives of MAT users (e.g., advocacy groups)
- Relevant participants from SDOs and/or CBDOs

The Steering Committee should have approximately an equal mix of public agency members and private sector representatives, with USDOT invited to provide a liaison representative.

The Steering Committee should have two co-chairs, one from the public sector and one from the private sector. Two co-chairs are suggested in the event one co-chair is unavailable. The co-chairs may be appointed or elected by the Steering Committee. The co-chair's responsibilities include presiding over the Steering Committee activities (such as calling and leading Steering Committee meetings, calling for votes) and guiding the Steering Committee in the development of a work plan and budget requests as appropriate.

Working Groups

The Steering Committee may form working groups to address specific areas or issues of interest. The Steering Committee shall appoint a chairperson for the working group. Each Working Group may consist

of up to 20 voting members. At least two of each Working Group members will also be members of the MAT Steering Committee. Potential working groups may include:

- Cybersecurity and privacy
- VRU
- PROW
- RSD

Meetings

The Steering Committee shall meet periodically. The Steering Committee co-chairs will work with the designated Working Group leads to determine each Working Group meeting schedule, but at least four times per year (once per quarter). In addition, the charter may add additional rules for meeting including the following:

- The co-chairs may schedule meetings and shall lead the meetings.
- All meetings are open to the public.
- A quorum of voting members must be present to vote on any matter.

8.2 Committee Roles / Responsibilities

The roles and responsibilities are where the purpose of the Steering Committee is described as a promoter of standard priorities, coordinator of standard activities, or standard developer.

At a minimum, the purpose of the Steering Committee should be to advise and recommend to USDOT in the area of developing standards and standards coordination for the MAT area. It may also provide advice and recommendations on where MAT standards are needed, what organizations should be involved with the development of a MAT standard, what organization should develop the MAT standard, areas where public sector involvement is needed, and areas where policies or guidance for deployment of standards are needed. As a result, the USDOT may provide resources to the Steering Committee to contract with SDOs/CBDOs for the actual development of standards, tools, training, best practice guidance and/or outreach.

The Steering Committee will need to define the roles and responsibilities of the voting members and likewise for each Working Group to be further refined by the members of that Working Group.

At the first meeting the Steering Committee should describe the following:

- Steering Committee scope
- Governance including:
    - Bylaws to set the voting rules, quorum requirements, alternate representation, and formation of working groups;
    - Definitions, such as standards categories (information reports, recommended reports, standards, etc.) and content;
    - A meeting cadence, and
    - A communications plan
- Role of SE in Coordination
- Role of Cybersecurity / Privacy across the Committee

- High level focus and parameters of each Working Group

9 Recommendations for MAT Standard Priorities

Previous chapters identified gaps in target areas for MAT standards, applications and stakeholders with interests addressing the gaps, and an organizational framework for developing the standards. This section describes a tactical plan for prioritizing the development activities for the four project coordination areas.

9.1 VRU Standard Priorities and Recommendations

As described in Section 3 on Project Coordination for Vulnerable Road Users using V2X, the key coordination goal is to coordinate the standards development effort around the VRUs in the V2X environment in order to address the key gaps identified.

The first key gap priority for VRU is to harmonize the definition of VRU, which addresses the classification and taxonomy of just what constitutes a VRU. Different definitions include or exclude various types of accessible conveyances in the definition of VRU. The proper venue to harmonize these definitions is ISO TC 204 Working Group 19 on Mobility Integration, so the recommended VRU project coordination effort should include coordination with this WG on a definition and classification of VRUs that will serve the full range of USDOT efforts.

The next gap area is VRU Incident data reporting. There is currently no standard that defines the specific data requirements relating to a VRU incident, which has distinct differences from the vehicle on roadway incidents defined by TMDD. Since there is no current standardization activity, the first step in addressing this gap would be to identify likely venues for this development. Could it be included in some of the wayfinding specifications, or other similar efforts?

A third priority gap would be to address confidence measures relating to personal safety messages for VRUs. The standard for the PSM for VRUs needs to be extended to include elements that describe confidence levels for items such as object detection, classification and existence. The key to addressing this gap is to work with existing SAE efforts to standardize V2X.

The final gap area relates to the standardization of VRU on-board unit communications. The development of these devices has sufficiently progressed that the data interfaces to them could be standardized. To develop these standards would require engagement with both the developers of the OBU devices (e.g., Spoke Safety and Autotalks) and the SAE efforts to standardize V2X.

9.2 RSD Standard Priorities and Recommendations

The primary reason for gaps in standards and specifications associated with transit reservations, scheduling, and dispatching is that this system functionality is provided mostly in proprietary software. While there are several open software products that include this functionality (e.g., RideSheet, Ride Pilot) they have been deployed in a very limited number of agencies. Further, standardizing this functionality has not been a priority in the transit industry in general. Many agencies claim that they take reservations, prepare schedules, and facilitate dispatching in unique ways; the basic functionality is the same across transit agencies that provide fixed-route, paratransit, and microtransit services. Finally,

there are several efforts to standardize these processes, but they are being conducted by non-traditional standards development organizations such as MobilityData and Cal-ITP.

There are four priorities associated with addressing the gaps: the availability of RSD standards and specifications will (1) result in more affordable RSD systems in the transit industry; (2) reduce the amount of risk associated with deploying RSD systems; (3) facilitate data sharing and integration; and (4) improve data quality. USDOT's role in addressing the gaps will be critical as it can provide funding, direction and training for developing the standards, and procuring and implementing systems using the standards. Funding of non-traditional SDOs to spearhead development and of agencies to demonstrate the use of standards should be considered.

First, making RSD systems more affordable will address an upcoming funding challenge across the transit industry: COVID funding expiring in FY 2024. Further, using standards to procure RSD systems will keep the cost of these systems down since less customization will be necessary.

Second, even though RSD systems have been in existence since the 1980s, the implementation of these systems has had risk associated with them primarily because of the software products being proprietary. This can result in an agency having to work with a particular software vendor over a longer period of time than is reasonable. Further, the existence of standards will make it easier for the transit industry as a whole to learn about them if USDOT provides training on the standards as they have with other transit technology standards through the ITS Professional Capacity Building (PCB) program. Having this training will reduce the risk during implementation and operation of RSD systems.

Third, data sharing among transit agencies that are coordinating service can be challenging because of the lack of standards. For example, the Transactional Data Specification (TDS) is one of the only existing RSD specifications to facilitate service coordination but to date, it has very limited deployment. Further, sharing data among agencies that are coordinating services often requires the development of one-off and proprietary interfaces that are much more costly than using standards/specifications.

Finally, the use of RSD standards will improve data quality which is critical to data sharing and reporting as well as operations. It is well known in the transit industry that the quality of reported data and information is one of the most challenging facets of using RSD software. Further, data quality is critical when RSD data is being migrated from one RSD system to another. Finally, improving the data quality will result in reducing the number of resources necessary to correct erroneous data.

9.3 PROW Standard Priorities and Recommendations

As described in Section 4 on PROW standard gaps and project coordination, the PROW project coordination goals would include:

- Establish a forum of organizations working on PROW standards
- Recommend actions to develop standards that address gaps for MAT-related applications, including coordination activities to enable interoperability among PROW-related standards and specifications
- Recommend guidelines for data feature quality conformance for profiles for specific downstream applications

- Recommend guidelines for encoding PROW standards that meet the quality and implementation of PROW standards

The major gaps in PROW standards are the lack of uniformity and consistency in describing inaccessible infrastructure. Critical missing pieces are the attribute or semantic ontology to ensure that PROW feature attributes and performance descriptions (conditions and measures) are consistent across multiple network models. There are existing network models in which the attributes may be associated, however, only one specification, the OpenSidewalks has drilled into the semantics to describe the PROW features. Furthermore, none of the specifications have described feature conditions and tests to measure infrastructure quality for different mobility modes.

The recommended starting point for the PROW project coordination is to engage the OpenSidewalks specification community to open their feature set as an ontology that can be reused by multiple standards development organizations and begin describing conformance testing to measure PROW quality for various mobility modes and personas.

9.4 Cybersecurity and Privacy Priorities and Recommendations

There are many cybersecurity and privacy standards, requirements, and best practices that were referenced throughout this project. For example, a few of those are the following: NIST Cybersecurity Framework, NIST Privacy Framework, CIS Controls, NIST SP800-53, and NIST SP800-84, SAE, and IEEE. A combination of these standards can fill any existing MAT/VRU "gaps." However, these are not uniformly applied to MAT/VRU projects.

In turn, there is a recommendation to select existing standards, requirements, and best practices for MAT/VRU related projects and any new technologies or applications with which VRUs interact. A selection of already existing cybersecurity and privacy standards, recommendations, and best practices can fill the gaps, but which ones to apply is currently a subjective decision with little correlation between the projects reviewed in this report; they all have cybersecurity and privacy referenced, but the references are different for technical projects that have similar objectives and operations.

As described in the cybersecurity white papers, the cybersecurity and privacy protection goals would include:

- Establish an advisory board composed of members from community-based projects, the private sector, and government where USDOT-funded MAT/VRU project leaders can interact and openly share technical details about cybersecurity and privacy standards, requirements, and best practices. An example of this might be discussions about incorporating blockchain into scheduling and ride-hailing apps or new technologies to sense pedestrians utilized by micro mobility devices and connected vehicles.
- Recommend or standardize the requirements for cybersecurity and privacy to which MAT/VRU projects must meet or exceed.
- Establish a forum where community-driven open-source project developers can find a list of applicable standards, requirements, or best practices to apply to their project as a requirement for them to interact with government-based transportation infrastructure (for example, pedestrian crossing apps).

Appendix A: Acronyms

Acronym	Description
ACT	Association of Commuter Transportation
ADA	Americans with Disabilities Act
API	Application Programming Interface
APTA	American Public Transportation Association
ATIA	Assistive Technology Industry Association
CAD	Computer-aided Dispatch
Cal-ITP	California Integrated Travel Project
CBDO	Community-based Development Organization
CEN	European Committee for Standardization
CV	Connected Vehicle
DRT	Demand-responsive transportation
ETSI	European Telecommunications Standards Institute
FGDC	Federal Geographic Data Committee
GBFS	General Bikeshare Feed Specification
GML	Geographic Markup Language
GOFS	General on-demand Feed Specification
GTFS	General Transit Feed Specification
HTTP	Hypertext Transfer Protocol
IEEE	Institute of Electrical and Electronics Engineers
ISO	International Organization for Standardization
MaaS	Mobility as a Service
MAT	Multimodal and Accessible Travel
MMV	Micromobility vehicle
MOD	Mobility on Demand
OBU	On-board Unit
ODS	Operational Data Specification
OGC	Open Geospatial Consortium
OMF	Open Mobility Foundation
OSS	Open-source software
OTP	OpenTripPlanner
PROW	Public Right-of-Way
PSM	Personal safety message
RSD	Reservations, Scheduling, and Dispatching
SAE	Society of Automation Engineers
SDO	Standards Development Organization
TDS	Transactional Data Specifications
TOMP	Transport Operators to or from MaaS Providers

TRB	Transportation Research Board
USDOT	United States Department of Transportation
V2X	Vehicle-to-Everything
VRU	Vulnerable road user
VTrans	Vermont Agency of Transportation
W3C	World Wide Web Consortium
WIP	Work-in-progress
WZDx	Work Zone Data Exchange

Appendix B: MAT Deliverables

This paper is based on the results of the **Multimodal and Accessible Travel (MAT) Standards and Vulnerable Road User (VRU) Cybersecurity Support Project**. The project resulted in an assessment of the gaps in standards for MAT systems and VRU technologies. Following the gap analysis, the project team extended existing use cases or developed scenarios that covered the scope of existing projects. These two papers -- *Task 3.1 Multimodal and Accessible Travel Use Case Review* and *Task 3.2 Multimodal and Accessible Travel Use Cases*, are discussed below.

The gap analysis, *Task 3.1 Multimodal and Accessible Travel Use Case Review*, identified several areas where gaps were a priority or where standards were missing. A gap was deemed a priority when many deployments were underway and the current standards only covered a partial area (e.g., customer facing vs. backoffice) or there were competing standards that were not compatible. Several VRU topics fell into the priority areas as did the PROW, and RSD. A gap was identified as missing when there were no open standards that covered the domain. The eligibility verification topic fell into this category.

MAT use cases further the understanding of the needs and behaviors in deploying a system. The four topics identified in the gap analysis were expanded to define ten use cases and multiple scenarios for review during a standards development activity. The Team reviewed existing, emerging and project concept use cases to develop the set that were included in the document. The result included an assessment about whether the use case was ready for standardization activities. Since there were limited experience in projects that covered automated eligibility and significant interagency coordination that is required to verify eligibility, the topic, though critical to lowering the barrier for underserved populations, was deemed not yet mature enough to warrant standardization.

Finally, a series of five white papers were developed to drill into the standards and applications of each of the gap areas. A set of four white papers were developed to describe the existing and emerging standards, the gaps in the standards (from a deployment viewpoint), and the stakeholders that are interested in the development or outcome of the standard. The four areas corresponded to the four gap topics including:

- VRUs using V2X, that is the active involvement of VRUs in the CV environment
- PROW models including networks, attributes, and intersection of PROW with road networks
- RSD standards particularly reservation transactions and their connections to scheduling and dispatch transactions
- Eligibility determination for mobility services and payment provisions

In addition, Task 2 included the development of a white paper that addressed gaps in standards and guidance on cybersecurity and privacy as it pertains to VRU and MAT deployments. The paper *Task 2 Multimodal and Accessible Travel Standards and Vulnerable Road User Cybersecurity and Privacy Report* covers existing standards, policies and guidelines used to address cybersecurity and privacy.

Summaries of the first three topics – VRU, PROW and RSD are included in this coordination plan for working groups to consider for addressing gaps. In addition, a summary of the cybersecurity and privacy white paper is included as a cross-cutting working group focus.

Again, because not enough is known about the needs and upstream systems that need to support eligibility verification, that topic is not included as a development project for the coordination activities.

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