

# Outreach Report

## Multimodal and Accessible Travel Standards Assessment

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<b>16. Abstract</b> This report summarizes the outreach and feedback on and industry priorities in standards to address multimodal and accessible travel. The report summarizes the feedback solicited from a variety of stakeholder meetings, interviews, and stakeholder outreach questionnaire. The effort focused on six key areas where gaps exist. These areas include four that support the USDOT's concept of "Complete Trip", and two that support design and operational principles around the concept of "Complete Streets". Complete trip and street areas include: <ul style="list-style-type: none"> <li>• Mobility Platform Application Programming Interfaces (API),</li> <li>• Wayfinding and Navigation (WaN) related to field and presentation needs,</li> <li>• Safety related to vulnerable road users (VRU) in a Connected to Everything (C2X) environment</li> <li>• Integrated Payment</li> <li>• Curb Access and Management</li> <li>• Public Right of Way (PROW) and Indoor Navigation Data</li> </ul> The report details seven sections that consolidates the outreach results for each of the six focus areas including a focus area summary, outreach efforts, needs, related standards, gaps, industry priorities and recommendations for filling gaps.			
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# Table of Contents

<b>Chapter 1. Introduction .....</b>	<b>1</b>
Scope .....	1
Background.....	1
References .....	2
Organization of this Document.....	2
Notation.....	3
<b>Chapter 2. Outreach Approach .....</b>	<b>5</b>
Summary of Outreach Plan .....	5
Outreach Methodology .....	6
Interviews.....	6
White Papers .....	7
Presentations.....	7
Questionnaire .....	7
<b>Chapter 3. Outreach Results .....</b>	<b>10</b>
Complete Trips .....	10
Mobility Platform APIs.....	10
Wayfinding and Navigation.....	17
Safety 23	
Payment Integration.....	32
Complete Streets.....	40
Curb Access and Management .....	40
PROW and Indoor Navigation Data Representation.....	48
<b>Chapter 4. Next Steps .....</b>	<b>55</b>
<b>Chapter 5. Appendices.....</b>	<b>57</b>
Appendix A. Acronyms .....	57
Appendix B. List of Stakeholders .....	61
Appendix C. Questionnaire Results .....	63
Appendix D. White Papers .....	64
Mobility Platform API Comparison.....	64
Uniform Transit Signage.....	64
Integrated Payment.....	64

## List of Tables

Table 1: Respondents to Questionnaire with Moderate to Expert Level of Knowledge .....	8
Table 2. Areas with Gaps in Current Standard Efforts .....	16
Table 3. Issues and Considerations for Uniform Transit Signage Development.....	19
Table 4: SAE and ISO Committees Interviewed on Safety Related Standards .....	25
Table 5: Payment Functions Through Trip Lifecycle .....	33
Table 6. List of Acronyms .....	57

## List of Figures

Figure 1: General Processes related to Detection and Communications of VRUs (source: ISO WD 24317) .....	24
Figure 2. Uber App integrated with Denver Regional Transit District (source: RTD).....	32
Figure 3: TS4448 Builds on Existing Data and Operating Standards (Source: Harmonize Mobility) .....	45

# Chapter 1. Introduction

## Scope

The purpose of this Outreach Report is to summarize stakeholder engagement and outreach conducted to gather input from end-user stakeholders such as advocacy groups, associations, governments, vendors, and standard organizations to provide insight, identify gaps, and provide feedback on priorities for standards development activities that will be incorporated into the Multimodal and Accessible Travel (MAT) Standards Roadmap (Task 5). The effort was guided by an Outreach Plan (OP) that identified six core outreach areas and activities to engage stakeholders. As initially planned, activities included interviews, conference and meeting presentations, MAT standards workshop, and white papers. Due to the onset of COVID-19, all travel, conference, and face to face activities were replaced with a stakeholder feedback questionnaire.

## Background

As Mobility on Demand (MOD) is increasingly implemented by transit agencies across the country, the development and use of standards will greatly benefit future system deployments in terms of data sharing, mobility product and service development, and privacy requirements. Development of these standards should be based on the needs of all travelers, including persons with disabilities, the older adult population, and US veterans. In particular, travel must facilitate the “complete trip”, through which a traveler “can get from point A to point B seamlessly, regardless of the number of modes, transfers, and connections<sup>1</sup>” and the corresponding information and infrastructure must be accessible for all travelers using uniform design principles. Standardization is essential to facilitate interoperability among systems and advance adoption of new technologies. Thus, ensuring high-quality, interoperable, relevant, and lower cost connected mobility services for everyone. The United States Department of Transportation’s (USDOT) Accessible Transportation Technologies Research Initiative (ATTRI), which is integrally tied to MOD, focuses on the various types of travelers including vulnerable road users (VRU), people in wheelchairs, people using micromobility vehicles, and other underserved groups.

In recent years, a spectrum of multimodal, mobility services, and accessible transportation technologies have been introduced to travelers. However, actual standards to support these technologies remain limited. Furthermore, these standardization activities are often taking place in silos, both in terms of geography and industry. To achieve the USDOT’s vision for accessible, equitable, seamless, and

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<sup>1</sup> USDOT definition of “Complete Trip”, <https://cms8.dot.gov/accessibility>

complete trips for all travelers, there is a need for collaboration and harmonization in standardization across industries representing various facets of the travel chain, whether they are segments of the trip, or integration of trip segments (i.e., trip planning and payment integration).

This harmonization process depends on collaboration among industries and stakeholders across all stages of the travel chain. The work of previous tasks in this project, Task 2: Forward Looking Assessment of Multimodal and Accessible Travel (FLA) and Task 3: Survey of Existing Standards and Standards Under Development (STD), have identified the topics of conversation that must happen among stakeholders, and the OP guided the methodology – people, organizations, venues and activities with which to have these conversations. This report is a summary of these conversations with end-users and standard developers about the end-user needs, standard gaps, and current and emerging development activities that may fill these gaps.

## References

Previous project documents inform the outreach efforts include:

- (FLA) Schweiger, Carol, et al. “FHWA-JPO-18-744 Multimodal and Accessible Travel Standards Assessment – Forward-Looking Assessment (FLA) White Paper”. 6/21/2019.
- (STD) Chang, Annie, et al. “FHWA-JPO-19-774 Multimodal and Accessible Travel Standards Assessment – Survey of Standards and Emerging Standards White Paper”. 10/29/2019.
- (OP) “Multimodal and Accessible Travel Standards Assessment – Outreach Plan”. 12/19/2019.

Additional reports cited in this document include:

- (MPI) Ingrid Bartinique and Joshua Hassol, “USDOT/FTA. Mobility Payment Integration (MPI) Program Scan of Practice.” Federal Transit Administration Report No. 0143, October 2019.
- (C-ITS VRU) ISO WD 24317 Intelligent Transportation Systems— Mobility Integration – C-ITS for light mode conveyances and accessibility travel standards gap assessment.

## Organization of this Document

The Outreach Report includes five chapters, as follows:

**Chapter 1: Introduction.** Chapter 1 provides the scope, background, and references associated with this Outreach Report.

**Chapter 2: Outreach Approach.** Chapter 2 summarizes the outreach methodology as guided by the OP and the stakeholder outreach activities that met the Plan’s objectives.

**Chapter 3: Outreach Results.** Chapter 3 presents the results of the outreach in the six core standard areas identified in the Plan. Each core area includes seven sections: a summary describing each area (Summary Description), outreach efforts in the area which includes presentations (Outreach Efforts), interviews and if appropriate a white paper of end-user needs (Needs), an annotated list of standards and standards development activities (Related Standards and Standards Development Activities), gaps in



standards and standards development (Standard Gaps), responses from the questionnaire on industry priorities (Industry Priorities), and recommendations (Recommendations for Filling the Gaps).

**Chapter 4: Next Steps.** Chapter 4 describes the next steps which includes developing the Task 5 deliverable, the MAT Roadmap.

**Chapter 5: Appendices.** The appendices included include:

**Appendix A. Acronym**

**Appendix B. List of Stakeholder**– list of organizations interviewed or participating in outreach effort.

**Appendix C. Questionnaire Results** – the raw results of the questionnaire conducted during the outreach task.

**Appendix D: White Papers** -- Three white papers that describes gaps and overlaps of standards or alternative approaches to addressing gaps. The three papers include:

- **Mobility Platform API Comparison** – an aggregation and comparison of application programming interfaces (API) and use cases associated with on-demand and demand-responsive use case that populate a mobility platform.
- **Uniform Transit Signage** – discussion and justification for a uniform form and function for transit signs.
- **Integrated Payment** – alternative approaches to fill the gap for standards that cover integrated payment.

## Notation

When international standards and related figures are cited in this report, they are referenced using their original spelling. ISO standards use British English spelling, for example, *traveller* rather than *traveler* in 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. In the case of *Figure 3: TS4448 Builds on Existing Data and Operating Standards (Source: Harmonize Mobility)*, the illustration uses both US and British English spelling to reference the original spelling of the standard referenced. In the diagram both US and international standards are referenced -- the international standards use “Kerb”, while the US specifications (e.g., CurbLR) use American spelling.



# Chapter 2. Outreach Approach

## Summary of Outreach Plan

The OP described the activities and stakeholder engagement necessary to gather input from standard developers and end-user groups. The activities were organized into two categories: the travel trip elements represented by the USDOT concept of **Complete Trips** and the infrastructure and paths of travel represented by the concept of **Complete Streets**, initially a USDOT initiative and later augmented by design, performance and policy elements promoted by the National Association of City Transportation Officials (NACTO) and Smart Growth America.

The four groups of MAT standards development initiatives related to Complete Trips include:

- Mobility Platform API
- Wayfinding and Navigation
- Safety
- Integrated Payment

The two areas of MAT standards development initiatives related to Complete Streets include:

- Curb Access and Management
- Public Right of Way and Indoor Navigation Data Model

The OP was organized into chapters introducing the outreach scope and objectives, identifying stakeholder groups, describing the six standards outreach areas listed above, and summarizing the planned outreach efforts. Each standard outreach area provided the scope for that area, related standards and dimensions, emerging standards, and planned outreach efforts.

The OP categorized stakeholders into two groups: end-user stakeholders and standards organizations. End-user stakeholders include application and equipment developers, research institutions, disability advocacy groups, and transportation organizations. Standards organizations include standards development organizations (SDO)s and transportation associations. Some end-user stakeholders are also standards organizations because they both influence and develop standards as well as represent user perspectives; examples of these stakeholders include transportation organizations and federal agencies. Standards organizations are critical to the development, implementation, and maintenance of standards and end-user stakeholders are critical to ensuring that those standards meet the MAT needs of all travelers. The OP included the purpose of outreach directed at the different stakeholder groups, identified the level of engagement, and a list of organizations, agencies, and departments that comprised the stakeholder group.

## Outreach Methodology

The OP proposed to conduct interviews, develop white papers, and present at meetings and conferences hosted by or including significant attendance of end-user and standard organization stakeholders. Travel restrictions caused by COVID-19 hindered some of these outreach efforts as many in-person conferences and meetings were moved to online venues or eliminated altogether. In response to these obstacles, the Research Team developed an online questionnaire to be distributed to appropriate stakeholders to supplement feedback that would have been gathered at in-person events.

These outreach activities and stakeholder groups engaged for each activity are summarized below.

### Interviews

The Research Team conducted interviews with key stakeholders representing disability organizations and advocacy groups, SDOs, private companies, and government agencies. The Research Team met with and gathered summaries of interviews with the following organizations:

- Access Explorers
- Alliance of People with Disabilities
- American Public Transportation Association (APTA)
- ARC-IT
- BikesforPeople.org
- Complete Street consultants
- Dutch Transport Operator Mobility Platform (TOMP) Consortium
- ENTUR
- FHWA/FHWA's Turner Fairbanks-Fairbank Highway Research Center
- Integrated payment transit agencies
- Integrated payment vendors
- ISO / TC 173/ SC 1 Wheelchairs
- ISO TC 159 / SC 4 Ergonomics of Human-System Interaction
- ISO TC 204 WG 19 Mobility Integration
- ISO TC 204 WG 8 Public Transport and Emergency
- ITS-A America (ITSA)
- MaaS Alliance
- Mobility Platform Vendors and Agencies
- MOD-Alliance
- MyData
- National Council on Independent Living (NCIL)
- Paralyzed Veterans of America
- SAE Mobility Data Collaborative
- SAE On-Road Automated Driving (ORAD) Committee
- SAE Safety and Human Factors Steering Committee
- SAE V2X Communications Steering Committee
- Shared Streets
- Shirley Ryan Ability Lab
- TOMESoftware (developing personal safety devices / C-V2X technology for bicycles)

- The Arc
- USDOT FHWA
- USDOT FTA
- USGS

## White Papers

The Research Team developed the following three white papers to supplement stakeholder outreach activities, including the following MAT standards development subject areas (see White Papers):

- Integrated Payment
- Mobility Platform API Comparison (version 2)
- Uniform Transit Signage

## Presentations

Presentations at committee meetings included:

- ISO, TC 204 WG 8 and 19
- ITSA, MOD Alliance
- MaaS Alliance Meeting
- SAE, On-Road Automated Driving (ORAD) Definitions Task Force
- SAE, On-Road Automated Driving (ORAD) Meeting

## Questionnaire

The Research Team developed an online questionnaire to supplement interviews and presentations. The questionnaire was organized by the six subject areas and respondents were asked to rate their level of knowledge of each subject area on a five-point scale, with 1 indicating no knowledge and 5 indicating an expert level of knowledge. Respondents were automatically advanced to the next subject area if they indicated little or no knowledge (score of 1 or 2) in a given subject area. Respondents who indicated a moderate level of knowledge (score of 3 or higher), were asked to do the following:

- 1) Indicate whether they are aware of existing or emerging standards and to list those they are aware of (open-ended question).
- 2) Rank potential needs for standards development related to the subject area (Likert scale<sup>2</sup> question).

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<sup>2</sup> The Likert Scale for SurveyMonkey is described on their website: <https://www.surveymonkey.com/mp/likert-scale/>; their weighted average score method is described at: [https://help.surveymonkey.com/articles/en\\_US/kb/Matrix-Question](https://help.surveymonkey.com/articles/en_US/kb/Matrix-Question).

- 3) Indicate what roles different types of organizations should take to advance standards and fill gaps (multiple choice).
- 4) State whether they believed any additional needs or considerations should be considered to advance standards development in the subject area (open-ended question).

The questionnaire was open from April 17, 2020 until May 12, 2020 and received 119 unique responses. Ninety-three (93) respondents indicated that they were a member of a committee or professional association invited to participate in the questionnaire, 15 respondents indicated that they were otherwise referred to the questionnaire (e.g., by a colleague or social media posting from someone who is a member of a committee or professional association that had been invited to participate), and 11 respondents did not indicate how they were referred to the questionnaire. The number of respondents who indicated moderate to expert level of knowledge, and who therefore contributed input to respective MAT standards development areas, is listed in Table 1.

**Table 1: Respondents to Questionnaire with Moderate to Expert Level of Knowledge**

Subject Area	Number of Respondents Indicating Moderate to Expert Level of Knowledge of the Subject Area
Mobility Platform API	66
Wayfinding and Navigation	47
Safety	76
Integrated Payment	38
Curb Access and Management	41
Public Right of Way and Indoor Navigation Data Model	26

The compiled questionnaire results are presented in Appendix C.

The questionnaire was distributed through identified stakeholder groups: disability advocacy organizations, transportation organizations and associations, SDOs, and other stakeholders. The questionnaire was sent to the following organizations and committees:

- SAE
  - Adaptive Cruise Control and Forward Collision Warning Committee
  - Advanced Applications Technical Committee
  - Advanced Driver Assistance Systems (ADAS) Committee
  - AV Test Site Community of Practice Task Force
  - C-V2X Technical Committee
  - Driver Metrics, Performance, Behaviors and States Committee
  - Driver Vehicle Interface Committee
  - Driving Automation Systems Committee
  - DSRC Technical Committee
  - Identifying ADS-DV User Issues for Persons with Disabilities Task Force
  - Infrastructure Applications Technical Committee
  - Infrastructure Needs Related to Automated Driving ORAD Task Force
  - ISO\_SAE Automation Taxonomy and Definitions Joint Working Group
  - ORAD Maneuver Task Force

- ORAD Simulation Task Force
- ORAD Committee
- ORAD Definitions Task Force
- ORAD Planning Task Force
- ORAD Verification and Validation Task Force
- ORAD Reference Architecture and Interfaces (RAI) Task Force
- Safety and Human Factors Standards Steering Committee
- Security Technical Committee
- Tolling Applications Technical Committee
- V2X Communications Steering Committee
- V2X Core Technical Committee
- V2X Vehicular Applications Technical Committee
- Vehicle Sound for Pedestrians Task Force
- International Organization for Standardization (ISO)
  - ISO/TC 204 Intelligent Transport Systems Working Group 8 (Public Transport) and Working Group 19 (Integrated Mobility)
- Transportation Research Board (TRB)
  - ABE60 Standing Committee on Accessible Transportation and Mobility
  - ABJ50 Standing Committee on Information Systems and Technology
  - ADB20 Standing Committee on Effects of Information and Communication Technologies (CT) on Travel Choices
  - AHB15 Standing Committee on Intelligent Transportation Systems
  - ANB60 Standing Committee on Safe Mobility of Older Persons
  - AP020 Standing Committee on Emerging and Innovative Public Transport and Technologies

## Chapter 3. Outreach Results

Feedback from stakeholders from presentations, interviews, white papers, and the questionnaire all informed the outreach results, which are presented by subject area. Each subject area provides a summary description, the outreach efforts undertaken, needs for the standard area, related standards and standards development activities, gaps in those activities, industry priorities for the subject area, and recommendations for filling the identified gaps. The subject areas are categorized by complete trips and complete streets.

### Complete Trips

According to the Task 2: Forward Looking Assessment [FLA], a “complete trip identifies all of the possible stages of a traveler’s journey, including key transitions (for example, boarding a vehicle, paying a fare) and major points of mobility access” [p. 3]. The concept covers several areas associated with standards development activities underway in the industry today. The Research Team categorized these development initiatives into four groups wherein significant work is currently underway.

- Mobility Platform APIs
- Wayfinding and Navigation
- Safety
- Integrated Payment

### Mobility Platform APIs

#### *Summary Description*

Over ten years ago, automated trip or journey planners that accounted for the accessibility of public transit services and facilities were beginning to be developed, mostly in Europe. Very few of them were adopted at that time, perhaps because of the lack of standards that described the required content as well as the fact that mobile devices were just becoming common place and had limited computing capabilities. Then, multimodal trip planners were developed to account for at least walking to and from public transit stops and stations, as well as fixed-route transit plans to describe a transit trip within a complete trip from point A to point B. De facto standards such as Google Transit Feed Specification (now the General Transit Feed Specification (GTFS)) were used. However, most of these trip planners did not take the accessibility of the paths to and from transit, nor the transit services themselves into account.

Now that the mobility ecosystem includes many more mobility services beyond public transit and walking, and mobile devices are nearly ubiquitous, mobility applications or platforms have become much more sophisticated. Further, these platforms can include trip elements beyond trip planning, such as payment (e.g., Mobility-as-a-Service (MaaS) platforms or mobility marketplaces). However, there is still a lack of harmonized standards that describe required data elements for MAT.



Access to mobility platforms may be from smartphone or mobile applications made up of APIs which simply send information back and forth between an application and a user. Also, mobility marketplaces such as MaaS, which provide multimodal “complete trip” planning and payment options, are accessed via smartphone applications driven by APIs.

Thus, the purpose of this section of this *Outreach Report* is to:

- Describe the outreach efforts associated with mobility platform API standards,
- Identify the needs for standards expressed by stakeholders within the MAT industry,
- Identify related standards and standards development activities,
- Describe the gaps in standards,
- Report on the standard priorities as expressed by the MAT industry, and
- Provide recommendations to fill the standards gaps.

## **Outreach Efforts**

### *White Paper*

One of the major efforts in this outreach area was to understand not only the gaps in standards development work, but also the duplication of efforts. The MaaS industry is global in nature and there are many efforts that originated in Europe that are much more mature than efforts underway in the United States. In the US, many of the efforts are private sector driven or one-time efforts deployed for MOD Sandbox or ATTRI projects. The European efforts are typically national efforts with some European Union (CEN)-based standards. Many of the efforts are limited in their focus, covering only a portion of the ecosystem or developed as a reference framework; only recently has there been an effort to address the breadth of the Complete Trip or at least each leg of a journey throughout the lifecycle (from planning to review). To understand the types of interactions required among critical stakeholders, the Research Team reviewed several standards that included frameworks / architectures, use cases, and APIs. Specifically, the Mobility Platform API Comparison (version 2) describes the framework, functions, and use cases that belong to this standards area, inclusive of a complete trip as a traveler plans, books, travels and reviews their journey. The Mobility Platform framework is derived from the use case categories and scenarios of existing standards, specifications, and technical reports. The framework identified exchanges between traveler and business (T2B) and between businesses (B2B). Each category included three phases – pre-trip, en-route, and post-trip. The categories covered the following use case areas (by exchange category).

#### T2B Exchange Categories

- Trip information
- Reservations / Booking
- Payment
- Registration

#### B2B Exchange Categories

- Rules / Service Information
- Scheduling / Dispatch
- Certification
- Payment

The framework, described in the Mobility Platform White Paper, provides a means of mapping standards and specifications that are related to mobility services to assess the gaps and overlaps in the standards development activities. After presenting the white paper and distributing it for review, additional efforts were identified that were incorporated into the Mobility Platform API Comparison (version 2).

In addition to the use cases, the white paper assessed data flows and functions to determine their coverage of multimodal / multiple provider seamless travel, transitions between traveler trip legs, support for vulnerable travelers, and integration of emerging technologies including wearables, indoor navigation aids, and Connected to Everything (C2X) technologies. Finally, the white paper results were combined with outreach interviews with advocacy groups for vulnerable travelers as well as several mobility platform vendors.

### *Presentations and Interviews*

Several presentations of the white paper and stakeholder interviews of developers and end-users were conducted to refine the gap results and formulate several possible recommendations for the Roadmap. The presentations and interviews are listed below:

- Presentations and distribution of White Paper
  - MaaS Alliance
  - ITSA MOD Alliance
  - ISO TC 204 WGs 19 and 8
- Stakeholder Interviews
  - Developers: Transit (Transit App), MaaS Global (WHIM App)
  - Advocacy Groups: Access Explorers, The Arc, Paralyzed Veterans of America (PVA), Shirley Ryan Ability Lab (SRAL)
  - Standard Developers: Norway ENTUR (Open Trip Planner), Dutch Transport Operator Mobility Platform (TOMP), SAE International, Mobility Data Collaborative

### **Needs**

In terms of mobility platforms and APIs, there are multiple needs expressed by the MAT industry as well as by disability stakeholders. While this overlaps with other outreach categories, the needs specific to mobility platforms can be summarized as follows:

- Mobility platforms need to be developed based on human system interaction, rather than just from a technical or infrastructure perspective.
- Platform design and usability must be based on human computer interaction (using human-centered design), particularly for persons with disabilities.
- Mobile applications are better than a website because the interface is much simpler.
- Vibrotactile technologies could gain popularity in mobility platforms. Information can be provided to the user through a range of vibrations, each with a unique meaning.
- Having a “call button” in a mobility app/platform while traveling could be a useful feature to ensure that a traveler can obtain assistance while en-route.
- Including real-time / dynamic information in mobility platforms (and possibly pushed to the platform user) is critical since conditions that will affect the ability to complete the trip could change while the traveler is en-route.

- Integrating curb and right-of-way access and management information within mobility platforms would greatly facilitate travel by persons with disabilities. For example, if conditions at a bus stop are inaccessible for a person using a wheelchair, the platform should provide an itinerary that is accessible to the user and note the inaccessibility of the stop.
- Information provided via mobility platforms should be available via other means since some people do not have access to the Internet or a smartphone, and may not have experience with accessing and using mobility platforms.
- In terms of pre-trip planning, the exact locations of accessible entrances and exits are necessary for persons needing to access or leave a facility via these specific locations.
- Mobility platforms should include the ability for a traveler to report obstacles they encounter during their trip (e.g., allow for crowdsourcing).
- Personally identifiable information (PII) privacy must be protected.

### ***Related Standards and Standards Development Activities***

Software development organizations in Europe and the US are developing frameworks, designs, and services to support mobility services application programming interfaces (APIs). The longest deployed standard serving this area since the 1990s is the Standardiserat Utbyte av Trafik Information (SUTI), implemented across Scandinavia<sup>3</sup>. The standard provides demand responsive services to the general public, older adults, persons with disabilities particularly mobility challenges, school children with cognitive disabilities, people needing transportation for health care, and other groups<sup>4</sup>. The scope of services provided by SUTI includes “comprehensive functionality for trip booking—via both agents in call centers and direct on-line access for many agencies, trip scheduling, assignment of transportation service providers and vehicles, vehicle tracking, and financial transactions for funding sources and service providers.”<sup>5</sup>

Concurrently, many European SDOs are also developing frameworks (architectures and use cases), messages, and data dictionaries to address similar needs for planning and executing multimodal travel including European Committee for Standardization (CEN), Association of German Transport Companies (VDV) and more. Another initiative underway that spans international boundaries (but does not include North America) is the MyData.org which is organized to develop policies, procedures and provisions to secure personal identifiable information, similar to the ISP 24014-1 Appendix B on Electronic Identification.

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<sup>3</sup> TCRP Report 210 Development of Transactional Data Specifications for Demand-Responsive Transportation, September 2019. (<http://www.trb.org/Main/Blurbs/179848.aspx>) p., 8

<sup>4</sup> Ibid., p 9

<sup>5</sup> Ibid., p.18

Finally, many industry associations and private companies sponsored by governments and public agencies are developing APIs and software development kits (SDK) to promote standardization of on-demand / demand-responsive lifecycle services (from discovery through execution and reporting). SDO, industry association and private sector open API references as listed below.

Many of the published APIs use the Open API format for exchanging information which is an agnostic form in which to encode the semantics of open data messages.

#### SDO standards development activities and technical reports

- ISO TC 204 / WG 17 developed several standards related to nomadic device services (smart phones) -- ISO/CD 22085-3, Nomadic Device Service Platform for Micro Mobility, with Part 3 focusing on Data Structure and Data Exchange Procedures
- ISO 24014-1 Public transport -- Interoperable fare management system (IFMS)-- Part 1: Architecture (Revision 3, expected publication date in 2020) (IFMS)
  - Including Appendix A: Mobility Platform – German example and Appendix B: Electronic Identification
- ISO Technical Report 21724-1 Intelligent transport systems -- Common transport service account (CTSA) systems -- Part 1: Framework and use cases
- Several national standards efforts (Calypso – France, VDV – Germany, Transmodel/ NeTex – CEN)
- Standardiserat Utbyte av Trafik (SUTI) (overview: <https://docplayer.se/4489858-Standard-for-battre-affarer-suti-standardiserat-utbyte-av-trafikinformation.html>)
- TOMP, Blueprint for an API from Transport Operator to MaaS Provider, version 1.2 (01-03-2020)
- ISO/TC204/WG19/TS4448-1 (just started April 2020) on Parking Standards; release scheduled for 2022

Taxonomies contribute to a list of values that are included in data dictionaries. The data concepts are typically called enumerated value terms. Taxonomies contributing to a consistent set of enumerated values include:

- ISO TC 173 SC 1 on Assistive Devices and Wheelchairs
  - ISO 7176-14 Wheelchairs — Part 14: Power and control systems for electrically powered wheelchairs and scooters — Requirements and test methods
  - ISO 7176-21 Wheelchairs — Part 21: Requirements and test methods for electromagnetic compatibility of electrically powered wheelchairs and scooters, and battery chargers
  - ISO 7176-5 Wheelchairs — Part 5: Determination of dimensions, mass and maneuvering space
  - ISO 11199-1 Assistive products for walking, manipulated by both arms — Requirements and test methods — Part 1: Walking frames
  - ISO 11199-2 Assistive products for walking, manipulated by both arms — Requirements and test methods — Part 2: Rollators
  - ISO 11199-3 Walking aids manipulated by both arms — Requirements and test methods — Part 3: Walking tables
  - ISO 11334-1 Assistive products for walking manipulated by one arm — Requirements and test methods — Part 1: Elbow crutches
  - ISO 11334-4 Walking aids manipulated by one arm — Requirements and test methods — Part 4: Walking sticks with three or more legs

- SAE C2X, Micromobility and Mobility Service Taxonomies
  - SAE J3194 Taxonomy and Classification of Powered Micromobility Vehicles
  - SAE J3163 Taxonomy and Definitions for Terms Related to Shared Mobility and Enabling Technologies
  - SAE J2735 Dedicated Short Range Communications (DSRC) Message Set Dictionary
  - SAE J2945/9 Vulnerable Road User Safety Message Minimum Performance Requirements
  - SAE On-Road Automated Driving standards (see safety)
- Mobility Data Collaborative
  - MDC00002202004 Data Sharing Glossary and Metrics for Shared Micromobility
  - MDC00001202004 Guidelines for Mobility Data Sharing Governance and Contracting

*Open APIs (or APIs provisioned through an open architecture)*

- BestMile – open APIs (requires access permission <https://developer.bestmile.com/>)
- MaaS Alliance -- <https://github.com/maas-alliance/apis>
- MaaS Global – Booking APIs for WHIM (<https://maasglobal.github.io/maas-tsp-api/redoc.html#section/Booking-explained>)
  - MaaS Global APIs will be absorbed into the MaaS Alliance effort
- Mydata.org (organization to manage personal identifiable information – PII)
- Open API (<https://swagger.io/specification/>)
  - Open API-hybrid: Denver Mobility Services for All Americans (MSAA) project (RTD, Broomfield, + providers) (see Transit Cooperative Research Program [TCRP] Report 210, p, 45)
- Open Trip Planner (OTP) APIs for multimodal trip planning  
<http://docs.opentripplanner.org/en/latest/>
  - A mirror effort is underway in Norway to augment the OTP to meet accessibility needs (person with mobility devices such as wheelchair or scooter).
- Software Development Kits (SDK) and APIs from various vendors (Masabi, Transit, INIT, etc.) including account- based APIs (requires permission from organizations)
- TCRP Report 171 Use of Mobility Devices on Paratransit Vehicles and Buses. March 2016. (<http://www.trb.org/Main/Blurbs/171162.aspx>)
- TCRP Report 210 Development of Transactional Data Specifications for Demand-Responsive Transportation, September 2019. (<http://www.trb.org/Main/Blurbs/179848.aspx>)

*Mode-based Service Information Standards*

- General Transit Feed Specification (GTFS), GTFS-Real Time, GTFS-Flex
- GTFS-Vehicles and GTFS Pathways (<https://github.com/google/transit/issues/108>)
- European Union Standards: Service Interface for Real Time Information (SIRI) and other CEN Transmodel/ Network Timetable Exchange (NeTEX) standards
- General Bikeshare Feed Specification (GBFS), GBFS Status
  - TOMP extends the GBFS standard for static and on-demand services
- Alliance for Parking Data Standards (APDS) International standardization efforts are underway at ISO/TC204/WG19/ projects include: TS5206-1 and TR24321
- Mobility Data Specification (MDS)

*Infrastructure Standards (PROW)*

- See sections: Curb Access and Management and PROW and Indoor Navigation Data Representation

**Standards Gaps**

As an encompassing area, there are numerous activities – development of architectures, use cases, information exchanges and feeds, and data dictionaries currently deployed, under development or envisioned for a mobility platform. There are several areas that are not covered by these efforts. These are enumerated below:

**Table 2. Areas with Gaps in Current Standard Efforts**

Area	Gaps
<b>Static trip planning</b>	<ul style="list-style-type: none"> <li>• Visualizations for pre-trip preparation (both traveler and caregiver)</li> <li>• Trip requests the use of elevators and ramps (avoid stairs and escalators)               <ul style="list-style-type: none"> <li>○ Missing trip preferences for slope of ramps, need for curb cuts</li> </ul> </li> </ul>
<b>Safe trip plans and real time travel information</b>	<ul style="list-style-type: none"> <li>• Data / attributes to support accessibility needs for vulnerable travelers               <ul style="list-style-type: none"> <li>○ Taxonomy for mobility aids / conveyance</li> <li>○ Standard list of amenities including car seats, wheelchair securements, lifts and ramps</li> </ul> </li> <li>• Matching and dispatching vehicle to traveler needs               <ul style="list-style-type: none"> <li>○ Wheelchair (size, folded or with occupant), car seat, luggage, etc.</li> </ul> </li> </ul>
<b>Structures for rule exchange</b>	<ul style="list-style-type: none"> <li>• Pricing Rules (Tariff/ Fare descriptions) – general structure, including discounts/incentives for transfers; includes different products and services               <ul style="list-style-type: none"> <li>○ Tariff by mode</li> <li>○ Clearing house settlement fees (liability)</li> <li>○ Transfer between modes</li> </ul> </li> <li>• Commercial rules – cancelation, rebooking, coordinated travel (for multiple service providers)</li> <li>• Service usage – shared data (subject PII), service information (schedules, mobility services, usage)</li> </ul>
<b>Consent APIs</b>	<ul style="list-style-type: none"> <li>• Traveler sharing account information / PII with multiple service providers: cover opt-in, cancel, revoke, augment/reduce options</li> <li>• Businesses secure and share account information with another provider based on traveler requests</li> </ul>

In addition to the gaps, there are growing overlaps in development activities. If these continue, then there will be multiple, competing standards. Even within each mode, there are diverging needs and efforts underway. Like the harmonization effort underway in ISO TC 204 around Connected Vehicle / Cooperative ITS, harmonization of standards around a mobility platform would be beneficial to bridge the semantic differences among modes, regions and organizations promoting siloed standards.

### ***Industry Priorities***

The outreach questionnaire asked participants (n=53) to identify potential needs to advance mobility platform API standards. The recommendations were ranked in order of highest priority to lowest as follows:

1. Information exchange to support discovery, planning, payment, en-route information/re-routing, and trip histories for fully accessible door-to-door multimodal journeys (score = 3.77).
2. Information exchange to allow customer to consent to share their personally identifiable information (PII) in an integrated, multi-organizational environment (3.22).
3. Information exchange to find the right path based on traveler mode and ability to complete their trip (score = 2.80).
4. Information exchange to match mobility devices (e.g., wheelchairs) with accessible vehicles (score = 2.73).
5. Information exchange and formats for mobility providers to share rules such as services, fees/tariffs, and operations (score = 2.54).

Most respondents believed that SDOs should take the lead in developing these standards (60%), with government (58%) and research organizations (28%) as alternative leaders.

### ***Recommendations for Filling Gaps***

The major recommendation to filling the gaps is to convene an international consortium of organizations – SDOs and ad hoc specification organizations to define a flexible reference architecture (defining actor roles), use cases, and a reference data dictionary so that standards and specifications developed separately are still interoperable.

For the US marketplace, one or more of these efforts may be applicable. For example, the Open Trip Planner (OTP) is adopted by several municipalities and is becoming more multimodal in nature. It provides discovery and planning APIs though not en-route and reporting services. However, the US and European back end data formats differ, where the US uses OSM, GBFS, GTFS and GTFS-Flex formats to populate the system, Europe has a set of robust public transport data exchange formats that better supports access and multimodal seamless services.

## **Wayfinding and Navigation**

### ***Summary Description***

Travelers require information about their trip to help them navigate through their entire journey. Real-time information about service availability and performance and the condition of the pathway can help a traveler determine whether there are any obstacles (e.g., construction or inoperable elevators) in a facility or on their path of travel that will prevent them from completing the trip as originally planned.

Wayfinding and Navigation (WaN) tools assist travelers in avoiding obstacles and finding their way through indoor and outdoor environments. These tools include technology-based solutions such as mobile applications and maps and directional systems at the location being navigated. Other tools include visual and tactile paths, such as signage with information or directions, and individual assistance through a facility by agency/provider staff.

All of these tools should pay special attention to the entire trip, including how the traveler gets from their starting point to their first stop or from their last stop to their ending point, how each transport mode or facility is entered or accessed, and what assistance might be needed for the traveler to access any of the trip segments.

WaN consists of navigational tools to assist a traveler in avoiding obstacles and finding their way through indoor and outdoor environments. Recent development of WaN tools has focused on technologies such as mobile wayfinding applications and on-site mapping and directional systems. The provision of real time information is covered in the Mobility Platform API section. The Curb and Access Management and PROW core areas cover information and management of curb and pathway representation, condition, and rules. This section covers the physical sensors, and communications signs and devices (including human machine interface of a mobile device) that support travelers while they are preparing for or traveling on their trip.

### ***Outreach Efforts***

The outreach effort was composed of several parts. It included interviews and presentations to advocacy groups for vulnerable groups, SDOs developing assistive device standards, and human factors experts and standard developers. The outreach also included the development of a white paper on uniform signage for static signs. These are in this section.

#### ***White Paper***

As part of WaN outreach efforts, the Research Team developed a white paper to seek stakeholder input on developing standards or specifications for uniform transit signage for static signs (see Uniform Transit Signage). Other transportation domain areas, such as highways and airports, promulgate standards and guidance, yet transit does not have similar guidance, and so there is no consistency in markings, colors, illumination, form and placement that provide transit users with a similar, familiar experience no matter where in the United States that they use transit services. Transportation organizations and grassroots organizing efforts have advocated that deploying signs with active technology support would lower barriers and mitigate obstacles for underserved communities by providing more consistent and inclusive design of wayside and navigation aids for all travelers. The paper poses the question about whether standards for shape, markings, illumination, reflectivity, and placement of signs, as well as provisioning information presented on static signs via existing communications protocols to assistive devices. Standards that do exist for static signage are not specific to transit and are not consistently applied by transit agencies.

In the white paper, the background, existing standards for other transportation signage uniformity, and a discussion on the need for transit signage uniformity to address the core issues presented in Table 2. The white paper provides the context for how transit signage standards may be developed and implemented.



**Table 3. Issues and Considerations for Uniform Transit Signage Development**

Issue	Considerations for signage assessment and standards development
<b>Adequacy</b>	<i>Are there enough signs? What major components or points of access might someone need to find (e.g., train platforms, bus stops, restrooms, exits)?</i>
<b>Lighting and Placement</b>	<i>Are the signs visible – at night, in the shade, in the sun, by someone seated or in a wheelchair?</i>
<b>Text</b>	<i>Is the text on signs in a straight-line, sans-serif font and large enough to be seen from some distance?</i>
<b>Colors</b>	<i>Is the color contrast between sign background color and text color significant enough that the text can be easily read in different lighting? Are words also used to describe information that is presented by colors? Someone who is color-blind might not recognize the information being displayed if they cannot see the difference between colors.</i>
<b>Words and Graphics</b>	<i>Is the information on signage presented in plain language and with direct speech? It is best practice to use language that is at an elementary-grade reading level. Do signs have accompanying graphics to reiterate message information?</i>
<b>Modes</b>	<i>Is the information printed on visual signs also presented by auditory messages or in braille/on tactile maps? How can users who are blind, low-vision, or are not at a level to see a sign access information on signage?</i>
<b>Information Protocols</b>	<i>Should signs broadcast information that is on a sign to mobile devices such as personal V2X equipment (e.g., personal ITS station)?</i>

### *Presentations and Interviews*

Stakeholder interviews of end-user advocacy groups and standard developers were conducted to solicit needs and priorities for standardization. Stakeholder interviews included the following:

- Access Explorers
- The Alliance for People with disAbilities
- The Arc of the United States (national organization)
- National Council on Independent Living
- Paralyzed Veterans of America
- Shirley Ryan Ability Lab (formerly Rehabilitation Institute of Chicago)
- ISO/TC 159/Subcommittee (SC) 4 Ergonomics of human-system interaction
- ISO/TC 173/SC 1 Wheelchairs

### **Needs**

Navigating through transit facilities and services can be difficult for any user but the challenges for people with disabilities and functional limitations can make this even more difficult. Based on interviews with stakeholders, more information in a universally accessible format is the primary need among people with disabilities. Travelers traverse many modes in different cities, regions, and locales. As such, consistency in presentation, access, and dissemination is a cornerstone of each of the needs articulated for WaN. Even with native and special apps on mobile devices, the organization, phrasing, layout and size of WaN

support is critical for travelers, particularly vulnerable groups including people with disabilities, older adults, low income, and non-English speakers. Specific areas that were identified include:

- Dynamic, real-time information about irregular operations, specifically those that affect accessibility (i.e., elevator outages, delays, detours, etc.).
- Updated, reliable information about obstacles and barriers in paths of travel such as sidewalk construction, facility maintenance, etc.
- On-site assistance and training standards for transit agency employees and operators.
  - This includes virtual and virtual reality (VR) training scenarios for people with cognitive disabilities.
- Information on signage, kiosks, displays, and more provided in consistent and accessible formats, specifically for people with vision loss.
- Customization capabilities in mobile applications to meet accessibility needs on an individual basis.

### ***Related Standards and Standards Development Activities***

There are a number of existing and emerging standards efforts for Wayfinding and Navigation. These are not universally implemented or even widely identified. The Americans with Disabilities Act Accessibility Guidelines (ADAAG) and Public Right of Way Accessibility Guidelines (PROWAG) policies are perhaps the best known and implemented guidelines, however, they do not promote any one consistent approach for deployment. Current standards and development activities include:

- International Telecommunication Union (ITU)- standards (developed from 2006 through 2018)
  - F.921: Audio-based indoor and outdoor network navigation system for persons with vision impairment
  - FSTP-UMAA - Use cases for assisting persons with disabilities using mobile applications
  - FSTP- TACL – Telecommunications Accessibility Checklist
  - ITU-T F.791 Accessibility terms and definitions
  - ITU-T F.790 Telecommunications accessibility guidelines for older persons and persons with disabilities
- W3C – WCAG 2.0 and 2.1
  - Web Content Accessibility Guidelines (WCAG)– 2.0 is the original document and 2.1 is a supplemental document that addresses aspects not fully addressed in 2.0 including mobile accessibility and the needs of people with low vision, cognitive and learning disabilities.
- W3C – Mobile Accessibility Task Force
  - This task force is a part of the Accessibility Guidelines Working Group (AG WG) that helps produce techniques, understand, and guidance documents, as well as updates to existing related to W3C material related to the mobile space.
  - List of Task Force members:  
<https://www.w3.org/2000/09/dbwg/details?group=66524&public=1>
  - Website for Task Force: <https://www.w3.org/WAI/GL/mobile-a11y-tf/#about>
- W3C – User Agent Accessibility Guidelines (UAAG) 2.0
  - Guidance on designing user agents such as browsers, browser extensions, media players, readers, etc.
  - Part of the W3C Web Accessibility Initiatives
- IEC Standard Management Board (SMB) – Strategic Group (SG) 10 – Wearable Smart Devices

- The SG10 was created to identify gaps and market requirements for wearable devices then established a new working group, WG10, which developed the ISO/IEC 30141:2018 Internet of Things – Reference Architecture to create standards and coordinate standardization work, in cooperation with other organizations.
- IEEE Standards Association – Project P360 Standard for Wearable Consumer Electronic Devices, Overview and Architecture
  - P360's goal is to provide a testing solution and consistent way of describing features for wearable consumer electronic devices. This is still an active project.
- ISO 9241-210:2019 Ergonomics of human-system interaction — Part 210: Human-centred design for interactive systems
  - Describes design techniques for keeping the user at the center of the design process for HMI.
- ANSI/CTA-2076 Inclusive, Audio-based, Network Navigation Systems for All Persons including those Who are Blind/Low Vision
  - Standards to help design professionals achieve an inclusive environment through Inclusive Audio-Based Network Navigation System (IABNNS) that augment physical environment by the provision of aural information about environments for users.
- ISO TC 204 WG 19 VRU Gap analysis (draft due in Dec)
- SAE Shared and Digital Mobility Committee
  - Published and now revising J3163 Taxonomy and Definitions for Terms Related to Shared Mobility and Enabling Technologies
- SAE Infrastructure Applications Technical Committee
  - Developing J2945/10 Recommended Practices for MAP/SPaT Message Development
  - Developing J2945/11 Recommended Practices for Signal Preemption Message Development
- SAE Traffic Signal Applications Technical Committee
  - Developing J2945/3 Requirements for V2I Weather Applications
  - Developing J2945/4 Road Safety Applications
  - Developing J2945/C Traffic Probe Use and Operation
- ISO 20524-1:2020: Intelligent transport systems — Geographic Data Files (GDF) GDF5.1, Part 1: Application independent map data shared between multiple sources
- ISO 17572-4:2020: Intelligent transport systems (ITS) — Location referencing for geographic databases — Part 4: Precise relative location references (precise relative profile)

Additional efforts and policies include:

- ATTRI prototyping apps including SMART wayfinding specifications and TRX Neon APIs
- Americans with Disabilities Act Accessibility Guidelines (ADAAG) and Public Right of Way Accessibility Guidelines (PROWAG) policies
- The National Building Information Modeling Standard-United States (NBIMS-US)
- Department of Transportation ADA Standards for Transportation Facilities
- USDOT Complete Trip descriptions (including transition and transfer between modes)
- SAE White Paper on Automated Vehicles
- EU reports on planning and designing walkable cities
- State and municipal Transition plans
- SAE Industry Technologies Consortia (SAE ITC)

- SAE ITC has launched the Mobility Data Collaborative, <https://mdc.sae-itc.com/>. The consortium convenes public and private partners and will develop a framework of best practices to support effective and secure mobility data sharing.

Some emerging standard or specification development activities filling the gap include:

- ISO/AWI TS 22726-1: Intelligent transport systems — Dynamic data and map database specification for connected and automated driving system applications — Part 1: Architecture and logical data model for harmonization of static map data (under development)
- In addition to traditional signage and urban design best practices, there are efforts by Google and others to provide detailed mapping, powered by AR and Street View images, for walking trips.
- Mobility Data GTFS / GitHub GTFS Accessibility Extensions

However, many of these standards are piecemeal and not widely implemented (except for the Google effort).

### **Standards Gaps**

- The gaps in standards apply mostly to adopting more consistent standards and promulgating those throughout the country, similar to how the FHWA developed the Manual on Uniform Traffic Control Devices (MUTCD) or inclusion of standards in the ADAAG and PROWAG. This includes: Standards for wayfinding field technologies that communicate with personal technologies such as wearables and mobile apps:
  - Use cases describing complete trips particularly for vulnerable travelers including transition points and pathway navigation scenarios
  - Consistent and accurate messaging for safety, pathway condition, status, and other pathway information
  - Consistent information formats, messages, and protocols for WaN
  - Guidance on where to put field devices (indoor and outdoor)
  - Standards that describe the types of communications stacks that should be included in the field that is consistent with personal mobile devices
- Standards that provide performance condition index for surface smoothness that supports people with mobility devices, bicycles, e-scooters, people pushing strollers or rolling suitcases, etc.
- Standards for consistent signage for transit, ridehailing pickup/drop off locations and directions to those places.

### **Industry Priorities**

The outreach questionnaire asked participants (respondents are 41) to identify potential needs to advance WaN standards. The recommendations were ranked in order of highest priority to lowest as follows:

1. **Dynamic RT Info Delivery.** Information exchange standards for the delivery of dynamic information (real-time information) related to transit operations (e.g., delays, cancellations, platform changes, elevator operability etc.) to transit user's personal electronic devices or electronic information displays on-site. (score = 6.36).
2. **Transit Uniform Signage.** Information standards for transit agency/provider signage, websites, and mobile applications for the display and delivery of essential information that may be needed to facilitate a seamless trip under any conditions (static information). (score = 5.68).

3. **Obstacle Collection/Reporting.** Information exchange standards to gather and report out obstacles (e.g. construction) on sidewalks, pedestrian crosswalks, and other paths of travel in real-time. (score = 5.31).
4. **Indoor Mapping.** Standards for indoor mapping on mobile wayfinding applications with specific guidelines on customization capabilities, compatibility with personal assistive technologies (screen readers, voice command software), accurate navigation assistance, and provided information including points of interest and accessible paths of travel. (score = 4.05).
5. **Design HMI.** Design and human-machine interface standards for haptic technologies that provide navigation assistance to users, specifically those with hearing and/or vision loss and cognitive disabilities (score = 3.68).
6. **Mobile Content Delivery.** Standards that allow mobile application users to customize how content is displayed and provided so the information is digestible and meets their individual accessibility needs (e.g., screen reader compatibility, text style, color, alignment, size, magnification, etc.) (score = 3.87).
7. **Indoor WaN Implementation Guide.** Standardized implementation guidelines for indoor wayfinding technologies that provide accurate navigation assistance to the user with minimal maintenance to the provider, including location of signage to ensure visibility for all users at all times. (score = 3.84).
8. **Employee Training.** Employee training standards for transit agency frontline staff that prepares staff for assisting customers with disabilities including disability awareness and etiquette, assistance techniques, and internal accessible services, facilities, and amenities. (score = 3.77).

Most questionnaire respondents believe that SDOs should take the lead in developing standards (62%) with all other stakeholder groups participant in over 50% for each category.

### **Recommendations for Filling Gaps**

The main recommendation for filling WaN gaps lies in how to involve user groups to validate inclusive designs and special requirements for different capabilities. At a minimum, this involves participation of advocacy groups in the standards process. Beyond that, the standards will not be proven until a system implementing the standards are piloted and tested for mitigating the challenges and validating the usability of the approach for all vulnerable groups.

Additionally, there is a role for government -- transportation agencies, cities, and municipalities, implementing standards and uniform design guidelines. There are many standards already developed, but fewer organizations that collect and/or interpret the provisions in a consistent way. For example, GTFS has an attribute for identifying accessible trips and stops, yet few transit agencies actually include the information in their data feeds. Fewer public sector organizations collect and report on pathways other than roads, or the conditions of pathways. An education and outreach component is recommended for filling the gaps in the WaN area.

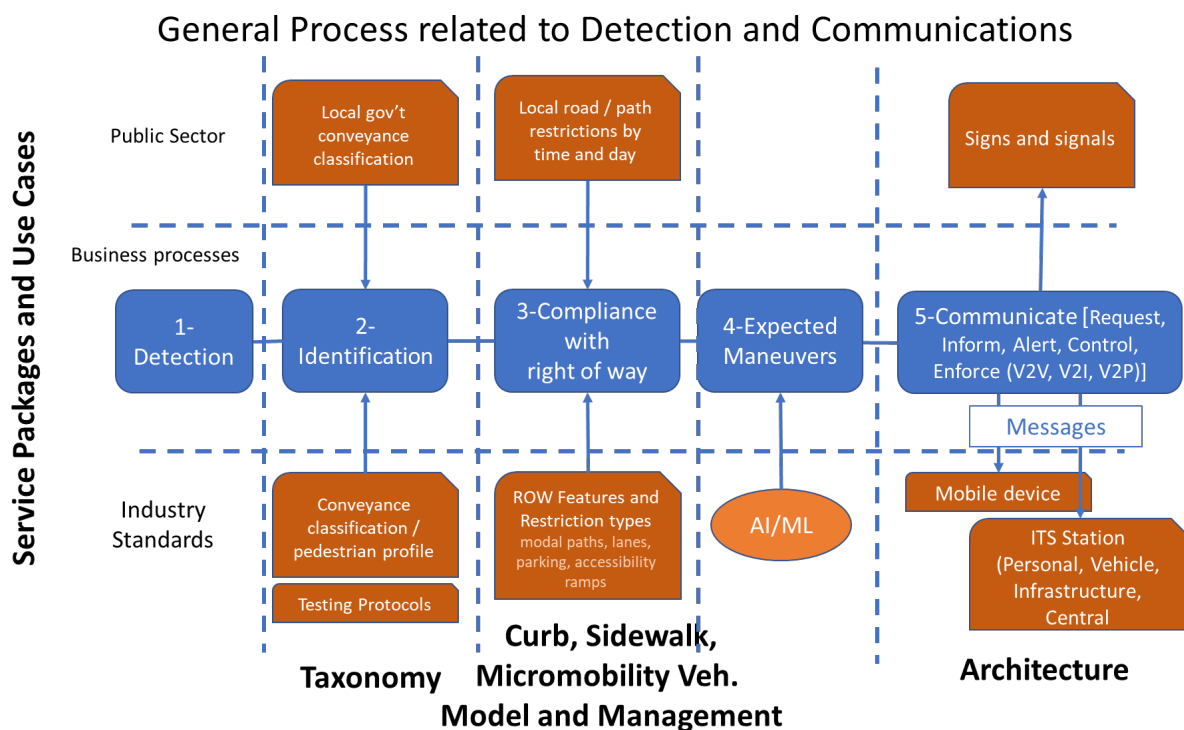
## **Safety**

### **Summary Description**

New technologies in areas such as connectivity, automation, and shared and digital mobility are disrupting travel and impacting travelers in all transportation sectors. Standards are being developed to help mature these disruptive technologies, but these standards mostly focus on technology and business models and

not the safety and accessibility of vulnerable travelers. In this section, “Safety” refers to the area of connected to everything (C2X) and autonomous vehicles with respect to vulnerable travelers or as referred to in the literature and standards as VRU. Both automation and C2X technologies hold different promises for travel.

In the C2X domain, the VRU is a type of traveler who is more vulnerable than people who are in a vehicle such as a truck, train, bus, or car. The “vulnerability” occurs as persons transition between modes (e.g., boarding a bus, exiting a ridehailing service), or take more active transportation modes such as walking, biking, including using mobility and assistive aids such as wheelchairs. Emerging C2X standards have one or two examples of technology and business models, use cases, architectures, and system requirements for VRUs, but they are not comprehensive. A gap assessment currently under development by the ISO TC 204 WG 19, ISO Working Draft 24317 (C-ITS VRU) identifies general safety processes associated with VRUs communicating with vehicles, infrastructure and other VRUs, and vice versa. In Figure 1, public sector regulations and services (such as road and curb restrictions, signs and signals) are shown in brown boxes in the top swimlane; types of standards and specifications are listed in brown boxes/ovals on the bottom swimlane. The blue boxes describe the core processes for either the VRU (P, where P indicates personal), infrastructure (I) or vehicle (V) point of view. This model identifies where standards are needed to implement this safety process. (Note the acronyms in the Figure 1 are described as follows: AI/ML = artificial intelligence / machine learning algorithms; V2V = vehicle to vehicle; V2I = vehicle to infrastructure; V2P = vehicle to personal.)



**Figure 1: General Processes related to Detection and Communications of VRUs (source: ISO WD 24317)**

**Automation standards cover uniform design standards for traveler accessibility including boarding (ingress), securing, and alighting (egress) automated vehicles.**

***Outreach Efforts***

The Research Team reached out to applicable standards development committees in SAE and ISO. Automobiles have become increasingly interconnected systems of systems. This is particularly true in emerging mobility areas such as Advanced Driver Assistance Systems (ADAS), C2X, and Automated Driving Systems. These technology suites require the input of many technical disciplines. Thus, the Research Team engaged international experts in the following technical disciplines:

- Engineering, Hardware and Software Development
- Sensor Technology and Sensor Fusion
- Automation and Robotics
- Functional Safety and Active Safety
- Human Factors
- Mobile Communications

***Presentations and Interviews***

The Research Team engaged international experts who are leaders in applicable standards development in SAE and ISO to give their detailed input regarding safety impacts on travelers, with a focus on travelers with accessibility needs and vulnerable road users.

The Research Team also achieved broad industry impact by briefing the following SAE and ISO committees and engaging their experts to participate in the project questionnaire (see Table 4):

**Table 4: SAE and ISO Committees Interviewed on Safety Related Standards**

<b>Committee</b>	<b>Impact</b>
<b>SAE Safety and Human Factors Steering Committee</b>	This steering committee includes 7 Committees and hundreds of international experts in the following expertise areas: <ul style="list-style-type: none"> <li>• Human Factors</li> <li>• Functional Safety and Active Safety</li> <li>• Engineering, Hardware and Software Development</li> </ul>
<b>SAE On-Road Automated Driving Committee</b>	This Committee includes 11 Task Forces and hundreds of international experts in the following expertise areas: <ul style="list-style-type: none"> <li>• Automation and Robotics</li> <li>• Engineering, Hardware and Software Development</li> <li>• Functional Safety and Active Safety</li> <li>• Human Factors</li> </ul>
<b>SAE V2X Communications Steering Committee</b>	This steering committee includes 9 Committees and hundreds of international experts in the following expertise areas: <ul style="list-style-type: none"> <li>• Engineering, Hardware and Software Development</li> <li>• Mobile Communications</li> <li>• Functional Safety and Active Safety</li> </ul>

<b>ISO/TC 204 Intelligent Transport Systems</b>	ISO / TC 204 is responsible for the overall system aspects and infrastructure aspects of intelligent transport systems (ITS). TC204 includes expert delegations from 29 nations and 12 Working Groups that focus on disciplines such as Connected Vehicle, Public Transport, Traveler Information Systems, and Mobility Integration.
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### Needs

Needs for this area are succinctly described by the outreach questionnaire and the (C-ITS VRU) assessment. The needs are described below.

- Considerations concerning the education and licensure of users, deterrence, and prevention of unwanted behaviors (e.g., micromobility devices on high speed highways, operating under the influence), and the current and future usages of infrastructure and its safety standards in light of competing interests.
- Cross-discipline development of standards. Safety will be achieved from coordination across committees that have expertise in all aspects of vehicle design and deployment.
- Standards for passenger vehicle accessibility are a high priority as these are necessary to realize the full benefits of AVs.
- V2V and V2I communications for non-line-of-sight object detection.
- Safety should not only be about vehicle detection, but also incorporate Vision Zero and the 5 E's, one of which is engineering, and Complete Streets.
- There's a lot of immediate safety data needs, especially with the quality, timeliness, and format of crash data. On the auto side, accelerating the implementation of safety features to protect both occupants and VRUs.
- Ongoing and structured information exchange for each of the areas where safety standards are being developed to ensure repetition is not occurring.
- Complete and safe trip scenarios that include vulnerable populations, e.g., people in wheelchairs, people with visual disabilities, adults with children, people crossing an intersection at different rates of speed, for example, joggers vs. adults with children, or older adults.

### Related Standards and Standards Development Activities

Based on interviews and questionnaire results, experts identified needs or considerations that they believe would be important to advance standards development in this area.

The following existing or emerging safety-related Standards, Standards Development Activities, and Technical Reports standards were identified. The standards in **bold** are those most frequently mentioned.

- Vehicle Automation
  - SAE J3016: Taxonomy and Definitions for Terms Related to Driving Automation Systems for On-Road Motor Vehicles
  - SAE J3171: Identifying Automated Driving Systems-Dedicated Vehicles (ADS-DVs) Passenger Issues for Persons with Disabilities
  - SAE J3114: Human Factors Definitions for Automated Driving and Related Research Topics



- UL 4600: Standard for Evaluation of Autonomous Products
- ISO 21959-1: Road vehicles — Human performance and state in the context of automated driving — Part 1: Common underlying concepts
- IEEE P2846: A Formal Model for Safety Considerations in Automated Vehicle Decision Making
- BSI PAS 1880:2020 Guidelines for developing and assessing control systems for automated vehicles
- BSI PAS 1881:2020 Assuring the safety of automated vehicle trials and testing Specification
- SAE J3018: Safety-Relevant Guidance for On-Road Testing of Prototype Automated Driving System (ADS)-Operated Vehicles
- SAE J3064: Standard Specification for Allowable Defects in Rolled Goods for Interior Trim
- SAE J3134: Automated Driving System (ADS) Marker Lamp
- SAE J3187: Applying System Theoretic Process Analysis (STPA) to Automotive Applications
- SAE J3196: Describing human roles and capabilities as part of driving automation systems
- SAE J3198: Driver Drowsiness and Fatigue in the Safe Operation of Vehicles – Definition of Terms and Concepts
- SAE J3206: Safety Principles SAE J3092 - Dynamic Test Procedures for Verification & Validation of Automated Driving Systems (ADS)
- SAE J3216: Taxonomy and Definitions for Terms Related to Cooperative Driving Automation for On-Road Motor Vehicles
- Vehicle Connectivity (C2X)
  - SAE J2945/x: Dedicated Short-Range Communication (DSRC) Systems Engineering Process Guidance for SAE J2945/X Documents and Common Design Concepts
    - Part 9 deals exclusively with VRUs and the Personal Safety Message (PSM) that may be exchanged between a VRU and Infrastructure or Vehicle.
  - SAE J3161/1: On-Board System Requirements for LTE V2X V2V Safety Communications
  - ISO TR 23049: Road Vehicles — Ergonomic aspects of external visual communication from automated vehicles to other road users
  - Vehicle Safety
    - ISO PAS 21448: Road vehicles — Safety of the intended functionality
    - ISO 26262: Road vehicles — Functional safety
- Vehicle Cybersecurity
  - ISO TR 4804 Road vehicles — Safety and cybersecurity for automated driving systems — Design, verification, and validation methods
  - ISO/SAE DIS 21434: Road vehicles — Cybersecurity engineering

### ISO WG 24317 Gap Assessment (C-ITS VRU)

In its assessment of the current focus of C2X standards, the (C-ITS VRU) working draft reported that most current and emerging standards include the following concepts with respect to VRUs:

- Vehicle awareness of VRU and activates avoidance
- Infrastructure awareness of VRU and notifies vehicle
- VRU requests assistance at pedestrian crossing

- VRU clusters in intersection (emerging)
- VRU awareness of other VRUs (emerging)

The standards that were reviewed are as follows (note some of these standards are included in the list above):

- ETSI TR 103 300-1, Vulnerable Road Users (VRU) awareness; Part 1: Use Cases definition. September 2019
- ETSI TS 103 300-2 v0.4.1, Vulnerable Road Users (VRU) awareness; Part 2: Functional Architecture and Requirements definition Release 2. 2020-01
- ETSI TS 103 300-3, Vulnerable Road Users (VRU) awareness; Part 3: Specification of VRU awareness basic service. TBD
- 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 17438-1:2016, Intelligent transport systems — Indoor navigation for personal and vehicle ITS station — Part 1: General information and use case definition
- 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
- ISO 7176-21:2009. Wheelchairs — Part 21: Requirements and test methods for electromagnetic compatibility of electrically powered wheelchairs and scooters, and battery chargers
- ISO TR 22085-1:2019, Intelligent transport systems (ITS) — Nomadic device service platform for micro-mobility — Part 1: General information and use case definitions
- 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
- Regulation (EU) No 168/2013 OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 15 January 2013 on the approval and market surveillance of two- or three-wheel vehicles and quadricycles<sup>6</sup>
- SAE 2735 Dedicated Short Range Communications (DSRC) Message Set Dictionary (J2735\_201603)
- SAE J2945/9, Vulnerable Road User Safety Message Minimum Performance Requirements Recommendations, published 2017
- SAE J3116:2017 Active Safety Pedestrian Test Mannequin Recommendations
- SAE J3157:2019 Active Safety Bicycle Test Target Recommendations

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<sup>6</sup> Regulation is available at <http://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32013R0168&from=EN>

- SAE J3194:2019 – Taxonomy and Classification of Powered Micromobility Vehicles

Additional standards that may be used to describe taxonomies for assistive devices include the following:

- ISO 7176-14 Wheelchairs — Part 14: Power and control systems for electrically powered wheelchairs and scooters — Requirements and test methods
- ISO 7176-21 Wheelchairs — Part 21: Requirements and test methods for electromagnetic compatibility of electrically powered wheelchairs and scooters, and battery chargers
- ISO 7176-5 Wheelchairs — Part 5: Determination of dimensions, mass and manoeuvring space
- ISO 11199-1 Assistive products for walking, manipulated by both arms — Requirements and test methods — Part 1: Walking frames
- ISO 11199-2 Assistive products for walking, manipulated by both arms — Requirements and test methods — Part 2: Rollators
- ISO 11199-3 Walking aids manipulated by both arms — Requirements and test methods — Part 3: Walking tables
- ISO 11334-1 Assistive products for walking manipulated by one arm — Requirements and test methods — Part 1: Elbow crutches
- ISO 11334-4 Walking aids manipulated by one arm — Requirements and test methods — Part 4: Walking sticks with three or more legs

### **Standards Gaps**

Experts' inputs pointed the Research Team to various gap areas. These gap areas were aligned into categories for easier examination.

- Standards for passenger vehicle accessibility, including those related to ingress/egress, assistive device securement, and human-machine interfaces, are a high priority. These standards are necessary to realize the full benefits of automated and non-automated vehicles.
- For automated vehicles, detection and alerts are the two highest since these are the key inputs to realizing the technology.
- A holistic approach to standards development where expertise is pulled from various sectors, geographies, and SDOs. For example, "safety" should be more encompassing than just vehicle safety to include other aspects of road safety including infrastructure, enforcement, etc.

For the holistic review of VRU Safety, the (C-ITS VRU) study identified five major gaps in standards with respect to C2X and VRU based on a review of national and international standards. Figure 1 shows a generic process. A key research result from the assessment identified that the differences among VRUs will impact the safety of the VRU. This includes who they are (person – adult, child, older adult, person with disability), what type of conveyance they use (e.g., wheelchair, stroller), or micromobility vehicle (MMV) they use, and the connectedness of a mobile device either on their person or docked with their conveyance/MMV. Detection of the VRU profile is a critical factor in determining the avoidance behavior needed to ensure their safety.

The list of standard gaps identified by the assessment includes the following:

**Gap 1:** Inconsistent or missing VRU type taxonomies including:

- Missing taxonomies for VRU and VRU vehicle types (including devices or vehicles used for people with disabilities),
- Need clear and consistent type definitions for VRU types.

**Gap 2:** VRU concept model (role-based architecture) that includes roles and responsibilities:

- Ambiguous relationship between VRU, VRU Device (personal ITS station or connected device), VRU conveyance (e.g., wheelchair), and VRU vehicle (MMV),
- Building blocks to describe different configurations and VRU profiles,
- Role of technologies – wearables (relationship with mobile devices/personal ITS station),
- Transition between road user and vulnerable road user roles and types (e.g., traveler alighting from a bus or car).

**Gap 3:** Missing Use Cases for VRU scenarios:

- Extend and Add Use Cases for VRUs
  - Extend current use cases to differentiate between VRU types and actors,
  - Extend Use Cases for detecting and notifying different VRU profiles,
  - Extend Use Cases for additional clustering scenarios.
- Develop VRU viewpoint use cases
  - Use Cases targeted for VRU with Public Right of Way (PROW) compliance,
  - Use Cases for safe journey planning and travel,
  - Use Cases where VRUs provide trajectory prediction information (by VRU profile).

**Gap 4:** PROW data models and condition measures for VRUs

- Missing micromobility vehicle and pedestrian PROW data models (e.g., bicycle lanes, cycle tracks, walkways),
- Missing PROW attributes on obstacles and performance metrics on surface conditions (i.e., for smooth travel by wheelchairs, e-scooter, etc.),
- Missing journey planning criteria for safe, cooperative intersections.

**Gap 5:** Extend and develop messages and performance measures to support additional Use Cases

- Extend and develop messages, data element and additional performance measures to meet requirements emerging from the use cases and PROW models.

### ***Industry Priorities***

Respondents (n=62) when asked about their priorities for standards development in this area identified in order of priority the following standard areas:

1. Connected Vehicle Standards to advance safety for all users and in particular, vulnerable road users (e.g. vehicle to vehicle, vehicle to pedestrian, vehicle to bicyclist, etc.) (score = 3.53).
2. Automated Vehicle Standards to advance safety for all users and in particular vulnerable, road users (e.g. accessibility to the automated controls for persons with disabilities, safety for external persons with disabilities) (score = 3.40).

3. Shared Use and Micromobility Standards to advance safety for all users and in particular, vulnerable road/bike lane/sidewalk users (e.g. accessibility issues for persons with disabilities, minimum operator safety requirements for scooter share, bike share, etc.) (score = 2.85).
4. Detection, alerts, and haptic sensory information to Vulnerable Road Users (VRUs) of near collision and avoidance (score = 2.64).
5. Detection by vehicles and infrastructure of different types of profiles for VRU (e.g., for CAVs) (score = 2.63).

When asked about who should **lead** the standards efforts, the respondents overwhelmingly identified SDOs (73%) and Government (66.7%). Trade, advocacy groups, private sector and research organizations were also identified as key stakeholders in participating in the standards development effort, each garnering over 60%, with advocacy groups receiving over 72% of the votes.

In addition, one comment mentioned the need to include legal review of standards stating that “Legal considerations [should be] included, with participation and support of legal as well as technical experts and stakeholders.” Another commented that health professionals such as the American Medical Association should be included in the stakeholder list.

### ***Recommendations for Filling Gaps***

Experts highlighted the importance of collaboration and coordination within and across disciplines as well as across SDOs and geographies. Safety is paramount and the industry must work together to improve safety rather than compete with one another. To realize the safety benefits of advanced mobility technologies for all travelers, stakeholders need to work collaboratively across industries, including private sector developers, public agencies, non-governmental organizations (NGOs), and academia. Furthermore, there is a pressing need for coordination across various areas of expertise and SDOs as safety standards must evolve together. There is a need for ongoing and structured information exchange for each of the areas where safety standards are being developed to ensure repetition is not occurring.

## Payment Integration

### Summary Description

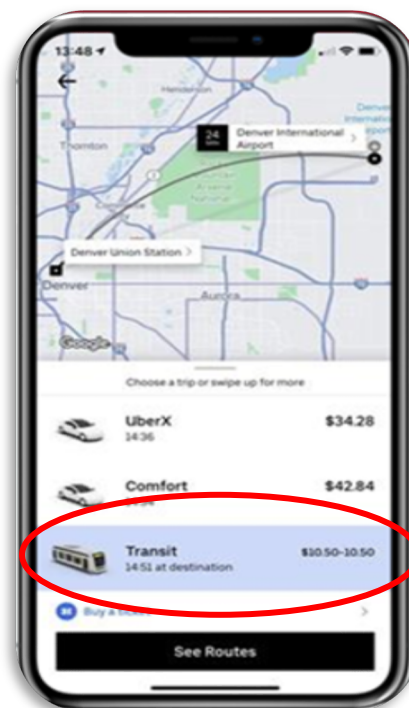
Integrated payment includes the process for facilitating payment across multiple modes using single or coordinated accounts. Different media and sales channels facilitate integrated payment which are moving towards account-based, mobile, and contactless payment systems. Public agencies have a major stake in the outcome of this ecosystem because they acquire a significant amount of customer information and usage information (e.g. ridership, origin-destination pairs, payment media) from the data, and can provide discounts and benefits to travelers, particularly to better serve underserved communities.

Payment systems are not only deployed by transit agencies through electronic fare payment systems (EFPS) and mobile fare apps, but also by public sector agencies contracting tolling, parking, electric charging stations, dynamic congestion pricing methods, and travel demand management options. Transit agencies work with non-traditional mobility providers (e.g., shared use providers, ridesourcing, and autonomous shuttles) to improve mobility options and address transit deserts, traffic congestion, and event management. Through payment integration, the public sector can better manage congestion and traveler load across all modes of transport for all types of travelers by offering discounts such as:

- High occupancy tolling (HOT) lane credit for multiple round trips on transit (example LA)
- Discounted or reserved parking for riders who carpool to transit stations.

There are several deployments around the United States and world-wide in which the public sector is developing open architecture “mobility platforms” to integrate multiple modes and non-traditional mobility services into an integrated payment platform. Some of these implementations offer “deep linking” to the payment channel of the service while others integrate the service information into a centralized back office module. This latter method exchanges information through a set of application programming interfaces (API) or software procedures using a software development kit (SDK). The emerging account-based systems that integrate mobility options enable an account holder to use their “transit account”, virtual or physical transit card on alternative mode options such as the MOD Sandbox demonstration deployed in Seattle by King County Metro where a rider can use their One Regional Card for All (ORCA) card to ride Via, a microtransit option.

Private sector companies, led by non-traditional mobility providers and app developers, are developing tools and platforms to integrate payment for public transportation options like transit and parking, as well as other shared use options. Examples include Pinellas Suncoast Transit Authority (PSTA) and Denver Regional Transit District (RTD) (see Figure 2), where transit is integrated in the Uber App. As of yet, none of the systems offer a single payment and access rights token (i.e., ticket) for a multiple mode trip



**Figure 2. Uber App integrated with Denver Regional Transit District (source: RTD)**

itinerary. Nor do they yet offer payment services for alternative modes such as fees for tolls, electric charging, or emerging dynamic pricing.

In other regions – in Europe and Asia, for example, some of these services are available but offered through publicly sponsored systems. These platforms integrate data using regional or national standards that are mandated by the national body. For example, the German standards body developed a “mobility platform” that incorporates journey discovery, booking, payment, validation, rebooking and reporting processes for a single or multi-leg trip.

The USDOT FTA Mobility Payment Integration (MPI) program in their scan of the practice (MPI, p., 57), addressed the issue of standards, specifically developing and accessing open APIs for use in any integrated payment system. The key takeaways from the discussion was that there are no open source APIs that cover mobility services and that even if an organization (public or private) licensed their payment APIs for use in a standard, those APIs would be tailored for their specific business needs.

### **Outreach Efforts**

Outreach efforts in this area consisted of the development of a white paper and interviews with numerous stakeholders from advocacy groups, transit agencies, vendors of electronic fare payment systems and mobile payment systems, as well as government and standard organizations.

The organizations interviewed are listed below.

- Advocacy Groups: Access Explorers and Paralyzed Veterans of America (PVA)
- Transit Agencies: Regional Transit District (Denver), Dallas Area Rapid Transit (Dallas), Smart Columbus (Columbus), PSTA, and KCM
- Vendors: Transit, American Eagle (OSPT Alliance), Bytemark, INIT
- Other Organizations: USDOT, ISO TC 204 Intelligent Transportation Systems, MyData

The Integrated Payment *White Paper* explored high level systems, functions, and challenges associated with standards development and adoption. The contents of the paper are summarized in this section.

### **Needs**

Unlike open payment environments for merchants, the mobility payment integration processes encompass traveler and business interactions as well as business to business interactions. The Mobility Platform API Comparison identified several major functions associated with payment (see Table 5).

**Table 5: Payment Functions Through Trip Lifecycle**

Processes \ Functions	Pre-Trip	En-Route	Post-Trip
Traveler and Business Processes for Payment  (where PAYG (pay-as-you-go) refers to open	Pre-payment and ticketing  Sales / product order	PAYG  Validation  Inspection	Post-payment  Authentication / settlement

or bank card payment methods)	Refund		
Traveler and Business Processes for Registration  (where eID refers to electronic identification)	Account registration / update / cancellation  Media registration / update / cancellation  eID registration / update / cancellation  Consent to share account content (cancel, update, usage info)  Secure ID registration / update	N/A	N/A
Business to Business Processes for Rules and Service Information	Rules – pricing, service usage, commercial  Service information (schedule, route, stops, calendar)	Cancellation and rebooking	Settlement for financial liabilities
Business to Business processes for Certification and Registration	Customer account / media/ eID information exchange (share account information)	N/A	N/A
Business to Business processes for payment and reporting	Valid/invalid lists (media, product, account)	Fare / fee Calculation  Validation / authentication  Inspection	Reporting (billing / invoice)  Daily Settlement and Reconciliation

Standardization for Integrated Payment standards should meet the needs for the following stakeholders:

- Public sector
  - General – equitable access to services by all residents and ability to provide subsidies from public funding programs.



- Transit – recording rider boarding (and alighting); provision for discount fare types, support for variety of ticket and pass products; first mile / last mile mobility options; inspection and enforcement.
- Tolling and dynamic road pricing – variable/dynamic pricing structure based on vehicle types and vehicle occupancy; enforcement.
- Electric vehicle charging -- including wireless charging methods anticipated for future deployment.
- Demand Responsive Services – for health and vulnerable populations requiring special services such as wheelchair accessible vehicles; inspection.
- Parking – collection of performance measures; inspection and enforcement.
- Vulnerable or underserved groups
  - Vulnerable groups needs are specialized by demographics (e.g., low income, non-English speakers, older adults), people with disabilities, geographical (rural), and technology availability (e.g., smart phone availability).
  - Ease of use, convenient and accessible.
  - Call in booking and payment to support people without access to cell or smart phones or cellular services (e.g., in rural environments).
  - Cash to credit / virtual wallet venues particularly important for unbanked or underbanked communities.
  - Autoload transportation account so that vulnerable populations do not need to physically add additional value to their accounts.
  - Validation for discount (e.g., age, disability) integrated with card so individual doesn't need to show credential while boarding.
  - Voice-activated or “be in” capability so person with physical disability can pay more easily.
  - Consistent screen readers at kiosks and ticket vending machines (TVMs) such as JAWS to provide consistency from system to system (impacts people with visual disabilities – blind or low vision community).
- Individual control and consent for sharing PII on different levels (e.g., personal information, health related information, transportation account information, payment cards/wallet information).

The public sector requirements have needs to validate access rights and data collection for transit, tolling and parking. For example, many mobile fare payment apps use visual verifiable validation (V3) or flash pass where the payment is verified by the operator, and not recorded in the electronic filing and payment system (EFPS). In addition, different modes have different methods of detecting and validating payment – transit uses “tap” readers, while tolling uses longer range readers. This payment method is not sufficient for a long-range option for the transit industry since critical information is not collected. Other critical needs that must be met to be inclusive are:

- Options for cash payment to meet the needs of the unbanked and underbanked.
- Provision for people without access to wireless or internet via computer and/or mobile smartphone (call center option).
- Provision for non-English speakers (translators either via payment/sales channels or via call center).

The Mobility Platform API Comparison (version 2) white paper identified additional needs during the outreach effort these include the following:

- Seamless, multimodal trip planning for travelers including booking, payment, providing access credentials (ticketing), and reporting<sup>7</sup>.
- Backoffice reconciliation and settlement standard formulas (for liabilities incurred by pre-paid functionality)<sup>8</sup>.

### ***Related Standards and Standards Development Activities***

Many standards and requirements that drive integrated payments system are in a nascent stage or are described as frameworks and use cases. The following organizations have developed standards or APIs for open architecture integrated payment:

#### **Framework/Architecture and Use Cases**

- ISO TC 204 WG 8 developed role-based architectures which include detailed use cases for multimodal service providers and media. In addition, the working group is developing testing protocols for validating interfaces from a variety of open architectures and standards developed by multiple national bodies. The specific standards that will be reviewed include<sup>9</sup>:
  - (CTSA) ISO TR 21724-1:2020 Intelligent transport systems -- Common transport service account systems -- Part 1: Framework and use cases
  - (IFMS) ISO 24014-1:2020 Public transport -- Interoperable fare management system -- Part 1: Architecture
- ISO TC 204 WG 5 and 19 are also developing payment standards that support parking, tolling and smart cities.
- APTA: Has developed Universal Fare Collection Standards, but primarily these are related to contactless payment and were developed in the late 2000s.

#### **APIs or SDKs**

- CEN/TS 16614-3 Public transport - Network and Timetable Exchange (NeTEx) - Part 3: Public transport fares exchange format (also includes fare systems use cases for train, bus, coach, metro, tramway, ferry and their submodes).
- Calypso and Open Standard for Public Transportation Alliance (OSPT Alliance) standards (ongoing)
  - Focused on user front-end interoperability standards (e.g., card (and virtual card) protocols, transaction, and messaging standards) in a regional setting
  - Calypso and CI-PURSE (from OSPT) joined forces to harmonize their standards activities

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<sup>7</sup> Input from RTD (1/23/2020)

<sup>8</sup> Input from DART, (5/6/2020)

<sup>9</sup> These standards will be published in 2020; ISO TR 21724-1 was approved in Spring 2019; ISO 24014-1 is currently being balloted; the previous version was published in 2015.

- MyData Global, Specification and Code and Reference Implementation ([www.mydata.org](http://www.mydata.org))
- Open Architecture APIs<sup>10</sup> for a mobility platform – (deployments)
  - New York Metropolitan Transportation Authority (MTA), OMNY payment system
  - Payment app vendors (Uber, Masabi, Lyft, etc.)
  - TriMet Hop Fastpass™ fare payment system
  - Columbus Smart Cities Pivot and Common Payment project
  - Dallas Area Regional Transit (DART) GoPass®
  - Los Angeles MTA (LA Metro), TAP system
- World Wide Web Consortium (W3C) Payment Handler / Request APIs (<https://developers.google.com/web/updates/2018/06/payment-handler-api>)
- Alliance for Parking Data Standards (APDS) International standardization efforts are underway at ISO/TC204/WG19/ projects include: TS5206-1 and TR24321
- Payment Card Industry (PCI) for card, hardware, and system security certification

### **Standards Gaps**

The gaps in integrated payment are in the process of being filled by proprietary vendors and closed application programming interfaces. The types of transactions and data exchanged need to enable integration is complicated, contain PII, and are subject to different commercial and pricing models.

Having said that, payment transactions using an open payment product such as a credit, debit, or prepaid card are not the major issue. Open payment systems that use these types of instruments are governed by banking rules and regulations subject to the following standards and protocols:

- ISO 8583 which defines messages, data element, code values, and organization registration rules
- ISO/IEC 14443 which defines rules and protocols for proximity, tap and virtual cards
- Standards for Near Field Communications (ISO/IEC 18093 and ISO/IEC 21481)

These standards have enabled transportation systems to interoperate with the leading card networks like Europay, Mastercard, or Visa (EMV). Integration with card network providers requires agreements and integration of proprietary platforms whether the network is provided by a card network company like the EMV networks, or a virtual wallet provider like ApplePay or GooglePay. Standardizing these agreements may be an area that should be addressed. Currently several transit agencies, platform vendors, and others have agreements with one of the major network companies and with wallet providers. Transit and multimodal providers are working with these organizations to address some specific transportation issues through several standard organizations.

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<sup>10</sup> These are APIs that are proprietary or owned by a developer but are shared with other systems to share information.

Perhaps the more critical area for standardization is the backend – business to business, exchange of information in order to build a seamless experience for transportation users. The mobility platform identifies these types of information data sets that require standardization:

- Data concepts to describe
  - Commercial rules (reconciliation and settlement timing, fees, data sharing agreements)
  - Pricing rules (fare, product, parking, and road pricing descriptions)
  - Service usage
  - Travel histories and reporting semantics for consistency
- Traveler consent data exchanges including by definition of each state (examples include agree (by level of data), revoke, cancel) and B2B actions to take regarding states
  - Business to business exchanges and rights based on traveler consent requests

### ***Industry Priorities***

In the outreach questionnaire, participants were asked to identify potential needs to advance payment integration standards. They were provided three options (shown in order of highest ranked result with 33 people responding):

1. Reference architecture that describes the actors and scenarios (use cases) that can be used to build and associate interoperable payment systems. (score = 46%).
2. Information exchange standards that define rules for exchanging service product, pricing, calculation, and product and customer account data (including privacy and consent). (score = 29%).
3. Information exchange standards for point of sale and proof of payment data that support seamless trip tariff and payment across transportation and mobility options. (score = 26%).

Most respondents believe that SDOs (57%) should take the lead in developing these standards, with government (52%), and private sector companies (33%) as alternative leaders.

Alternative approaches were also voiced in the questionnaire. Most identified that different modes – transit, parking, tolling, shared use - have different needs. Some advocated for commercial vendors to open their APIs for public use, by standardizing meaning and formats.

“There is a fine line between the need for "standards" and the need for "clear ability to communicate." Different modes and types of organizations have differing needs for information and how they collect them. It's unclear if a single "one standard to rule them all" could be created and even if so, adopted by those keen on proprietary communications. Rather, commitments to make available APIs, make the documentation for those APIs available subject to reasonable screening, standardized nomenclature and variable definition, etc., could go a long way to making multi-agency/multi-mode integration easier without dictating policies of agencies, private providers, or technology vendors.”

### ***Recommendations for Filling Gaps***

Developing standards for integrated payment is very hard. There are multinational players in this arena, and the development requirements for “inventing” a standard from scratch is a significant, expensive, and complex. As mentioned by several outreach interviews, the effort would never be implemented due to length of time needed to develop the standard. There are several ways to reduce the level of effort by

basing the standards on existing efforts, and they can be combined to establish a solid foundation for comparing and harmonizing APIs from multiple vendors.

**Option 1 - Develop Detailed Reference Architecture:** Develop a reference architecture that drills down into detailed information flows. Similar to the National ITS Architecture, the detailed reference architecture will describe the actors and information flows that support the processes identified in the T2B and B2B On-Demand framework.

**Option 1 Approach:** Existing architecture specifications already support integrated payment including a role-based architecture called the Interoperable Fare Management System (IFMS) standard. The architecture does not drill down to the detail needed to ensure interoperability, though it provides a solid framework by which to start the process. The IFMS approach will need to more clearly define back office B2B processes and drill down to information flow descriptions which it currently does not support; the detailed level will need to drill down to the use case level of detail as described in Option 2.

**Option 2 - Standard Use Cases:** Develop detailed use cases that drill down to the typical and alternative flows that are needed to address all information flows. Include similar methods used by the Unified Modeling Language (UML) methodology by augmenting the use cases with context or sequence diagrams.

**Option 2 Approach:** Work with a public sector organization (e.g., TriMet) who “own” the use cases that document the information flows of their payment system, specifically the areas identified in the B2C and B2B processes. Augment and normalize the approaches so they are generic for all organizations and modes. Concurrence on system and stakeholder names is essential for making this approach consistent for use. The set of use cases will need to be augmented to support dynamic pricing, tolling, parking, demand responsive and on-demand payment options.

**Option 3- Data Dictionary for defining Mobility Payment Options:** In coordination with Options 1 and 2, develop a data dictionary to standardize the message content/data concepts including their meaning, syntax and enumerated values.

**Option 3 Approach:** Similar to the approach for addressing option 2, many transit agencies have data dictionaries and data models that support their payment systems. The data dictionary will need to be augmented with dictionaries to support dynamic pricing, tolling, parking, demand responsive and on-demand payment options.

**Option 4 - License Existing APIs from Owner:** USDOT establishes an agreement with a public or private vendor who agrees to publish and open source their proprietary APIs that allows them to be updated and augmented to meet all modes and payment methods as needed. The effort would augment the APIs, set testing requirements and procedures, identify the encoding / serialization method. Certification requirements should be established to verify compliance of the API.

**Option 4 Approach:** Engage a public or private sector developer to use their APIs and publish them in an on-line password protected website. This approach may be implemented as a public/private partnership to ensure the APIs are sustained and support public and private needs. The consortium should also include a governance structure which manages contributors,

developers, subject matter experts, including update and participation by different modes, operator types, and end-users to ensure that the changes meet the needs of the multimodal and accessible traveler.

All the options would be implemented under an existing trade association or standards organization depending on the origin of the work effort.

## Complete Streets

As summarized in the *Standards Survey White Paper* [p., 25], major efforts are underway to address infrastructure / paths of travel domains. The infrastructure and paths of travel domains are categorized in this report by the concept of **Complete Streets**. This concept was initially a USDOT initiative and later augmented by design, performance and policy elements promoted by NACTO and Smart Growth America, which defines Complete Streets as those “designed and operated to enable safe access for all users, including pedestrians, bicyclists, motorists, and transit riders of all ages and abilities<sup>11</sup>.”

The Complete Streets infrastructure elements consist of representing transportation and modal networks including their geometry, connectivity, condition, and performance (management, usage and reporting on the network elements). For example, the design elements that drive standardization may include ADA Accessibility Guidelines (ADAAG) and Accessibility Guidelines for Pedestrian Facilities in the Public Right-of-Way (PROWAG), as well as emerging planning approaches for walkability (outdoor and indoor), bicycle / micromobility vehicle paths, including location of sensors to support navigation. These Complete Streets initiatives were categorized into two groups wherein significant work is currently underway:

- Curb Access and Management
- Public Right of Way (PROW) and Indoor Navigation Models

## Curb Access and Management

### *Summary Description*

Considerable efforts are taking place in the area of curb management standards, primarily due to the “rise of ride services and the growth in urban goods delivery”<sup>12</sup>– this situation is “challenging traditional ways of

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<sup>11</sup> Smart Growth America, What are Complete Streets, n.d.

<https://smartgrowthamerica.org/program/national-complete-streets-coalition/publications/what-are-complete-streets/>

<sup>12</sup> International Transport Forum, The Shared-Use City: Managing the Curb, © OECD/ITF 2018, page 7, [https://www.itf-oecd.org/sites/default/files/docs/shared-use-city-managing-curb\\_3.pdf](https://www.itf-oecd.org/sites/default/files/docs/shared-use-city-managing-curb_3.pdf)

managing curb space.”<sup>13</sup> Further, navigating the curb and the space around the curb is challenging for persons with disabilities, making curb management even more critical. The curb and attached rights of way, especially the sidewalk, can be blocked by infrastructure (e.g., electric or telephone pole), can be in poor condition, and can be obstructed by micromobility vehicles or other moving devices such as delivery robots.

Overall, the curb management standards efforts include the following:

- Developing common referencing standards for encoding information about curb use.
- Allowing automatic integration of curb use rules directly into third-party apps and algorithms by making regulatory intent available directly in machine-readable language.
- Enabling detailed knowledge of curb use rules and facilitating their monitoring.

One aspect of curb management as mentioned earlier is micromobility vehicle management. The efforts to develop these standards include the following:

- Cities are establishing and adapting new oversight tools, metrics, and practices. E-scooters, in particular, pose unique challenges and opportunities as a new vehicle type, with emerging regulatory standards.
- Guiding operator policies or practices to create a floor for equipment standards.
- Regulating and managing shared electric scooters and other shared micromobility devices at the local level.

A few of these efforts address access for persons with disabilities.

There are several use cases associated with curb management including the following:

- Collection, storage, and sharing of curb data and regulations to support, for example mapping tools, analytic models, and digital information exchanges,
- Collection and use of mobility service provider data, to, for example, monitor/measure regulatory compliance and performance in real-time or near real-time,
- Parking-related data sharing including on-street parking, accessible parking, and topological relationship with other curb elements, and
- Data sharing on obstacles that would hinder active mobility along a sidewalk or other right-of-way attached to a curb, such as street furniture, electric poles, curb cuts and the presence of parked micromobility vehicles.

Thus, the purpose of this section of the Outreach Report is to:

- Describe the outreach efforts associated with curb management standards,
- Identify the needs for standards expressed by stakeholders within the MAT industry,

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<sup>13</sup> [Ibid.](#)

- Identify curb management related standards and standards development activities,
- Describe the gaps in curb management standards,
- Report on the standard priorities as expressed by the MAT industry, and
- Provide recommendations to fill the curb management standards gaps.

### ***Outreach Efforts***

Stakeholders engaged for this effort include representatives from the following organizations:

- National Council on Independent Living (NCIL)
- Paralyzed Veterans of America (PVA)
- Shirley Ryan Ability Lab (SRAL)
- The Arc
- FHWA Office of Planning, Human Environment, and Realty
- ISO/TC204 WG 19
- SharedStreets
- SAE Mobility Data Collaborative

### ***SAE Mobility Data Collaborative Needs***

This section summarizes stakeholder feedback on issues and needs related to the development and use of multimodal and accessible curb access and management standards from both consumer and developer perspectives.

In addition to stakeholder engagement interviews, the list of issues and needs summarized below were informed by the questionnaire of MAT industry professionals. These findings have been grouped into the following four categories:

- Curb-Transit Interface Issues and Needs
  - Lack of data standards specifying conditions for bus lift and ramp deployment such as surface conditions, space requirements for user approach, and level boarding.
  - Inadequate environmental control standards for transit stops (shade, temperature regulation, ventilation, etc.).
- Sidewalk Issues and Needs
  - Inadequate maintenance of sidewalk surface conditions.
  - Inadequate enforcement and removal of environmental barriers such as snow and ice.
  - Inadequate monitoring, regulation and enforcement of mobile encumbrances such as shared bicycles and scooters parked in the path of travel.
- Standards development
  - Data for representing the curb, managing the curb, and provisioning this data to travelers is lacking; what can be said about curb access and management standards at present is immature in the scale of what needs to be resolved.
  - The goods movement aspect of curb management merits consideration along with the potential impacts of good movement on other curb users.
  - A plethora of data such as individual's origin/destination and their disability type and individual characteristics are required to enable AVs to provide accessible pick-up and drop-offs.



- Some flexibility or defined use cases is critical to making sure curb access and management standards are adopted appropriately. Policy makers should be involved from the beginning.
  - Sidewalk activities require close coordination of agencies to harmonize policies; these efforts will be particularly challenging, but necessary for automation of curb activities.
- Real-time performance metrics for the curb could include issues such as shifting travelers from a given corridor or travel period to another to get more throughput of that mode (e.g., off-hours freight delivery or shifting bicyclists to a corridor with a cycle track).
- Sustainability and Usability of Standards
  - Curb access and management data collection may be especially labor-intensive relative to other MAT standards areas.
  - Curb revenue streams (parking, fines, commercial loading/unloading, food trucks, etc.) could fund collection and maintenance of relevant data.
  - Local governments should coordinate to avoid redundant curb standards development efforts.

### ***Related Standards and Standards Development Activities***

Several emerging standards efforts for curb access and management encompass the following:

- **CurbLR (originally called CurbSpec)** – an open-source structured, standardized format developed by SharedStreets that is built on the OpenLR linear referencing system (an open-source, compact and royalty-free software project launched by TomTom International) that can be used by government agencies, citizens, and companies who want to store and share information about curb regulations.
- **Mobility Data Specification (MDS)** – a data standard and API for mobility service providers (e.g., dockless micromobility) developed by LA Metro that helps cities and regulators ingest and analyze mobility service provider data.
- **General Bikeshare Feed Specification (GBFS)** – a standard developed by the North American Bikeshare Association (NABSA) that describes basic bikeshare system information, such as location, operating hours, and company contact information; bikeshare docks (if present) and their capacity/utilization; and bike locations and availability (if dockless).<sup>14</sup> The purpose of GBFS is to provide current status information to the customer on bikeshare services and availability.
- **Alliance for Parking Data Standards (APDS)** – APDS are developing a consensus-built, international standard that establishes a common language for data elements and definitions in the parking, transportation, and mobility sectors in consultation with ISO TC 204 WG 19.
- **SAE J3194™** – a Taxonomy and Classification of Powered Micromobility Vehicles.
- **SAE Mobility Data Collaborative**

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<sup>14</sup> [https://www.dropbox.com/s/gl542a6ikyjsquy/RemixMobilityBrief\\_02\\_MicroMobilityDataPolicies.pdf?dl=0](https://www.dropbox.com/s/gl542a6ikyjsquy/RemixMobilityBrief_02_MicroMobilityDataPolicies.pdf?dl=0)

- MDC00002202004 Data Sharing Glossary and Metrics for Shared Micromobility – provides consensus-driven definitions for terms related to performance metrics of shared micromobility.
- MDC00001202004 Guidelines for Mobility Data Sharing Governance and Contracting – provides privacy-minded guidelines for data sharing agreements between public and private entities.

Interviews were conducted with members of organizations involved in the development and promulgation of these standards, including:

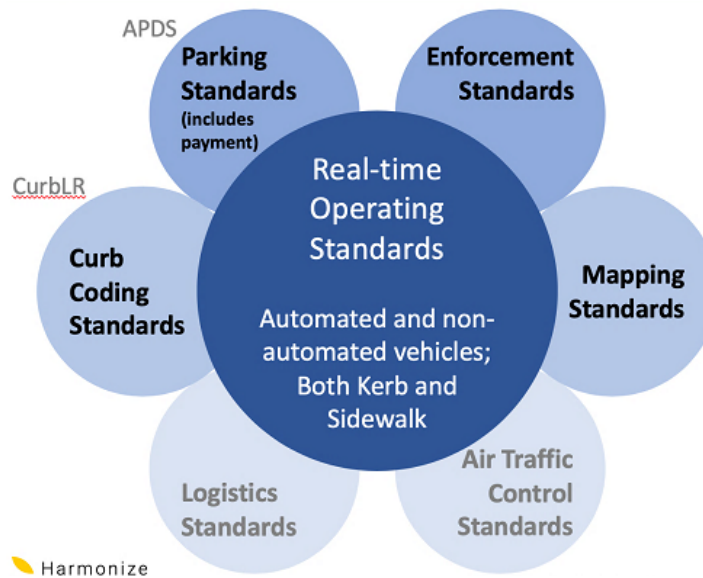
- **SharedStreets** – a project of Open Transport Partnership and NACTO which provides seamless information exchange between public and private entities.
- **Mobility Data Collaborative** – a consortium of mobility partners led by SAE focused on promoting cross-sector collaboration in data sharing, including promotion of data privacy protections and the establishment of performance metrics to effectively communicate the impacts of new mobility modes.
- **ISO TC 204 WG 19** – an international standards development working group within ISO’s intelligent transport systems working committee that is focused on addressing aspects of mobility integration including but not limited to curb, sidewalk, parking, and enforcement standards.

Interviews with these stakeholders focused on open-standards development activities and the identification of gaps and redundancies related to seamless MAT, including the following focus areas:

- Inventory, storage, and sharing of curb assets, regulations, and uses
  - Developers of the CurbLR standard are working to address demand side gaps through collaborations with transportation network companies and freight companies.
  - At this time, CurbLR does not include accessibility features such as curb cuts or curb ramps, however, the underlying linear referencing system could accommodate these features in future iterations; current accessibility features are limited to marking locations of disabled placards and related accessibility signage.
  - CurbLR does not factor for curb-adjacent uses such as sidewalks or bike-lanes, however, a complimentary specification called SharedROW is being developed to address this gap for use in planning applications such as modeling of the built environment; the SharedROW specification also seeks to provide a crosswalk between “slice-based” representations of the public right-of-way and tabular representations of features such as those used in OpenStreetMap.
  - One-dimensional linear referencing systems such as CurbLR that aggregate features to a street centerline are designed to ease and facilitate interoperable storage and sharing of curb assets and regulations. These specifications may facilitate accessible pick-up and drop-off but have limited applications for accessible navigation that requires dynamic modeling of real-world, real-time conditions in multiple dimensions (e.g., the presence of an undulating curb or a scooter obstructing an accessible path).
  - ISO/TC204/WG19 is developing the TS4448 roadmap for curb and public right of way standards in anticipation of increased demand for curb space and eventual automation of ridesharing fleets and automation of deliveries (e.g., sidewalk delivery drones) that will place demand on both curbs and sidewalks.
  - TS4448 entails a four-stage effort that kicked off in April 2020. Two-and-a-half years are allotted for each of the four stages, the first of which includes defining terminology,

taxonomy, and architecture. Later stages will include curb operations protocol, sidewalk operations, and curb-sidewalk operations integration.

- Accessibility concerns such as conflicts between sidewalk drones and people using mobility aids such as wheelchairs are under consideration as preliminary scoping for TS4448 sidewalk standards.
- Institute of Transportation Engineers (ITE) is building a geographic information system (GIS) curb management plug-in that accounts for existing curb allocations, curb allocation priorities, adjacent land uses, and goods movement. This development of this tool and an accompanying curb management practitioner guidance resource is sponsored by FHWA.



**Figure 3: TS4448 Builds on Existing Data and Operating Standards (Source: Harmonize Mobility)**

- Mobility Service Data
  - Efforts are also underway to develop data feeds and a data dictionary for micromobility vehicle static and real-time information.
  - Digital privacy concerns have stymied the wider use and adoption of MDS for managing and regulating micromobility fleets in real-time or near real-time (e.g., compliance concerns related to the California Consumer Privacy Act and the General Data Protection Regulation).
  - SharedStreets, the organization behind the development of Curblr, has built a tool and aggregation method to aggregate micromobility trips to the street centerline level to address privacy concerns related to MDS. The organization has also developed a tool to query MDS trips that protects user privacy.
  - There is a gap where free-floating bikes and scooters need to be identified as obstructions in the public right-of-way in real-time and where fleet operators can promptly respond and remedy the situation. However, privacy concerns along with telemetry and GPS data precision issues will make this a challenging gap to fill.

In addition to the above standards, several proprietary curb management and curb asset inventory data formats and tools are available. These include examples such as the following:

- **Coord** – a tool that employs augmented reality technology to quickly collect curb data through an iPhone app and transfer it to a central database for display on a map interface tied to relevant parking, traffic, and land-use regulations.
- **Allvision Parkview** – aggregates 3-D Lidar data collected by AVs other sources and analyzes this data using machine learning and cloud computing to deliver "ingestible data to inventory, track, and monitor...curb real estate and its assets."<sup>4</sup>
- **SPOT** – provides tools to digitize curbs by collecting curbside and curbside-related data and interpreting complex rules into APIs.
- **Flex Zones by AECOM** – a digital curbside management system enabling municipalities to exercise control over their most in-demand assets and to align curb use with the priorities and needs of these municipalities.

### **Standards Gaps**

There are numerous gaps in the curb access and management standards that were described above. These gaps can be categorized as follows:

- Characteristics of the curb and adjacent rights of way (e.g., sidewalks) specific to physical accessibility and paths of travel. For example, if the sidewalk is uneven in places, this could hinder a traveler who needs to access that sidewalk to make a trip. Another example is where a bus stop may be in a location without a sidewalk. If a person in a wheelchair wishes to access this particular bus stop, it may be impossible without a sidewalk.
- Dynamic / real-time aspect of curb and sidewalk usage: real-time obstacles for persons with disabilities. For example, curb, curb cut, and sidewalk conditions can change because of temporary obstacles, incidents, construction, or weather (e.g., snow, slush, or ice). For example, having real-time information about an accessible path of travel will allow any person with a mobility disability to choose a different bus stop that has an accessible path of travel.
- Performance metrics that indicate the physical accessibility of the curb and sidewalk. For example, in examining the presence or absence of sidewalks, a performance metric called sidewalk gap length ratio indicates the connectivity of the most critical sidewalk network<sup>15</sup>. The use of performance metrics might also indicate when a sidewalk needs repair to ensure that there is a viable path of travel for those using the sidewalk.
- Inclusion of goods movement particularly as it relates to curb and sidewalk usage. For example, given the use of delivery robots, if they occupy space on a sidewalk or block infrastructure like a curb cut, it could hinder traveler movement. There are standards that identify regulations that govern the use of the curb by delivery vehicles, but none that incorporate identifying delivery vehicles that use the sidewalk to transport goods. As with several of the other gaps, this particular gap includes both static and dynamic use of the curb and sidewalk.

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<sup>15</sup> Sidewalk Network Inventory and Assessment for the Champaign Urbana Urbanized Area, February 2016, <https://ccrpc.org/wp-content/uploads/2016/02/SidewalkNetworkInventoryAssessment.pdf>, Page 77

- Harmonization of curb and mobility data standards to support, for example, visualization and real-time navigation of curbs and sidewalks. While considerable efforts are being conducted in standardizing curb access and management, the efforts do not necessarily incorporate other right-of-way characteristics (e.g., road centerline network), mobility data standards or even certain curb / sidewalk characteristics (e.g., sidewalk angle). Also, there is a gap between standards that reflect data that can be used for navigation and those that describe the right-of-way. In order to create routing opportunities in a multimodal situation, these standards should be integrated. In the interviews, it was recognized that this integration is very challenging and somewhat elusive even in a high capacity context like New York City.

There are a wide variety of organizations attempting to fill these gaps. They include the following:

- SharedStreets, which is a project of the Open Transport Partnership, a nonprofit organization;
- Harmonize Mobility, which is a private sector firm working with the International Organization for Standardization (ISO) on a standard drafted for operating automated vehicles and devices at curbs and sidewalks
- Private companies with proprietary standards including Coord, SPOT, Allvision and AECOM
- Institute of Transportation Engineers (ITE)
- International Parking and Mobility Institute (IPMI)
- Alliance for Parking Data Standards (APDS)
- North American Bikeshare Association (NABSA)
- Open Mobility Foundation (membership organization that governs MDS)
- SAE International
- Mobility Data Collaborative (A program of SAE Industry Technologies Consortium)
- MobilityData (membership organization that governs GTFS extensions – pathways, vehicles, fare, flex, translations, text to speech, attributions, and GBFS)

In addition to the above organizations, some specifications such as SharedROW are being developed through crowdsourcing efforts.

Standards with the most promise to fill the gaps identified earlier are:

- SharedStreets and SharedROW to fill the gaps related to the (1) characteristics of the curb and adjacent rights of way (e.g., sidewalks) specific to physical accessibility and paths of travel; and (2) dynamic / real-time aspect of curb and sidewalk usage,
- Open Mobility Foundation to address the integration of curb access and management, and mobility data standards, and inclusion of goods movement,
- ISO/TC 204 WG 19 by Harmonize Mobility and others to continue to address automation of the curb (e.g., pickup/drop-off and delivery), and
- ITE to fill the performance metrics gap.

### **Industry Priorities**

Based on earlier research activities, MAT industry professionals were asked to rank the following four curb access and management standardization needs based on order of priority, from highest priority to lowest priority. The 35 respondents returned the following the rankings:

1. Standardized data formats to support collection, storage, and sharing of curb data and regulations to support a variety of stakeholder needs and use cases such as mapping tools,

- analytic models, and digital information exchanges that support third-party information exchange. (score = 3.12).
2. Development of information exchange standards that help cities and regulators collect mobility service provider data and monitor and measure regulatory compliance and performance in real-time or near real-time while providing sufficient user privacy protections and spatial accuracy. (score = 2.76).
  3. Information regarding obstacles that would hinder active mobility along a sidewalk or other right-of-way attached to a curb, such as street furniture, electric poles, curb cuts and the presence of parked micromobility vehicles. (score = 2.17).
  4. Information exchange standards to support sharing of parking related data including on-street parking, accessible parking, and topological relationship with other curb elements. (score = 1.97).

Most questionnaire respondents believe that government should take the lead in developing these standards (71%), with SDOs (59%) and research organizations (24%) as alternative leaders.

### ***Recommendations for Filling Gaps***

There are two major recommendations to filling the gaps. The first recommendation is to focus on the harmonization of the efforts regarding curb management given that there are multiple and overlapping efforts to describe curb and connected right of way (ROW) (e.g., sidewalk) features, regulations, and related information including parking information. Since the current efforts are taking place around the world, this effort could be housed in one of the international SDOs. To ensure that accessibility is included in this harmonization effort, it is recommended that the US Access Board take part in this effort. To ensure that the goods movement industry is included in this effort, the appropriate ISO Technical Committee that addresses goods movement should participate in this effort.

The second recommendation to help filling the gaps is the development of real-time curb management standards – those that would be used to identify dynamic curb conditions. Given the advent of new curb pricing, reservations and management strategies, and automation and its anticipated impacts on curb use, real-time information describing curb use are necessary. In terms of automation, the machine readability of curb signage should be considered and included. Further, this development effort should include the real-time location of micromobility devices since there is no effort currently to standardize the identification of device locations in real-time. This is crucial to ensure that accessible travel paths can be determined in real-time as part of a “complete trip.” This effort could be accomplished by the same group undertaking the harmonization effort mentioned in the prior paragraph in addition to the Open Mobility Foundation because of their management of the MDS.

## **PROW and Indoor Navigation Data Representation**

### ***Summary Description***

Methods are being developed to describe and assess the performance of navigable paths for outdoor/indoor wayfinding and the public right of way (PROW) for travel by light transportation modes, rail modes, and for persons with disabilities or others using mobility devices. Collection, curation, representation and exchange of this information is critical to support a variety of applications including wayfinding and navigation; assessment of sidewalk and pavement conditions to support ADA compliance; and assessment of physical infrastructure conditions and connectivity to optimize MAT trip planning, navigation, and performance measures.

The following scenarios illustrate the need for standardization of PROW and indoor navigation data from individual, agency, and application development perspectives:

- An electric wheelchair user finds that their device will not clear the doors of a transit hub elevator or they need to exit the platform area in order to access the elevator.
- An assistive mobility device user is forced to circumnavigate a tree blocking the sidewalk
- A person with a visual disability collides with a protrusion extending from the side of a building
- To comply with ADA Transition Plan requirements, an agency hires a consultant team that collects and stores data on sidewalk surface conditions, inaccessible pathways, and intersection conditions in a custom format that is then documented in a report
- A mobile app developer is forced to reconcile a multitude of data sources to get an accurate representation of the multimodal travel network for a given area.

Many standards activities and deployments are underway to help address these and other PROW and indoor navigation issues. To facilitate complete trips, these standards need to account for the dynamic and multidimensional nature of MAT (services outages, surface topology, etc.). They should also account for the relative levels of stress or comfort that influence mode and route choice. Generation of navigable complete trips relies on the development of vocabulary and semantics to unambiguously describe all pathways on maps whether they are a particular class of bike lane, sidewalk, building/station portal, or conveyance between floors (e.g., elevator, escalator, stairs). PROW and indoor navigation standards based on “navigable map” criteria and building information modeling (BIM) also need to describe nodes, edges, and faces of areas.

The standardization of navigable paths in the PROW and indoors offers opportunities to improve MAT through a variety of applications. Example applications currently under development include:

- Multimodal level of service measurements (LoS) for bicycle paths and pedestrian footways (including indoor conveyances such as elevators and escalators)
- Use of electronic sensors to automate and standardize collection of physical infrastructure data
- Indoor and “small space” mapping models for collecting, navigating, and rendering travel path information particularly junctions between modal paths (e.g., parking to sidewalk)

These standards also offer potential for three dimensional (3D) and Virtual Reality (VR) rendering of travel paths, with applications including training for travelers with cognitive or mobility disabilities.

Addressing these standards gaps offers significant potential to improve multimodal and accessible trip planning, wayfinding, and navigation. However, developing, deploying, and using these standards presents a variety of challenges. Issues include:

- Data collection and maintenance will require significant effort and expense
- Public agencies have limited regulatory incentive to collect PROW/indoor navigation data for accessibility purposes
- Modal conflicts in the PROW are likely to increase as demand for these spaces increases (e.g., conflicts between sidewalk delivery drones and other sidewalk users)
- PROW and indoor navigation standards also need to support safe trips for wayfinding and navigation purposes

### **Outreach Efforts**

Outreach consisted of interviewing stakeholders from a variety of areas to identify needs including advocacy groups, government, transportation organizations and associations who are developing tools and specifications, and industry. Many of these interviews were held in coordination with the Curb and Micromobility Management focus area. The PROW representation is needed to manage its use.

- Advocacy Groups: Access Explorer, Paralyzed Veterans of America (PVA)
- Government: Federal Geographic Data Committee (FGDC)
- Transportation Associations: SharedStreets, Harmonize Mobility
- Other Stakeholders: Fehr & Peers developing a separate specification (Shared ROW) that builds upon SharedStreets' CurbLR specification

### **Needs**

Sidewalks, bicycle paths (lanes, cycle tracks), and junctions between modal paths are not well represented even though mobile apps and wayfinding and navigation tools depend on these tools. As described in the Summary Description, the centerline representation of navigable maps does not adequately represent paths people (vs. vehicles) use. More importantly, as the PROW and indoor paths become more connected to personal mobility devices and wearables, mapping and characterizing the C2X communications technologies and consistent messages along PROW and at intersection will become necessary. Enumerated below are critical needs that require representation in navigable maps:

- Sidewalk Paths
  - Attributes: sidewalk-segments, width, surface type, thru width, non-thru width, surface conditions
  - Paths of travel to safe, and accessible pick-up / drop-off points
- Sidewalk Obstacles
  - Furniture, protrusions from buildings, and rough or broken sidewalk surfaces
  - Location and 3D rendering
- Sidewalk Conditions
  - Roughness / smoothness based on surface type
  - Safety/accessibility rating for different types of VRUs and VRU conveyances (bikes, scooters, wheelchairs, strollers, people with mobility disabilities)
- Nodes and junctions
  - Describe transition from one mode to another (pickup drop off points for buses/ TNCs/taxis/ shared use, intersections/crosswalks, parking, etc.)
- Curb cut



- Attributes: type, surface, location, slope – including if it is greater than 1:12, 3D description of slope<sup>16</sup>
- Conveyance (elevator / stairs /escalator)
  - Attributes: location, dimensions, control buttons (outside/inside for elevator)
  - Conditions and operating status<sup>17</sup>
- Ramps
  - Attributes: slopes, lengths, width, railing (height), etc.
  - Conditions: icy, slippery, etc.
- Navigation aids for navigation through indoor facilities and signs
  - Communication / device types and protocols: C2X / RSE (e.g., radio-frequency identification (RFID), DSRC, Bluetooth)
  - Paths and places (locations) in a building
  - Standard formats for messaging places within a building or directions to places within the building

The most important set of needs comes from the United States Access Board who is developing Public Right-Of-Way Accessibility Guidelines (PROWAG). These guidelines will provide clear policies and rules that address accessibility characteristics for public sidewalks. As stated,

- “The Board’s ADA and ADAAG focus mainly on facilities on sites. While they address certain features common to public sidewalks, such as curb ramps, further guidance is necessary to address conditions and constraints unique to public rights-of-way.”

The implementation of these policies can guide attribute naming and enumerated values, as well as the assessment of “safe” PROW features.

### ***Related Standards and Standards Development Activities***

There are many competing standards that support topological features associated with indoor navigation mapping, building information modeling (BIM), connections between levels, and public right of ways.

### **Navigable Maps / Indoor Navigation**

- Open Geospatial Consortium (OGC) –

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<sup>16</sup> Interview identified that “crosswalks should not have a slope greater than 1:12, especially when there’s a slant next to the slope.”

<sup>17</sup> From interview: “When **elevators are out of service**, entire stations can become inaccessible at the drop of a hat. Standards should exist that address how/when information about this outage is provided to the public, in addition to additional standards or requirements that help facilities avoid one outage hindering access to the entire building or service.”

- CityGML for building/indoor navigation  
[https://portal.opengeospatial.org/files/?artifact\\_id=49000](https://portal.opengeospatial.org/files/?artifact_id=49000)
- Indoor Geography Markup Language (IndoorGML) for the seamless navigation between indoor and outdoor spaces
  - Pilot (2019) -- <http://docs.opengeospatial.org/dp/19-004.html>
  - Description of seamless transitions from indoor to outdoor spaces -- <http://docs.opengeospatial.org/dp/19-004.html>
  - Use case for mobile location services for people with visual disabilities -- [https://portal.opengeospatial.org/files/?artifact\\_id=64644](https://portal.opengeospatial.org/files/?artifact_id=64644)
- ISO TC 204 – Geographic Data Files (GDF) used to model and describe road network and other geographic data.
- ISO 17438 series on Indoor navigation for personal and vehicle ITS station<sup>18</sup>
  - Part 1: General information and use case definition
  - Part 2: Requirements and specifications for indoor map data form
  - Part 3: Requirements and specifications for indoor positioning reference data form
  - Part 4: Requirements and specifications for interface between P/V and central ITS station
    - Note: P/V refers to Personal/Vehicle ITS Station
- Open Street Map (OSM) (includes attributes for ramps, sidewalks, bicycle paths) but population of the map is dependent on crowd-sourced data. Individuals may not apply the attributes in a consistent manner
- SharedROW (Fehr & Peers) is investigating methods (rules) to transition from navigable maps to 3D to VR
  - SharedROW is being developed to address this gap for use in planning applications such as modeling of the built environment; the SharedROW specification also seeks to provide a crosswalk between “slice-based” representations of the public right-of-way and tabular representations of features such as those used in OpenStreetMap. (see additional information in Curb Management focus area)

### **Pavement condition standards**

- ASTM E3028 - 16e1. Standard Practice for Computing Wheelchair Pathway Roughness Index as Related to Comfort, Passability, and Whole Body Vibrations from Longitudinal Profile Measurements
  - This standard is difficult to apply and measure according to researchers<sup>19</sup>.

### **Related Standards**

- SharedStreet specifications including OpenLR, CurbLR (see Curb Management section for more details)

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<sup>18</sup> An ITS-Station is the equivalent of a personal connected mobile device.

<sup>19</sup> Discussion with R. Guensler, Georgia Institute of Technology. July 2020.

- Note OpenLR is required to delineate uses of the curb. The specification provides a universal linear referencing system that can be used to relate different base maps to each other.
- GTFS-Pathways which describes navigation between levels using elevators, escalators, and stairs in transit hubs / stations; models the topological connections between levels by conveyance type.
- GTFS-Pathways Extensions being developed by Mobility Data Collaborative which includes station portals/entrances, levels, evolution (construction impacts on pathways), updates (status of pathways including portals)  
[https://docs.google.com/document/d/1qJOTe4m\\_a4dcJnvXYt4smYj4QQ1ejZ8CvLBYzDM5lyM/edit#heading=h.edxt3s6om1lm](https://docs.google.com/document/d/1qJOTe4m_a4dcJnvXYt4smYj4QQ1ejZ8CvLBYzDM5lyM/edit#heading=h.edxt3s6om1lm)).
- ISO/TC204/WG19/TS4448 series as it relates to sidewalks (the series of standards address curb management including sidewalks; the first part will define taxonomy which directly relates to this focus area).

### **Standards Gaps**

There are many efforts to develop standards in this area with limited harmonization among them. Many of the leading efforts, represented by the Open Geospatial Consortium (OGC), GDF, SharedStreets, ISO 17438 series, OSM, are all independent efforts. None of them are leaders in the effort, nor are there comprehensive tools to collect, manage, test conformance, and provision data. GTFS-Pathway Extensions and GDF specify a number of features associated with transit stations, platforms, conveyances, however, GDF is not implemented extensively in the US, and GTFS-Pathway Extension is still in development. Additionally, the standards have not been vetted or reviewed by advocacy groups for vulnerable populations.

Some specific gaps associated with most of the existing or emerging standards are as follows:

- Limited set of standards and stakeholder buy-in for attribute, condition and status definitions, terms, and values (see list in Needs section).
- Description of asset features that provide C2X WaN functionality.
- Limited reference architecture for collecting data on PROW characteristics, status, and condition.
- Missing data feed formats, verification/compliance methods, tools for collecting data.
- Knowledge gap on existing standards including how to apply the standard to collect, curate and distribute information.<sup>20</sup>

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<sup>20</sup> From the outreach effort, one questionnaire respondent stated that “Most state DOTs barely have a handle on conditions of their curb ramps, much less their sidewalk/path accessibility, but it is of high interest. See <http://vtrc.virginiaidot.org/PubDetails.aspx?PubNo=20-R17>”

### **Industry Priorities**

Based on earlier research activities, MAT industry professionals were asked to rank the following four public right of way / indoor data modeling standards needs based on order of priority, from highest priority (1) to lowest priority (4). They returned the following rankings (where the number of respondents is 21):

1. Use of electronic sensors to automate and standardize collection of physical infrastructure data such as sidewalk surface conditions. (score = 2.90).
2. Measures of the quality, completeness, and connectivity of bicycle paths and pedestrian footways. (score =2.75).
3. Standards that identify the presence and operational status of indoor/outdoor conveyances such as moving walkways, elevators, and escalators. (score = 2.24).
4. Indoor and PROW mapping models for collecting, navigating, and rendering travel path information. (score = 2.20).

When asked to indicate what roles stakeholder organizations should take in advancing public right of way / indoor data modeling standards and identified gaps, questionnaire respondents identified that government (63%) or SDOs (58%) should lead this effort. While all the other stakeholder categories should participate (Trade Associations (79%); Advocacy Groups (79%); Private Sector Companies (68%); Research Organizations (53%); Crowdsourced (50%); SDOs (42%); Government (42%)).

The most important take-away from the question on roles is that Government and SDO are the highest ranked for leading the development effort.

### **Recommendations for Filling Gaps**

Based on the questionnaire rankings and the gaps, the following activities may be recommended for filling the gaps:

- Create data dictionary of terms recommended by advocacy stakeholders that conforms with PROWAG.
  - From the questionnaire, one of the respondents stated: “Harmonization amongst adjacent standards via harmonized and consistent data dictionaries. This is why parking standards have failed to date, and why systems integration is so dammed hard.”
- Work with OSM to describe best practices for crowdsourced information.
- Engage trade associations and SDOs to discuss harmonization among the different indoor and PROW navigation standards.
- Facilitate the development of data collection, curation and verification tools that meet approved standards to accelerate adoption by public sector stakeholders.
- Work with C2X community to enumerate characteristics and values for C2X protocols and standardized message sets.

# Chapter 4. Next Steps

The outreach activities associated with this report gathered extensive and detailed end user and industry feedback to inform MAT standards activities and priorities. This included perspectives from disability organizations/advocacy groups, industry and government interest groups, SDOs, private companies, research bodies, and government agencies concerning the six MAT standard focus areas covered in this report (Mobility Platform APIs, Wayfinding and Navigation, Safety, Payment Integration, Curb Access and Management, and Public-Right-of-Way/Indoor Navigation Data Models). These outreach activities included:

- 30+ interviews with industry experts and disability community representatives.
- Presentation and discussion of relevant standards issues at five (5) industry expert committee meetings.
- Collection of 119 questionnaire responses representing a cross-section of industry, government, and disability community perspectives.

In addition to these outreach activities, three standards-focused white papers were developed on payment integration, mobility platform API comparison, and uniform transit signage. Information gathered from the above activities informed the MAT standard needs, related standards, and standards development activities, gaps, industry priorities, and gap filling recommendations presented in this report.

Next steps include a comprehensive assessment of outreach efforts to further develop and refine the Survey of Standards and Emerging Standards White Paper developed in earlier stages of this project. Following this, the Roadmap for Development of MAT Standards (Roadmap) will be developed. The Roadmap will identify standards development activities from the variety of SDO and non-SDO organizations along with additional activities that will support adoption of those standards in the near and long term. The Roadmap will also add drivers/impacts, stakeholder communities, support tools, and demonstration projects that will support standards development and adoption.



# Chapter 5. Appendices

## Appendix A. Acronyms

Table 6 lists the acronyms and defines the terms that are used in this document.

**Table 6. List of Acronyms**

<b>Acronym/Abbreviation</b>	<b>Definition</b>
ADA	Americans with Disabilities Act
ADAAG	ADA Accessibility Guidelines
ADS	Automated Driving System
ANSI	American National Standards Institute
APTA	American Public Transportation Association
API	Application Programming Interfaces
ATTRI	USDOT Accessible Transportation Technologies Research Initiative
APDS	Alliance for Parking Data Standards
AV	Automated Vehicle
BIM	Building information modeling
CEN	European Committee for Standardization
CT	Communication Technologies
CTSA	Common Transport Service Account
C-V2X/C2X	Cellular Vehicle to Everything [technology]/ Connected to Everything
DSRC	Dedicated Short Range Communications
EFPS	Electronic filing and payment system
FGDC	Federal Geographic Data Committee
FHWA	Federal Highway Administration
FLA	Forward Looking Assessment of Multimodal and Accessible Travel
FTA	Federal Transportation Administration
GBFS	General Bikeshare Feed Specification
GDF	Geographic Data Files
GTFS	General Transit Feed Specification
HMI	Human-machine Interface
IABNNS	Inclusive Audio-Based Network Navigation System
IEC	International Electrotechnical Commission
IEEE	Institute of Electrical and Electronics Engineers
IFMS	Interoperable Fare Management System
ISO	International Standards Organization
ITF	International Transportation Forum
ITS	Intelligent Transportation Systems

<b>Acronym/Abbreviation</b>	<b>Definition</b>
ITSA	International Transportation Society of America
ITU	International Telecommunication Union
MaaS	Mobility as a Service
MAT	Multimodal and Accessible Travel
MATSA	Multimodal and Accessible Travel Standards Assessment
MDS	Mobility Data Specification
MOD	Mobility on Demand
MPI	Mobility Payment Integration
MUTCD	Manual on Uniform Traffic Control Devices
NACTO	National Association of City Transportation Officials
NBIMS-US	National Building Information Modeling Standard-United States
NCIL	National Council on Independent Living
NGO	Non-governmental Organization
OECD	Organisation for Economic Co-operation and Development
OP	Outreach Plan
OSM	Open Street Map
OTP	Open Trip Planner
ORAD	On-road automated driving
PAS	Publicly Available Specification
PAYG	Pay as you go, refers to open or bank card network payment
PII	Personally Identifiable Information
PROW	Public Right of Way
PROWAG	Public Right of Way Accessibility Guidelines
PSTA	Pinellas Suncoast Transit Authority
PVA	Paralyzed Veterans of America
RT	real-time
RTD	Regional Transportation District (refers to Denver RTD)
SAE	SAE International
SC	Subcommittee
SDK	Software development kits
SDO	Standards Development Organization
SG	Strategic group
SIRI	Standard Interface for Real-time Information
SMB	Standard Management Board
STD	Survey of Existing Standards and Standards Under Development
SUTI	Standardiserat Utbyte av Trafik Information
TC	Technical Committee
TOMP	Transport Operator Mobility Platform [Dutch]
TRB	Transportation Research Board
TVM	Ticket Vending Machines
USDOT	United States Department of Transportation
VR	Virtual Reality
VRU	Vulnerable Road Users
WaN	Wayfinding and Navigation



<b>Acronym/Abbreviation</b>	<b>Definition</b>
WCAG	Web Content Accessibility Guidelines
WG	Working Group



# Appendix B. List of Stakeholders

Outreach interviews were conducted between December 2019 and May 2020 with these stakeholder groups.

Type of Stakeholder Group	Name of Organization	Standards Activity Area(s)
Advocacy	Access Explorers	All
Advocacy	Alliance of People with Disabilities	All
Advocacy	Complete Street consultants	PROW, Curb Access
Advocacy	Integrated payment transit agencies	Integrated Payment (IP)
Advocacy	Integrated payment vendors	IP
Advocacy	Mobility Platform Vendors and Agencies	Mobility Platform
Advocacy	National Council on Independent Living (NCIL)	all
Advocacy	Paralyzed Veterans of America	all
Advocacy	SAE Mobility Data Collaborative	Curb Access
Advocacy	Shirley Ryan Ability Lab	all
Advocacy	The Arc	all
Association	American Public Transportation Association (APTA)	Mobility Platform
Association	BikesforPeople (also Advocacy)	Safety
Association	ITS-A	Mobility Platform
Association	MOD-Alliance	Mobility Platform
Association	MyData	Mobility Platform, IP
Association	Shared Streets	PROW, Curb Access
Association (International)	Dutch Transport Operator Mobility Platform (TOMP) Consortium	Mobility Platform
Government	ARC-IT	Safety
Government	FHWA/ Turner Fairbanks	Safety
Government	USDOT FHWA	Safety
Government	USDOT FTA	IP
Government	USGS	PROW
International Government	ENTUR	Mobility Platform
SDO	ISO / TC 173/ SC 1 Wheelchairs	Safety
SDO	ISO TC 159 / SC 4 Ergonomics of Human-System Interaction	WaN
SDO	ISO TC 204 WG 19	Curb and Access, Safety
SDO	ISO TC 204 WG 8	Mobility Platform
SDO	MaaS Alliance	Mobility Platform
SDO	SAE On-Road Automated Driving Committee	Safety
SDO	SAE Safety and Human Factors Steering Committee	Safety
SDO	SAE V2X Communications Steering Committee	Safety, Mobility Platform



# Appendix C. Questionnaire Results

View the following document under “Supporting Files” tab for this document’s entry on the National Transportation Library’s ROSA-P system.

See [Questionnaire\\_Results\\_AllData.pdf](#)

# Appendix D. White Papers

View the following documents under “Supporting Files” tab for this document’s entry on the National Transportation Library’s ROSA-P system.

## **Mobility Platform API Comparison**

MATSA WP Mobility Platform API comparison.pdf

## **Uniform Transit Signage**

MATSA WP Transit Signage\_V6\_final.pdf

## **Integrated Payment**

MATSA WP Integrated Payment\_Final.pdf

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