Survey of Standards and Emerging Standards White Paper

Multimodal and Accessible Travel Standards Assessment - Survey of Standards and Emerging Standards White Paper

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16. Abstract

The Standards Planning for Multimodal and Accessible Travel services task will provide an assessment of standardization needs to support multimodal and accessible travel options by conducting a study to review standardization needs, assessing impacts on ITS and related standards that currently exist or are under development, and developing a roadmap for multimodal and accessible travel standardization work.

This document describes the methodology and description of a survey of standards and emerging standards supporting multimodal and accessible travel. The framework is based on the Open Systems Interconnection (OSI) model which characterizes the communications, interconnections, and encoding of information between systems. In addition, related standard artifacts (technical specification) such as architecture, use cases, safety and technology are also identified in "higher" layers of the framework.

The objective of this task is to conduct a survey of standards on the topic of multimodal and accessible travel. As presented in the standards inventory, there are many existing standards on this topic with more currently under development. The recent surge of standardization efforts in this topic can be largely attributed to the rise of shared mobility and emergence of new vehicle types, such as micromobility vehicles. Over 50 directly related and 150 related standards were reviewed and cataloged in this survey.

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Chapter 1. Introduction

Scope

This white paper lists standards, protocols and open specifications that address multimodal and accessible travel. In this report, “standards” are understood as any technical work items that are developed with the following goals: (i) streamline language and processes; (ii) facilitate interoperability; and (iii) reduce costs of technology deployment. These work items are housed, governed, maintained, and issued by various types of bodies. The document provides a framework using an enhanced Open System Interconnection (OSI) model to identify and classify current standards and standards under development that fall within the nine dimensions and six Mobility on Demand (MOD) program areas discussed in the Forward-Looking Assessment White Paper (see References, § 1). This survey groups standards into “profiles” that work together to better understand gaps and duplication of content and interoperability.

Background

As Mobility on Demand (MOD) is increasingly implemented by transit agencies across the country, it is clear that 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. In developing such standards, it is critical that they be identified based on the needs of all travelers, including persons with disabilities, the aging population, and US veterans. 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 these travelers. Through its efforts, the ATTRI initiative determined the importance of standards across four foundational considerations.

These considerations, combined with the six key areas identified for standards development under the MOD Operational Concept Report (Figure 1) and nine dimensions (see Figure 4, cited from the Forward Looking Assessment White Paper), provide the foundational factors for consideration in development of multimodal and accessible travel system standards.

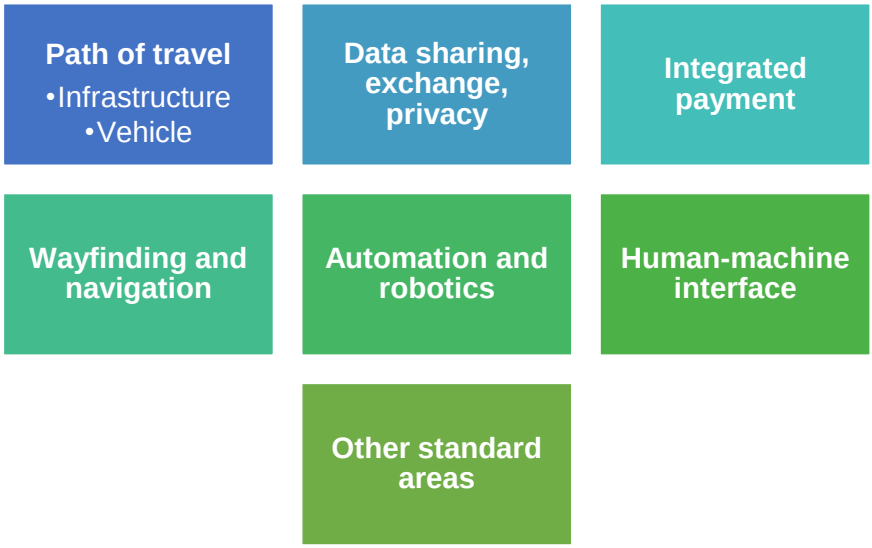


Figure 1. Key Areas Identified for Standard Development under Operational Concept Report

Standardization is essential to facilitate interoperability among systems and advance adoption of new technologies. In recent years, a spectrum of multimodal, on-demand, and accessible 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 vision for accessible, equitable, seamless, and 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).

References

1. Schweiger, Carol, et al. “FHWA-JPO-18-744 Multimodal and Accessible Travel Standards Assessment – Forward-Looking Assessment White Paper”. 6/21/2019.

Chapter 2. Standard Typology

The method used to classify the survey elements supports the discovery of gaps in deploying interoperative information technologies to better serve travelers. This section discusses the methodology used to classify the survey items using three perspectives to assess information technologies:

- **Interoperability** through traditional information technology typology, an enhanced Open Systems Interconnection (OSI) Layer model.
- **Domain** which covers policy and stakeholder dimensions. The nine domains are described in detail in the Forward-Looking Assessment White Paper.
- **Application area coverage** which associates the standards with the key USDOT MOD key program areas (detailed in the Forward-Looking Assessment White Paper).

The enhanced OSI model does not cover all the issues related to interoperability. Researchers, standard developers and standard development organizations[1] sometimes extend the model to include an information layer (layer 8) that describes data and architecture characteristics. The information extension is described in OSI Model Extension. In addition, this section describes the relationship of the survey elements to the Multimodal and Accessible Travel (MAT) standards to the Forward-Looking Assessment nine dimensions and six key areas in Relationship to MAT Forward Looking Assessment. Finally, each standard is subject to periodic reviews and updates. These systematic reviews and maintenance activities ensure that the standard stays relevant as technology changes and innovation alters user behavior.

OSI Model Extension

The OSI model extension is often used to classify information technology standards. Layers 5 through 7 are often called the data layers because they provide services that support the format, invocation, encoding, and transmission of data. Layers 3 and 4 describe the transport and networking requirements, and layers 1 through 3 describe the physical communications and are sometimes referred to as the plant layers. These seven layers are only part of the requirements to promote system interoperability. Data meaning, fitness for use (including quality, currency, lineage, etc.), and provision for use (including privacy) are other critical elements that drive interoperability. The National Transportation Communications for Intelligent Transportation System Protocols (NTCIP) standard framework[2] (as depicted in

[1] NTCIP 9001 v04, The NTCIP Guide. 2009 AASHTO, ITE and NEMA.
[2] Ibid.

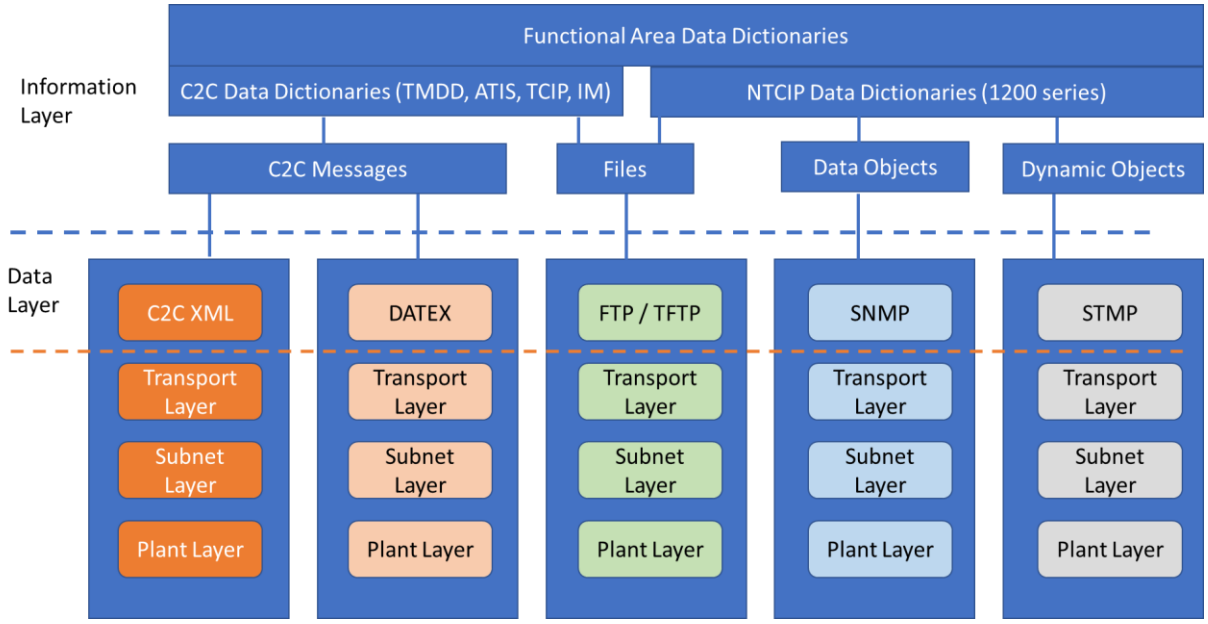


Figure 2 shows an additional information layer to the OSI model[3], as well as the bundled stacks that enable interoperability among standards.

In this “enhanced” NTCIP model, the information layer is composed of the data concept definitions, as well as their fitness for use, that is, the use cases and driving requirements and performance measures associated with their use.

[3] The NTCIP model is based on the Internet (also called the TCP/IP) adaptation of the OSI model. For more information see https://study-ccna.com/osi-tcp-ip-models/

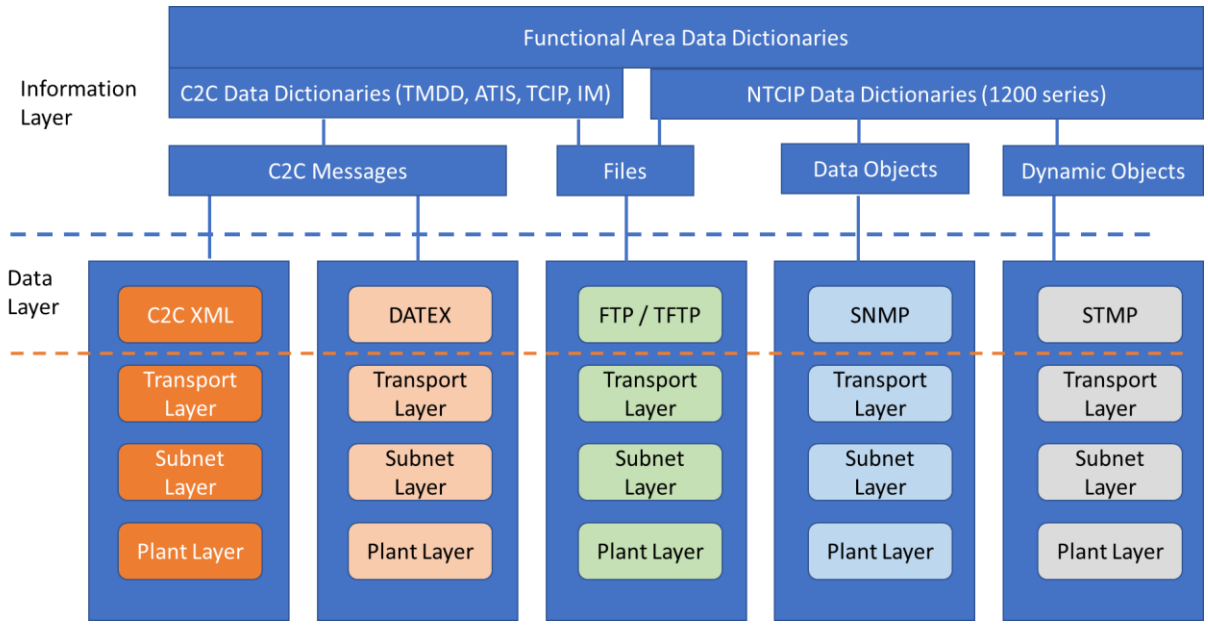


Figure 2. NTCIP Bundled Stack with Information Layer (Adapted from: NTCIP 9001 v04)

The “information” layer is adopted in the Multimodal and Accessible Travel Standards Assessment (MATSA) project as an eighth layer in order to incorporate the technical research developed by most standard development efforts as technical reports. The information layer is described in more detail in Information Layer below. Harmonization of multiple information layer standards is discussed in Information Harmonization.

This standards survey will focus on layers that are related to semantics, messaging, data security, and human machine interaction. These functions fall into layers 6 through 8 of the enhanced OSI model as shown in Figure 3.

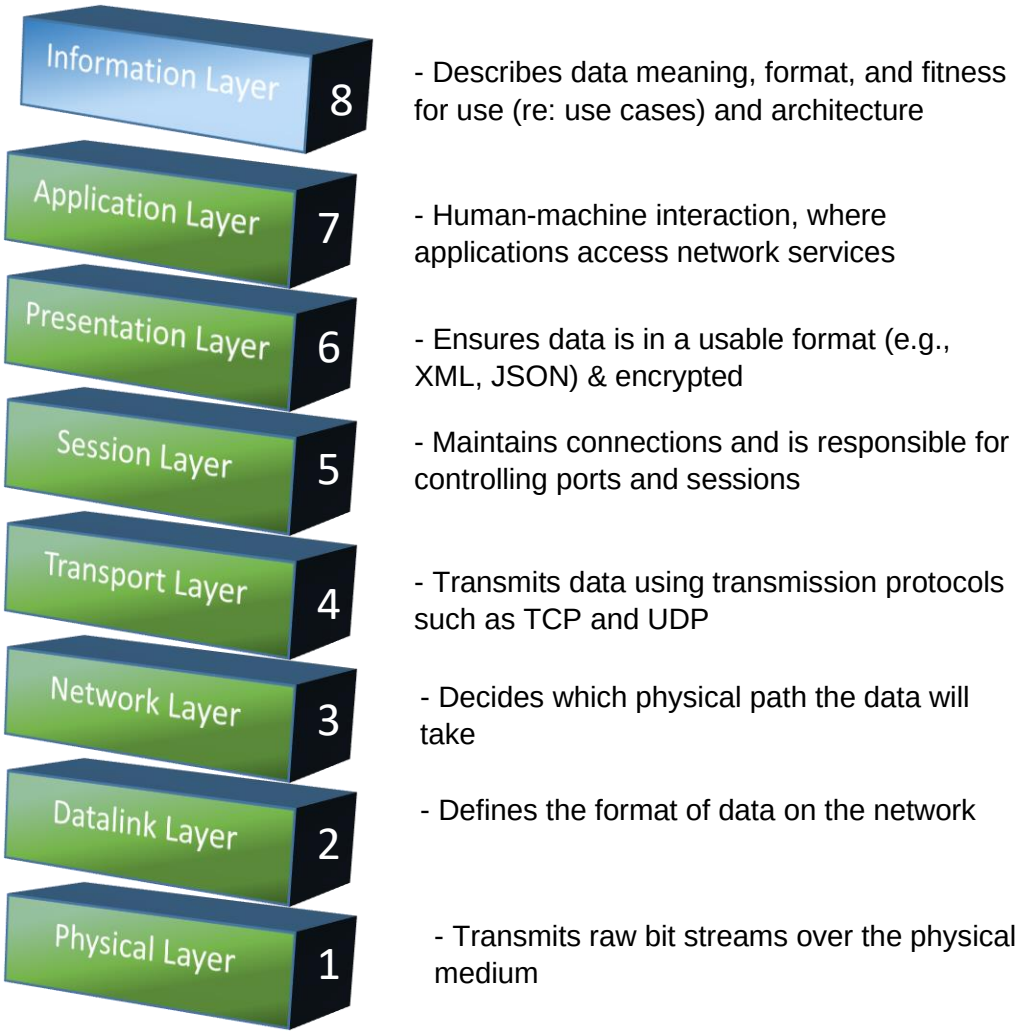


Figure 3. Using an Enhanced OSI Model to Classify Technology Standard Gaps

Information Layer

The artifacts that compose the information layer are typically published as technical specifications or reports by standards bodies, and specifications by trade associations, consortia, or grass roots organizations. These products generate the framework for deploying standards using industry standards associated with OSI layers 6 and 7.

The technical reports and specifications typically describe the following types of information:

- **Reference framework** – an architecture, typically role-based or functional that describes user roles and functions, as well as general interactions between entities.

- **Use Case** – scenarios that detail the flow of control, functions, and data flow between components in the reference framework. The use case descriptions typically incorporate performance needs, exception handling, and policy and regulation drivers. For example, a payment system data exchange changes when a prepaid versus pay as you go interaction is depicted.
- **Requirements** – derived from the reference framework; these include specific data, message, and service specifications.

The content of the requirements may be detailed in a technical specification or promulgated standard. Table 1 describes three specification types. These three types are usually contained in the same technical specification or standard to ensure consistency. In some cases, a data dictionary is referenced by message and service specifications to ensure consistency among a family of similar standards. This information harmonization approach will be discussed in the next section.

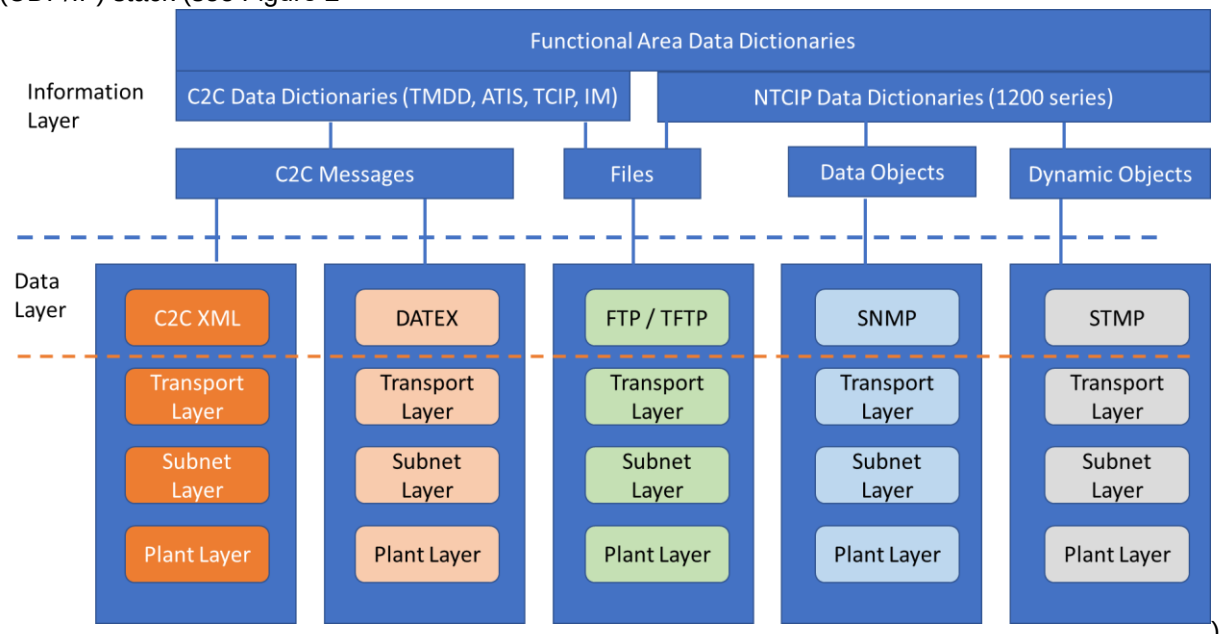
Table 1. Specification Types

Spec Type	Description of Typical Content
Data specifications	• **Glossary** -- defines the meaning of the data concept including exceptions and related definitions. • **Data dictionary** -- describes data semantics and syntax. • **Data frames** -- describes related data that may be grouped together based on functionality or to convey a data concept (e.g., latitude and longitude; transit route) • **Data model** -- describes the data entity identity, relationships between data concepts and rules between those relationships
Message specifications	• **Message** -- describes the set of information that communicates within a context. The message is typically composed of data concepts and incorporates constraints and conditions on its distribution or transmission. The constraints and conditions may include the encoding method, security provisions, message header content, as well as mandatory, conditional and optional data content. • **Dialog** -- describes a specified exchange of messages between two components as depicted in a reference architecture. Performance measures such as time to respond, latency, and response content are typically included in the message specification. • **Validation methods** -- describes how the message and message exchange (dialogs) will be tested to ensure that they meet the message specifications.
Service specifications	As more systems adopt services that perform a service such as transforming, visualizing or analyzing data, the methods used will become increasingly important. For example, machine learning techniques, linking microservices for situational awareness. To anticipate these service invocations, the following types of content is relevant: • **Functions and methods** – includes algorithms, rules and microservices applied to data to transform, analyze or process data. For example, estimating time of arrival from several input sources. Typically, the specification also includes the defined input, output and

	data quality provisions. Typically, this service definition is called a "white box" service, since the computational method is exposed. • **Inputs / outputs and quality** – describes a "black box" function, where the computational method is not known. • **Orchestration of linked services** – describes the order in which microservices are executed to produce a complex function.

Information Harmonization

Although the OSI approach builds modularity by layer, not all standards and protocols work together. To that end, standards are bundled into a profile that is tailored to meet specific criteria such as a Transmission Control Protocol/Internet Protocol (TCP/IP) or User Datagram Protocol/Internet Protocol (UDP/IP) stack (see Figure 2



).

Harmonization for the information layer requires that the architecture, data semantics and models are similar if not the same. These are required to ensure that data are interoperable across multiple modes, systems, and platforms.

Special care must be taken for the information layer. The MATSA roadmap cannot recommend two standards where the data meaning is not similar, if not the same. Definitions for Mobility as a Service (MaaS) is an example, where different glossaries are emerging that use different terms, conditions and rules for defining services. Recognizing the need for alignment of terms derived from different modes and domains, the International Standard Organization Technical Committee 204 (ISO TC 204) on Intelligent Transportation Systems is developing a data dictionary that maps all the standards, technical reports and specifications developed by working groups and related standard development organizations that provides a normative definition for all transportation related concepts inclusive of facilities, features, conveyances, transportation related assets, etc.

There are several competing traveler information standards as well as Technical Association authored specifications that promote concept names and definitions for a family of standards. A list of relevant bundled Intelligent Transportation System (ITS) standards are listed in Table 2. The list includes NTCIP, ITS standards (developed in 1990 and early 2000 by SAE, American Public Transportation Association (APTA), Institute of Electrical and Electronics Engineers (IEEE) and Institute of Transportation Engineers (ITE)), Dedicated Short Range Communications (DSRC) standards, Open GIS Consortium (OGC) standards, and General Transit Feed Specification (GTFS) family of standards. The list describes the family of standards as well as presents layer characteristics. Additional European Union mandated standards are also included in the table.

Table 2. Harmonized Information Standards

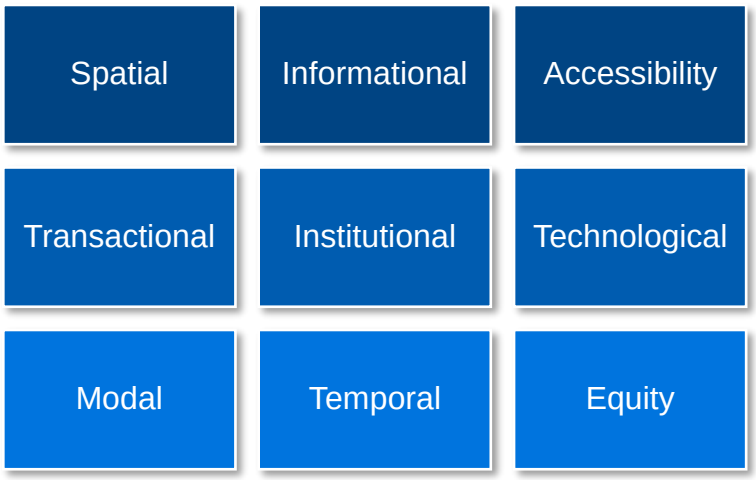
Harmonization Name	Description	OSI Application / Presentation Layer Standards
Connected Vehicle Standards	Connected vehicle or Dedicated Short Range Communication (DSRC) standards. Messaging standards are being developed by SAE (J2735 and J2945), while many communications (Wireless Access in Vehicular Environments (WAVE)) standards supporting connected vehicles (CV) are being developed by IEE	Abstract Syntax Notation One (ASN.1), Hex and eXtensible Markup Language (XML)
GTFS	A grass roots effort that describes public transit schedules (GTFS), real time position, status and estimate time of arrival (GTFS-realtime), flexible services (GTFS-Flex), and several other specifications under development that describe facilities and vehicle accessibility	American Standard Code for Information Interchange (ASCII (comma delimited files)) and gtfs-realtime protocol for Protocol Buffer cardinality
ITS Standards	Standards developed in late 1990s and early 2000s through a standard development effort underwritten by the USDOT. These include standard development organizations (SDOs) -- APTA, IEEE, ITE, and SAE. Standards include: • Advanced Traveler Information System (ATIS), • International Traveler Information Systems (ITIS), • Location Referencing Message Specification (LRMS), • Transportation Communications for Intelligent Transportation System Protocols (TCIP), • Traffic Management Data Dictionary (TMDD), • Emergency Management (EM)	XML, ASN.1, Representational State Transfer (REST)
NTCIP	Standards that describe several communications stacks and a common set of data for managing, controlling and monitoring	Simple Network Management Protocol (SMNP), Web Services (XML, Simple Object

	field equipment such as weather sensors, traffic signals, Closed Circuit Television (CCTV), etc.	Access Protocol (SOAP), and REST)
Open GIS Consortium (OGC) (TC 211)	OGC standards describe methods and formats to share spatial data files, including map and feature geometries, imagery, addressing, linear referencing, and positioning services. OGC and TC 211 work cooperatively to promulgate standards	Web service formats
CEN/ISO Geographic Data Format (GDF)	Similar to OGC standards, GDF map and data standards focus on transportation features and navigable maps. Much of the feature definitions are derived from European Committee for Standardization (CEN) data modelling efforts such as TRANSMODEL. The EU performed a gap analysis of GDF with respect to Connected ITS (C-ITS, similar to the US CV initiatives), Smart Cities and MaaS.	XML, REST, JavaScript Object Notation (JSON)
Other CEN family of standards	DATa EXchange standards (DATEX), similar to NTCIP and ITS Standards – ATIS and TMDD, are not compatible with US standards. The standards are used to provide information on current traffic network status.	
CEN Public Transport Standards	These include a data specification TRANSMODEL. It serves as the data dictionary and object model for other implementation models. Implementation models and specifications include Network Timetable Exchange (NeTEX) and Standard Interface for Real-time Information (SIRI).	XML

Relationship to MAT Forward Looking Assessment

The MAT Forward Looking Assessment [1] describes nine dimensions of policy and technology gaps that exist as well as technology standard areas to consider. The nine dimensions are shown in Figure 4 and are cross referenced against the seven standard areas shown in Figure 1.

This framework connects USDOT efforts to the standards that are listed in the Standards Survey. To that end, each standard in the list is associated with one or more of these dimensions and types. More information on the details of the dimensions and types are described in [1].



The following MAT dimensions together provide a framework of standards to consider

- **Spatial** identifies the physical location of a traveler at each stage of a "complete" trip, along with the infrastructure associated with each location (e.g., sidewalk ramps, lack of elevator), the features associated with the location (e.g., points, lines, paths), and the land use associated with the locations.
- **Informational** identifies data and information needs, and potential communication/ dissemination media at each trip stage and each stage of service provision.
- **Accessibility** can be infrastructure-based (handled in the spatial dimension), vehicle-based, and person-based (e.g., needs such as mobility aids and personal care attendants, abilities and opportunities to access life activities such as jobs, health care, and entertainment). Please note that in this white paper we differentiate between access and accessibility for people with disabilities. Access to mobility services refers to equity (this dimension is described below), and accessibility refers to a facility, vehicle, or other infrastructure being built in such a way that it can be traversed by a person with disabilities.
- **Transactional** covers trip request, reservation, and payment, and data exchange, sharing and privacy.
- **Institutional** identifies the organizations that provide transportation services and the relationships among the mobility service providers.
- **Technological** identifies the types of technology that facilitate MAT. These include but are not limited to those identified in the MOD Operational Concept, the ATTRI program, and the Future of Mobility white paper (written in January 2018 for the California Department of Transportation [Caltrans]).
- **Modal** identifies the types of transportation services that comprise MAT.
- **Temporal** identifies variations in the availability of opportunities across the day, week, or other time period.
- **Equity** identifies characteristics such as economic disadvantages, digital poverty, and the urban and rural divide.

Figure 4. Forward Looking Assessment Dimensions

Chapter 3. Organizations

Organization Types

As mentioned in the scope, this report describes “standards” as any technical work items that are developed with the following goals: (i) streamline language and processes; (ii) facilitate interoperability; and (iii) reduce costs of technology deployment. These work items are housed, governed, maintained, and issued by various types of bodies. In this section, the key bodies in the fields of multimodal transportation and accessibility are examined. The identified bodies are categorized in three dimensions: (i) geography; (ii) organization type; and (iii) industry.

Types of standard organizations

Standards can be either developed in a formal standards development organization (SDO) or non-SDO, industry- or community-based groups. Notable SDOs in the mobility field include the International Organization for Standardization (ISO) and SAE International, where formal standards are produced. In some cases, standards developed in non-SDO groups become de facto standards through widespread use and acceptance. Many of the non-SDO, de facto standards stem from grassroot efforts, industry groups (e.g., consortia, trade associations), non-profit or small corporations. An exemplary de facto standard is the General Bikeshare Feed Specification (GBFS), which was developed by a group of bikesharing operators under the facilitation of the North American Bikeshare Association (NABSA). It is important to note that the majority of de facto standards that were not developed in formal SDOs supports open-source development and open access, which has arguably contributed to the widespread adoption.

Industry

As some standards organizations, such as SAE International, ISO, European Committee for Standardization (CEN), and International Electrotechnical Commission (IEC), serve almost all industries with the need for standards development, most standards organizations specialize in specific domain and usually serve only one industry sector. For example, SAE International primarily has the standards portfolio in automotive, aerospace and commercial vehicle areas, and therefore it has attracted stakeholders throughout the mobility industry. It is also noted that the border between industries is not distinct--transportation and automotive industries have common stakeholders and frequently share similar standard needs, technical interest, and roadside electronic devices are mostly produced by transportation industry vendors.

Geography

The names of the organizations where the standards are housed often shed light on their geographic focus and footprint. The geographies specified in the name of the organizations represent where the organizations’ standards are widely adopted or the most influential. Government agencies in those

regions often cite their standards to address government regulatory issues, as the standards development processes engage stakeholders in their regions. For example, the European Union (EU) International Electrotechnical Commission Standardization (CENELEC) or European Telecommunications Standards Institute (ETSI) feed to their European focus. A growing number of standards organizations are expanding their footprint to more regions to meet the needs for international trade. Regional standards organizations, by mirroring international organizations, frequently develop and publish same standards by sharing publication number, such as between CEN and ISO, and between CENELEC and IEC.

Organization Table

A detailed table of organizations involved with developing standards and specifications related to MAT are presented in Table 3. These organizatons are leading development efforts of the standards inventoried in Appendix B.

Table 3. Organizations Developing Standards

Organization Name	Geography	Org. Type	Industry
American Association of State Highway and Transportation Officials (AASHTO)	US	SDO	Highway Design
American Public Transportation Association (APTA)	US	SDO	Public Transportation
European Committee for Electrotechnical Standardization (CENELEC)	EU	SDO	Electrical and Electronical Device
European Committee for Standardization (CEN)	EU	SDO	All
General Transit Feed Specification (GTFS)	Int'l	Community	Public Transportation
Institute of Electrical and Electronics Engineers (IEEE)	Int'l	SDO	Electrical Eng.
Institute of Transportation Engineers (ITE)	US	SDO	Transportation
International Electrotechnical Commission (IEC)	Int'l	SDO	Electrical and Electronical Device
International Organization for Standardization (ISO)	Int'l	SDO	All
International Telecommunication Union Standardization Sector (ITU-T)	Int'l	SDO	Telecommunication
National Electrical Manufacturers Association (NEMA)	US	SDO	Electrical Eng.
North American Bikeshare Association (NABSA)	N. America	Trade Association	Bikesharing
Open Mobility Foundation (OMF)	Int'l	Consortium	Transportation

Rehabilitation Engineering and Assistive Technology Society of North America (RESNA)	N. America	SDO	Assistive Devices
SAE International (SAE)	Int'l	SDO	Automotive Transportation
SharedStreets	N. America	Non-profit corporation	Transportation
Transportation Research Board (TRB)	US	Non-profit corporation	Transportation

Chapter 4. Standard Inventory Description

Standard Inventory Table

The standards inventory is contained in Appendix B (see separate Excel spreadsheet). The spreadsheet provides an inventory of current standards and standards under development that are related directly or indirectly to support multimodal and accessible travel applications, systems and technologies. At the time of compilation (2019 Aug 1), many new grassroot and consortium, in addition to the traditional standard development organizations started or identified initiatives to develop standards and specifications that support micromobility vehicles, intregated payment and uniform designed standards for all travellers.

The inventory table columns are described in Table 4. Description of Standard Inventory Table.

Table 4. Description of Standard Inventory Table

Col #	Tab Name	Subtab Name	Description
1	Relevant		Ranking of "relevant" standards. Relevance is ranked by number [1, 2, 3], unknown [?], and obsolete or not used in the US [x]. Ranking values are assigned as follows: 1 – directly related to MAT services, applications or travelers 2 – duplicate standards (same standard published by two organizations), associated with infrastructure or network performance, or enabling technology standard 3 – associated with network performance or enabling technology, but limited to another geographic region (e.g., EU) ? – not known x – obsolete or not used in the US
2	Org name		Standard, Association or grass roots organization name (see Section 3.2, Table 3)

3	Std name		The formal number and name of the standard or specification.
4	Timeline: Pub dates	Project start date	The date when the project started (unless this is an ongoing effort that is over ten years old, e.g., GTFS)
5	Timeline: Pub dates	(Anticipated) publication date	If in development, the expected when the standard will be published and available to the public.
6	Timeline: Pub dates	Revision start date	If published, when the next date the standard is expected to be revised.
7	URL or Access information		The hyperlink or location where the standard may be accessed. Standards that are underdevelopment will not include a link where information or draft documents are available.
8	MAT Std Type		The Standard Type including Path of Travel, Data Sharing, Integrated Payment, Wayfinding and Navigation, Automation and Robotics, Human-machine interface, or Other as defined in FHWA-JPO-18-744 (6/21/2019) and listed in the Standards Survey Section 1.2.
9	MAT domain		One of nine dimensions described in FHWA-JPO-18-744 (6/21/2019) and described in the Standards Survey, Section 2.2. The values include: Spatial, Information, Accessibility, Transactional, Institutional, Technological, Modal, Temporal and Equity.
10	Abstract/Description		A short description of the standard content.

Standard Information Cards

Standards that are the most relevant for MAT have been identified as highlighted in the information cards below. In each of the five information card categories, the scope addresses mobility and accessible travel standards.

Taxonomy

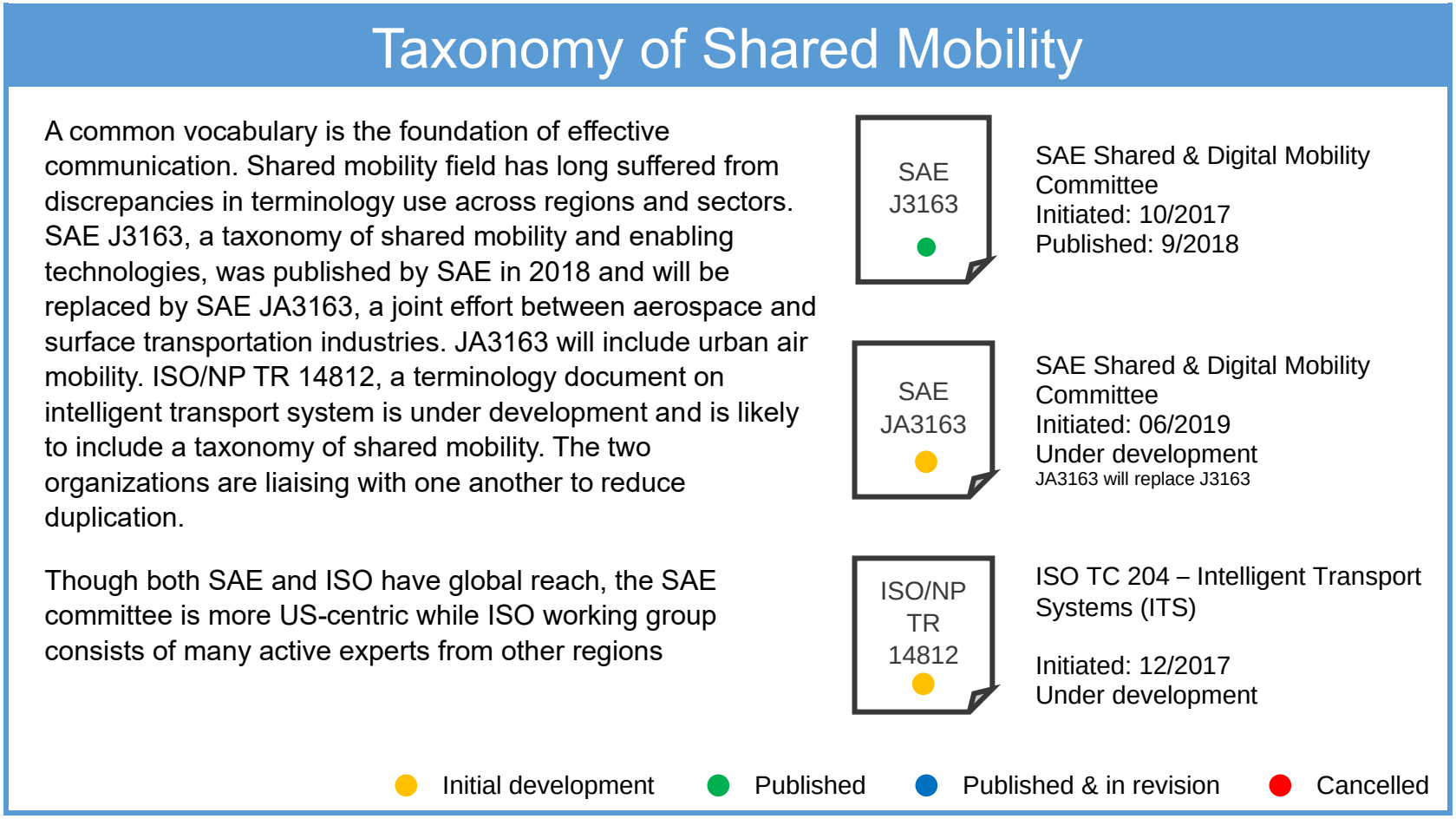


Figure 5. Taxonomy of Shared Mobility Information Card

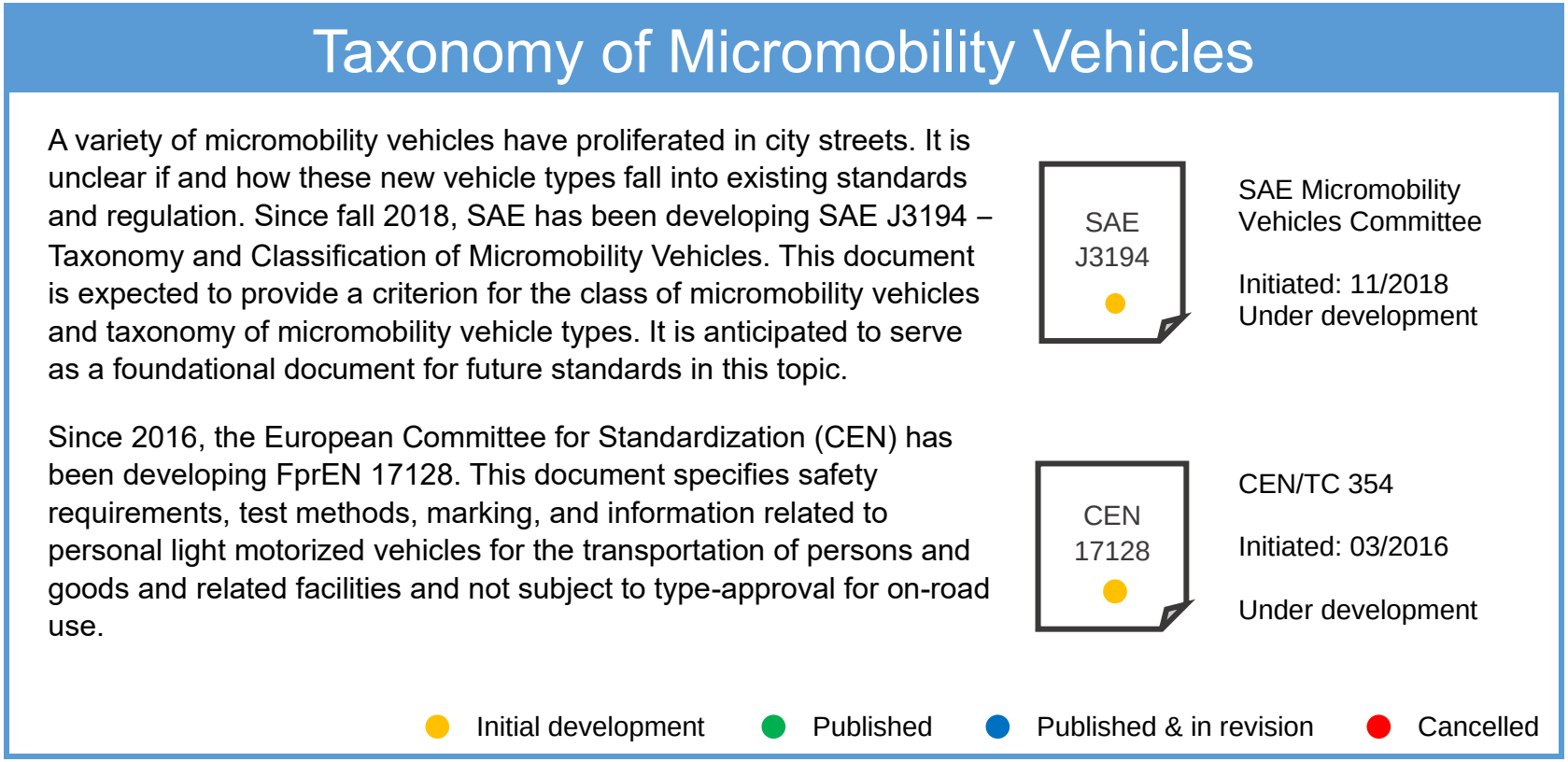


Figure 6. Taxonomy of Micromobility Vehicles Information Card

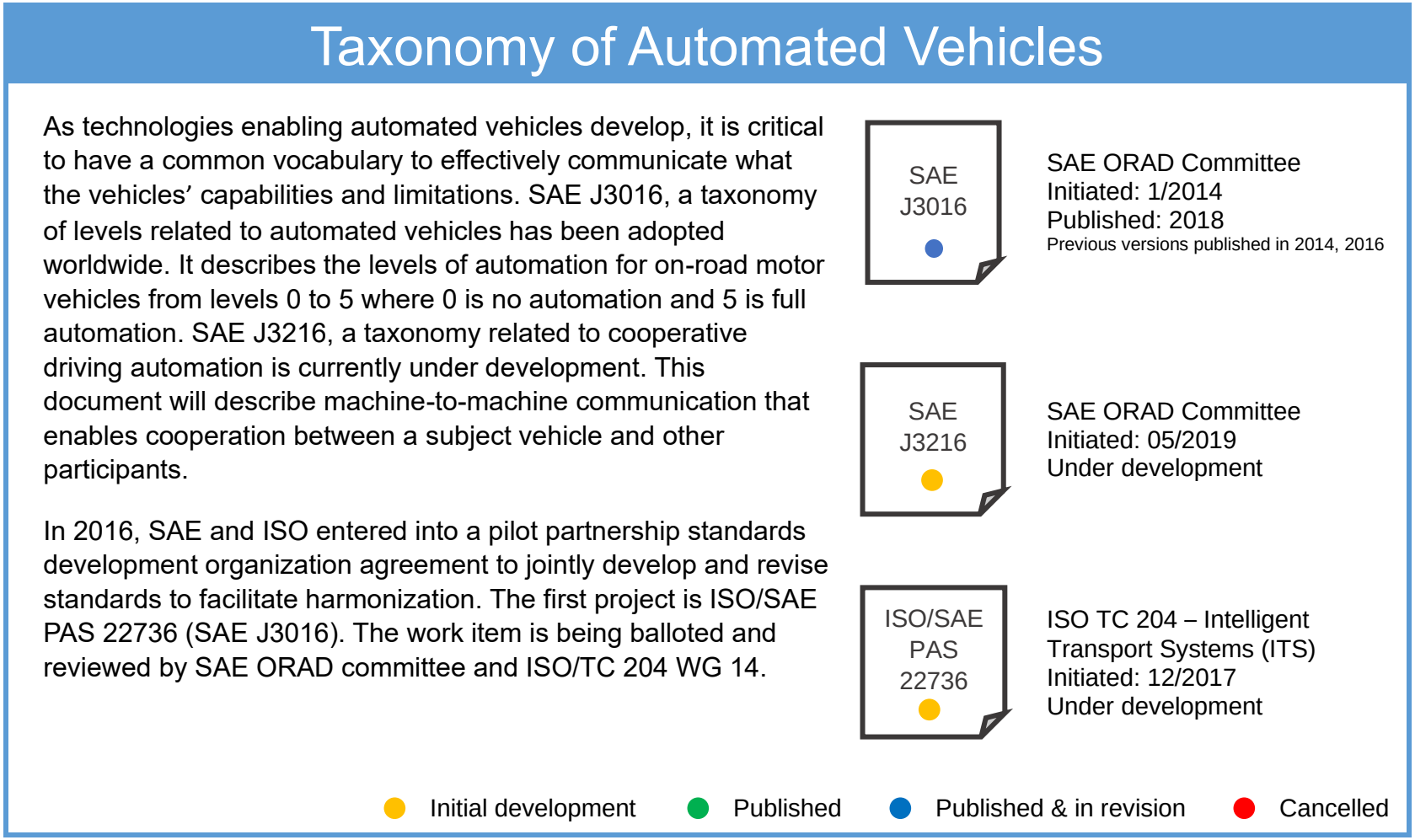


Figure 7. Taxonomy of Automated Vehicles Information Card

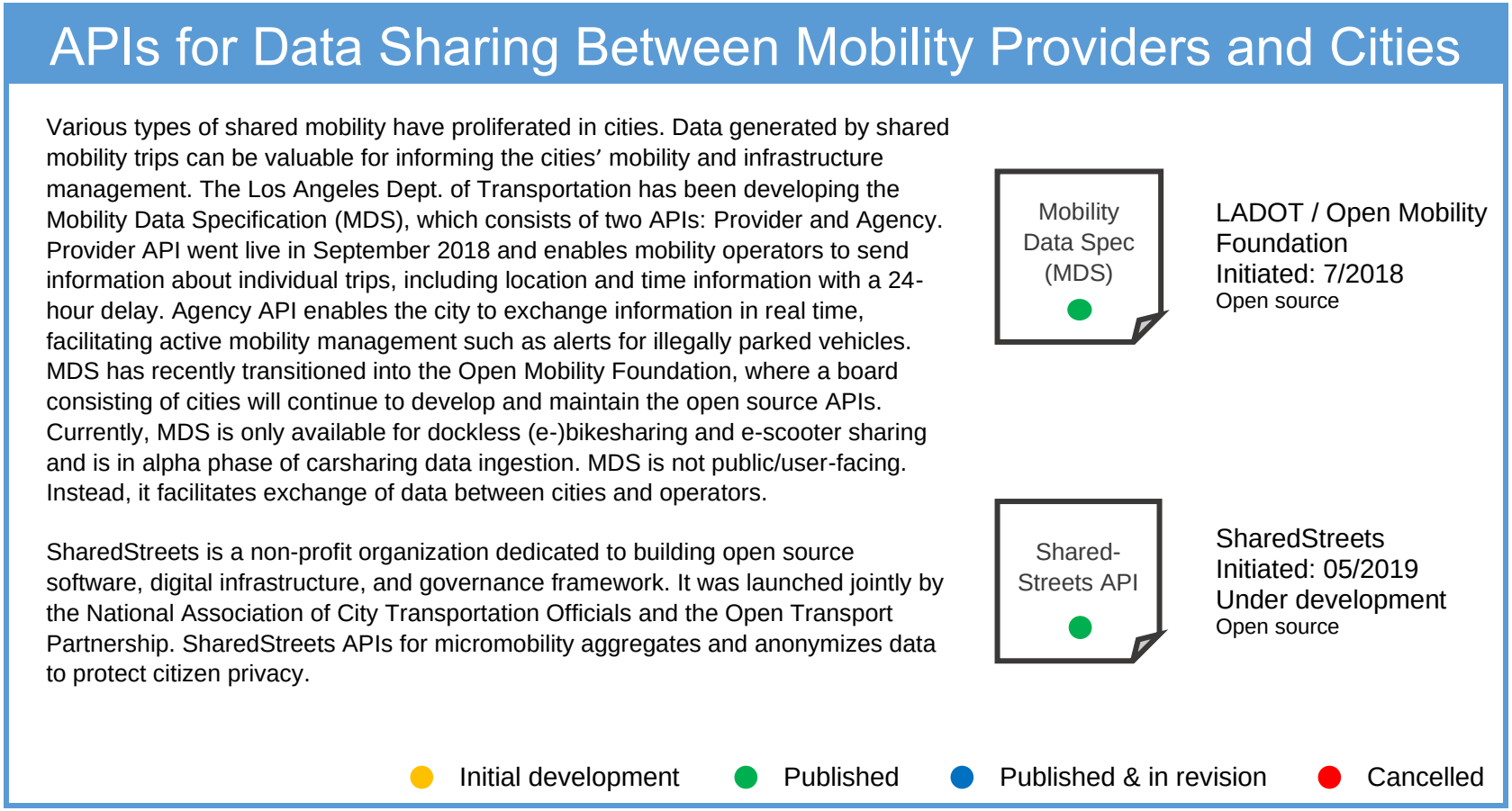


Figure 8. APIs for Data Sharing Between Mobility Providers and Cities Information Card

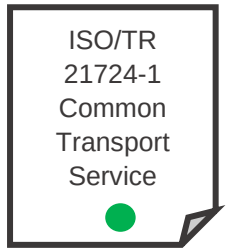
Multimodal Payment Architecture, Use Cases, and APIs

As integrated payment expands, many vendors and transit agencies are employing "deep linking" mobility provider APIs. Deep linking is a means to transferring trip plans, ticket/ride requests and user information without exposing personal and payment information. Additionally, most mobile and account-based fare systems publish open APIs (albeit reserved for partners) to enable third party event planners, mobility providers, and other transit agencies to interface to the transit agency payment systems.

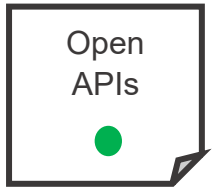
Open payment standards are typically governed by banking and media protocols like ISO/IEC 8583 for payment verification and validation, ISO/IEC 14443 and EMV for smart cards, PCI DSS for device and data security, NFC for mobile device communications. Each credit card provider has their own proprietary interfaces. These standards apply to a much broader audience then just transport and shared mobility systems.

The ISO TC 204 developed several technical reports and specifications that describe the platform that describes integrated payment architectures with over 50 use cases with data flows. The ISO 24014-1v3 Integrated Fare Management System (IFMS), although described for public transport includes provisions for shared mobility, third party financial / settlement services, and security. ISO Technical Report 21724-1 describes aggregated reservations and processing for all modes of transport including public transport, tolling, parking, shared mobility, third party transport aggregators.

ISO TC 204
In Revision: Version 3
Replaces Version 2: 2016
Expected Publication: 2020



ISO TC 204
Approved for Publication: estimated publication in late 2019



Several Vendors / Transit Agencies
Open API development

Initial development · Published · Published & in revision · Cancelled

Figure 9. Multimodal Payment Architecture Information Card

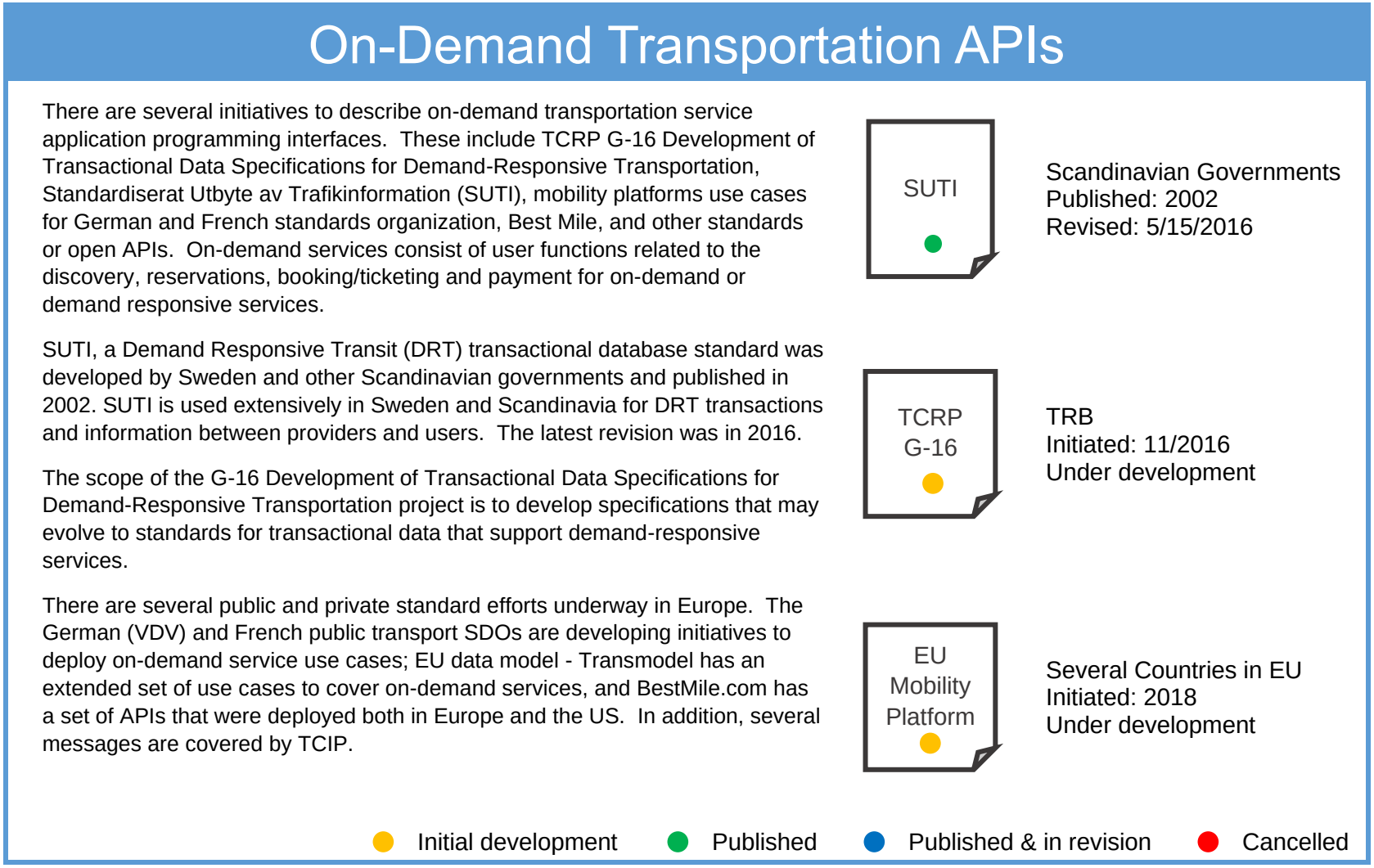


Figure 10. On-Demand Transportation API Information Card

Informational

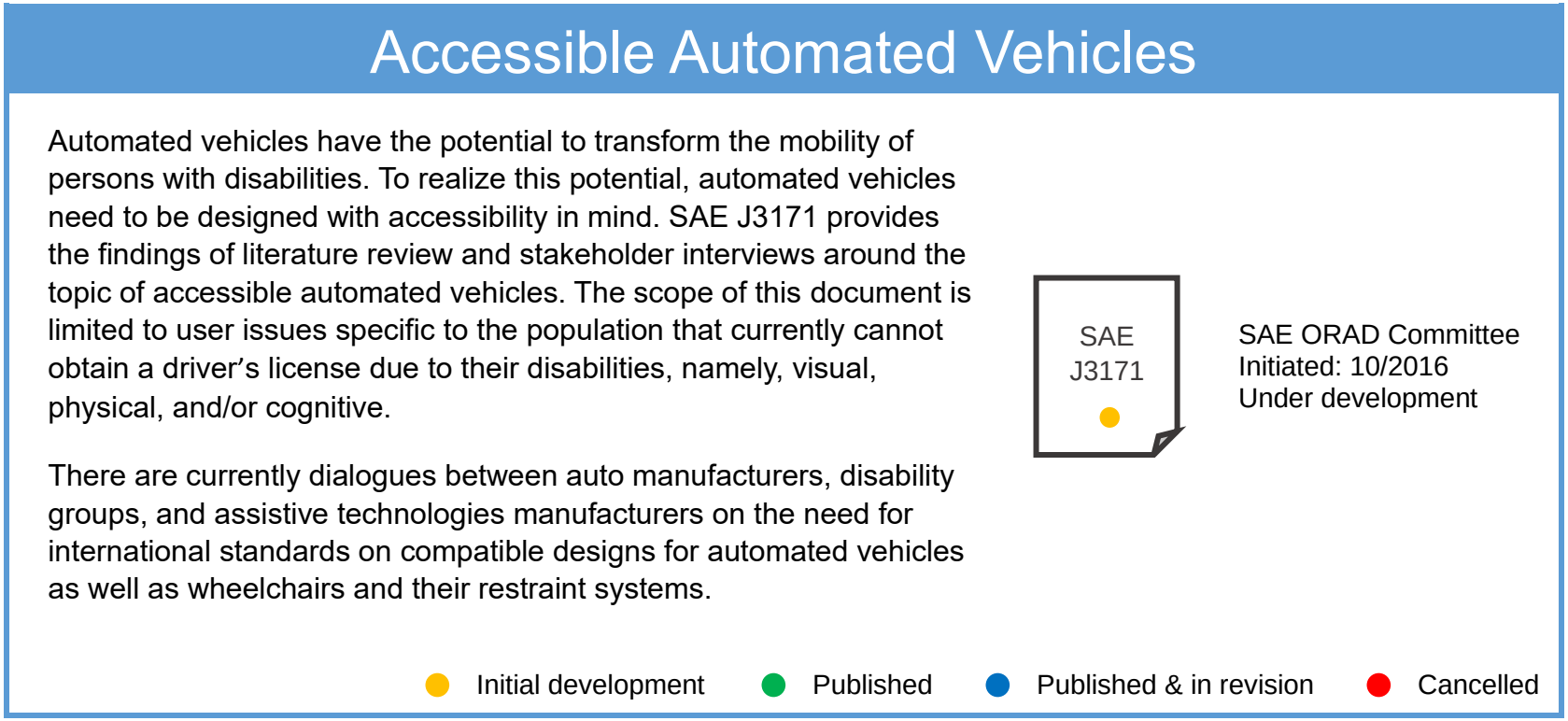


Figure 11. Accessible Automated Vehicles Information Card

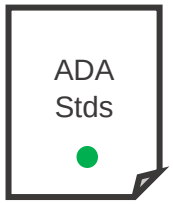
ADA Standards for Transportation Facilities

Among other things, the Americans with Disabilities Act (ADA) ensures access to the built environment for people with disabilities. The ADA Standards establish design requirements for the construction and alteration of facilities subject to the law. These enforceable standards apply to places of public accommodation, commercial facilities, and state and local government facilities.

The Access Board is responsible for developing and updating design guidelines known as the ADA Accessibility Guidelines (ADAAG).

DOT's ADA standards (2006) apply to facilities used by state and local governments to provide designated public transportation services, including bus stops and stations, and rail stations. They include unique provisions concerning:

- Location of Accessible Routes (206.3)
- Detectable Warnings on Curb Ramps (406.8)
- Bus Boarding and Alighting Areas (810.2.2)
- Rail Station Platforms (810.5.3)



U.S. DOT & DOJ
Updated: 2006

U.S. Access Board
Updated: 2002

Initial development Published Published & in revision Cancelled

Figure 12. ADA Standards for Transportation Facilities Information Card

Traveler Information

APIs for Vehicle Information Integrated Multimodal Trip Planning

As the need and desire for seamless, integrated, multimodal travel expands, user-facing APIs play a critical role. The first widely adopted API was the General Transit Feed Specification (GTFS). GTFS defines a common format for public transportation schedules and associated geographic information. The original GTFS is for static transit. GTFS-realtime extension has been developed to facilitate real-time public transit data. GTFS-flex has been developed for demand-responsive and paratransit. GTFS and its extensions are open source and maintained by ad-hoc community groups. TCRP G-16 study is developing specifications for transactional data for demand-responsive transit.

The General Bikeshare Feed Specification (GBFS) is an open source API that is widely used for docked and dockless (e-) bikesharing and e-scooter sharing. GBFS is housed and maintained by the North American Bikeshare Association (NABSA). GBFS describes the availability and location of the vehicles and stations.

The Mobility-as-a-Service (MaaS) API, which is currently being developed by the MaaS Alliance is predominantly developed by European experts.

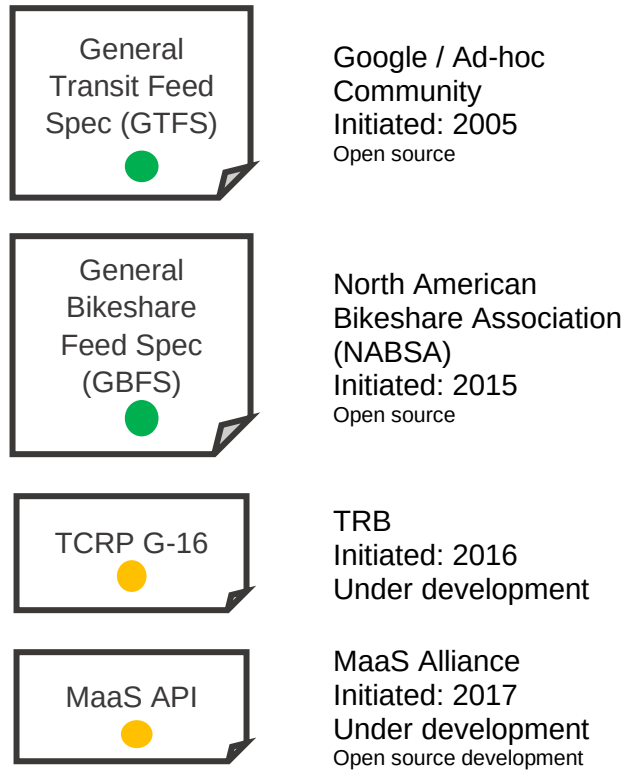


Figure 13. APIs for Vehicle Information Integrated Multimodal Trip Planning Information Card

Accessible Traveler Information

Standards have been developed by ISO/IEC and ITU for travelers with disabilities to access traveler information on handheld mobile devices and on board in buses and trains. Notable standards are ISO/IEC TS 20071 family: Information technology – User interface component accessibility, including Part 21: Guidance on audio descriptions, Part 23: Guidance on the visual presentation of audio information (including captions and subtitles), Part 25: Guidance on the audio presentation of text in videos, including captions, subtitles and other on-screen text. Also notably, ISO/IEC and W3C released ISO/IEC 40500 (W3C) Information technology -- W3C Web Content Accessibility Guidelines (WCAG) 2.0 in 2012 to guide the website and browser design for users with disabilities.

ISO/IEC JTC1
Part 21
Published: 11/26/2015
Part 23
Published: 2/24/2017
Part 25
Published: 9/25/2018

Initial development Published Published & in revision Cancelled

Figure 14. Accessible Traveler Information Card

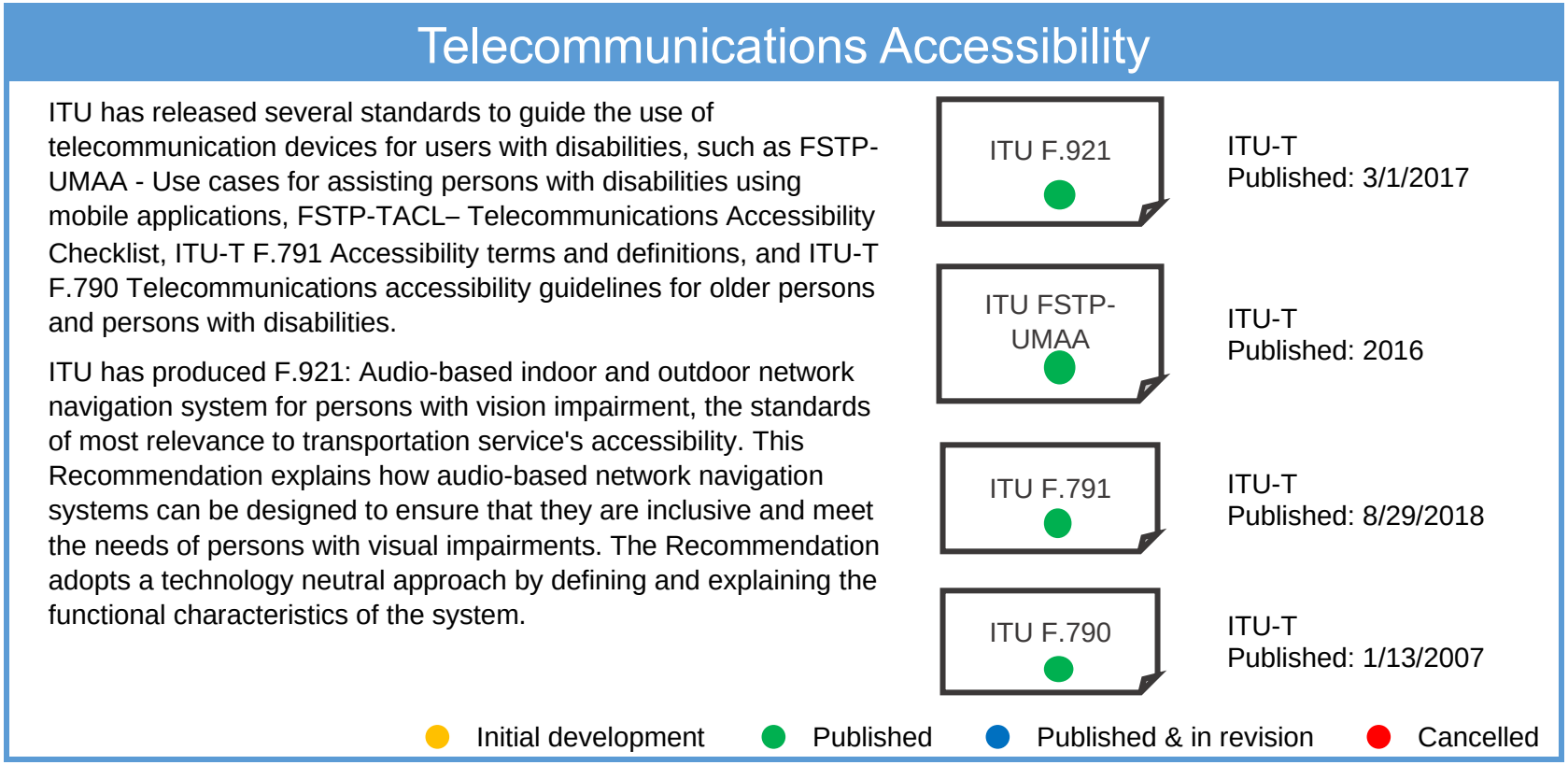


Figure 15. Telecommunications Accessiblity Information Card

Dedicated Short Range Communications (DSRC)

DSRC-based vehicle communication enables vehicle and travelers to access traveler information, as well as to enhance the safety of vehicles and vulnerable road users. DSRC may well be used in multimodal travel by users with disabilities.

SAE is the major standards development organization to develop DSRC standards. SAE J2735 defines the basic DSRC safety message, as SAE J2945 family specifies the interface and performance for DSRC-based vehicle-to-vehicle and vehicle-to-infrastructure deployment and applications. SAE J2945 has several parts: J2945/1 On-Board System Requirements for V2V Safety Communications, J2945/2 Dedicated Short Range Communications (DSRC) Performance Requirements for V2V Safety Awareness, J2945/3 Requirements for V2I Weather Applications, J2945/4 DSRC Messages for Traveler Information and Basic Information Delivery, J2945/9 Vulnerable Road User Safety Message Minimum Performance Requirements, J2945/10 Recommended Practices for MAP/SPaT Message Development, J2945/11 Recommended Practices for Signal Preemption Message Development, J2945/12 Traffic Probe Use and Operation. The development and revisions of several parts of the DSRC standards are active.

SAE DSRC Committee
Published: 3/1/2017

SAE DSRC Committee
Part 1
Published: 3/30/2016
Revised: 4/28/2019
Part 2
Published: 10/30/2018
Part 3
Initiated: 6/23/2017
Part 4
Initiated: 9/30/2016
Part 9
Published: 3/21/2017
Part 10
Initiated: 4/5/2016
Part 11
Initiated: 4/5/2016
Part 12
Initiated: 1/17/2012

Initial development Published Published & in revision Cancelled

Figure 16. Dedicated Short Range Communications Information Card

Transit Technology and Accessibility

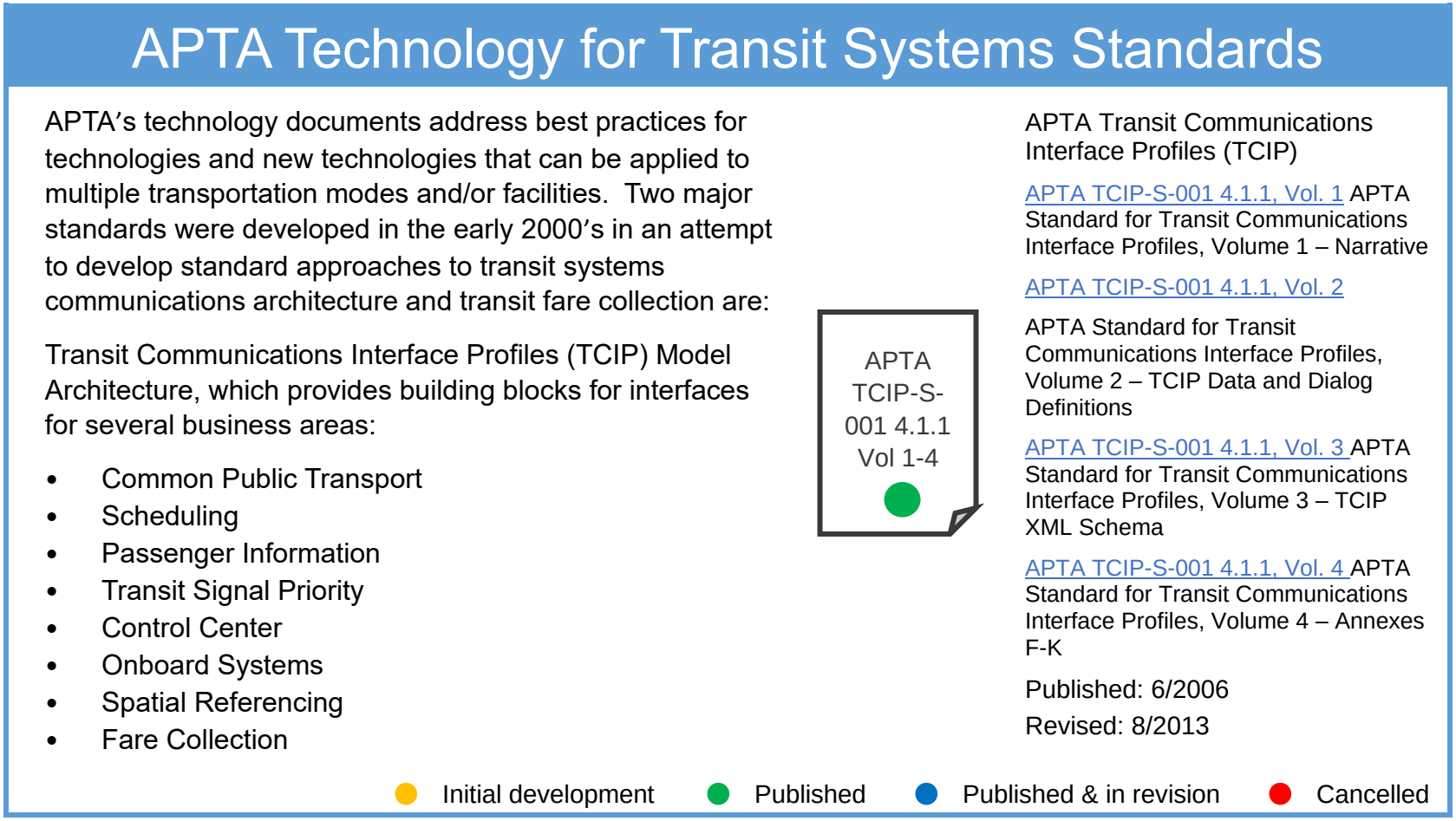


Figure 17. APTA Transit Communications Interface Profiles

APTA Technology for Transit Systems Standards

The Universal Transit Fare Systems (UTFS) program was a major development in the early 2000's to develop a standard approach to fare collection systems using contactless smart cards. In addition to publishing the Contactless Fare Media System Standard (CFMS) Parts 1-5 from 2006-2009, the program developed several worksheets and aids for transit professionals planning advanced fare systems:

- CFMS Training Case Study Worksheets
- CFMS Training Workbook
- UTFS Business Issues
- UTFS Ops Comm Planning
- UTFS Trends Electronic Fare Media 1-50

These standards have not been revised since their publication. While they may have use as a primer, the standard does not have information on modern approaches and the UTFS approach was not used to create "standard" fare collection systems in North America.

APTA UTFS Parts 1-5

APTA UTFS Committee and Working Groups

Part 1 Contactless Fare Media System Standard Part I Intro and Overview
Published: 2007

Part 2 Contactless Fare Media System Standard Part III Regional Central System Interface Standard
Published: 2008

Part 3 Contactless Fare Media System Standard Part II Contactless Fare Media Data Format and Interface Standard
Published: 2007

Part 4Contactless Fare Media System Standard Part IV Security Planning and Implementation Guidelines and Best Practices
Published: 2006

Part 5 Contactless Fare Media System Standard Part V Compliance Certification and Testing Standard
Published: 2009

Initial development Published Published & in revision Cancelled

Figure 18. APTA Universal Transit Fare Systems Standard

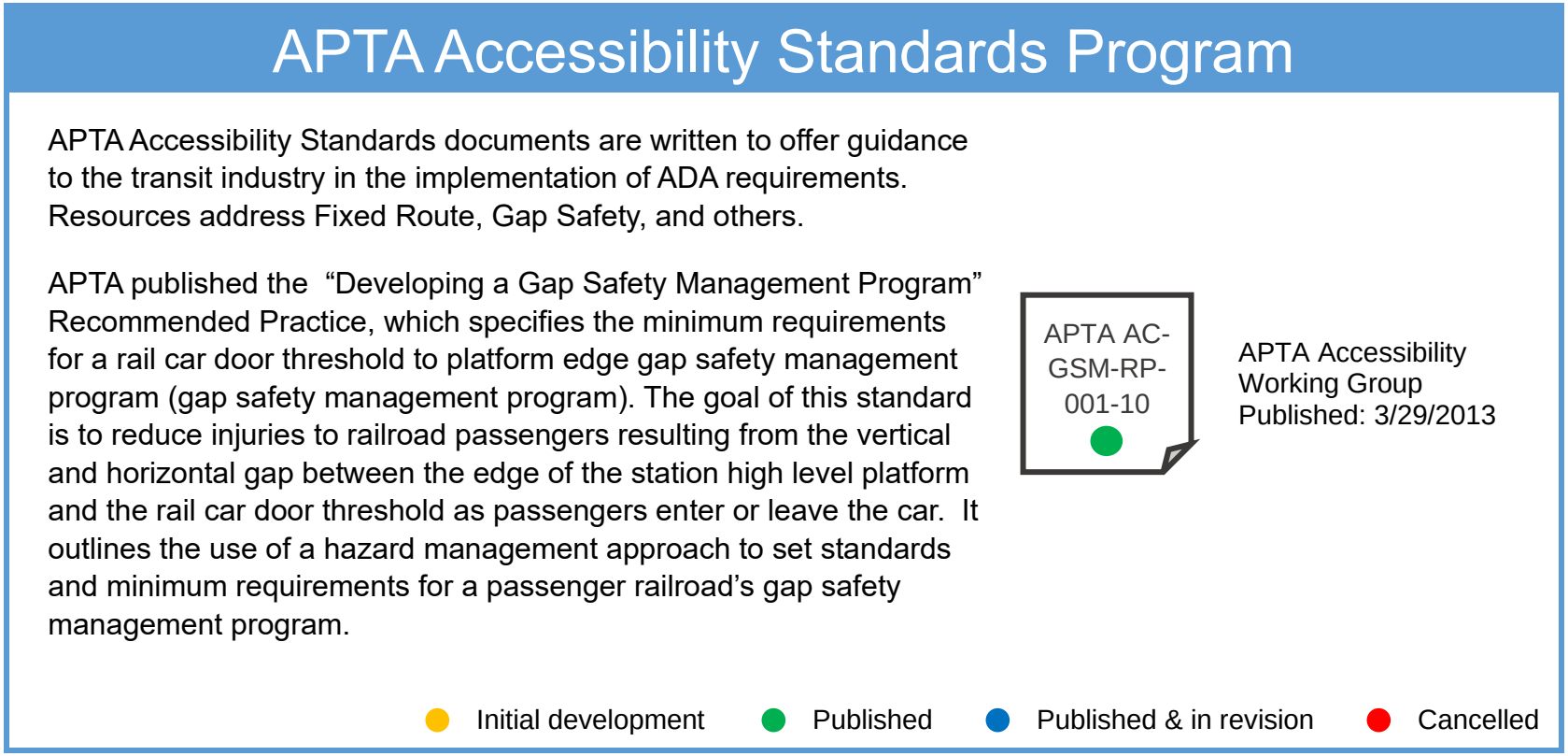


Figure 19. APTA Accessibility Standards

Chapter 5. Analysis and Next Steps

The objective of this task is to conduct a survey of standards on the topic of multimodal and accessibl travel. As presented in Appendix B. Standard Inventory, there are many existing standards on this topic with more currently under development. The recent surge of standardization efforts in this topic can be largely attributed to the rise of shared mobility and emergence of new vehicle types, such as micromobility vehicles. The survey results demonstrate some key trends of the current standards landscape.

Multi-industry effort

Standards in this field require active participation from stakeholders that belong to various industries, including ITS, automotive, shared mobility, public transportation, and accessibility. The multi-sector collaboration is required to facilitate interoperability among the user community, infrastructure, smartphone applications, and public sector. As this topic pertains to many sectors, standardization efforts are scattered across several industry-focused standards developing organizations and ad-hoc community groups. This creates challenges of potential duplication of efforts, lack of harmonization, and gaps in standards.

Geographic boundaries

The need for “roam-able” multimodal travel technologies, such as mobility as a service (MaaS) apps have been highlighted. To achieve true roam-ability, standards that support such technologies need to be roam-able and adopted internationally. The usual scenario is that standardization efforts “catch up” to the present-day technologies, which are evolving rapidly in the field of multimodal travel. In some cases, this has led to acceleration of standards development, which does not allow much flexibility for inter-organization and inter-region coordination. As a result, we have multiple standards being developed on very similar topics globally, which could contribute to confusion and lessen the value of each standard.

Standards development processes are evolving

Traditionally, standards are developed in formal SDOs. Many of these organizations follow formal, consensus-based development procedures that are monitored and certified by the national standards bodies. In the U.S., the American National Standards Institute (ANSI) serves this role. IEEE and SAE are examples of ANSI-certified SDOs. They house and maintain most of the key standardization efforts highlighted in this report (Section 4.2). Other standards are developed as grass-root initiatives such as the GTFS or by community-based groups or consortia such as the MaaS API specifications by the MaaS Alliance. There is a strong trend to apply an open-source development approach to software- and code-based standards. Open-source development is particularly popular in API specification and data standards as it allows interested parties to collectively develop and modify software with transparency. In many cases, open-source development does not follow the formal standards development and/or publication procedures. Most SDOs copyright their standards and users must purchase the documents, while grass root and community-based efforts are using Github and other open web sites to promote their standards.

Support and longevity of standards

Standards where communities of users generate guidance, architecture and use case technical reports, and test protocols/tools have more acceptance and use. For example, NTCIP and GTFS standards garner significant public agency, third party developer, and traditional transportation vendor support, use, and ongoing acceptance.

Dynamic technology advancement

With technologies rapidly evolving and the slow pace of standard development and acceptance, standards that address technologies may be at their end-of-life by the time they are deployed. For example, although XML as an encoding format is far from its end of life, most interfaces are programmed in JSON today. Communications may move swiftly from 4G Long-Term Evolution (LTE) to 5G, and with the launch of low earth orbiting (LEO) satellites, the rural / urban communications coverage disparity may no longer be an issue.

The next steps in identifying gaps and analyzing solutions will measure the challenges, trends, and reach out to stakeholders including standards organizations, developers, community groups, vendors, public agencies and more to formulate a roadmap that will build a harmonized, comprehensive set of standards that support multimodal and accessible standards for all travelers.

International Standardization Trends

Significant work in the area of Mobility Integration that incorporates data sharing and transactions for multimodal, shared use and mobility options. These activities address developing taxonomies, use cases and reference architectures for areas such as vulnerable road users, curb and micromobility device management, and integrated payment. Additional work in the areas of connected and autonomated vehicles including accessibility, indoor navigation and on-demand mobility transactions is also undergoing significant activity by both national and community standard developers. Standards that address uniform design are not as obvious in the current standards or in the emerging standards under development.

Next Steps

Given the observed trends, outreach efforts should initially incude the following types of activities:

- Review and compare standards and emerging standards that overlap such as those related to on-demand transportation transactions, integrated payment, and multimodal/indoor (bike and ped) navigation data models.
- Engage organizations where duplicative efforts or inconsistent taxonomies exist to coordinate definitions and data representations. Coordinate with organizations developing standards to use formal taxonomies for these emerging travel tools.
- Engage organizations developing standards where gaps in access exist and discuss application of uniform design principles.

Appendix A. Acronyms

Table 5 lists the acronyms and defines the terms that are used in this document.

Table 5. List of Acronyms

Acronym/Abbreviation	Definition
ADS	Automated Driving System
ANSI	American National Standards Institute
API	Application Programming Interface
APTA	American Public Transportation Association
ASCII	American Standard Code for Information Interchange
AASHTO	American Association of State Highway and Transportation Officials
ASN. 1	Abstract Syntax Notation One
ATTRI	USDOT Accessible Transportation Technologies Research Initiative
CCTV	Closed Circuit Television
CEN	European Committee for Standardization
CENELEC	European Committee for Electrotechnical Standardization
CV	Connected Vehicles
DATEX	DATa EXchange standard (an ISO and CEN standard focused on exchange of traffic information)
DSRC	Dedicated Short Range Communications
EMV	Europay, MasterCard and Visa (Chip-based payment cards)
FLA	Forward Looking Assessment (See Reference [1])
FSTP	Standards promoted by ITU to assist people with disabilities
FTA	Federal Transportation Administration
GBFS	General Bikeshare Feed Specification
GDF	Geographic Data Files
GTFS	General Transit Feed Specification
IEC	International Electrotechnical Commission
IEEE	Institute of Electrical and Electronics Engineers
IFMS	Integrated Fare Management System
ISO	International Organization for Standardization
ITE	Institute of Transportation Engineers
ITS	Intelligent Transportation Systems
ITU-T	International Telecommunication Union Standardization Sector
JSON	JavaScript Object Notation
LEO	Low Earth Orbiting
MAT	Multimodal and Accessible Travel
MATSA	Multimodal and Accessible Travel Standards Assessment

MaaS	Mobility as a Service
MDS	Mobility Data Specification
MOD	Mobility on Demand
NABSA	North American Bikeshare Association
NEMA	National Electrical Manufacturers Association
NeTEX	Network Timetable Exchange
NFC	Near-field communication
NTCIP	National Transportation Communications for Intelligent Transportation System Protocols
OGC	Open GIS Consortium
OMF	Open Mobility Foundation
ORAD Committee	On-Road Automated Driving Committee
OSI	Open Systems Interconnection
PCI DSS	Payment Card Industry Data Security Standard
RESNA	Rehabilitation Engineering and Assistive Technology Society of North America
REST	Representational State Transfer
SAE	SAE International
SDO	Standards Development Organization
SIRI	Standard Interface for Real-time Information
SMNP	Simple Network Management Protocol
SOAP	Simple Object Access Protocol
SPaT	Signal phase and timing
TC 211	Technical Committee 211 (an ISO standards committee focused on vehicle technology standards)
TCP/IP	Transmission Control Protocol/Internet Protocol
TMDD	Traffic Management Data Dictionary
TOCOR	Task Order Contracting Officer Representative
TRB	Transportation Research Board
UDP/IP	User Datagram Protocol/Internet Protocol
USDOT	United States Department of Transportation
V2I	Vehicle to infrastructure
V2V	Vehicle to vehicle
WAVE	Wireless Access in Vehicular Environments (IEEE communications standard)
WCAG	Web Content Accessibility Guidelines
XML	eXtensible Markup Language

Appendix B. Standard Inventory

See attachment MATSA_StdsStandards_Catalog_Appendix B Final.csv

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