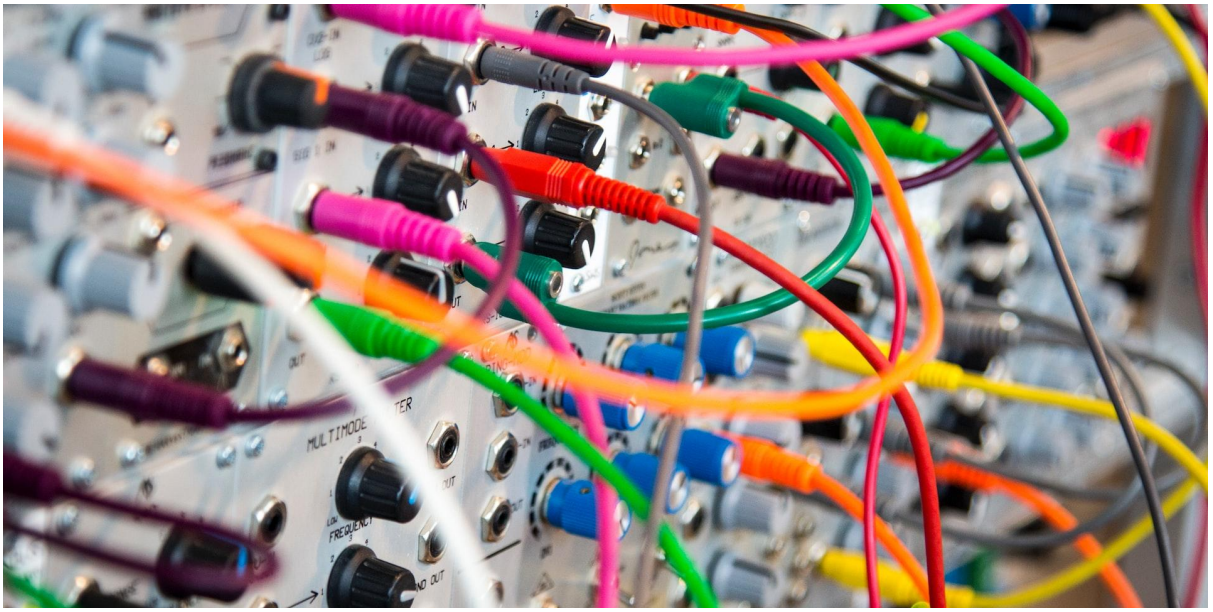
Data Standardisation for Shared Mobility, a Study.



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Summary sheet

Project name	eHUBS
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Deliverable	D2.1 Researching other equal or partial standards in Europe and keeping up with the existing standard by participation in the TOMP working group and stakeholder engagement
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Table of contents

1. Introduction

1.1. Shared mobility - a fast-moving landscape with data at its core

Over the last decade, the mobility landscape has been changing rapidly. New mobility systems such as shared mobility services, Mobility as a Service (MaaS) and mobility hubs are arising and actively promoted by cities and public authorities as a means of reducing private car ownership to minimise congestion and climate change emissions as well as to reorganise public space to evolve towards a more qualitative living environment.

These evolutions make it easier for users to make use of shared modes: both physical and digital integration will help to bridge the gap in existing transportation networks, thus making multimodal mobility a genuine alternative.

Central to these developments are the increasing adoption of information and communications technology (ICT) and the widespread use of smartphones, and digital platforms. The new mobility modes rely heavily on the availability of data and over the last couple of years, numerous initiatives have arisen that aim to standardise data exchange and interoperability between systems.

According to Shaheen et al (2019) *Shared Mobility is the shared use of a vehicle, bicycle, or other travel mode. It is an innovative transportation strategy that enables short-term access to transportation modes on an "as-needed" basis. Sharing can include sequential sharing (i.e., different users share the same transportation vehicle or equipment, one after the other) or concurrent sharing (i.e., sharing of the same transportation vehicle or equipment by multiple non-household users for the same trip). Shared mobility can also include core services such as: public transport (scheduled or demand-responsive (DRT)), shuttles and taxis*

In this document, we will give an overview of the existing standards and specifications and the expected developments. It draws from own research and builds on earlier reports compiled by the MaaS Alliance (MaaS Alliance, 2021) and the MobiDataLab project (MobiDataLab, 2022).

Not all standardisation efforts can automatically be considered to be actual standards, they are almost always specifications instead. Throughout this report, we use the term 'standard' as a common name, even though in some instances we are, in fact, describing a specification.

1.2 The shared mobility data ecosystem

If you want to build a working ecosystem, data and ICT systems have to work together in harmony. Agreements on what should be exchanged, how this is structured and described, at what frequency, how it should be interpreted, etc.

These agreements can be made between parties individually, but that is time-consuming and costly. When new technologies are adopted, the need for standardisation will grow. Standards will slowly start emerging as the need for collaboration and exchange between systems grow.

The reality for the moment is, however, that most of the shared mobility operators have different ways of organising their data. When this data needs to be integrated into a MaaS-platform, companies need to make considerable investments, mostly in terms of staff costs, to standardise and integrate their data. For smaller providers in particular, who usually do not have the means or time to develop their own system to exchange data, considerable savings regarding work time and staff costs are possible by using already existing interoperability standards (SmartHubs, 2022, p. 13).

In this respect, the parallel with mobile telephony is sometimes drawn. Mobile telephony has known a faster diffusion once the uncertainties regarding standards were settled *(Rouvinen, 2004)*. It is expected shared mobility as well will take advantage of standards development and that it will reduce cost and stimulate competition by making it easier for smaller players to enter the market.

As for mobility data, there have been many developments over the last few years, but slowly, the dust seems to be settling. Still, the mobility data ecosystem is very complex and there are multiple different standards and interfaces with different objectives and focus. Among others, standards vary depending on:

- The communicating parties involved and the aim of the information sharing:
    - End user: has a mobility need, needs to know the different options, availability and conditions for meeting this need travelling;
    - Operator: needs to be able to deliver the service (schedules, position of the vehicles, fuel or charging level, maintenance, etc.) and to publicise its offer;
    - Mediator / MaaS Provider / eHUBS (or mobility hubs in general) / Mobility Brokers : must be able to do the matching between the mobility needs of the customer, based on the customer's preferences, and the actual offer. Moreover, the mediator must be able to handle numerous practical issues like booking, payment and complaints handling;
    - Regulator / public authority: must be able to define and enforce its policy and monitor actual use to adapt it.
- The mobility modes covered:
    - Public Transport
        - Scheduled
        - Demand Responsive Transport (DRT)
    - shared transport: vehicle sharing, vehicle rental, vehicle pooling, …
        - Company owned
        - Peer-to peer
    - private transport
- The kind of data offered:
    - schedules
    - Real-time data

    - historical data
    - projections
- Passenger or cargo transport
- The regional scope (global, European, national, regional)
- The level of abstraction:[1]
    - Conceptual data model: defines concepts and the relationship between them, like a dictionary;
    - Data exchange format: the format in which to exchange data;
    - Protocol: the communication procedure used to exchange data;
    - API specification: describes the data format (like in the exchange format), but also specifies actions to fetch and/or modify the data.
- The level of integration they potentially provide for MaaS services (see illustration below):[2]
    - Level 0: no integration
    - Level 1: integration of information
    - Level 2: integration of booking and payment
        - Focusses on a single trip
    - Level 3: integration of service offer
        - Based complete mobility needs, morning to evening, Monday to Sunday and spring to winter
    - Level 4: integration of societal goals
        - Implements incentives that reflect local, regional, or national policies

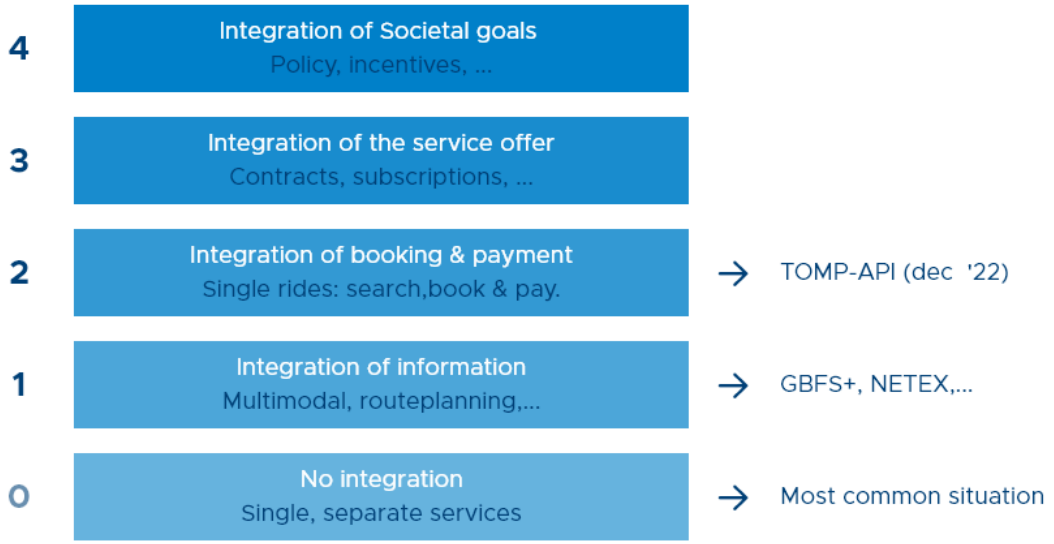

Image: The 4 levels of integration (after Sochor et al.) (source: Tjalle Groen)

This partly explains the complex landscapes of standards, specifications and interfaces, as illustrated in the figure below, drawn from the MaaS Alliance white paper.

[1] MaaS Alliance , 2021
[2] Sochor et al., 2018

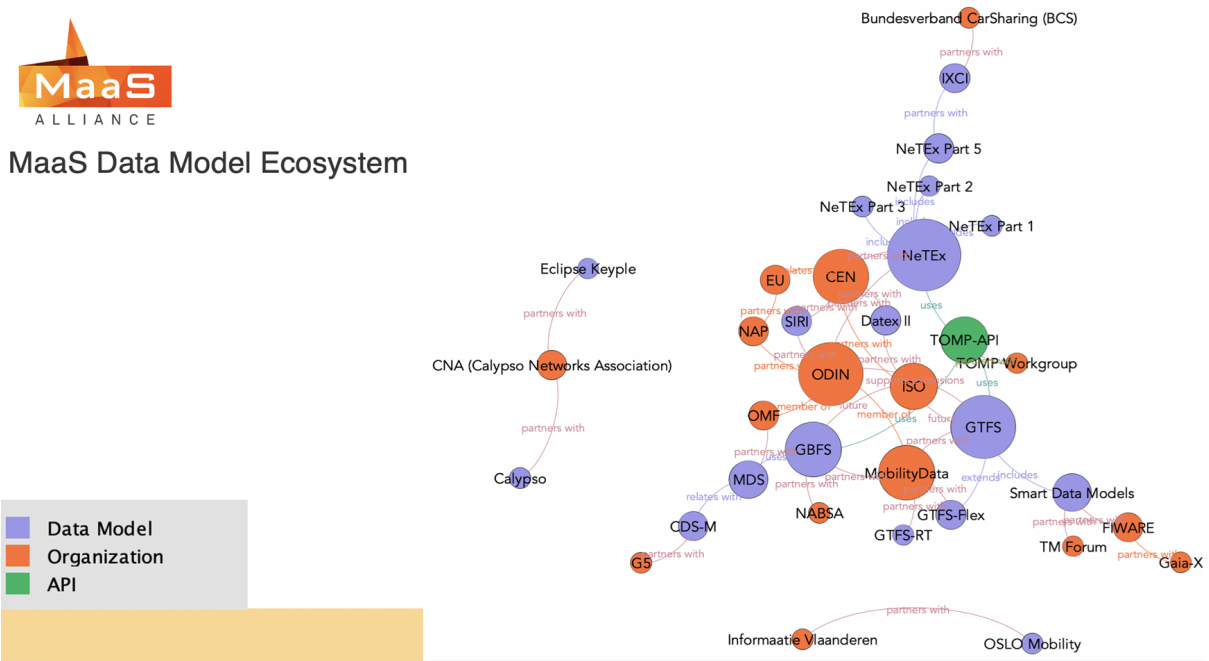

Image: Network view of the mobility data ecosystem (source: Maas Alliance + references)

However, not all of them are at the same level of maturity and the difference between intention and realisation is not always clear. In practice, for shared mobility passenger information, only a limited number of standards seem really relevant and can boost wider adoption.

- Firstly, there are several standards that originated in the US and seem to acquire global adoption (GBFS, GTFS and MDS).
- The US-standards are complemented or extended by some European initiatives that are mainly driven by EU regulation (Transmodel, NeTEx, Siri, CDS-M) or want to extend their functional scope (TOMP-API, RDEX+).
- Finally, a number of national or regional initiatives try to set a standard at the national or regional level (IXSI5 in Germany or OSLO - Mobiliteit in Flanders).

Before 2020, some global standards or specifications were incompatible with EU requirements, mainly regarding privacy legislation. This meant they were not (or only partially) suitable for the European market. Now, however, most of them have caught up and created adaptations specifically for Europe, making them an essential part of the ecosystem.

The European standards, particularly the official Transmodel, NeTEx and SIRI, are very comprehensive but not always adapted to lightweight and fast data exchange.

In the next section, we will give a more in-depth overview of the most relevant initiatives for **shared passenger mobility in a European context**.

1.3 Issues

[This topic will be further explored in the final version of this paper.]

1.4 Food for thought - should public authority or private sector take the lead

[This topic will be further explored in the final version of this paper.]

1.5 Regulatory Framework and GDPR

The eHubs Digital Blueprint gives an overview of the relevant regulation concerning shared mobility (Module 9). When it comes to data, the Intelligent Transport Systems Directive (ITS) and the Open Data directive are especially relevant as they stipulate the specifications and availability of public data.

Because shared mobility involves a large array of personal data (location, payment details, etc.) the following regulations regarding data protection and security are relevant as well:

- GDPR / General Data Protection Regulation (EU) 2016/679
- Directive 2002/58/EC concerning the processing of personal data and the protection of privacy in the electronic communications sector
- Regulation (EU) 2019/1150 on promoting fairness and transparency for business users of Online Intermediation Services

The recently introduced GDPR framework has an influence on the data standards development as well.

The General Data Protection Regulation (GDPR) is the European regulation that aims to protect citizen's right to privacy and is intended to enhance individuals' control and rights over their personal data.

As of May 2018, all organisations collecting or processing personal data of EU citizens, whether in the EU or not, are required to be GDPR-compliant. Put differently, organisations may not collect or use personal data unless there is a lawful basis to do so.

Personal data is any information that relates to an individual who can be directly or indirectly identified. In the context of shared mobility, geolocation or trip information is susceptible to be personal data if it is relatively easy to identify someone from it.

A lawful basis to collect and process personal information can be contractual or legal obligations, public or vital interest (you can save somebody's life with it) or explicit and informed consent. These purposes need to be documented and transparently notified.

Additionally, several basic principles have to be respected, among which

- Purpose limitation: You can only process data for the legitimate purposes specified explicitly to the data subject when you collected it.
- Data minimization: You should collect and process only as much data as absolutely necessary for the purposes specified.
- Storage limitation: You may only store personally identifying data for as long as necessary for the specified purpose.
- Accuracy: You must keep personal data accurate and up to date.
- Integrity and confidentiality: Processing must be done in such a way as to ensure appropriate security, integrity, and confidentiality (e.g. by using encryption).

Organisations that handle personal data need to be able to demonstrate compliance with all of these principles. If you can't show how, then you're not GDPR-compliant.

More information about the practical implications of GDPR can be found here.

2. Existing standards and specifications - the shared mobility data landscape

The goal of this section is to list the currently existing standards and specifications. Rather than giving an exhaustive overview, we will briefly discuss what the main goal of each is, who it was developed by, why it was developed, its relevance, technical specifications, compliance and governance. We provide links through dedicated websites that provide more (technical) detail related to the standard under consideration.

We make a distinction between global, European, and some national standards or specifications:

Global	European	National
GBFS	Transmodel	IXSI
GTFS	NeTEx	OSLO Mobility
MDS	SIRI	
	OJP	
	TOMP-API	
	CDS-M	
	RDEX+	

2.1. Global standards and specifications

2.1.1 GBFS

General Bike sharing Feed Specification

What

GBFS is a data specification that defines a common format to share the real-time status of a shared mobility system. It can handle different types of mobility data (bicycles, cars, mopeds, scooters, …) and is focused on finding available vehicles.

Who

GBFS is maintained by MobilityData, a French-Canadian non-profit consisting of a variety of mobility stakeholders including public authorities, technology firms and mobility providers. It aims to broaden the adoption and increase the functionality of the GBFS (and the GTFS, see below) data formats to improve the traveller experience through standardised, high quality, up-to-date data.

GBFS was originally created as a data-standardisation project for bike share programs by NABSA (North American Bikeshare & Scootershare Association). It was first released in 2015. The ownership was handed over to MobilityData in October 2022 (*Mobility Data, 2022*).

Why

The main objective of GBFS is to provide public, realtime, read-only data on the availability of shared mobility systems (bicycles, cars, scooters, cargo bikes, …). The focus is on finding available vehicles. This allows, for example, trip-planning applications, to help travellers plan and locate devices for shared micro mobility trips.

Relevance

GBFS is currently the de facto standard for publishing realtime micro mobility data. It is used in hundreds of cities in 40 different countries by trip-planning applications such as Google Maps to help travellers plan and locate devices for shared micro mobility trips.

Technically

GBFS defines 13 endpoints in JSON, a lightweight format for storing and transporting data.

Known issues and limitations

GBFS is intended to make information publicly available online. For this reason, information that is personally identifiable is not currently part of the core specification, and will not become part of it. GBFS also does not support, nor is intended, for historical data such as trip

or maintenance records.

Compliance and Compatibility

Current versions of GBFS are compliant with GDPR because they do not contain any personal or personally identifiable data. Thanks to the mandatory rotation of vehicle identification numbers, there is also no trivial way to reconstruct a single user's journey or habits.

GBFS is recognized by CEN (Comité Européen de Normalisation, see below), as compatible and convertible to NeTEx/SIRI based on a canonical mapping soon to be approved by CEN. This convertibility reduces the burden of data production and consumption for all stakeholders of the shared mobility industry.

Governance

GBFS is governed as an open-source project developed under a consensus-based governance model. Contributors come from across the shared mobility industry, public sector, civic technology and elsewhere. Anyone can propose a change. Change proposals are subject to the governance process and require at least 3 votes in favour, and none opposed. One vote must be from a data producer and one from a data consumer. The party proposing the change is not eligible to vote[3].

Notes and remarks

In its early years, variants like GBFS+ (bike sharing organisations in the Netherlands) and GMFS+ (MaaS Alliance) emerged in Europe in response to growing concerns about privacy and GDPR-compatibility or to include other mobility solutions (bikes, cars, station-based, free floating,...). These concerns seem to have been considered in recent versions of GBFS, and the variants do not seem to be under active development.

2.1.2 GTFS

General Transit Feed Specification

What

The General Transit Feed Specification (GTFS) is a data specification that allows public transport agencies to publish their transit data in a format that can be consumed by a wide variety of software applications. It is split into a schedule component that contains schedule, fare, and geographic transit information and a real-time component that contains arrival predictions, vehicle positions and service advisories

[3] https://gbfs.mobilitydata.org/participate/

Who

GTFS is currently hosted and maintained by MobilityData, the French-Canadian non-profit that also maintains GBFS (see above).

Why

GTFS is intended to facilitate the communication of service information to passengers for use in journey planning applications. It was originally developed in 2005 by TriMet, the public transport transit provider in Portland, Oregon, to enable the incorporation of Portland's public transport schedules into Google Maps. At that time, Google Maps was already offering driving directions, and the idea was to make it just as easy to get public transport directions as it was to get driving directions.

It was not intended to be proprietary, and has gradually been adopted by other cities and applications.

Technically

A distinction can be made between:

- GTFS Schedule - A GTFS feed is a group of text files (csv-format) that contains infrequently changing transit data, like stops, routes, trips, and other schedule data. They are typically updated every few months.

- GTFS Realtime - GTFS Realtime consists of three binary files that contain real-time vehicle positions, real-time arrival information, and service alerts. They are typically updated every minute.

Where GTFS Schedule is intentionally designed to be easy to implement, GTFS Realtime is a bit more technically challenging and may be harder to implement, especially for smaller transport agencies *(D'Augostino et al., 2019).*

Relevance

It is designed to be relatively simple to create and read for both people and machines. Unlike NeTEx (see below), it does not provide an exhaustive vocabulary for managing operational details, but only offers just enough detail to provide good trip planning and timetables to public transport riders.

GTFS is used by thousands of organisations, making it a de facto standard for consumer oriented public transport information. As such, even organisations using NeTEx, may use GTFS for publishing data to be used in consumer applications[4].

Compliance and Compatibility

[4] https://gtfs.org/background/

GTFS does not handle privacy-sensitive information and as such is not impacted by GDPR or privacy related legislation.

GTFS is compatible with NeTEx (see below) for schedule information and SIRI (see below) for real-time information. It is possible to generate a full GTFS data set from NeTEx or SIRI, but not vice versa[5]. Official mapping packages are available.

Governance

GTFS is an open specification developed and maintained by the community of transit agencies, developers, and other stakeholders that use GTFS. Anyone can propose and advocate a change that needs to be announced in a dedicated mailing list[6]. These proposals are then discussed and voted for implementation following a well-defined procedure[7].

Variants

GTFS is deliberately kept simple and easy to adopt. Several extensions have been developed that allow extra functionalities. Two cases are GTFS-ride and GTFS-flex:

- **GTFS-ride** offers transport agencies a standardised way to collect, store, share, report, and analyse their ride data that allows them to answer questions like:
    - How many people rode the bus/train/ferry last week?
    - Which routes have the most riders?
    - What time of day is the busiest?
    - What are the busiest stops in the system?

- **GTFS-flex** adds the capability to model various Demand-Responsive Transportation (DRT) services to GTFS, as GTFS currently only models fixed-route public transportation. Contrary to fixed-route public transport, Demand-Responsive Transportation or Dial and Ride Transport services, do not use a fixed route or timetabled journeys, but typically pick-up and drop-off passengers in locations according to passengers needs.

2.1.3 MDS

MDS - Mobility Data Specification

What

MDS is a data standard that enables two-way communication between mobility companies

[5] https://netex-cen.eu/?faq=how-does-netex-compare-with-gtfs
[6] https://groups.google.com/g/gtfs-changes
[7] https://github.com/google/transit/blob/master/gtfs/CHANGES.md

and local governments. It is inspired by projects like GTFS and GBFS and focuses on shared mobility services such as dockless scooters, bicycles, mopeds, and car sharing. It is capable of handling real-time as well as historic data and allows cities to digitally share and validate policy, as well as to obtain the relevant data from private mobility providers for further analysis. Access to MDS APIs is meant to be restricted and treated with care and taking privacy measures in mind. They are not intended to directly support public consumption or consumer-facing applications.

Who

MDS was created by the Los Angeles Department of Transportation (LADOT) and first released in May 2018. In November 2019, stewardship of MDS and ownership of the repository were transferred to the Open Mobility Foundation (OMF). This is a US-based foundation that develops open-source mobility standards and tools by bringing together stakeholders from both public and private sectors. It is a non-profit membership organisation, funded by annual member fees and philanthropic support.

Why

When it comes to managing transportation in the public space, cities need to understand current and historic use patterns and need to have relevant data generated by mobility service providers at their disposal. MDS offers a way to standardise data collection to make sure cities have the necessary tools and information to actively manage vehicle deployments.

The advantage of this standardised framework for mobility service providers, instead of different standards for different cities, is that it saves them time and money.

Technically

MDS consists of a set of API modules (Application Programming Interfaces) that allow data to flow securely between cities and mobility providers. They are designed to be modular and allow cities and providers to communicate in different ways.

The modules used in MDS are:

- Provider allows private mobility companies to report data to cities on the number, location, status, and ride history of devices in use.

- Policy allows cities to set rules regarding how and where different vehicles can operate, how many can operate, and other high-level policy initiatives.

- Agency is designed for real-time data collection and allows cities to maintain an authoritative database of information reported by all providers to support real-time analysis and adaptive regulation.

- Geography allows regulatory agencies to share geographical regions for regulatory

and other purposes.

- Jurisdiction allows cities to communicate territorial boundaries between one another and to mobility providers.

- Metrics allow regulatory agencies or their appointed third-party representatives to request historical calculated core metrics and aggregations of MDS data.

Relevance

MDS has been rapidly adopted and has been implemented by a good deal of major mobility service providers. In November 2022, it is used by more than 130 cities and public agencies around the world.

Compliance and Compatibility

As MDS is designed for collecting historical and real-time trip data, and as geolocation data is known to be easily identifiable *(de Montjoye et al., 2013)*, it entails some major privacy risks. To handle these risks, the Open Mobility foundation has published guidelines for handling privacy related issues and for using MDS under GDPR. It argues that MDS data is generated by vehicles and not riders. MDS datasets do not contain personal information about the users, but information about the status of vehicles, their location, and where they are going. Furthermore, the data does not come directly from the riders, but from the company operating the service.

Nevertheless, MDS datasets which include native vehicle IDs are to be considered personal data and are, as such, subject to GDPR. We also recommended that single vehicle location data be treated as personal data, especially in low-density environments where such location data may be sufficient to single out a given vehicle. This is likely to be the case, as MDS uses unchanging vehicle IDs (instead of rotating vehicle IDs), and does not only cover the vehicles available for use but also actual on-trip data.

The earlier releases of MDS were not up to par with European privacy legislation. The OMF has taken action to tackle this issues and meet the requirements, opening up the standard for use in a European context.
More info:
https://www.openmobilityfoundation.org/guidance-for-using-mds-under-gdpr-released-by-omfs-privacy-committee/

Governance

MDS is an open specification and anyone can contribute to its development. MDS explicitly encourages regulators, mobility service providers and software providers to take part in the development process. Guidelines on how to contribute are available online.

2.2 European standards and specifications

2.2.1 Transmodel

Public Transport Reference Data Model

What

Transmodel is a European standard (EN 12896) that provides a consistent language for Public Transport data. It can be described as a dictionary with common public transport concepts and data structures that can be used to share accurate and interoperable public transport information across organisations. Transmodel is very comprehensive and covers multimodal conventional public transport (bus, tramway, light-rail, metro, coach, long-distance rail), Demand Responsive Transport (DRT) as well as alternative modes (vehicle sharing, vehicle rental, vehicle pooling,...). It is not limited to routing and timing information but covers the whole area of public transport operations ranging from network topology, scheduling, operation monitoring, fare management, passenger information, driver management, management information and statistics.

Transmodel is a conceptual model. Therefore, it does not depend on a specific technology for implementation.

Who

Transmodel is developed and maintained by the European Committee for Standardisation (CEN - Comité Européen de Normalisation), one of three standardisation organisations in the European Union. Within the CEN, standards are drafted by Technical Committees (TCs) of particular scope based on national participation by the CEN members, i.e. the National Standardisation Bodies (NSB's) of the European Union member states and some additional European countries. The Technical Committee responsible for developing Transmodel is Technical Committee 278 (TC278), Working Group 3 (WG3), Sub Group 4 (SG4).

Why

Historically, different companies and organisations in Europe developed their own terminology for public transport operators, which resulted in a confusing situation and misunderstanding when trying to interact with each other. By using matching definitions, structures and meanings, Transmodel facilitates interoperability within organisations and between transport operators and agencies.

Technically

Transmodel consists of a data model available in Enterprise Architect format and several data definitions available in PDF format.

Relevance

Transmodel is normative and has to be viewed in the context of the European ITS Directive (2010/40/E): it facilitates the definition of the requirements to make EU-wide multimodal travel information services accurate and available across borders to ITS users.

Transmodel has been used to underpin a number of CEN data standards, such as SIRI and NeTEx (see below), and also to rationalize national standards, thus allowing for harmonization and interoperability.

Governance

European standards like Transmodel are consensus-built in working groups composed of experts nominated by CEN national members. The experts are representatives of national stakeholders.

To become a standard, the final draft is voted on by the national standardisation organisations. The voting process is based upon weighted votes, based upon the population of the member state.

2.2.2 NeTEx

Network Timetable Exchange

What

NeTEx is the European technical standard for exchanging public transport data related to network topology, scheduled timetables and fare information.It is based on Transmodel and specifies the format and protocol to exchange passenger information such as stops, routes, timetables and fares.

As of 2020, it also includes shared mobility (car sharing, cycle sharing, carpooling, car/cycle rental, …). But its primary focus remains on static data, namely describing the service that is offered and associated infrastructure, more than its current running status. The corresponding real time information is provided by SIRI (see below).

Who

Like Transmodel, NeTEx is developed and maintained by the Committee for Standardisation (CEN, see above). The Technical Committee responsible for developing NeTEx is the Technical Committee 278 (TC278), Working Group 3 (WG3), Sub Group 9 (SG9).

Why

NeTEx was developed to rationalize national standards and to allow for harmonization and cross-border interoperability in the European Union. It replaces the EU members' respective

national standards that were mainly designed for operational purposes and were ill-suited for transnational interoperability *(Tibaut et al., 2012)*.

Technically

NeTEx consists of:

- a CEN Specification document,
- a data model in the standard UML modelling language,
- an accompanying XML schema providing a formal electronic description that can be used by data processing software.

Data in NeTEx format is encoded as XML documents (a markup language and file format for storing, transmitting, and reconstructing data) that must conform exactly to the scheme – standard XML validator tools can check conformance automatically. The schema can also be used to create bindings to different programming languages.

Relevance

NeTEx is the EU-standard for the exchange of static scheduled data such as public transport, long-distance coach and maritime transport including ferries. It is free for everybody to use under the very open Apache 3.0 licence. EU national access points (NAPs) are required to use it as provided for in the ITS Directive.

Compliance and Compatibility

NeTEx does not cover passenger information and thus is not susceptible to privacy issues.

NeTEx is thus very similar to GTFS in that it covers the same type of information, but it has a much wider scope. Where GTFS is primarily designed for provisioning journey planning systems, NeTEx can be used by both operational management systems and customer-facing systems. GTFS has thus limited itself to be able to provide the minimal necessary information in the most straightforward way, where NeTEx is required to be able to accurately handle all kinds of complex use cases.

Governance

Like Transmodel, NeTEx is consensus-built in a working group composed of experts nominated by CEN national members. The experts are representatives of national stakeholders. The final draft is voted by the national standardisation organisations. The voting process is based upon weighted votes, based upon the population of the member state.

2.2.3 SIRI

Service Interface for Real-time Information

What

SIRI is the European standard for exchanging real-time information about public and shared transport services and vehicles. It allows exchanging structured real-time information about schedules, vehicles, connections, vehicle and parking availability and general informational messages related to the operation of the services.

Its original focus was on public transport, both scheduled and on-demand, but the current version (v2.1) also includes alternative modes such as vehicle sharing, pooling and rental for all kinds of vehicles (cars, cycles, mopeds), taxi services and transport network companies (TNC) such as Uber or Cabify (*Data4PT, 2022*).

Who

Like Transmodel, NeTEx is developed and maintained by the CEN (see above). The Technical Committee responsible for developing SIRE is Technical Committee 278 (TC278), Working Group 3 (WG3), Sub Group 7 (SG7).

Why

SIRI is a natural complement to NeTEx. NeTEx provides the scheduled information, while SIRI provides the real-time data. Both SIRI and NeTEx share a common conceptual model provided by Transmodel. It is meant to facilitate the exchange of data between operators, between systems of the same operator, between operators and journey planners and other passenger information systems.

Technically

SIRI consists of a general purpose model, and an XML schema. Messages consist of XML documents, whose tags and content are exactly specified by the SIRI XML schemas.

It consists of different services that all use a common architecture, terminology, reference data:

- Production Timetable Service: Supports the dynamic exchange of planned schedules for a specific day, including updates (update of a calendar-based schedule, most often previously exchanged with NeTEx). These may be used by Automatic Vehicle Management Systems (AVMS) s to predict and monitor vehicle progress.
- Estimated Timetable Service: Supports the exchange of estimated schedules in real time, including updates. These may be used by AVMS systems to predict and monitor vehicle progress.
- Stop Timetable Service: Provides information about schedules for arrivals and departures at a stop point.
- Stop Monitoring Service: Provides information about arrivals and departures at a Monitoring, i.e. Stop point. It has a similar scope as the Production Timetable Service,

but from a stop-centric perspective.

- Vehicle Monitoring Service: Provides information about the movement of a vehicle, and its progress against the target schedule.
- Connection Timetable Service: Provides information about schedules for interchanges at a connection point.
- Connection Monitoring Service: Provides information for interchanges at a connection point to support guaranteed connection services.
- General Message Service: Supports the exchange of general text messages (usually related to a stop, a line, etc.).
- Situation Exchange Service: Covers the exchange of information describing an incident, typically an unplanned event such as a disruption, but also planned events that affect public transport or its use, such as engineering works, or major public events that will affect the use or availability of transport. This information is structured in a way that makes it usable by a journey planner in its optimization algorithm.
- Facility Monitoring Service: Covers the exchange of information concerning the current status of facilities (equipment, sites, etc.). It provides a brief description of the facility itself, the availability status, and specifically the impact of the availability status on PRMs (Person with Reduced Mobility)

Because SIRI is very comprehensive, it requires the definition of an implementation profile, i.e. a subset of that complies with the standard and meets a set of identified needs.

Although it is complementary with NeTEx, it is designed as an autonomous solution and does not need an external reference. This approach makes processing real-time data a bit heavier and less efficient than for instance GTFS Real-time and less suited for web application development *(MobiDataLab, 2022)*.

Relevance

SIRI is the EU standard for the exchange of dynamic public transport data. As provided for in the ITS Directive, the EU national access points (NAPs) are required to use it as of 2019. For publicly available passenger oriented information, GTFS Real-time is often used.

Compliance and Compatibility

As an official EU-standard, GDPR compliance can be expected to be a requirement. From our research, it was not clear to what extent this is currently the case after the introduction of new modes like car and bike sharing or rental. No specific mention of privacy nor GDPR is made, and it is not clear whether particular precautions need to be taken. In our research, however, we have not found any issues with personal data.

Governance

Like Transmodel, SIRI is consensus-built in a working group composed of experts nominated by CEN national members. The experts are representatives of national stakeholders. The final draft is voted by the national standardisation organisations. The voting process is based

upon weighted votes, based upon the population of the member state.

2.2.4 OJP

Open API for Distributed Journey Planning

What

OJP defines a schema for establishing an Open API (Application Programming Interface) for exchanging journey planning information between local, regional, or national journey planning systems. It is intended to exchange information about public transport services and to implement systems able to provide multimodal information for longer-distance journeys.

Technically

OJP consists of a XSD-file (XML-schema definition) freely available on github and a standards document (PDF) made available by the EU national standardisation bodies.

Relevance

OJP is an EU Technical Standard approved by the CEN (see above) in 2017. As to date, it has not been adopted as a standard. This means that its use is only recommended for local, regional and national travel information service providers, but not compulsory. It is not clear to what extent it is actually implemented. One recent example, however, is the Swiss "Open Journey Planner backend routing system. It can be used by multimodal journey planning systems and routing can be based on public transport connections (including realtime data), walking routes and private transport routes for vehicle sharing services.

Compliance and Compatibility

OJP does not handle privacy-sensitive information and as such is not impacted by GDPR or privacy related legislation.

2.2.5 TOMP-API

Transport **O**perator to **M**aaS **P**rovider - Application Programming Interface

What

The TOMP-API is an open-source standardised and technical interface between MaaS providers and transport operators. It aims to cover all the different stages of a trip made by a user and every usable mobility mode and allows participating companies to communicate about planning, booking, execution, support, general information and payments of multimodal, end-user specific trips. The TOMP-API consists of six separate modules that can

be combined for the actual use case.

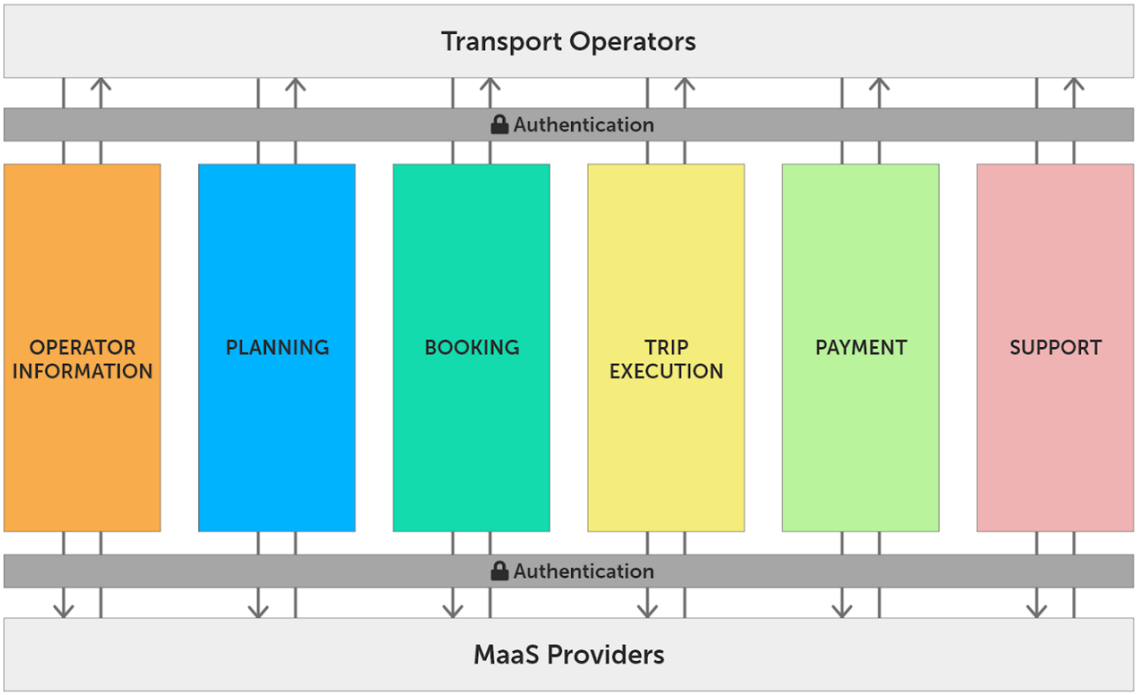

Image: Tjalle Groen - TOMP working group

Who

The TOMP-API is developed and maintained by the Transport Operators and MaaS Providers - Working Group (TOMP-WG). The TOMP-WG is an initiative started in the Netherlands by the Ministry of Infrastructure and Water Management in 2018. The goal of the group is to provide standardised APIs to facilitate the development of the MaaS ecosystem. Since 2020, the TOMP-WG has been moved to become an open-source community with an international scope. In January 2023 NTM[8] (the Dutch National Access Point) took over the supporting role for the working group.

Why

The TOMP-API is intended to facilitate the interoperability between parties in the MaaS ecosystem.

Before TOMP-API, there was no industry standard for booking and payment *(Cooper, 2020)*. MaaS providers had to negotiate with each transport provider to be able to use their API. It made integration time-consuming and expensive and was an important barrier for MaaS providers to enter the market, especially for the smaller ones.

[8] The Dutch National Access Point - https://www.toegangspuntmobiliteit.nl/

Technically

Endpoints are in JSON, a lightweight format for storing and transporting data.
One of the advantages of the TOMP-API is its modularity. There is no need to implement the full specification at once, it is possible to build the implementation gradually. This also enables a high level of interoperability with other standards/specifications. For the exchange of information (up to MaaS level 1) it is possible to not use the TOMP Operator Information module but a possible existing implementation of f.e. GBFS+ or NeTEX[9].

Relevance

In February 2021, the TOMP-API was implemented by over 50 organisations in Europe, Australia, and the USA. By the beginning of 2023, it is safe to say TOMP-API is settling as the standard for technical communication between MaaS Providers and Transport Operators. It builds on established standards as GBFS and NeTEx, but moves up one level in the MaaS-topology *(Sochor et al., 2018)* and can handle the full user journey, including booking, trip execution and payments.

Compliance and Compatibility

TOMP-API is aligned with GBFS (*Van Den Belt, 2021a*) and compatible with NeTEx (*Van Den Belt, 2022b*).

Because TOMP-API can handle individual travel, booking and payment information, it is subject to GDPR-legislation. The developers of the TOMP-API acknowledge this liability and is designed to be compliant to this legislation (Van Den Belt, 2021b). As is the case for GBFS 2.0, TOMP-API it uses rotating asset-IDs, which makes it harder to trace individual vehicles. Parties implementing the TOMP-API should however carefully evaluate what data to collect, how to use it and how to handle it securely for each implementation.

Governance

The TOMP-API is open-source and licensed under the Apache License 2.0. It is developed and maintained by the main TOMP-Working Group, which is organized in 5 teams to handle specific tasks. There are working teams for:

- WT 1 : Technical issues
- WT 2 : Reference implementations
- WT 3 : Standardisation & Collaboration
- WT 4 : Dissemination & Communication
- WT 6 : Governance

Everybody is free to join the working group. You can be added to the mailing lists and invited to the meetings. This can be requested via the contact form on the website

[9] Version 1.4 Interoperability - blogpost - https://tomp-wg.org/?p=545

www.tomp-wg.org.

Other ways to contribute are by contributing code or posting suggestions, feature requests or bug reports on Github.

2.2.6 CDS-M

City Data Standard for Mobility

What

CDS-M is a protocol to ensure secure and effective data exchange between Business and Government organisations (B2G). It is intended for cities that want to develop shared mobility in their territory and is focused on ensuring compliance with existing EU legislation relating to transportation standards and privacy.

The aim of the protocol is not to agree on a specific standard that will be used for the communication, but on the agreement for the use of this data. The protocol addresses policy, planning and enforcement, while the agreement addresses security and privacy considerations relating to the collection, storage, usage, and removal of data.

CDS-M could be a category on its own, since it covers multiple standards and help cities to make the best choice for their specific needs.

Who

CDS-M is an initiative of the cities of Amsterdam, Utrecht, Groningen, Eindhoven and Rotterdam and the Dutch Ministry of Infrastructure and Water Management. It started in 2019, thanks in part to the eHUBS project, which opened up funds to optimize the exchange of mobility data more uniformly. Starting 2023, NTM[10] is supporting the further development & dissemination of CDS-M.

Why

With the increased use of shared mobility modes, a lot of data is generated. This enables cities to develop policies based on actual use instead of assumptions, but it also entails several risks regarding privacy and cybersecurity.

CDS-M is conceived as a practical working method that meets these concerns and ensures safe and effective data exchange in accordance with legal requirements in the EU.

Technically

[10] The Dutch National Access Point - https://www.toegangspuntmobiliteit.nl/

The CDS-M procedure consists of seven steps and is documented on their website.

The steps are:

- Problem definition
- Use case selection
- Privacy assessment
- Security assessment
- Legal agreements
- Data Exchange
- Data analysis and evaluation

The result of the procedure is a list of relevant technical specifications in JSON file format and a ready-made set of contracts and agreements on how the corresponding data should be used.

Relevance

This toolkit is currently being tested in the Netherlands by the cities of Amsterdam (shared e-scooters and cargo bikes), Utrecht (shared cargo bikes), Eindhoven (mobility HUBS and shared scooters) and Rotterdam-The Hague (car permits for both cities).

Compliance and Compatibility

CDS-M is specifically intended to be in line with existing EU laws and legislation relating to transportation standards and privacy. It wants to avoid creating new standards and re-uses existing standards where possible[11]. Among others, it references DATEXII, GBFS, GTFS-Realtime, MDS, NeTEx, SIRI and TOMP-API.

Governance

The protocol is publicly accessible and can be applied by all local authorities in cases where shared mobility is used. It is open source and is released under an Apache 2.0 licence. Development is done by the closed CDSM-WG on Github, where suggestions and requests can be posted by everybody.

2.3 Country specific standards and specifications

2.3.1 IXSI

Interface for X-Sharing Information

IXSI is an interface for exchanging information between a Travel Information System and a Ride Sharing System (car sharing, bike sharing).

[11] https://github.com/CDSM-WG/CDS-M/wiki

The standard started out with a strong bias towards car sharing, but has been redesigned to to handle other types of vehicles as well. It can share information about vehicles, parking spaces and electric charging stations as well as data on their status and availability. Earlier versions, before v5, also covered booking or usage information, but they are not part of the IXSI core any more.

IXSI was initially developed for eConnect Germany, an R&D partnership between several local municipalities, industrial partners and research institutions and funded by the German Federal Ministry of Economics and Technology (BMWi). It is aimed at developing smart grid and smart traffic solutions in the areas of ICT for the sustainable introduction of electric vehicles in the urban and rural area[12]. It is currently hosted by the Bundesverband CarSharing e.V. (BCS), the umbrella organisation of German car sharing providers.

Technically, IXSI has been worked out as an XML Schema Definition File (XSD) file.

IXSI is intended as a national standard in Germany, and IXSI does not specifically mention its relationship to other standards like GBFS or NeTEX. It is currently mainly used in carsharing applications[13].

It could be considered an alternative to TOMP-API, but is limited to sharing information (MaaS level of integration 1 (Sochor et al., 2018), and does not include booking, billing or payment.
It is licensed under the Creative Commons Attribution-NoDerivatives 4.0 International License (CC BY-ND 4.0).

2.3.2 OSLO Mobility

Open Standaarden voor Linkende Organisaties - Open Standards for Linked Organisations

OSLO Mobility is a semantic standard for basic information about mobility as promoted by the Flemish government (northern half of Belgium). It is intended as a reference model to allow fast and structured mapping from and to other standards like MDS, GBFS, Transmodel, NeTEx, TOMP-API[14]. It can be expanded with information about roads and traffic, autonomous vehicles and other reference models that are being developed within the Flemish Government and can be integrated in tenders for public procurement for future MaaS-related tenders.

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[12] https://ses.jrc.ec.europa.eu/econnect-germany

[13] https://carsharing.de/themen/carsharing-schnittstelle/einheitliche-carsharing-schnittstelle-ixsi-50

[14] Webinar OSLO Mobiliteit Trips en Aanbod 09/04/2020

Its development took place in 2019 and 2020 in a public working group consisting of various stakeholders and coordinated by the Flemish Department for Mobility and Public Works.

It has been adopted as an official standard for voluntary use and consists of a data model available in Enterprise Architect format and its corresponding descriptions and definitions.

2.3.3 RDEX+

Ridesharing Data EXchange

What

RDEX+ is a standard/specification intended to facilitate the exchange of carpooling data between different operators or with Multimodal Information Systems. It makes it possible for a user to gather the carpooling offer from different operators and, as of v.2.0 it also allows making bookings.

The RDEX+ standard is developed for France, mainly in collaboration with French carpooling providers. It is however useful for other countries and organisations in Europe.

Who

RDEX+ is developed by la Fabrique des Mobilités (FabMob), a French association that works to accelerate the transition towards sustainable mobility[15].

It is promoted by carpooling operators, transport authorities and the French sector organisation Gart[16] .

Why

The carpooling offer is a very fragmented one with numerous providers. Without a standard for data exchange, a user wishing to have an overview of the different offers, would have to consult each service separately.

RDEX+ addresses this concern and facilitates data exchange between different carpooling websites in compliance with (French) privacy legislation, as devised by CINIL.

Technically

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15 https://expertises.ademe.fr/air-mobilites/mobilite-transports/passer-a-laction/fabrique-mobilites

16 https://docs.google.com/document/d/1JfZbMinFonIUQd76yebgux-h_3MdWzfqM5LytkRGnBY

RDEX+ is written in YAML (a human-readable data-serialization language) and defines endpoints in JSON, a lightweight format for storing and transporting data.

Relevance

Currently, RDEX+ is mainly used in France, but it has the ambition and the potential to evolve to a more international standard[17].

RDEX+ is considered to be an intermediate version that forms the starting point of further development efforts by a working group on carpooling standards coordinated by Fab Mob (see above).

Compliance and compatibility

RDEX + is compliant with French privacy legislation.

Governance

RDEX+ is developed as an open standard/specification based on stakeholder consensus and is released under an Apache 2.0 open-source licence.

2.4 Other standards and specifications

The landscape is in full evolution, we therefore had to make choices related to the standards on which we wanted to communicate in more detail. There are several standards that show merit that we did not want to exclude. They are briefly discussed below.

2.4.1 Datex II

Datex II or Datex2 is a data exchange standard for exchanging traffic information between traffic management centres, traffic service providers, traffic operators and media partners. It contains for example traffic incidents, current road works and other special traffic-related events. These data is presented in XML-format and is modelled with UML.

2.4.2 ISO 4448

ISO 4448 is a technical data and communication standard for managing real-time mobility flows among automated vehicles and devices at side walks and curbs.

2.4.3 CDS

The Curb Data Specification (CDS) is a digital tool that helps cities and companies pilot and scale dynamic curb zones that optimize commercial loading activities. This tool provides a

[17] https://pro.mobicoop.fr/rdex-un-demarrage-reussi-pour-le-standard/

mechanism for cities to express curb regulations, measure activity, and develop policies that create more accessible, useful curbs. CDS is managed by the Open Mobility Foundation that also manages MDS. It focuses on curb loading zones in the public space.

2.4.4 APDS

The Aliance for Parking Data Standards includes support for many types of parking facilities and activities across public and private facilities.

2.4.5 OCPI

The Open Charge Point Interface protocol (OCPI) supports connections between eMobility Service Providers who have EV drivers as customers, and Charge Point Operators who manage charge stations. This protocol is free to use and independent. It can work both bilateral as well as in combination with roaming hubs.

The Transport Protocol Experts Group (TPEG) is a data protocol suite for traffic and travel related information. TPEG can be carried over different transmission media (bearers), such as digital broadcast or cellular networks (wireless Internet). TPEG applications include, among others, information on road conditions, weather, fuel prices, parking or delays of public transport.

2.6.6 Open Trip Model

OpenTripModel is a simple, free, lightweight and easy-to-use data model, used to exchange realtime logistic trip data on the web, and making it easier for shipping, carriers, software vendors, OEMs, and truck manufacturers to create new multi-brand applications and services.
OpenTripModel is currently used and implemented by multiple logistics service providers, shipping, and IT suppliers for different use cases.

The OpenTripModel was initiated and developed by Simacan. To speed up innovation in the market, Simacan decided to open up the OpenTripModel specification for everyone to use, modify, and enrich. Ultimately, this will make it cheaper and easier for everyone in the logistics sector to exchange data, and develop and use new applications and services.
Therefore, Simacan handed over the Open Trip Model to SUTC - Stichting Uniforme Transport code in 2018 for further development, implementation and adoption. SUTC acts on behalf of Transport en Logistiek Nederland and the knowledge hub evofenedex. SUTC is an expertise centre for Logistics ITstandard and develops and maintains the Open Trip Model for and together with logistics service providers, shippers and IT suppliers.

2.7.7 MobiVoc

The MobiVoc v1.0.0 Release provides an open vocabulary to describe parking facilities and charging points for electric vehicles.

2.8.8 Rideal

Rideal is a backend platform which enables public and private organisations to manage, monitor and control all their rider-incentive programs – centralized, transparent, in real-time, and vendor-agnostic.

Rideal is a micro subsidy calculation engine which can be plugged into any #MaaS or Mobility Service Provider platform

2.5 How to choose your standard or specification

CDS-M is giving some very concrete guidelines for public authorities in their use case store and standards manual. The included standards are weighed on with privacy considerations. This use-case store can be found at the following address, https://www.cds-m.com/.

There is no right or wrong when choosing the standard or specification that fits your needs. This is determined by your specific use-cases and internal capabilities, there is no need

[This topic will be further explored in the final version of this paper.]

3. Conclusions

Exploring the different standards and specifications for Mobility data around the globe is an interesting endeavour. In the last years, a significant amount of progress has been made, and the field keeps evolving with the needs of the market. At this point in time (early 2023), all the essential technical tools for elaborate data-sharing are available. Which ones will survive, only time will tell.

As a general recommendation for individuals or groups who are reading this report while researching for the development of a new specification, we would like to give the following advice. Start by looking at what is already available and try to find common ground, most specifications are open source and open for collaboration. Most technical challenges are tackled, improvements and innovations are often fastest achieved when working together.

[This topic will be further explored in the final version of this paper.]

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