Data Standardisation for Shared Mobility, a Study.

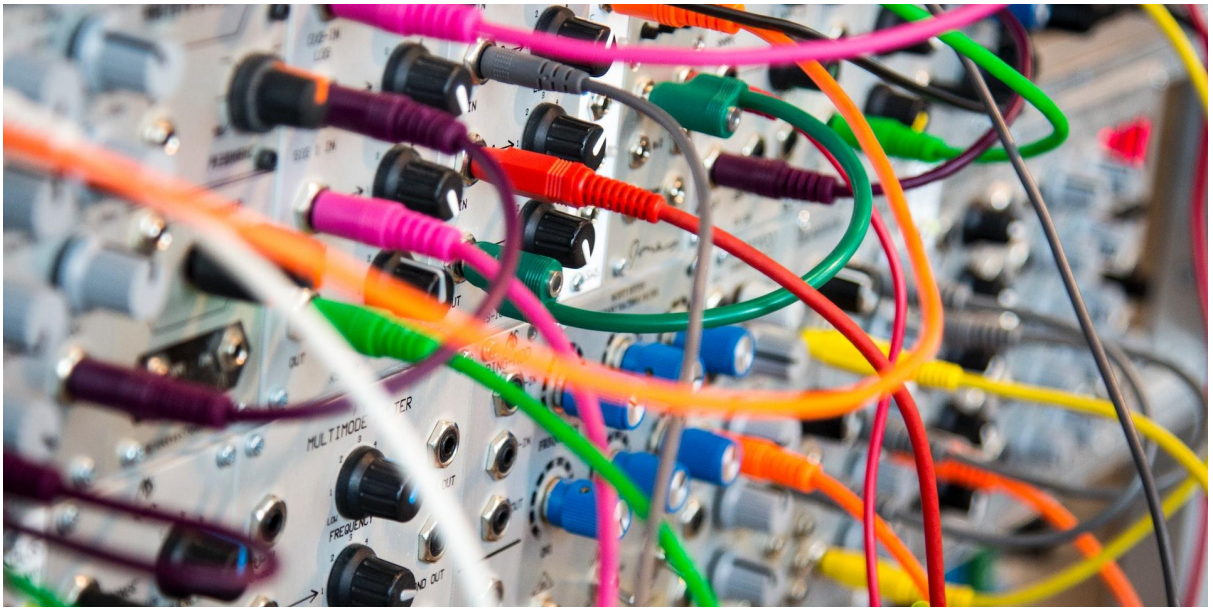

Image by John Barkiple on Unsplash

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Summary sheet

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Title	Data standardisation for Shared Mobility, a study.
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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Authors	Tjalle Groen Jelten Baguet Joris van Mol
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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. Especially in urban contexts, the widespread uptake of shared mobility systems can be considered as a game changer. Shaheen et al. (2019:8) defines shared mobility as *"the shared use of a vehicle, motorcycle, scooter, bicycle, or other travel mode [which] provides users with short-term access to a transportation mode on an as-needed basis. Shared mobility includes various travel modes and service models that meet the diverse needs of users, including carsharing, bike sharing, transportation network companies (TNCs, also known as ridesourcing and ride hailing), and others."*

Next to shared mobility, 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, as well as to reorganise public space to evolve towards a more qualitative living environment. These evolutions give users smoothened access to shared modes: both physical and digital integration will help to bridge the gap in existing transportation networks, thus developing multimodal mobility into a genuine alternative.

Central to these developments is the increasing adoption of information and communications technology (ICT), the widespread use of smartphones, and the growing number of digital platforms. After all, the new shared mobility modes rely heavily on the availability of data. Over the last couple of years, numerous initiatives have arisen that aim to standardise data exchange and interoperability between systems. In this document, we will give an overview of the existing standards and specifications.

This study draws on our own research and builds further on earlier reports compiled by the MaaS Alliance (Abella et al., 2021) and the MobiDataLab project (Chevalier, 2022). We will start by providing some background information regarding the shared mobility data system, the (dis)advantages of data standardisation and sharing, and some reflection regarding the role of governments and the private sector in this. Next, we will give an overview of the most commonly used standards on a global, European and national level. In doing so, we will consistently discuss what the standard is, why it has been developed, who manages it, why it is a relevant standard, the technical difficulties, its relevance, compliance and compatibility, governance structures and additional relevant information. Next to the major standards, we also briefly devote our attention to smaller standards. The last section of this study draws some conclusions.

Before going into more detail, we would like to inform the reader about the difference between 'standards' and 'specifications'. This difference between both relates to whether they have been recognised by an official certification body:

- Standard: has been recognised by an official body such as the CEN: Comité Européen de Normalisation - European Committee for Standardisation. Examples of standards are NeTEx and Transmodel.
- Specification: has not yet been recognised by an official standardisation body.

Examples are GTFS and TOMP-API. Being a specification instead of a standard does not mean that the set of data-rules is of inferior quality or that it is not widely used. GTFS has for instance been developed by Google and is used for the Google Maps application.

Throughout this report, we mostly use the term ‘standard’ as, 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. The involved parties have to agree 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 this is time-consuming and costly. It is presumed that when new technologies are adopted, the need for standardisation will grow as well. 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 that shared mobility as well will take advantage of the development of standards in a sense that it will reduce the costs related to data-exchange and stimulate competition by making it easier for smaller players to enter the market, thus creating an equal level playing field.

Although there have been many developments regarding mobility data over the last few years, slowly but surely, 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 publish 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 on the one hand (based on the customer’s preferences), and the actual offer on the other. 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, for instance regarding data requests, and adapt this policy if needed.
- 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 territorial scope (global, European, national, regional)
- The level of abstraction (see Abella et al. 2021):
    - 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 - Sochor et al. 2018):
    - Level 0: no integration
        - This is the most common situation: the information of one operator is available in one source, via which it is not possible to find information on other (complementary or competing) modes.
    - Level 1: integration of information
        - This can be a multimodal travel planner or devices integrating information on various modes (price, real-time data,...).
    - Level 2: integration of booking and payment
        - For single rides, it is possible to plan, book and pay. Thus, one platform offers multiple modes.
    - Level 3: integration of service offer
        - It is possible to combine multiple modes and to book, unlock and pay for them via a single platform.
    - Level 4: integration of societal goals
        - In this case, the local or regional policy is implemented in the platform, such as reducing car usage.

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

The different elements and considerations cited above explain the complex landscapes of standards, specifications and interfaces. This complexity is illustrated in the figure below, drawn from the MaaS Alliance (Abella *et al.* 2021) white paper.

Although there is a growing number of standards and specifications, not all of them are at the same level of maturity and not all standardisation efforts meet the predetermined scope and/or quality levels. 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 mobility data ecosystem. The European standards, particularly the official Transmodel, NeTEx and SIRI, are very comprehensive but not always adapted to lightweight and fast data exchange.

1.3 Potential of data-exchange

One of the main barriers to facilitating data-exchange in the shared mobility ecosystem, is the lack of harmonisation due to different interests and scopes of the parties involved (Abella et al. 2021:3). Therefore, to avoid further fragmentation, the MaaS-alliance suggests developing standards at a more global level: all initiatives related to data-standardisation should be examined to define the most fitting standard, and the different stakeholders should be convinced to use this solution. (Abella et al. 2021:18-19).

Although this means that the development of some standards will be halted, a global adoption of data specifications and standards can have numerous advantages, not in the least for the users of shared mobility services. In a world without data standardisation and data-exchange, the traveller would have to retrieve travel, route and mode information entirely by him- and herself from different websites and via different operators. This unnecessarily complicates basic inquiries, such as checking whether one can seamlessly connect between bus and train, or finding out whether there is a scooter or shared bike available to cover the first/last mile of a trip. Data standardisation, however, makes multimodal travel much more convenient: based on their preferences, the traveller can make an informed decision on whether to take the quickest, cheapest or greenest (combination of) mode(s) as he, she or they desire(s).

Not only for the users, but for the mobility operators as well, data standardisation has benefits. Currently, most of the shared mobility operators have different ways of organising their data. When this data needs to be integrated into a MaaS-platform or when governmental bodies request specific data, the operators have to make considerable investments, mostly in terms of staff costs, to standardise and integrate data. For smaller mobility providers in particular, who are shorter on staff, providing the data in the desired format can be a challenge. By making use of standards and specifications that require information to be organised in a pre-defined format, transportation and mobility providers will, regardless of their size, be better suited to communicating data between each other; provide a better customer experience due to the multitude of travel options that can be proposed; and provide relevant data to public authorities regarding the usage of the modes, length of trips, start- and end-points of journeys, and etc. Also, having standardised data formats will make it easier for transport operators and MaaS providers to enter new markets since no costly data-restructuring has to be done before launching their operations (Abella et al. 2021:19, Baguet 2022:13).[1]

Although some authors doubt whether the exchange of mobility data is commercially viable - for instance in MaaS-apps (International Transport Forum 2021:99, Vij & Dühr 2022) - the MobiDataLab project has developed five business model archetypes related to data-sharing and -exchange (Benyayer 2022). We discuss two models in more detail, since they can be relevant and viable models for MaaS-providers. Firstly, a ‘two-sided model’ allows the users to access the data for free. Revenue is generated via advertisements or sponsorships, which allows paying the data-providers. Such a platform is comparable to Facebook or Google.

[1] See https://learn.sharedusemobilitycenter.org/casestudy/the-role-of-data-specifications-in-creating-an-integrated-transportation-system as well.

This model has an advantage that it is highly scalable and that the data and service providers get compensated for the data they offer. The disadvantage, however, is that publicity-based platforms are usually less trusted by the users and governments, and that the marketing costs to attract users and gain recognizability in the start-up phase are quite high.

<table>
<tr>
<td rowspan="2">KEY PARTNERS
Analytics service providers</td>
<td>KEY ACTIVITIES
Platform technical maintenance and monitoring
Users support
Data quality control
Marketing and partnership management</td>
<td rowspan="2">VALUE PROPOSITION
Access to FAIR data to make better decisions and develop services
Communicate to targeted audience
Collect revenues</td>
<td>CUSTOMER RELATIONSHIPS
Network effects</td>
<td rowspan="2">CUSTOMER SEGMENTS
Data consumers
Sponsors, advertisers, marketers
Data Providers</td>
</tr>
<tr>
<td>KEY RESOURCES
Data, Platform, catalogue, knowledge base</td>
<td>CHANNELS
Future transport cloud portal
APIs
Transport applications</td>
</tr>
<tr>
<td colspan="3">COST STRUCTURE
Platform maintenance, user support, data, analytics services
Marketing and partnerships</td>
<td colspan="2">REVENUE STREAMS
Data consumers access for free
Advertising / sponsorship revenue is collected</td>
</tr>
</table>

Image: Two-sided business model based on advertisements and sponsorships (Benyayer 2022:25)

An alternative is the ‘data marketplace model’ in which users can buy and sell data. When purchasing a ticket, the platform takes a commission on the transaction to maintain the platform. The data consumers and data producers both pay for the data, while the analytics services providers are paid for their digital services. An example of such a platform is the Moovit-app.[2] This model has been judged as feasible in a MaaS-context by stakeholders, provides a financial incentive to share data, and is scalable. It is, however, technically more complex to implement and would increase prices for the end-user.

[2] https://moovitapp.com/belgium-1682/poi/nl.

<table>
<tr><td>KEY PARTNERS
Analytics service providers

Payment processors</td><td>KEY ACTIVITIES
Platform technical maintenance and monitoring
Users support
Data quality control
Marketing and PR

KEY RESOURCES
Platform, catalogue, knowledge base</td><td>VALUE PROPOSITION
Access to FAIR data to make better decisions and develop services

Collect revenues</td><td>CUSTOMER RELATIONSHIPS
Network effects

CHANNELS
Future transport cloud portal
APIs
Transport applications</td><td>CUSTOMER SEGMENTS
Data consumers

Data Providers</td></tr>
<tr><td colspan="3">COST STRUCTURE
Platform maintenance, user support, analytics services
Marketing and partnerships</td><td colspan="2">REVENUE STREAMS
Commission on every transaction</td></tr>
</table>

Image: Data-marketplace model (Benyayer 2022:26)

Despite a smoother data exchange, improved user experience and business opportunities, we may not forget that data standardisation will not be a 'miracle solution' to make public transport and shared mobility more equitable. After all, data standardisation is only beneficial to smartphone owners or people with sufficiently high digital skills. Figures from EUROSTAT illustrate that only 54% of the 16-74 year olds in the EU member states have at least basic digital skills.[3] For groups that have reduced (or no) access to this technology, alternatives to app-based multimodal planning solutions need to remain accessible, such as printed timetables, staffed information kiosks or help centres that can be contacted by phone.

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

Different types of stakeholders are involved in developing standards and specifications - GTFS was developed by Google, TOMP-API by an open working group with the support of the Dutch government. It can therefore be asked who is most fitted to develop data standards: should this be managed by the market, or via government intervention? For the authors of this deliverable, the most important element to consider in this discussion, is that mobility does not stop at a regional or national border, so data-exchange should not stop there either. Especially in the context of increased cross-border travel because of European political and economic integration, we believe that standards and specifications should be implemented on a European (or even global) scale rather than having standards that are limited to one specific country or region.

The most efficient way to achieve supranational data standardisation will probably be by

[3] https://ec.europa.eu/eurostat/web/products-eurostat-news/-/ddn-20220330-1#:~:text=In%202021%2C%2054%25%20of%20people,least%20basic%20overall%20digital%20skills.

means of public-private partnerships with players from within the shared mobility data ecosystem. In these partnerships, each party has a specific role. The ‘market’ (be it commercial, non-profit or research institutions) is best suited to develop standards. First and foremost, it has the technical and operational knowledge to develop the formats to allow for data exchange and interoperability. Moreover, as standards are often open source and developed in open working groups (as will become clear in the overview of the major standards), they are open to requests and feedback from software architects and can thus continuously integrate the needs of the market. Consequently, the private sector can respond more quickly to changing needs and technological advancements and is more flexible in adapting to trends in the shared mobility sector. Furthermore, as these standards are developed in a bottom-up fashion with specialists from different countries, they will have much more support than when it would have been developed ‘from scratch’ and top-down by a (national) administration.

The public authorities’ role, according to the authors, should be related to facilitating the choice for a certain standard and its dissemination. Since implementing a new standard on a supranational scale is a costly process, the government’s choice for a specific data format should be made cautiously and in agreement with the relevant stakeholders in the field, such as shared mobility operators, MaaS-providers, urban administrations, travellers’ or commuters’ organisations, developers and so forth. Once a choice for a certain standard has been made, it will become much easier to roll it out on a large scale. Currently, many operators remain hesitant to implement some perfectly functioning standards because (a) it is a costly process and (b) because the providers do not know whether the authorities will adopt a standard, and which one. A clear choice for a standard by a certified body such as CEN (see further) will not only take these institutional uncertainties away, but will also generate trust, as the accreditation of a standard can be seen as a quality label.

In a recent paper, the International Transport Forum has positioned itself regarding the data exchange in the market for MaaS-providers. In broad lines, they opt for a pro-market approach with moderate regulation through government intervention. They argue, for instance, that public authorities should be able to participate in the MaaS provider market themselves, but to avoid market distortion, their role can be phased out as soon as the private sector can deliver a viable MaaS-solution (International Transport Forum 2021:46). Another strategy in this respect would be to provide subsidies to the MaaS-providers to ensure their commercial viability (International Transport Forum 2021:97). Still, both in the case of a government that develops and manages its own app or in an entirely free market with little government intervention, it can happen that one MaaS-provider (government-initiated or not) becomes too dominant. This might slow down innovation and make it more difficult for new, smaller providers to enter the local MaaS-market. It might, for instance, happen that the dominant player refuses to share data or to adapt their standards to preserve their market position (see International Transport Forum 2021:83 for some of the arguments). To mitigate this, the ITF recommends a pro-competitive approach in order to create an open-entry market and to foster innovation (International Transport Forum 2021:14).

1.5 Regulatory Framework and GDPR

Because shared mobility involves a large array of personal data (location, payment details, etc.), specific regulation regarding data-protection has to be considered. The eHubs Digital Blueprint gives an overview of the relevant regulations related to this topic for shared mobility (Module 9).[4] The Intelligent Transport Systems Directive (ITS) and the Open Data directive are especially relevant, as they stipulate the specifications and availability of public data.[5] Additionally, the following regulations regarding data protection and security are relevant:

- GDPR / General Data Protection Regulation (EU) 2016/679,[6]
- Directive 2002/58/EC concerning the processing of personal data and the protection of privacy in the electronic communications sector,[7]
- Regulation (EU) 2019/1150 on promoting fairness and transparency for business users of Online Intermediation Services.[8]

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 citizens' right to privacy and is intended to enhance individuals' control and rights over their personal data.[9] 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 being 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 minimisation: 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.

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[4] https://elopage.com/payer/s/eHubs/courses/ehubs-digital-blueprint?course_session_id=5320499&lesson_id=1837512.

[5] https://eur-lex.europa.eu/eli/reg_del/2017/1926/oj and https://eur-lex.europa.eu/legal-content/EN/ALL/?uri=CELEX%3A32010L0040.

[6] https://eur-lex.europa.eu/eli/reg/2016/679/oj.

[7] https://eur-lex.europa.eu/legal-content/de/ALL/?uri=CELEX%3A32002L0058.

[8] https://eur-lex.europa.eu/legal-content/de/TXT/?uri=CELEX:32019R1150.

[9] https://eur-lex.europa.eu/eli/reg/2016/679/oj.

- Integrity and confidentiality: Processing must be done in such a way as to ensure appropriate security, integrity, and confidentiality (for instance by using encryption).

Organisations that handle personal data need to be able to demonstrate compliance with all of these principles. If an organisation is not able to do so, they cannot be considered as GDPR-compliant.[10]

[10] https://gdpr.eu/.

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

The goal of this section is to list existing standards and specifications. Rather than giving an exhaustive overview, we will focus on the most important standards, hereby briefly discussing the main goal of each standard, who it was developed by, why it was developed, its relevance, technical specifications, compliance and governance, and governance structure. We provide links to 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:

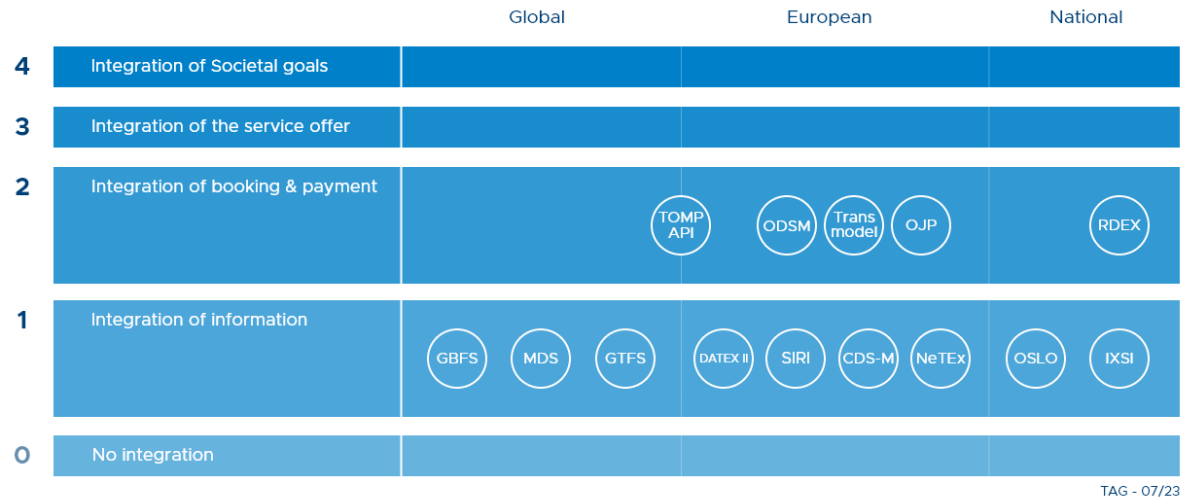

Image: Overview of the different standards - Tjalle Groen

1.1. Global standards and specifications

2.1.1 GBFS

General Bike sharing Feed Specification.[11]

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 sharing programs by NABSA (North American Bikeshare & Scootershare Association). It was first released in 2015. The ownership was handed over to MobilityData in October 2022.[12]

Why

The main objective of GBFS is to provide public, real time, 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 real-time 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.

MobilityData, which hosts GBFS, has developed a guide with recommendations aimed at policymakers on the urban and municipal level.[13]

Technically

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

[11] https://gbfs.mobilitydata.org/.
[12] https://nabsa.net/2022/10/04/gbfs/.
[13] https://mobilitydata.org/gbfs-and-shared-mobility-data-policy-in-europe/.

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 historical data such as trip or maintenance records, and has not been developed with the intention to do so.

Compliance and Compatibility

Current versions of GBFS are GDPR-compilant 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 recognised 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.[14] 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.[15]

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.[16]

What

The General Transit Feed Specification (GTFS) is a data specification that allows public

[14] https://data4pt.org/w/images/5/5b/Canonical_mapping_-_NeTEx_and_SIRI_new_modes_with_GBFS.pdf.
[15] https://gbfs.mobilitydata.org/participate/.
[16] https://gtfs.org/.

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

Who

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

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 (see below),

may use GTFS for publishing data to be used in consumer applications[17].

Compliance and Compatibility

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

GTFS is compatible with NeTEx 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.[18] 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.[19] These proposals are then discussed and voted for implementation following a well-defined procedure.[20]

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?[21]

- 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.[22]

2.1.3 MDS

[17] https://gtfs.org/background/.
[18] https://netex-cen.eu/?faq=how-does-netex-compare-with-gtfs.
[19] https://groups.google.com/g/gtfs-changes.
[20] https://github.com/google/transit/blob/master/gtfs/CHANGES.md.
[21] https://gtfsride.org/.
[22] https://github.com/MobilityData/gtfs-flex.

MDS - Mobility Data Specification.[23]

What

MDS is a data standard that enables two-way communication between mobility companies 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).[24] 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.

[23] https://www.openmobilityfoundation.org/about-mds/.
[24] https://www.openmobilityfoundation.org/about/.

- 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.

A new version of the specification, MDS 2.0, was released in May 2023.[25] It now also supports new passenger services (taxis and ridesharing), carshare and delivery robots; the policy API has been expanded; and the data-structures of the 'agency' and 'provider' modules have been aligned.

Relevance

MDS has been rapidly adopted and has been implemented by a good deal of major mobility service providers. More than 160 cities and public agencies around the world, among others in the cities of Bergen (NO) and Ulm (DE), make use of it.[26]

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.[27] 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 should 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

[25] https://www.openmobilityfoundation.org/announcing-mobility-data-specification-version-2-0-release-candidate/.
[26] https://www.openmobilityfoundation.org/mds-users/.
[27] https://www.openmobilityfoundation.org/using-mds-under-gdpr/.

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 these issues and meet the requirements, opening up the standard for use in a European context.[28]

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.[29]

[28] https://www.openmobilityfoundation.org/guidance-for-using-mds-under-gdpr-released-by-omfs-privacy-committee.
[29] https://github.com/openmobilityfoundation/governance/blob/main/CONTRIBUTING.md.

2.2 European standards and specifications

2.2.1 Transmodel

Public Transport Reference Data Model.[30]

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, namely 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.[31]

[30] https://transmodel-cen.eu/.
[31]

Relevance

Transmodel is normative and has to be viewed in the context of the European ITS Directive (2010/40/E).[32] 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 rationalise national standards, thus allowing for harmonisation 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.[33]

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, …). It remains, however, primarily focused 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

https://www.google.com/url?q=https://www.transmodel-cen.eu/model/Transmodelv6%2B2022March.EAP&sa=D&source=docs&ust=1687358374985691&usg=AOvVaw0ItOU3ra6oMfCMDVqwIvYk and https://www.transmodel-cen.eu/wp-content/uploads/2015/01/TRM6_DataDefinitions-1.pdf.

[32] https://eur-lex.europa.eu/eli/reg_del/2017/1926/oj.

[33] https://netex-cen.eu/.

Technical Committee 278 (TC278), Working Group 3 (WG3), Sub Group 9 (SG9).

Why

NeTEx was developed to rationalise national standards and to allow for harmonisation 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.[34]

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

[34] https://eur-lex.europa.eu/eli/reg_del/2017/1926/oj.

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.[35]

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, as well as general information messages related to the operation of the services.

SIRI's initial 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 (Duquesne et al, 2022).

Who

Like Transmodel, NeTEx is developed and maintained by the CEN (see above). The Technical Committee responsible for developing SIRI 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

[35] https://www.siri-cen.eu/.

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 a 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 optimisation 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).

Given that SIRI is very comprehensive, it requires the definition of an implementation profile, namely a subset 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 heavier and less efficient than for instance GTFS Real-time and less suited for web application development (Chevalier 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.[36] For publicly available passenger oriented information, GTFS Real-time is often used.

Compliance and Compatibility

[36] https://eur-lex.europa.eu/eli/reg_del/2017/1926/oj.

As an official EU-standard, it can be expected that SIRI is GDPR compliant. 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.[37]

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.[38]

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.[39] It can be used by multimodal journey planning systems and routing can be based on public transport connections (including real time data), walking routes and private transport routes for vehicle sharing services.

Compliance and Compatibility

[37] https://www.transmodel-cen.eu/ojp-standard/.
[38] https://github.com/VDVde/OJP.
[39] https://opentransportdata.swiss/en/cookbook/open-journey-planner-ojp/.

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 Operator to MaaS Provider - Application Programming Interface.[40]

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.

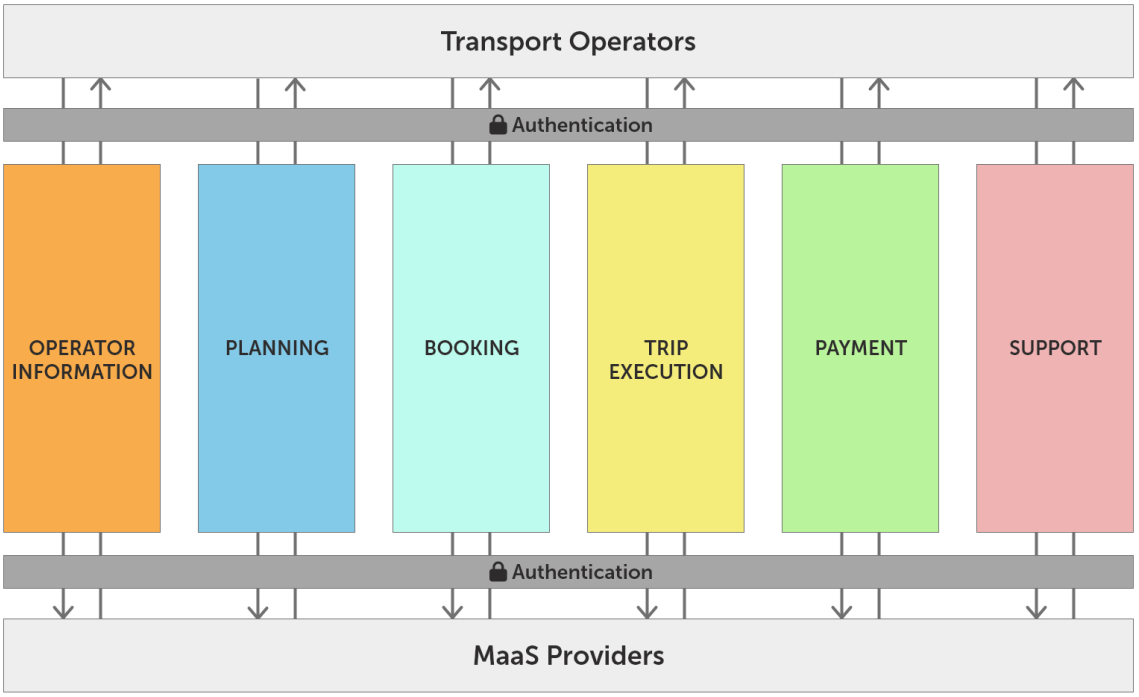

Image: Tjalle Groen - TOMP working group

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

[40] https://github.com/TOMP-WG/TOMP-API/wiki/.

international scope. In January 2023, the Dutch National Access Point NTM took over the supporting role for the Working Group.[41]

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. A study commissioned by the Dutch Ministry of Infrastructure and Water Management (Ecorys 2022) shows that implementing TOMP on a large scale will have several benefits:

- It will result in savings regarding the development and maintenance costs that are related to data-exchange;
- It will create an equal level playing field and avoid monopolies;
- It will improve the quality and experience of travel using MaaS-applications, increase demand and thus increase the size of the MaaS-market.

The study shows that there is a business case for mobility operators to implement the TOMP-API instead of developing their own APIs. Both a proprietary API and the TOMP-API can have positive effects for all types of transport providers, with the TOMP API yielding slightly more favourable results due to efficiency advantages. One prerequisite hereby is that the MaaS-market continues to grow in the following years. Moreover, a Social Cost Benefit Analysis indicates that the efficiency gains for the operators and MaaS-providers are higher than the investments the government made to develop and facilitate the use of the TOMP-API (Ecorys 2022).

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 for example GBFS+ or NeTEX.[42]

Relevance

In February 2021, the TOMP-API was implemented by over 50 organisations in Europe, Australia, and the USA. Examples of operators and providers using this API include Donkey

[41] https://www.toegangspuntmobiliteit.nl/.
[42] See the following blogpost 'Version 1.4 Interoperability' by Edwin van den Belt: https://tomp-wg.org/?p=545.

Republic, Nazza and Check Mobility.[43] At the moment of writing (Summer 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 and is compatible with NeTEx.[44]

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 the specification is designed to be compliant with this legislation.[45] As is the case for GBFS 2.0, TOMP-API 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 organised in 5 teams to handle specific tasks. There are working teams for:

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

Everybody is welcome to join the Working Group, can be added to the mailing lists and invited to the meetings. This can be requested via the contact form on the TOMP-website.[46] Other ways to contribute are by contributing code or posting suggestions, feature requests or bug reports on GitHub.[47]

2.2.6 CDS-M

City Data Standard for Mobility.[48]

What

[43] https://tomp-wg.org/?page_id=186.
[44] See the blogpost 'TOMP-API & GBFS'' by Edwin van den Belt, available here https://tomp-wg.org/?p=178, as well as the LinkedIn-article by the same author, 'Best of both: NeTEx & TOMP-API', available here: https://www.linkedin.com/pulse/best-both-netex-tomp-api-edwin-van-den-belt/.
[45] See the blogpost 'TOMP-API 1.2.0: personal information' by Edwin van den Belt, available here: https://tomp-wg.org/?p=237.
[46] http://www.tomp-wg.org.
[47] https://github.com/TOMP-WG/TOMP-API/wiki/Contribution.
[48] https://www.cds-m.com/.

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 helps 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 optimise the exchange of mobility data more uniformly. From 2023 onwards, the Dutch National Access Point NTM is taking care of the further development & dissemination of CDS-M.[49]

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

The CDS-M procedure consists of seven steps:[50]

- 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

[49] https://www.toegangspuntmobiliteit.nl/.
[50] https://www.cds-m.com/3/.

and a ready-made set of contracts and agreements on how the corresponding data should be used.

Relevance

This toolkit is in use 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).
The toolkits' usefulness is not limited to the Netherlands, it can be used in any European city as it is today.

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 whenever possible.[51] Among others, it references DATEXII,[52] GBFS,[53] GTFS-Realtime,[54] MDS,[55] NeTEx,[56] SIRI,[57] and TOMP-API.[58]

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.[59]

[51] https://github.com/CDSM-WG/CDS-M/wiki.
[52] https://datex2.eu/.
[53] https://github.com/MobilityData/gbfs.
[54] https://github.com/google/transit/tree/master/gtfs-realtime/spec/en.
[55] https://github.com/openmobilityfoundation/mobility-data-specification.
[56] https://github.com/NeTEx-CEN/NeTEx.
[57] https://www.siri-cen.eu/.
[58] https://github.com/TOMP-WG/TOMP-API.
[59] https://github.com/CDSM-WG/CDS-M.

2.3 Country specific standards and specifications

2.3.1 IXSI (Germany)

Interface for X-Sharing Information.[60]

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

The standard started out with a strong bias towards car sharing, but has been redesigned 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).[61] 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 areas.[62] 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.[63]

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 (Belgium/Flanders)

Open Standaarden voor Linkende Organisaties - Open Standards for Linked Organisations.[64]

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

[60] https://github.com/RWTH-i5-IDSG/ixsi.
[61] http://www.econnect-germany.de/uber-econnect/.
[62] https://ses.jrc.ec.europa.eu/econnect-germany.
[63] https://carsharing.de/themen/carsharing-schnittstelle/einheitliche-carsharing-schnittstelle-ixsi-50.
[64] https://data.vlaanderen.be/doc/vocabularium/mobiliteit-trips-en-aanbod/erkendestandaard/2020-04-23/.

allow fast and structured mapping from and to other standards like MDS, GBFS, Transmodel, NeTEx, or TOMP-API (Schepers 2020). 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.

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.[65]

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.[66]

2.3.3 RDEX+ (France)

Ridesharing Data EXchange.[67]

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.

RDEX+ is developed by la Fabrique des Mobilités (FabMob), a French association that works to accelerate the transition towards sustainable mobility.[68] It released under an Apache 2.0 open-source licence, governed by stakeholder consensus

It is promoted by carpooling operators, transport authorities and the French sector organisation Gart[69] .

Since 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 CNIL.[70]

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[65] https://overheid.vlaanderen.be/opleiding/publieke-werkgroepen-oslo-mobiliteit.
[66] https://github.com/Informatievlaanderen/OSLOthema-mobiliteit-trips-en-aanbod and https://data.vlaanderen.be/ns/mobiliteit/trips-en-aanbod.
[67] https://github.com/fabmob/rdexplus.
[68] https://expertises.ademe.fr/air-mobilites/mobilite-transports/passer-a-laction/fabrique-mobilites.
[69] https://docs.google.com/document/d/1JfZbMinFonIUQd76yebgux-h_3MdWzfqM5LytkRGnBY.
[70] https://www.cnil.fr/fr.

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

Currently, RDEX+ is mainly used in France, and compliant with French privacy legislation, but it has the ambition and the potential to evolve to a more international standard[71]. It 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).[72]

[71] https://pro.mobicoop.fr/rdex-un-demarrage-reussi-pour-le-standard/
[72] https://github.com/fabmob/standard-covoiturage.

2.4 Other standards and specifications

Given that the mobility data landscape is in full development, we had to make some choices regarding the standards that could be discussed in more detail in this study. 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.[73] It contains for example traffic incidents, current road works and other special traffic-related events. This data is presented in XML-format and is modelled with UML.

2.4.2 ISO 4448

ISO 4448 or “Intelligent transport systems – Sidewalk and kerb operations for automated vehicles”. This is a technical data and communication standard for managing real-time mobility flows among automated vehicles and devices at side walks and kerbs.[74]
Up to our knowledge, this ISO standard is still under development.[75]

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 optimise commercial loading activities.[76] This tool provides a mechanism for cities to express kerb regulations, measure activity, and develop policies that create more accessible, useful kerbs. CDS is managed by the Open Mobility Foundation that also manages MDS. It focuses on kerb loading zones in the public space.

2.4.4 APDS

The Alliance for Parking Data Standards includes support for many types of parking facilities and activities across public and private facilities.[77]

2.4.5 OCPI

The Open Charge Point Interface protocol (OCPI) supports connections between eMobility

[73] https://datex2.eu/.
[74] https://harmonizemobility.com/sidewalkandcurb/.
[75] https://www.mobilityits.eu/kerbside-management.
[76] https://github.com/openmobilityfoundation/curb-data-specification/wiki/Release-1.0.0.
[77] https://www.iso.org/organization/8356444.html.

Service Providers who have EV drivers as customers, and Charge Point Operators who manage charge stations.[78] 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 real time 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.[79] It 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.[80] SUTC is an expertise centre for Logistics IT-standard 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 V.1.0.0 Release provides an open vocabulary to describe parking facilities and charging points for electric vehicles.[81]

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 – centralised, transparent, in real-time, and vendor-agnostic.[82]

[78] https://github.com/ocpi/ocpi.
[79] https://otm5.opentripmodel.org/.
[80] https://www.evofenedex.nl/.
[81] https://www.mobivoc.org/.
[82] https://harmonizemobility.com/HMS/.

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

2.8.9 OSDM

OSDM[83], or Open Sales and Distribution Model, is a specification aiming to simplify and improve the booking process for customers of public transport trips and to lower complexity and distribution costs for retailers, distributor and carriers.

It can be used as an offline model or an online API. OSDM operates in two modes, Retailer Mode and Distributor Mode. The main difference is that distributor mode has additional (bookable) options like Admissions, Reservations or Ancillaries.

The OSDM API and documentation is available under an Open-Source licence.

[83] https://osdm.io

3. Conclusions

The goal of this report was to sketch the landscape regarding data standards in shared mobility. Our ambition was not to be exhaustive, but rather to provide more detail to the most frequently used standards. We have observed that in the last few years, a significant number of standards have matured and that the field keeps evolving in parallel with the needs of the market. At this point, it remains very hard to predict which ones of the many standards will still be used within a decade, or whether the ecosystem will be dominated by new standards. Is it even necessary to invest time and resources in developing new standards, especially since at the moment of writing (Summer 2023), all the essential technical tools to make efficient data-sharing possible are available?

Whether many new standards will emerge, or whether the existing ones will gain in popularity, will depend on several elements, such as the way in which the shared mobility market will evolve and the financial viability of data-exchange in MaaS. The decisive element in the future of data-standardisation will probably be related to the role public authorities will (not) play in developing and managing standards and specifications. Gradually, national governments are designing frameworks to manage data-standardisation and sharing in the mobility market. An interesting case study in this respect is Finland, whose 2018 Transport Act (PART III, Chapter 2 - Interoperability of information and information systems) looks at the transport system as a whole, rather than focusing on single and separate services. In its essence, the Act removes existing barriers to MaaS development by, among others, requiring transport service providers to make ticketing functionality available to third-parties, and grants access to data including timetables and prices (Ministry of Transport and Communications 2017, Sørensen 2018). In the region of Flanders, by contrast, the approach is a bit softer in the sense that all stakeholders have engaged themselves to digitise non-digitally available information, to reach a minimum level of interoperability, and to develop a data governance framework.[84] These are engagements, and not a strict regulatory framework as is the case with Finland.

If governments decide to regulate the development and implementation of data standards, the next set of questions that has to be answered is related to the extent to which governments may and can extend their influence. Is it desirable that a government, for instance, enforces transport operators and MaaS-providers to use the TOMP-API for their mutual communication? Or would this kind of government intervention hinder innovation? If a government-led approach were privileged, another question would be *which* government has to take the lead: should this be done by local governments because they are most familiar with the situation on the terrain (such as OSLO for Flanders), or supraregional bodies such as CEN, that have the ability to enforce standards on a larger scale. When it comes down to communicating data to municipal administrations, it will for instance be much more cost-efficient when one standard is applied on a national or even European level, thus putting an end to the current situation in which operators have to maintain different formats to communicate with different parties. From a juridical point of view, the example of Finland is

[84] https://maasafsprakenkader.vlaanderen.be/finaletekst.

quite interesting to follow because the country is currently a forerunner regarding data-standardisation and -exchange in the mobility landscape.

Besides these meta-reflections that require the development of governmental frameworks, our recommendation to software architects who are looking for solutions to structure their data, our advice would be quite straightforward: Start by looking at what is already available and try to find a common ground. Since most specifications are open source, almost all the (technical) information on the existing standards and specifications is quite easy to find. Also, we recommend practitioners to get involved in the working groups that manage the standards and specifications. In these teams, changes can be proposed and most technical challenges are tackled. After all, improvements and innovations are often fastest achieved when looking for common ground and by working together.

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4.2 Websites

All the references to the consulted websites are available in footnote.

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