Interoperability for Mobility, Data Models, and API

Building a common, connected, and interoperable ground for the future of mobility

Executive Summary

Mobility as a Service (MaaS) provides a new approach to travel as an all-inclusive experience: it opens several mobility options to travellers via a single mobile application. It has been received with enthusiasm by all.

However, an all-inclusive mobility experience requires a standardized way to share information between stakeholders. Compared to other domains, mobility involves a particularly diverse set of stakeholders coming with their own perspectives, constraints, and information needs.

To provide a wider perspective, MaaS Alliance set up two working groups to examine existing API and Data Models in August 2020. The working groups initially consisted of MaaS Alliance members, but were later opened to non-members to gain wider involvement from the mobility sector. They jointly drafted this position paper in September 2021.

The primary audience for the position paper is transport operators. The second audience includes mobility data system architects and consultants for MaaS stakeholders.

The aim was to define an all-purposes API for MaaS and/or a recipe to reach one common standardized way to exchange information between all stakeholders. First, the joint working group compared different existing data models, formats, API specifications, etc. Then, they thought it would bring them to identify a minimal set of common elements.

The exercise proved to be more complicated than was first perceived. It led the authors to the following conclusions:

- There is no need of creating yet another standard for MaaS but there is a crucial need for better, more fruitful conversation between all standardisation stakeholders to build consensus together, realigning models from a relationship point of view;
- *Pivotal Points of Interoperability, Consensus Framework* and *Minimum Interoperability Mechanism (MIM)* are approaches which help to build interoperability;
- Mapping data models at concept level is difficult. It requires a lot of time and detailed knowledge about each of them. This can only be achieved as a continuous and collective effort.

Projects and groups advocating for open standards (such as MaaS Alliance, DATA4PT, ITxPT, MobilityData, or NAPCORE) need to work together. We all share a similar vision to ensure a seamless travel for all across the continents.

Background

Mobility as a Service (MaaS) is a concept that arose several years ago in the Nordics and in Austria. MaaS was sometimes described as aspiring to be the “Spotify® of mobility”. It envisioned a new approach to travel as an all-inclusive experience, opening up to travellers all their available mobility options via a single mobile application. It could even be extended to include an all-inclusive subscription to pay for the consumption of different forms of travel.

MaaS was received with enthusiasm. However, it was clear that an all-inclusive mobility experience required:

- Definition of the information to be shared amongst mobility stakeholders;
- Standardisation amongst mobility operators of the information (data) to represent their services;
- Standardisation of the data exchange processes;
- A means of orchestrating and consolidating payment processes and ticketing.

Compared to other domains of data standardisation, mobility involves a particularly wide and diverse set of concepts and stakeholders. In contrast to domains such as power supply or mobile communications where an integrated global family of standards have evolved, the mobility industry is still fragmented with sets of stakeholders coming from different backgrounds, perspectives, languages and purposes.

In acknowledgement of this, the MaaS Alliance set up an open forum for platforms to share their views on how to combine data and turn it into information. Through this, it became apparent that better, higher-quality data were essential in order to improve inclusivity, sustainability and efficiency in the realm of mobility. The first step would be to ensure that data semantics are harmonised, so as not to compare apples and oranges.

For this reason, the MaaS Alliance set up working groups for Technical development and Standardisation purposes. Within the working groups, it was thought that some kind of all-purpose API would do the trick. The working group, which initially consisted of MaaS members, was then opened up to gain a more extensive overview and wider involvement in building the API from other stakeholders in the industry. Several organisations, both private and public, shared the results of their own initiatives in organising and sharing data. Coming from different approaches, ranging from a single type of transport (e.g. shared car) to a specific branch (e.g. shared bikes, taxis) to complex domains (e.g. mass transit), this has given the group the benefit of both of deeper knowledge about everyone’s respective domains and different angles to reach their common objective.

The exercise proved to be more complicated than was first fathomed. For the past year, the working group has compared what exists and was known to them in order to identify some minimal commonality that would enable interoperability between existing data models, data formats, API specifications, etc. Working from different angles, the group put together a large, though not comprehensive, repository of applicable standards and tools. In doing so, they realised that there are differences on several grounds. One general rule of thumb, however, is that all were designed to support different objectives or purposes.

In the transition towards a broader approach to mobility, a trendy mantra is that “ownership will change into usership”. As in other digitalisation/data driven services, it is the customer’s needs that should drive the design of the system, rather than the operator’s traditional approach that there is a supply of data that only needs to be presented in certain ways. Most of the traditional databases have been supply-driven rather than focused on the needs of the individual passenger.

Thus, the perspective needs to change from where the vehicle is going to where the individual wants to go. It is similar, but not the same. The individual does not actually care about routes, stops or the overall timetable. She just wants to go to her destination as quickly, as cheaply, and as greenly as she can. To achieve this, she is facing a choice between two options which can hardly be compared as of today:

- using her private vehicle (e.g. car, bike) in which she has already invested part of her capital and is perceived as more economically efficient than making a new purchase (e.g. a ticket, a shared mobility subscription);
- adapting her constraints to the one imposed by the current supply chain (e.g. schedule, registration).

Using the traveller’s lense, we can consider how, in some respects, the current supply chain is limiting or restricting her options to achieve her simple goal. It might also be seen as wasteful of global resources.

In the future, if it wants to be cost effective, the design of public transport should aim to fit individual needs, dynamically, and not just the legacy supply. Furthermore, it should use the many possibilities offered by MaaS to help with sustainability, making a more efficient use of transport resources, spreading demand across the network, dynamically optimising supply to meet demand, increasing use of green modes, etc..

Looking at the subject of mobility through the lense of a person, we see that a travel activity is made of overlapping processes. Consider how you, as a person, go anywhere for the first time. First, you look up how you might get there, perhaps comparing different modes of transport. Secondly, once you have decided which way is best for you (fastest, cheapest, most

accessible, etc) and you make sure that you have the required access (e.g. seats on the train, your car not being in the shop), if needed. Thirdly, you will be expected to pay for use of the service either before or after the travel has taken place; it can also be made in different parts either via the usage of a MaaS system or taking into account the price of the car, gas, tax, depreciation, maintenance, parking, etc. Last, you need to showcase a token of payment of a sort, ranging from a parking ticket to a bus pass. In short we can categorise these as

1. plan;
2. book;
3. contract to pay / pay;
4. travel;
5. after sales.

These activities are applicable for any kind of mobility.

Though the primary activities related to mobility are identified, there is still a big difference between riding an owned vehicle and travelling as a passenger on a train/bus/tram/taxi. In the first case I am responsible for the vehicle; in the second the responsibility is held by a transport operator, which might be subject to public services obligations erected by local authorities. Additionally, in recent years, other options have increased significantly with the addition of ride sharing, vehicle pooling, etc. We have also seen the revolutionary possibilities of direct peer-to-peer and other business-to-consumer engagements, conducted online anywhere and at any time. It created a change of paradigm in the traditional operator-passenger relationship.

Mobility, other than walking, requires a vehicle, a machine (or animal!) that uses some form of propulsion to make you go faster than you can go on foot alone. Any trip usually comprises several different transitions and means, as you progress from start to end. These transitions can be referred to as trip ‘legs’. For example, when I step off the bus and walk to the train platform to continue my journey, I have three legs in scope: the one made within the bus, the one when I am walking, and the one on the train.

These legs share a set of specifics, describing the relationship:

- a sort of service;
- a type of transport;
- a reference to an individual;
- a reference to an asset;
- a starting point, in space and time;
- an ending point, in space and time.

Concluding that a leg can involve any mode of transportation, from bus to walking to cycling. We can categorise them based on type of transport, like walking, going by bike, by car, bus, train or plane. And looking to the actual sort of service provided: ‘private’, ‘peer-to-peer’ (related to the asset or the service/ride), ‘business-to-consumer’ (also related to the asset or the service/ride), and ‘mass transit’ (a special case of the last, i.e. transport operator-to-consumer’)

Looking at mobility solely from the viewpoint of the individual traveller means that we must place the individual at the centre. It does not mean that a fixed route or a schedule should adapt to the individual but rather that the individual’s objectives of moving from A to B should be at the center of the process of building robust specifications. Then, mobility options would be described using the travellers’ lense, facilitating the match between their needs and what exists.

From the perspective of the relationship we want to gather the essential parameters of both the individual and the mobility services in order to match their start and end points (as to location and time), their availability, and any other characteristics required for a fit. The latter can include cost, but also necessary qualifications (e.g. owning a driver’s licence), or the specific needs of individual travellers (e.g. visually-impaired, not being able to take stairs). Other criteria, such as reliability and comfort (e.g. seat options, air conditioning) may also matter to the users but are not handled well by traditional systems.

The work set out to be orchestrated by the authors will now go into a next phase, where they will focus on the matching of the individual and with all sorts and types of mobility and the information required. It will kick off with minimal datasets which we can expand over time to provide further details around both the individual and the transport assets. They foresee a gradual and clearly identified roadmap, against which operators and platforms can assess their own current status and orientate their further activities.

To support this and in order to ultimately achieve interoperability, the working group wants to harmonise transport data models and protocols amongst the diverse mobility data administration systems. Specifically, it is aiming to provide support to mobility industry stakeholders, in particular transport operators, to help them build their information systems and tools, to make data handling easier and less costly for all.

What does interoperability mean here? The authors draw here the distinction between connectivity (a simple communication between devices) and actual interoperability. The latter entails an alignment of data semantics sufficient to enable the remote exchange of products and services and which, given the number of stakeholders and complexity of the industry, typically requires robust open standards and rules of engagement to be established.

However, the first steps of mapping the existing data models, exchange formats, API specifications, and standards have proved to be more complicated than some participants expected. Some challenges are inherent in understanding any complex domain subject to many different design constraints. They arise when developing common concept definitions, the vision of the travellers' journey, etc. Other challenges also derived from the authors having different backgrounds, native languages, and perspectives on mobility; all of them reflecting some of the particular challenges faced by the industry itself when it comes to interoperability.

Members of the Working Group have decided to share with the mobility industry their conclusions so far. Bearing in mind that just four components of MaaS are deemed critical for the traveller (plan, book, pay and travel), the authors of this position paper came up with the following conclusions:

- There is no need of creating yet another standard for MaaS but there is a crucial need for better, more fruitful conversation between all standardisation stakeholders to build consensus together, realigning from this relationship point of view;
- In making the study and comparing data and services, the methodologies of *Pivotal Points of Interoperability*, *Consensus Framework*, and *Minimum Interoperability Mechanism* have been effective and can be used to build interoperability in future;
- Mapping is a difficult task that requires (a lot of!) time, precision, dedication, and comprehensive knowledge about each single initiative. It must be viewed as an ongoing process. It can only be achieved as a collective effort, under the constraint that only a limited number of new standards emerge.

The present position paper will introduce the objects of the study, consensus reached among the authors for mapping, and their mapping of Pivotal Points of Interoperability. It will be followed by a comprehensive mapping of the data models and standards selected by them for this study.

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Introduction

The mobility industry is constantly evolving and growing: over the past years, we have seen the birth, growth, and reorganisation of new mobility providers such as car-sharing, bike sharing, ride sharing, etc. At the same time, public transport operators have also developed new services to serve the changing needs of their riders, such as the integration of on-demand services. They are also revolutionising the nature and extent of their interaction with customers through mobile apps, digital ticketing, smartcards, and real-time information amongst others.

Mobility as a Service (MaaS), which describes the combination of mobility providers through a unified digital solution in service to the travellers, has become even more crucial to support these changes and serve all users better. The providers of MaaS services need to communicate with each transport operator they integrate, to handle data amongst many transport operators and different modes. Sometimes, they must do so across borders, at the regional or international level. However, transport data is often proprietary or localised due to its inherently regional organisation, past development history, the need for monetisation, etc. The diffusion and variety makes it difficult to inter-communicate, especially regarding the semantics and data portability.

MaaS Alliance is aiming to harmonise transport data models and protocols amongst mobility stakeholders. The purpose of this is to make data handling easier. We have a desire to be able to exchange and share mobility data across European data spaces. This desire extends the European strategy of data across all mobility industries in pan-European states and beyond.

The use of concepts such as "*Pivotal Points of Interoperability*", "*Consensus Framework*" and "*Minimum Interoperability Mechanism*" enabled the “API, DataModels and Architecture Working Group” within the MaaS Alliance to find consensus and common ground. The results and status of this research are documented in the following pages.

Audience

This position paper was designed with two main levels of readers in mind.

The primary audience is transport operators. This position paper intends to provide them with an overview of the current and evolving API and data modelling landscape related to MaaS projects globally. The intent is not to draft a comprehensive list of existing data models, standards, specifications, or API (hereafter referred to as *initiatives*), nor to provide in-depth detail of each of them. Instead, it is intended to allow operators to understand the overall

considerations and differences relevant to their particular industry. With that in mind, they can make better informed choices regarding data models and compliance to legal obligations.

The second audience comprises mobility data system architects and consultants for stakeholders of the MaaS ecosystem. Here, we define stakeholders as operators, cities, and public and private entities that need to have a better understanding of the critical interoperability requirements. These requirements are necessary for scalable cross-providers of Mobility as a Service. Stakeholders will also get an overview of the level of effort that has already been invested across the host of initiatives considered in this position paper.

The information contained here is also relevant for MaaS operators, National Access Points (NAPs), and similar entities. The generic approach provided in this position paper for transport operators is relevant to both inter-operating services and extracting information from a MaaS deployment in operation. For example, some of the standards mentioned such as GBFS, NeTEx, and DATEX are essential for NAPs and MaaS providers to consistently and precisely provide the information to travellers.

Scope

In this paper, we examined different initiatives (data exchange formats, ontologies, and APIs) tackling communication and standardisation in the mobility sector. The goal is to set an alignment, find out where the overlap and discrepancies are, and expose them clearly for all readers to choose the initiative meeting best their needs.

In the subsequent paragraphs, initiatives refer to all the data exchange formats, API specifications, or data models known by the authors. They are also referred to as objects of study.

The choice was made to focus on the user journey to classify and compare the concepts used in the selected initiatives. However, before doing so, the authors have found out that the essential first step is to adopt the same semantics[1]. Taking a step back, the authors have agreed on crafting their own definition of the key objects of mobility and the main concepts of the traveller's journey. They chose not to use any existing definitions and references in respect to all of them coming from different backgrounds and perspectives but to create simpler, consensus-driven definitions.

[1] Note: Words can have different meanings and different words for the same content. For example, "trip" and "booking" are nouns that describe a slightly different reality as the actions "planning" and "booking". Here, "booking" creates a confusion and that is why authors have chosen a different noun for the object while keeping it for the action.

They agreed to define the key objects of mobility as follow:

- **User**: A person who has an account (and/or contract) with a MaaS provider;
- **Traveller**: A person who uses mobility assets to travel (between locations), often the same individual as the user;
- **Leg**: A movement by one and/or a group of travellers, using an asset;
- **Trip**: A journey made by a traveller, a chain of legs;
- **Trip option**: A possible trip that can be selected by the traveller;
- **Booked trip**: A confirmed trip option which can be optionally reserved.

The processes included in the traveller's journey[2] can be described as follow:

- **User registration**[3]: User provides details to register as a traveller, such as payment cards, specific needs, data consent, sometimes a registration number required for Know Your Customer (KYC) policies;
- **Planning**: User plans the trip, providing parameters (e.g. location, time, budget and other preferences) for the trip and chooses an offer based on the schedules, trip options, and similar aspects provided;
- **Booking**[4]: User reserves the chosen offer that can later be changed or cancelled;
- **Purchasing**: User purchases the chosen offer;
- **Travelling**: User travels according to the booked offer;
- **Payment**: User pays the chosen offer based on the contract or the actual usage;
- **Support**: When users need help during travelling by different means;
- **After sales**: User can get a refund of a booked offer (e.g. due to the interruptions).

Some might ask why booking and purchasing have been separated? It was intended that this position paper can describe any journey. This can include:

- Trips where booking might not be required before purchasing (e.g. metro, bike-share systems), or trips that may be booked in advance before formal purchasing (e.g. some trains or coaches);
- "Pay As You Go" ticketing with pricing based on the amount of consumption -- and often payment taking place at a different time (e.g. some shared mobility options);

[2] Note: There are additional activities of which some of them are not visible to the user, such as Managing fares (transport provider collects the fare after a sale, fulfilment, validation, control, payment and financial clearing (between MaaS operators, transport providers etc.); Registration & provisioning of user information, etc.

[3] Note: For some mobility services (e.g. taxi, public transit), the possibility for anonymous travelling and payment may be possible, in which case user registration is not necessary.

[4] Note: In some systems, reservation and booking can be separated (e.g. put an option on a train without obligation to confirm and pay for the booking). The authors have chosen to simplify the steps and include reservation within booking in this position paper.

- Trips where the overall trip plan is created and orchestrated by a MaaS provider but certain individual legs are paid for separately through other channels.

From the perspective of a MaaS provider, the user registration is seen as the initial ‘purchase’ of an umbrella product: it establishes both a contract, under which further purchases may be made, and an account, against which purchases can be debited and rebates credited.

Though presented as linear in the glossary, the authors would like to highlight that some processes are not linear and may be repeated several times such as booking and travelling.

Objects of the study

There are many different initiatives to develop data models, APIs, and open formats for the standardisation of mobility data and their exchange. To make this white paper easier to read, the authors have made a selection of the most representative ones to illustrate the mapping process used. The list of objects is not meant to be comprehensive, but the idea is that the same process can be applied to others as well.

To classify the initiatives considered, were used the terms defined as follow:

- **Conceptual data model**: A systematic model, describing the specific concepts for a domain and the relationships between them;
- **Data exchange format**: A clearly specified format in which to exchange data;
- **Protocol**: A communication procedure used to exchange data;
- **Application Programming Interface (API):** A set of structured messages providing access to the function of another system, enabling systems to exchange data or invoke services remotely. Here, a running, implemented instance of a proprietary or standard API specification covering a specific domain;
- **API specification**: A specification that defines interactions between multiple software applications or mixed hardware-software intermediaries. In this context an API is often described using an OpenAPI specification. The API specification does not only describe the data format (like in the exchange format), but also specifies actions to fetch and/or modify the data

Taking the classification a step further, it has been decided to also categorise the initiatives based on their level of MaaS maturity identified by Sochor, Karlson, Sarasini, and al[5]. The description of each maturity level is captured in Figure 1.

Figure 1: Levels of MaaS maturity

The levels 3 and 4 are merely related to technical standards. Inasmuch, they are not part of the scope of this position paper.

Using both classifications mentioned above, the results shown in Figure 2 draw the following conclusions:

- Most initiatives are in the level 1 due to the fact that they only expose information;
- Only API specifications and API can be considered as initiatives looking at integrating booking and payment, at the exception of Transmodel[6].

[5] The reference article by Sochor, Karlson, Sarasini et al. (2017)
[6] Transmodel has been included at this level due to its definitions and semantics being used to develop API specifications.

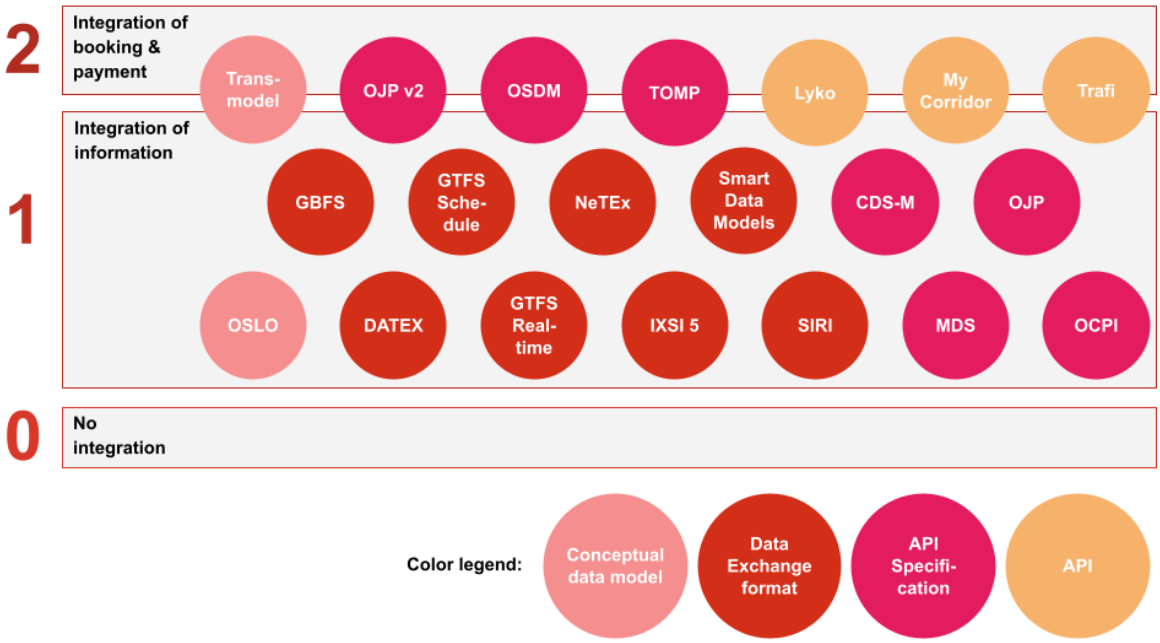

Figure 2: Classification of the objects of study[7]

In each row, the objects of the study are sorted:

- By the order provided in the color legend;
- Then, alphabetically.

For further clarity of the relationships between the initiatives and the organisations that either host or govern them, the authors have drafted a network representation in Figure 3. The network view is not designed as comprehensive of all ties and relationships between the objects of study and their respective organisations. It only serves the purpose of illustrating how connected the existing initiatives are.

[7] Note: The authors acknowledge that not ALL existing conceptual data models, data exchange formats, API specifications, and/or API are listed in this figure. For example, standards for rail bookings. For more details about the railways: https://eur-lex.europa.eu/legal-content/EN/TXT/?uri%3Duriserv%253AOJ.L_.2011.123.01.0011.01.ENG&sa=D&source=editors&ust=1632482759224000&usg=AOvVaw2SIWCrSBIQ94Gm_ptgxwQU

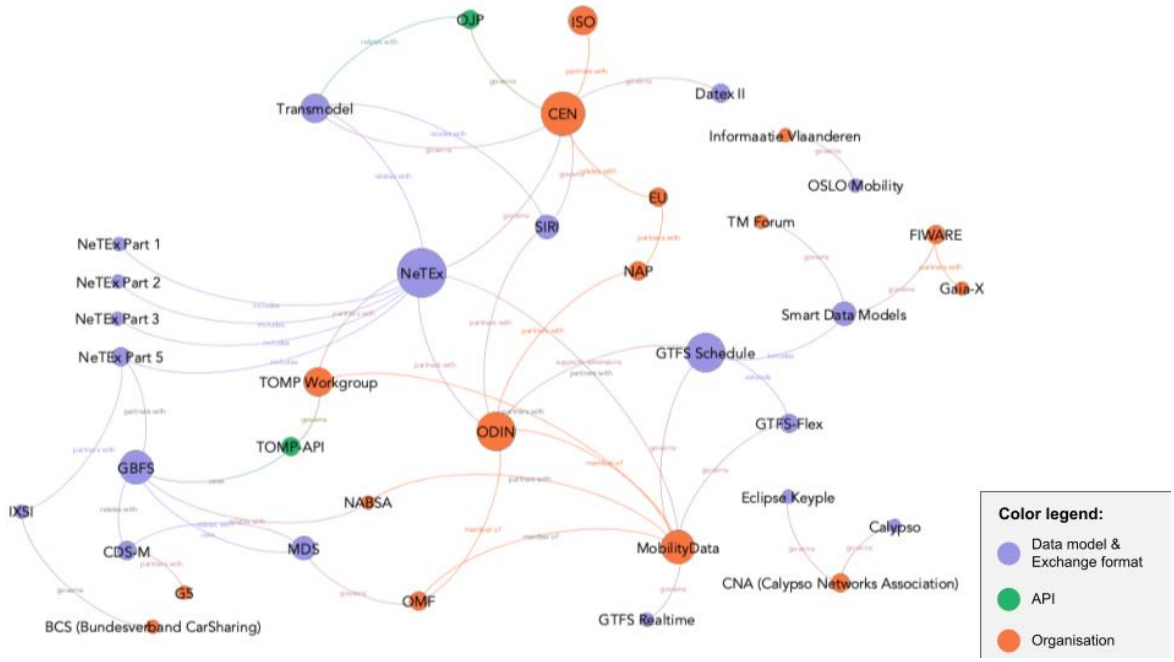

Figure 3: Network view of the objects of study

For each identified objects of study, the authors have classified them based on:

- Category;
- Level of usage;
- Included mobility mode(s).

It resulted in the table, sorted by alphabetical order, as follow:

Name	Category	Level	Mode(s)
DATEX-II	Data Exchange Format	European	Road
GBFS	Data Exchange Format	International	Shared mobility
GTFS Realtime	Data Exchange Format	International	Public transit
GTFS Schedule	Data Exchange Format	International	Public transit
IXSI-5	API Specification	National (Germany)	Shared cars
Lyko	API	Supplier	All
MaaS Global API	API	Supplier	
NGSI-LD API + “Smart Data Models”	API + API Specification	European	Mobility and transport
OJP	API Specification	European	All

OJP v2	API Specification	European	All
OSDM[8]	API Specification	European	Railways (could be extendable to All public modalities)
TOMP-API	API Specification	International	All
Transmodel ● Part 1 (Common Concepts) ● Part 2 (Network) ● Part 3 (Timing) ● Part 4 (Operations) ● Part 5 (Fares Management) ● Part 6 (Passenger Information) ● Part 7 (Driver Management) ● Part 8 (Management Information) ● Part 10 (Alternative modes)	Conceptual Model	European	All
NeTEx ● Part 1(Common Concepts, Network) ● Part 2 (Timing) ● Part 3 (Fare Management) ● Part 5 (Alternative Modes API)	Data Exchange Format	European	All
SIRI	API Specification	European	Public transit
TAP TSI	Data Exchange Format	European	Rail and partially public transport
Trafi	API	Supplier	All

Out of simplicity, the following position paper will only share the definition of four objects of study: Transmodel and thereby its data exchange format NeTEx, GTFS, GBFS, and TOMP-API. The choice was made based on the most commonly used standards at the European level.

Transmodel

Transmodel is the short name for the European Norm “Public Transport Reference Data Model” (EN 12896), a data standard that covers many aspects of public transport information and service management. In particular, the standard facilitates interoperability between the information processing systems of transport operators and agencies by using matching **definitions, structures and semantics for the data elements** used by their various systems. This is of substantial benefit both when connecting different applications within an organisation, when connecting the applications of different interworking organisations or in the case of MaaS platforms combining multisource information.

[8] Note: As of today, no known implementation exists (to the best of the authors’ knowledge).

The most notable benefit, however, is for the Public Transport end-user. Transmodel-based systems allow data from multiple sources to be integrated coherently to provide detailed, reliable information for door-to-door trips made on multiple modes; this can include information about the accessibility features of all components related to the trip, (as well as their real-time status), supporting travel by persons with restricted mobility.

The Transmodel standard provides a modular framework for defining and agreeing a **common data language**, and covers the whole area of public transport operations. Transmodel covers not just the downstream passenger facing data that is the main focus of MaaS services, but also the upstream data needed to plan and operate the system, giving operators a consistent and efficient reuse of data between the respective subsystems.

By making use of this European Standard, and of data models and exchange formats derived from it, it is much easier and cheaper for operators, authorities and software suppliers to share information. This helps to build integrated and interoperable systems. Moreover, the breadth of the standard helps to ensure that future system developments can be accommodated with the minimum of difficulty, for instance extensions for new modes (cycle sharing, carpooling, etc).

The following European series of data exchange standards derived from Transmodel belong to the Transmodel ecosystem, enabling system interoperability in the considered domains across Europe:

- NeTEx (CEN/TS 16614-1/2/3/5): European technical specification for the exchange of Public Transport scheduled information (concerning network, timetables, fares and alternative modes),
- SIRI (EN 15531-1/2/3/4/5): Exchange of real-time information about PT services, vehicles, events and facilities,
- OpRa is currently under development at CEN and will cover all the observed operational raw data of public transport (for operational reporting, KPI and statistics, service quality analysis, etc.) ,
- OJP (prCEN/TS 17118): Open API for Distributed Journey Planning that can be implemented by any local, regional or national journey planning system in order to exchange journey planning information with any other participating local, regional or national journey planning system.

GTFS

The General Transit Feed Specification (GTFS) is an open data exchange format that allows transit agencies to produce data describing their transit service in a format that can be

commonly understood and consumed by a variety of rider-facing software applications. GTFS is split into two components: GTFS Schedule and GTFS Realtime.

GTFS Schedule can be used to describe a transit system (i.e. agency, stops, routes, and trips) and its associated service schedules (i.e. operating days of a service, stop times, and frequency of service). Supplementary information, such as the path taken by a vehicle, transfers, fares, text translations, and navigation for in-station pathways, can also be described.

GTFS Realtime can be used to describe arrival time predictions, vehicle positions, and service alerts that are captured and expressed in real time. The GTFS Realtime component is complementary to the GTFS Schedule component.

GBFS

The General Bikeshare Feed Specification (GBFS) is an open data exchange format for shared mobility information, developed through a consensus-based process on GitHub. GBFS enables the exchange of information in a way that ensures all parties agree on what the information represents.

GBFS is a real-time data specification. It describes the current status of a mobility system at this point in time. GBFS does not support, and is not intended for historical data such as trip or maintenance records.

TOMP-API

The TOMP-API is being developed by an open source working group, the TOMP-WG (Transport Operator, MaaS Provider – Working Group), with public and private stakeholders, aimed at facilitating the implementation of MaaS and the corresponding exchange of data. The TOMP-API describes a full MaaS journey, including operator information, planning, booking, support, payments and trip execution.

With this API MaaS Service providers can get information about the services of transport operators (GBFS-like), request planning options, book them and execute the booked/reserved trips. The aim is to support every modality, public or private. The process of operating the endpoints in the API is flexible and described.

Challenges

The ambition of MaaS is to connect all modes of transport, be it at the scale of a city, a region, or between countries.

One of the keys to the success of MaaS is data sharing. But, how can this be done when there are so many means of transport and so many stakeholders? The standardisation of data formats and the use of standards should provide a partial answer to this problem.

However, we should not think that this problem is local to individual countries. The mobility providers, and in particular the private sector, operate in different countries. That is why standards should be developed at a more global level. Whether they are of local, European, or have any other origin, all initiatives must be examined and studied in order to define the best choice. This should guarantee sufficient coverage of needs as well as independence in terms of the evolution of these norms and standards.

So, the challenges that have to be addressed are:

- Identifying the existing standards and data models;
- Agreeing together on what to use at this stage of knowledge;
- Studying the possible/necessary evolutions;
- Convincing the different stakeholders to use these solutions.

This last point is likely to be the most difficult to achieve as some local initiatives have already begun. But, it is not too late and initiatives are still in the evolution stage. It should be recognized that the very act of comparing standards, data models, and APIs drives harmonisation as developers clarify their concepts, learn from each other, borrow useful notions, and start to use the same semantics.

In addition to the above points, the European Commission requires certain parties within the mobility industry to adopt and work within existing European frameworks such as CEN's Transmodel. Operators within the MaaS ecosystem must have the ability to operate in an inclusive and agile way to be compliant with these requirements. This opens up the need for more standards to be adopted by more stakeholders in order to become compliant to local, regional, national, and European regulations.

Exchange of data occurring between different parties in the MaaS ecosystem provides benefit to all parties. For example, local transportation authorities and infrastructure providers can use the exchanged data, when standardised, to evaluate and analyse the usage made of their infrastructure, the stress put upon them by travellers in order to maintain, improve, or develop them. Similarly, standardised data can be used to cross compare offers from the different providers to build up relevant and insightful data with reduced effort.

Standardisation also means that different providers can share, where possible, their own datasets with partners, gain a greater understanding of data models and patterns across a wider geographic area, and above all get access to much more data at a reduced cost of ingestion. It also enables the integration of workflows and processes.

A standardised data format greatly reduces the overhead of developing and managing data requirements when dealing with multiple parties. This creates a much lower boundary to entry for transport operators (TO) and MaaS providers (MP) entering new markets. It also makes it easy for cities to adopt and grant licences to new modalities that may arise and become desirable in the future. Without data being shared in this manner a fragmentation and diversity of datasets arise, presenting a major burden for all parties involved.

In pursuing the above goals, we should bear in mind the requirements of the General Data Protection Regulation (GDPR) guidance on the use of certain types of data, making sure that use is necessary and proportional to the end objectives of the collection of data, and secure.

Interoperability: the next steps

Pivotal points of interoperability (PPI)

« Open and interoperable are two words in the Information Technology (IT) world susceptible to misunderstanding at best, at worst to self-serving abuse. It is important to clarify their accepted meanings, because how they are understood in the market has direct practical consequences for consumers, vendors and regulatory authorities. The spread of true interoperability in IT markets, based on truly open standards, ultimately depends on market demand. A clear understanding of what both words mean – and don't mean – is the place to start. », reported by ECIS[9].

Open means truly open - all pertinent data from data producers is discoverable and available on equal terms (usually free and usually subject to some sort of open licence) to anyone who wants to consume it. In an open data society, consumers also have responsibilities: to follow the licence requirements, provide feedback on quality, and respect performance limitations.

What does interoperability mean here? The authors draw here the distinction between connectivity (a simple communication between devices) and actual interoperability. The latter entails an alignment of data semantics sufficient to enable the remote exchange of products and services and which, given the number of stakeholders and complexity of the industry, typically requires robust open standards and rules of engagement to be established. Open

[9] http://ec.europa.eu/idabc/

standards will give the opportunity to all stakeholders involved to keep on formalising exchanges at the pace of the industry's evolution.

From the demand and supply side, the interpretation and the meaning of interoperability may differ. More often than not, they have a different vision and understanding of the kind of interoperability that should be achieved.

Figure 4 shows a method for approaching consensus among stakeholders, with the goal of agreeing on "common ground" in areas of high complexity and diversity. This approach is well founded and has been used successfully before in the context of "standardisation" and stakeholder alignment (REF[10]). The process has five steps, starting from architectures and deployments, ending with a document about the "interoperability" touchpoints.

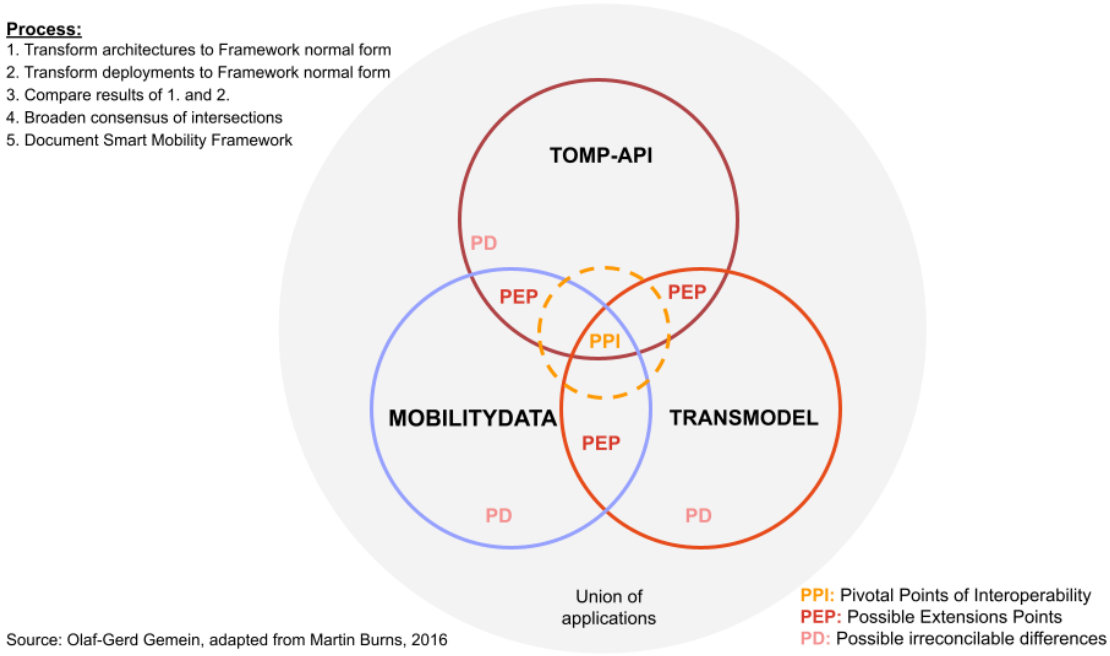

Figure 4: Illustration[11] of the method for approaching consensus

Minimal Interoperability Mechanism (MIM)

[10] Martin Burns, 2016, Washington, https://pages.nist.gov/smartcitiesarchitecture/community/consensusppi/

[11] Note: The authors have voluntarily chosen to map 3 entities that are of different nature for illustration purposes. TOMP-API is an API specification, MobilityData is an organisation, and Transmodel is a conceptual data model. The choice was made to avoid presuming any final mapping and PPI between the objects of the study.

The Pivotal Points of Interoperability lead to the recognition of the Minimum Interoperability Mechanism (MIM) as a model of implementation.

The Minimal Interoperability Mechanism dictates that MaaS providers apply a clear but minimal set of interoperability criteria « *[...] the smallest common denominator that is needed to guarantee interoperability between (city) systems and data. MIMs are for example "Context Management Information" and "Common Data Models". The former is necessary, because without such metainformation – such as when data was last generated, how often it is updated, where it was recorded, what did it record, etc. – open data is often useless for third parties to use in their solutions. Common Data Models help to structure data and facilitate the automated exchange of data between systems and stakeholders, but only when cities use the same data models, such as the schema data models, that are available on open development platforms such as Gitlab/ Github and free for everyone to use* » said Martin Brynskov in an interview with Haye Folkertsma, the Coordinator of the IRIS project.

The first formal approval of the Minimal Interoperability Mechanisms took place during a vote in January 2019 at the OASC Council of Cities, a council representing 100+ cities global network in 25 countries.« *With this vote, we see OASC maturing as an organisation and multiplying its efforts to support member cities and communities on their path of digital transformation. The OASC MIMs are the key ingredient for cost-effective innovation and procurement for cities around the world as they allow companies to develop once and deploy many times. This drives down cost dramatically. MIMs also allow cities to avoid vendor lock-in, a big problem in the market today* »,said Bart Rosseau, OASC Council of Cities Coordinator and Chief Data Officer of the City of Ghent (Belgium); « *almost as important as the adoption of the MIMs by the OASC member cities, is the fact that cities are finally talking standards. They are finding out just how important standards are when procuring new digital services. We are reaching a new level of awareness which will not only help cities* », Rosseau states further.

The implementation of an innovation procurement process based on MIMs is a fairly straightforward and practicable way to ensure interoperability. It also gives an approach for fitting as yet unknown future data services into the given reference architecture of the city and mobility.

Then, the Minimum Information Interoperability Standards (MIOS) can be defined as a formal standard for instantiating the respected MIMs. Figure 5 illustrates the virtuous circle, called the Consensus Framework, that gets initiated by PPI and MIMs.

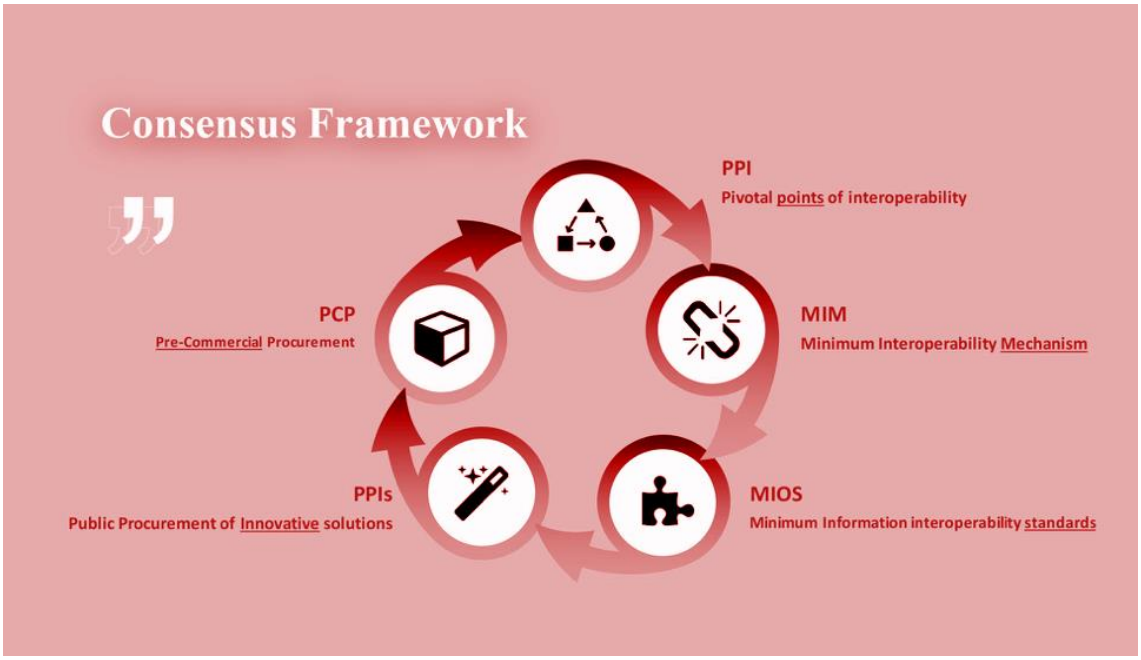

Figure 5: The concept of "MIM" in relation to ancillary or higher-level concepts to achieve interoperability: the Consensus framework (Gemein[12], 2016)

Interoperability requirement

Ensuring "interoperability" within intelligent transport systems (ITS) means "**building coherent services for users when the individual components are technically different and managed by different organisations**" (Wikipedia[13]). Achieving system interoperability and an efficient exchange of information, even when limited to one business area such as passenger information, is a challenge. Traveller information services over several regions have to provide information to the final user concerning both space (where to board, where to transfer, where to alight, what line to use, etc.) and time (departure time, arrival time, etc.) Trip planning algorithms moreover have to process interlinked data coming from different sources and combine them to one or more coherent trip plans. Such information relies on a coherent description of the space and time-related network data across Europe.

12 https://www.researchgate.net/publication/331176426_5_Methoden_zur_Konsensfindung_in_marktnahen_Standardisierungsprozessen_Pivotal_Points_of_Interoperability_Werkzeuge_Praxisbeispiele_und_Entscheidungshilfen_fur_innovative_Unternehmen_Normungsorganisat

13 https://en.wikipedia.org/wiki/Interoperability

Full mobility services for travellers require more information than this, including the provision of fare information associated with a particular trip. However, **fare data and the network data** structures are closely related and, for cross border or even **inter-regional** trips, a common understanding of the underlying data concepts is particularly important. In addition, operational changes, delays, accidents, and other events influencing public transport services may modify information provided to travellers at different points in time. This means that **operational data** is also important in the context of passenger information, and has to be expressed in relation to the network data.

In brief, to make the systems interoperable at the **European-wide** level the requirement is:

- To provide a common framework that allows systems from different sectors (passenger information, fare management, scheduling, operations control, etc.) to exchange information between each other in an easy and reliable way thus ensuring **cross-domain interoperability**;
- To create systems that communicate smoothly, "understanding" the information they exchange without ambiguity, and avoiding the need for complex translators, thus ensuring **semantic interoperability**.

Mapping and preliminary results

Focusing on the user journey, we can create a matrix, relating the steps in the user journey with the different objects of study. If one contains concepts related to a process of the traveller's journey, the matrix cell is coloured. The chosen color scheme is:

- Light green, indicating that information can be shared;
- Dark green, indicating that operations can be done.

Figures 6 show the matrix created by the authors and used as a basis to their mapping. The authors acknowledge the fact that:

- The list of the objects of study is not comprehensive and only focuses on the travellers' journey. There are a lot of standards in adjacent areas, like payment, static information distribution or city communication (like MDS, CDS-M);
- The matrix is imperfect in its colouring and is bound to evolve along with authors gaining more knowledge about each object;
- The mentions 'Yes', 'No', 'Partly' are too vague to constitute an effective mapping.

	user registration	planning	booking	traveling	fare collection	payment	support	after sales
OSDM	Yes	Yes	Yes	Yes		No	No	Yes
TOMP-API	Yes	Yes	Yes	Yes		Yes	Yes	Yes
Lyko	Yes	Yes	Yes					
Trafi	Yes	Yes	Yes			Yes	Yes	
GTFS Schedule	No	Yes	No	Yes	Yes	No	No	No
GTFS Realtime	No	Yes	No	Yes	No	No	No	No
GBFS	Yes	Yes	Yes	Yes	Yes	No	No	No
Transmodel	Yes	Yes	Yes	Yes	Yes	Partly	Partly	Yes
OJP	No	Yes	Yes	Yes		No	No	No
OJP V2	Yes	Yes	Yes	Yes		No	No	Yes

Figure 6: Partial matrix serving as a basis to the authors' mapping

Further analysis can be done on each cell, trying to relate the concepts of initiatives (on concept or even on attribute level). For instance, taking a look at the column 'User registration', several concepts can be defined as follow:

- **(Type of) license:** Official permission or permit to do, use, or own something, e.g. a driver license
- **(Type of) card:** An official card to pay, proof membership or subscription
- **(Dis)ability:** Societal imposition on people who have impairments
- **(External) Account:** The account of the user. Related to Identity and Personal aspects
- **User group:** A group of users, might imply extra rights or extra available assets

To illustrate further the tentative mapping based on the single column "User registration' and these concepts for the first four listed initiatives, Figures 7 shows how quickly it gains in complexity to the point that it is getting harder to draw. It also illustrates how each object of study is unique. For instance, the Trafi API uses Identities and the TOMP-API facilitates communicating Requirements (=disabilities). This way of mapping creates an intuitive impression to find MIMs, but adding another (like OJP v2 or GBFS) will explode the number of extra lines, making it very hard to distinguish the MIMs (highly connected concepts over multiple initiatives).

It also reinforces the fact that the mapping process[14] needs an extensive knowledge of at least two initiatives. It is time consuming, even on a conceptual level.

[14] Canonical method for mapping designed by DATA4PT and approved by CEN: https://data4pt-project.eu/wp-content/uploads/2021/03/Data4PT-Methodology-for-comparing-data-standards.pdf

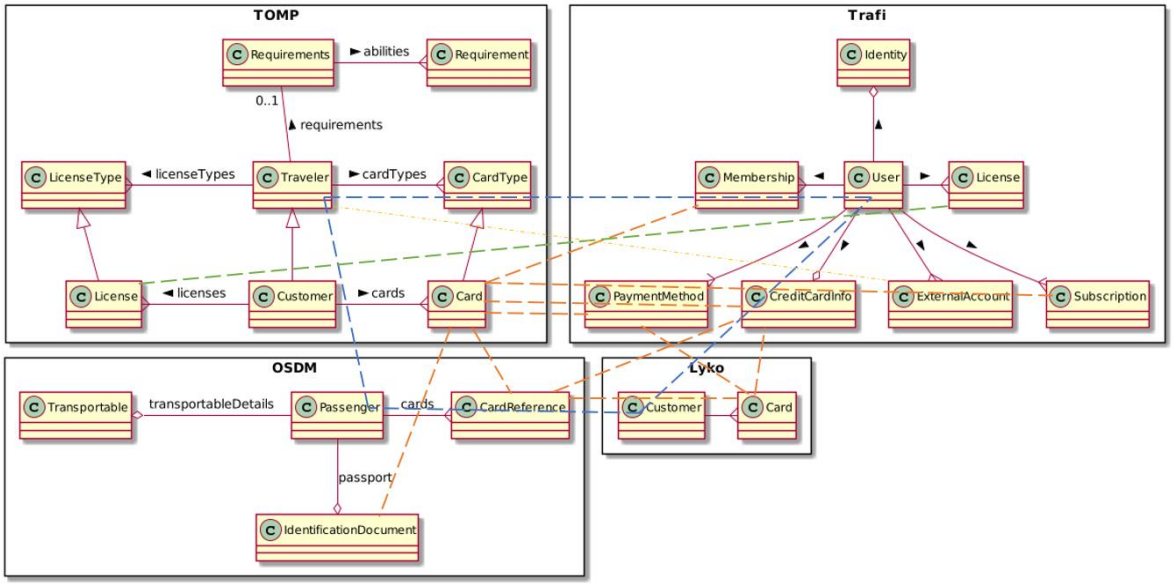

Figure 7: Tentative mapping of concepts between four initiatives for the column 'User registration' only - Created for illustration purpose only by Edwin van den Belt, 2021

Going back to identifying where Pivotal Points of Interoperability (PPI) can be found to set a Minimum Interoperability Mechanism (MIM), the authors have created a "work in progress" matrix with concepts known to them per initiative. The matrix is shown in Figure 8.

	Lyko	Trafi	TOMP-API	OSDM
Customer	Customer	User	Customer, Traveler	Passenger
PaymentCard	Card	Payment methods	Card, CardType	CardReference
License		License	License, LicenseType	
Disability			Requirement	
External account		ExternalAccount	Traveler.knownIdentifier	
Subscription		Subscription	Card, CardType	
Membership		Membership	Card, CardType	
Identification document			Card, CardType	IdentificationDocument
Identity		Identity		
Transportable				Transportable

Figure 8: Identification of concepts know to the authors for four initiatives looking at 'User registration' only

Figure 8 reflects that there are at least two PPIs in these four initiatives: Customer and PaymentCard. It supports the authors' idea that MIMs can be found but better knowledge of each object of study is needed.

If anything, it highlights that mapping the initiatives to define PPI and MIMs is very much a continuous work in progress.

Conclusions

These preliminary results of the mapping undertaken by the authors reveal clearly three main points:

- There is no need to create yet another standard for MaaS but there is a crucial need for better, more fruitful conversation between all standardisation stakeholders to build consensus together;
- Between all the objects of this study, *Pivotal Points of Interoperability, Consensus Framework* or *Minimum Interoperability Mechanism* can be identified and used to build interoperability;
- Mapping is a difficult task that requires (a lot of!) time, precision, dedication, and comprehensive knowledge about each single initiative. It must be viewed as an ongoing process. It can only be achieved as a collective effort, under the condition a limited number of new standards emerge.

In regards to the mapping, the authors are still working to find a consensus among them on how to conduct it best. While it is broadly accepted that a reference standard can be of great help when it comes to comparing concepts and choices made by each existing standard, there has been no agreement reached in regards to which reference to use. The authors are also acutely aware that the choice of reference(s) depends on the scope of their work: for example, a reference standard model for the infrastructure representation is different from the reference standard for public transport[15].

As next steps after this position paper, the authors of this white paper will look into:

- Reaching an agreement in which reference to use to pursue their mapping efforts;
- Releasing a more comprehensive version of their mapping of data models, specifications, API, etc.;
- Based on the mapping, propose and explore the Minimum Interoperable Mechanisms for all stakeholders of Mobility as a Service;
- Opening their working group to all volunteers who would like to contribute.

[15] https://publications.jrc.ec.europa.eu/repository/handle/JRC118744

For their last words, the authors of the position paper would like to advocate a better, more constructive collaboration between all stakeholders of the mobility community, starting with agreeing on public data-sharing and its best practices.

Projects and groups advocating for the latter, such as DATA4PT, ITxPT, MaaS Alliance, MobilityData, or NAPCORE, should be working together since they share similar goals. They are all working towards the ultimate goal of ensuring seamless travel for all across whole continents.

Glossary

Why a glossary? While it may seem trivial to some readers, the authors of this position paper have found that it is a real challenge to find a common ground when working on very different standards. Coming from different backgrounds, native languages, and perspectives, specific words often have different meanings and connotations.

To facilitate the reading of this position paper and as the first major milestones accomplished by the authors and members of the MaaS Alliance working group, below is the glossary defined by consensus. It might not be perfect but it is definitely essential to further mapping.

The below glossary is in alphabetical order, so as not to presume of any order of importance.

Level 1: the journey main objects

- **Booked**: An authorised or confirmed planned leg/trip.
- **End**: the point in time and space at the end of a leg.
- **Individual**: A human being (not a bot).
- **Leg**: A single relationship between an individual and a mobility asset going from A to B in space and time, according to a particular mode.
- **Mobility asset:** A physical means of transport either public (train, bus, etc.) or private (car, taxi, cycle, scooter, h eetc.) - in effect the 'vehicle'.
- **Mode**: A method of transport - by train, bus, cycle, walking, etc., irrespective of any specific asset.
- **Pay**: the administrative transaction of transferring funds with regards to a booked or executed leg/trip from the individual to the creditor.
- **Plan**: A (set of) leg/trip option(s) put to the individual, based on the available assets and/or services.
- **Start**: the point in time and space at the start of a leg.
- **Travel**: the combination of the actual start and actual end of a leg in combination with the authorised or confirmed planned leg/trip executed by the individual.
- **Traveller**: An individual using mobility assets to travel (between locations), often the same individual as the user.
- **Trip**: A chain of legs constituting the whole sequence of movements by the traveller from start to destination.
- **User**: An individual having an account (and contract) with a MaaS provider.

Level 2: the traveller's journey process

- **After sales**: User modifies his booking or gets a refund or rebate (e.g. due to cancellation or service disruptions).
- **Booking**: User reserves the chosen offer provisionally before travel; it can be changed or cancelled later .
- **Payment**: User pays the chosen offer based on the contract, either for a fixed amount or based on actual usages. May be prepaid or postpaid.
- **Planning**: User plans the trip providing parameters (e.g. location, time and other preferences) for the trip and chooses an offer based on the schedules, trip options, and similar aspects provided
- **Purchasing**: User purchases the chosen offer, establishing a contract.
- **Support**: Help for users before or during travelling. May be provided by various channels.
- **Traveling**: User travels according to the booked offer
- **User registration**: User provides details to register as a traveller, such as payment cards, specific needs, data consent, sometimes a registration number required for KYC (Know Your Customer) policies

Level 3: behind the traveller's journey data

- **API specification**: A specification that defines interactions between multiple software applications or mixed hardware-software intermediaries. APIs are often described using the OpenAPI specification. An API specification doesn't just describe the data format (like the exchange format), but also specifies actions to fetch and/or modify the data
- **Application Programming Interface (API):** A specific set of messages to invoke functionality on another system, including the exchange of data. APIs enable systems to invoke programs and access information remotely. In our context. an API is a running, implemented instance of a proprietary or standard API specification
- **Conceptual data model**: A systematic model describing the relevant concepts of a domain and the relationships between them. 'Relevant' means needing to be represented in the system in order to fulfil the business objectives of the system
- **Data exchange format**: A clearly specified format to encode data for exchange.
- **Protocol**: Communication procedure used to exchange data between two systems.

Other abbreviations (used in this position paper)

- CEN: European Committee for Standardisation (Comité européen de normalisation)
- EU: European Union

- MaaS: Mobility as a Service
- IT: Information technology
- ITS: intelligent transport systems
- MIM: Minimal Interoperability Mechanism
- MP: MaaS provider
- PPI: Pivotal Points of Interoperability
- TO: Transport operators

List of figures

Authors

Individual authors

- Alberto Abella, FIWARE Foundation, Project Manager Smart Data Models Initiative
- Edwin van den Belt, Dat.mobility, Software architect; TOMP-WG, Chairman
- Ferdinand Burgersdijk, MaaS Alliance, Leader of the technology, standardisation and ticketing working groups
- Hiroyuki Sano, Sony Group, Engineer
- Jørgen Wanscher, Hermes Traffic Intelligence, CTO & Partner
- Kasia Bourée, Data4PT, CEN TC278 WG3 SG4 (Transmodel) leader
- Lionel Lepoutre, Systra, Ticketing & MaaS Consultant
- Merja Kajava, Aavista, CEO
- Nicholas Knowles, Data4PT, CEN TC278 WG3 (Transmodel, NeTEx)
- Olaf-Gerd Gemein, Smart Cities Lab, Business Architect
- Paul Theyskens, Flanders Dept of Mobility, Consultant MaaS
- Ross Curzon-Butler, City Data Standard-Mobility, Chairperson
- Tu-Tho Thai, MobilityData, Director, Partnerships Europe

Supporting groups

DATA4PT

"The DATA4PT project[16] aims to advance data-sharing practices in the public transport sector by supporting the development of data exchange standards and models in order to fulfil the needs of multimodal travel information service providers: "By supporting EU Member States in deploying a set of harmonised European public data standards (Transmodel, NeTEx and SIRI), DATA4PT wants to enable union-wide multimodal travel information services and contribute to a seamless door-to-door travel ecosystem across Europe that covers all mobility services."

The main objectives of DATA4PT consist of technical and organisational activities to facilitate the development and deployment of the European public transport data standards Transmodel, NeTEx and SIRI.

All these actions aim to enable the interoperable exchange of travel and traffic data and enhance partnerships amongst public authorities and travel information service providers.

[16] DATA4PT is coordinated by UITP (International Association of Public Transport) and ITxPT is the Technical Manager.

ITxPT

ITxPT is a non-profit association which develops and delivers specifications of a standardized IT architecture with open interfaces enabling interoperability for on-board and back-office IT-systems in public transport.

ITxPT was formed in 2013 as follow-up of European Projects and is now joined by more than 150 members representing all Public Transport stakeholders : PTA, PTO and industry partners to support the adoption and development of IT standards.

ITxPT leads technical work in DATA4PT and NAPCORE (multimodal data working group).

MaaS Alliance

The Mobility as a Service (MaaS) Alliance is a public-private partnership creating the foundations for a common approach to MaaS, unlocking the economies of scale needed for successful implementation and take-up of MaaS in Europe and beyond. The main goal is to facilitate a single, open market and full deployment of MaaS services.

The MaaS Alliance is governed by a Board of Directors and driven forward by its Members and Partners.

MobilityData

MobilityData began in 2015 as a Rocky Mountain Institute project and became a Canadian non-profit in 2019 with the mission to improve travellers' information. MobilityData was incorporated in France in April 2021. Building on the strength of more than 20 employees, MobilityData brings together and supports mobility stakeholders such as transport agencies, software vendors, mobility apps, and cities to standardize and expand data formats for public transport (GTFS) and shared mobility (GBFS).

NAPCORE

NAPCORE is an upcoming European project supported by all the Member States of the European Union as well as Norway and Switzerland as associated partners.

The general objective of this action is to empower the National Access Points (NAPs) as the backbone for ITS digital infrastructure. Also, it will facilitate national & EU wide operational coordination for the harmonisation and implementation of the European specifications.

Its specific objectives are to create a coordinated European mechanism of national access points based on a coordinated governance and architecture, interoperability, standards and services.

One main objective is to contribute to harmonization and alignment of standardisation work to establish interoperability of EU multimodal data standards.

TOMP-API Working Group

The TOMP-WG (Transport Operator, MaaS Provider – Working Group) is a collaborative initiative to create a standardized language for the technical communication between Transport Operators and MaaS Providers within the MaaS ecosystem by means of an API (Applicable Programming Interface). The standard language describes how the different stakeholders should communicate with each other.

The TOMP-API is being developed by an open source working group with public and private stakeholders, aimed at facilitating the implementation of MaaS and the corresponding exchange of data. The TOMP-API describes a full MaaS journey, including operator information, planning, booking, support, payments and trip execution.