MOBIDATALAB

Labs for prototyping future mobility data sharing solutions in the cloud

D2.5 Report on new Mobility Data sharing standards

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Summary sheet

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Abstract	This document provides an update on mobility data sharing standards and shows how these standards have been implemented in the different stages of the MobiDataLab project. The methodology followed was based on the identification of standards and their context, their application in MobiDataLab, and their evolution and related support for implementation. It concluded with information about how standards were used by MobiDataLab and with general recommendations to be considered about standards and trying to answer the methodology questions, such as: How can we provide appropriate metadata? How can we link local, regional, and national travel information services? How are we following these new standards?

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Project partners

Organisation	Country	Abbreviation
AETHON SYMVOULI MICHANIKI MONOPROSOPI IKE	Greece	AETHON
AKKODIS	France	AKKODIS
CONSIGLIO NAZIONALE DELLE RICERCHE	Italy	CNR
HERE GLOBAL B.V.	Netherlands	HERE
HOVE	France	HOVE
KATHOLIEKE UNIVERSITEIT LEUVEN	Belgium	KUL
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Executive Summary

Standardisation is essential when producing and exchanging data, especially if this can be used by many organizations to improve or find solutions to our current mobility problems. This report contains information about the last updates regarding mobility standards (public transport, micro-mobility and shared mobility, traffic road data, journey planning, vehicle related data, mobility as a service and ticketing data) and cross-domain standards related to new mobility data sharing. This report is part of task 2.3 on Standard Requirements of the MobiDataLab project and it follows the State-of-the-art on Mobility Data sharing (deliverable 2.4). This document will provide an overview of standards, and it will discuss their application in this project, their evolution, and the way their implementation is carried out.

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Abbreviations and acronyms

Abbreviation	Meaning
API	Application Programming Interface
AWS	Amazon Web Services
CEN	Comité Européen de Normalisation (European Committee for Standardisation)
CDS	Curb Data Specification
CDS-M	Common Data Sharing Model for Mobility
CityGML	City Geography Markup Language
CNA	Calypso Network Association
CSV	Comma-Separated Values
CSW	Catalogue Service for the Web
DEI	Digitising European Industry
DCAT	Data Catalogue Vocabulary
DCAT-AP	DCAT Application profile for data portals in Europe
DTR	Demand-Responsive Transportation
DR	Delegated Regulation
EC	European Commission
EAFO	European Alternative Fuels Observatory
EPIP	European Passenger Information Profile
EPIAP	European Passenger Information Accessibility Profile
ESRI	Environmental Systems Research Institute
EU EIP	EU External Investment Plan

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FOT	Swiss Federal Office of Transport
GBFS	General Bikeshare Feed Specification
GML	Geographic Markup Language
GNSS	Global Navigation Satellite Systems
GTFS	General Transit Feed Specification
IAM	Identity and Access Management
IFOP	Identification of Fixed Objects in Public Transport
ISO	International Standardisation Organisation
ITxPT	Information Technology for Public Transport
GBFS	General Bikeshare Feed Specification
GML	Geographic Markup Language
GTFS	General Transit Feed Specification
IAM	Identity and Access Management
IdP	Identity Provider
IFOP	Identification of Fixed Objects in Public Transport
ISO	International Standardisation Organisation
ITS	Intelligent Transport Systems
KVP	Key-Value pairs
LOD	Linked Open Data
LoS	Level of Service
JSON	JavaScript Object Notation
MaaS	Mobility as a Service
MDS	Mobility Data Specification

MMTIS	Multi-Modal Travel Information Services
NAP	National Access Point
NAPCORE	National Access Point Coordination Organisation for Europe
NTFS	Navitia Transit Feed Specification
NDS	Navigation Data Standard
NeTEx	Network timetable Exchange
NFC	Near Field Communication
NFV	Network Function Virtualisation
OCPI	Open Charge Point Interface protocol
OGC	Open Geospatial Consortium
OMF	Open Mobility Foundation
OJP	Open Journey Planning
OpRa	Operating Raw Data
OSM	OpenStreetMap
OSPT	Open Standard for Public Transport
OTP	OpenTripPlanner
OWL	Web Ontology Language
PBF	Protocolbuffer Binary Format
RDF	Resource Description Framework
REST	Representational State Transfer
RTTI	Real-Time Information Services
S3	Simple Storage Service
SaaS	Software as a Service

SAML	Security Access Markup Language
SKI	Customer Information System Tasks
SDN	Software Defined Network
SIRI	Service Interface for Real-time Information
SOAP	Simple Object Access Protocol
SP	Service Provider
SPARQL	SPARQL Protocol and RDF Query Language
SRTI	Safety Related Traffic Information
SSO	Single Sign-On
SSTP	Safe and Secure Truck Parking
TEN-T	Trans-European Transport Network
TOMP	Transport Operator and Mobility Provider
TOSCA	Topology and Orchestration Specification for Cloud Applications
UML	Unified Modelling Language
URV	Universitat Rovira I Virgili
URI	Uniform Resource Identifier
UVAR	Urban Vehicle Access Regulations
WFS	Web Feature Service
WMS	Web Map Service
WMTS	Web Map Tile Service
W3C	World Wide Web Consortium
WP	Work Package
XSD	XML Schema Definition

XMI	XML Metadata Interchange
XML	eXtensible Markup Language

1. Introduction

1.1. Project overview

There has been an explosion of mobility services and data sharing in recent years. Building on this, the EU-funded MobiDataLab project works to foster the sharing of data amongst transport authorities, operators, and other mobility stakeholders in Europe. MobiDataLab develops knowledge as well as a cloud solution aimed at easing the sharing of data. Specifically, the project is based on a continuous co-development of knowledge and technical solutions. It collects and analyses the advice and recommendations of experts and supporting cities, regions, clusters, and associations. These actions are assisted by the incremental construction of a cross-thematic knowledge base and a cloud-based service platform, which will improve access and usage of data-sharing resources.

- Transport users want information on mobility that they can trust (reliable, accurate, and of quality) which is intuitive, widely available, discoverable, shareable and that reflects the real world.
- Cities want harmonized information for users, transport authorities, and operators to tackle traffic problems and develop cleaner and smarter transport systems.
- Data consumers want also efficient tools to develop interoperable mobility services.

1.2. Purpose of the deliverable

The growing interest to achieve interoperability and harmonization among the different actors in the transport and mobility sector has pushed communities to work on the development of standards and specifications that encompass the interoperable exchange of different types of mobility data. The idea is to provide data of quality, make data accessible and discoverable, linkable internationally, and adaptable to the needs of different regions and to complex as well as simple travel information services. Standards keep evolving and some new ones emerge increasing the opportunity to cover new types of data such as private mobility data and ticketing data, but also allowing the exchange of data to be used in distributed journey planning and as Mobility as a Service (MaaS). However, some of them might be discontinued if they are not visible or flexible enough, especially if they are not properly updated and aligned with new requirements.

There are projects like *La Fabrique des Mobilités* that work on the development of strategies to improve and support the implementation of MaaS standards, while others like DATA4PT focus on training and providing support on the implementation of very particular standards for Public Transport. These strategies are keen to make successful the development of standards by having appropriate guidance for implementation, development, and promotion.
The aim of this deliverable is to provide suggestions about future standards and specifications to be adopted for improved Mobility data sharing and to show how these standards have been implemented in the different stages of the MobiDataLab project (for instance in the cloud architecture, the uses cases, the data catalogue, and more).

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To attain this objective, the methodology followed was based on the identification of standards and their context, their application in MobiDataLab, and their development and related support for implementation.

The purpose of MobiDataLab Task 2.3 (Standard Requirements) has been to define a standardization roadmap for both integrating existing data sharing standards and promoting standardization results. This task has resulted in the mapping of technical requirements to current standards and any necessary extensions for development across all relevant WPs. To achieve this objective, a first deliverable was submitted in October 2021 consisting of a state of the art of the different standards existing today in the field of data sharing and their applicability to MobiDataLab (D2.4), and the present document is showing how standards have been used within the project and how standards are evolving, are being implemented and maintained for improved data sharing (D2.5).

The present document D2.5 makes an overview of standards for mobility data sharing, whether from public transport, micro-mobility and shared mobility, road traffic, and vehicle-related standards. Data sharing standards for private mobility in the context e.g., of Mobility as a Service (MaaS), ticketing data, and journey planning are also considered. Multi-sectoral standards (geospatial data, metadata, semantic and mobility data spaces related standards) and standardization entities will be covered in this report as well.

1.3. Intended audience & Review process

The dissemination level of this D2.5 deliverable is ‘public’ (PU). AKKODIS as WP2/Task 2.3 leader is responsible for it with the contribution of CNR, HERE, HOVE and URV. Appointed peer reviewers are AETHON, and KUL. It should be noted that the content of this WP2 deliverable will be included in the MobiDataLab Open Knowledge Base and therefore it should be considered as a living document.

1.4. Structure of the deliverable and its relationship with other work packages/deliverables

This document will serve as input for most of the WP4 tasks (Transport Cloud prototype). The Mobility data sharing standards covered in this deliverable were taken into consideration for the support of the Reference Data catalogue (Task 4.2) while the horizontal standards for data exchange in the cloud were considered for the Architecture Design of the cloud solution (Task 4.1) and Data Privacy (Task 4.5).

Also, the best practices for sharing data on the web are very important recommendations for the Data Access Services and Data Channels (Task 4.3), and the Geodata sharing standards and Semantic Interoperability standards which are covered by the Data Processors (Task 4.4).

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Not only the WP4 is related to this deliverable but also the WP2 itself. De jure standards, i.e. standards according to law such as the Transmodel standards (NeTEx, SIRI, etc.) or the INSPIRE data models, are by definition related to the regulations (Task 2.1). In addition, data sharing standards are important for defining the use cases (Task 2.6) as most of the standards propose typical use cases. This means that including a standard in the MobiDataLab solution means thinking about its application in relevant use cases. And on the other hand, proposing a use case means implementing the most appropriate standard(s) for this use case.

Standard requirements are also related to WP1. For instance, the Data Management Plan (Task 1.4) relies on standardised data models (e.g., Transmodel which proposes data categories for mobility) for defining types of mobility data. Furthermore, the relationships of the MobiDataLab consortium with the experts from the Advisory Board (Task 1.5) are extremely important to follow the evolution of the different standardisation efforts, through working groups in different sectors such as public transport, new forms of mobility, Mobility as a Service, geolocation data, etc.

1.5. Findability, Accessibility, Interoperability and Reusability (FAIR)

While different types of data are nowadays quite standardized it does not mean that among different sectors or different organizations; data can be easily shared and/or interpreted. The design of some standards was not at first thought to be used, shared with other sectors (horizontally), or for external purposes. However, to increase the quality and detail of certain information, it is important to be able to enrich data with information from other sectors. Therefore, it is pertinent to have a common language to permit the integration of the data exchanged in a consistent and operationally efficient manner. With the multiplication of data portals and datasets offer, it is important to follow the same legal compliances to be able to ensure interoperability and enhance collaboration across sectors.

While many standards exist and are in use, there is still a lot of work in progress and technical challenges that need to be addressed if we aim to achieve fully interoperable common standards and protocols. Several groups are working on the development of technical standards, specifications and on the dissemination of best practices. This is particularly the case and goal towards which the European Commission (EC) and its member states work through diverse actions and the EU Intelligent Transport Systems Platform (ITS)[1] which aims to develop more interoperable mobility services and harmonize the European transport network.

[1] https://www.its-platform.eu/

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2. Methodology

The general methodology for preparing this deliverable has been the following:

1) Define the use cases and contextualise them in living lab challenges
2) Explore the existing standards and select the most suitable ones

This corresponds to the "Application to MobiDataLab" sub-section common to every standard-related section of this document.

3) Join the community behind any identified standard, explore the roadmap and compare with the MobiDataLab perspectives and when possible, become an active stakeholder by participating in meetups, conferences, events, etc.

This corresponds to the "Developments and support for implementation" sub-section in the following chapters.

More specifically, for every standardised domain identified, the MobiDataLab partners contributing to this document have tried to answer the following questions:

- Why was this standard of interest for MobiDataLab?
- How did MobiDataLab use this standard?
- How did the MobiDataLab consortium keep informed?
    - How can we ensure that we have covered the standard requirements?
    - How can we make data accessible?
    - How can we provide appropriate metadata?
    - How can we link local, regional and national travel information services?
    - How can we identify and/or confirm standard-related gaps to be filled (e.g., the several NeTEx implementations or profiles in Europe make it difficult to harmonize in a cross-border solution)
    - How can we identify standard-related gaps and harmonization of cross-border solutions
    - How are we following these new standards?
    - What is the level of implementation/adaption of these standards?

2.1. Standard identification

When it comes to standardisation, the first thing to do is to clearly define the use cases to be solved through their intermediary. It then becomes possible to explore what exists in terms of standards and specifications and select the one that will best meet the identified need.

In the MobiDataLab project, use cases were the subject of two deliverables, D2.9 "Use cases definition v1" and D2.10 "Use cases definition v2". In the first version, at the very beginning of the project, the theoretical use cases identified included optimisation of transport flows, arrival time estimation, emission reporting and re-use of transport data for journey planning, Mobility as a Service, inclusivity and sustainability, tourism and mobility.

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These preliminary use cases (which allowed us to identify a first set of standards described in D2.4) were further described in real-world scenarios with the reference group of municipalities of the project, namely: emission reporting, routing and urban planning in Eindhoven, modal shift with focus on micro-mobility, bicycle lane infrastructure and conflicts between transport modes in Leuven, data quality assessment, data interoperability and adaptation of the transport network for large events in Milan, etc.

2.2. General differences among standards

2.2.1. Data standards vs specifications

Standards and specifications provide a set of rules on how to write a data language to ease the exchange of information between different informatic systems[2]. They are both developed and employed in the mobility and transport sector in different proportions. Both have been refined a lot over the last few years to enhance interoperability and to fit better into current modes of transportation and increasing demand for data quality. Both require to be endorsed, coordinated and follow general principles.

A **specification** or a ***de facto*** standard is developed by a community that reaches an agreement of all parties on what the information represents to allow the exchange of it. To achieve consensus the specification is characterized by a set of rules, best practices and a minimal content definition. Its adoption process is usually simpler and fast, which makes it more interesting for emerging sectors which might require a more flexible and reactive process (Grandjean & Delabie, 2022).

A **standard** is a specification developed, created and recognised officially by a standards entity, e.g., the European Committee for Standardization (CEN) or the European Telecommunications Standards Institute (ETS). This can be developed to respond to different conditions by keeping a common base, but it can also be adapted to different administrative levels (MobilityData, 2022). It might define the structure of a process, attributes, objects, data models, relationships or a data format for the standard to be exchanged or stored (Conceição et al., 2022).

Table 1: Comparison of standards vs specifications (adaptation of the tables "Description" and "Governance", source: MobilityData – Introduction to GBFS and GTFS, 2022)

	Specification	Standard
Governance	Formal governance by the community	Treaty. It follows a structured, formal and complex governance process ruled by treaty
Adoption	Majority or consensus	Majority or consensus
Voters	The entire community	The official members of the standardization body (e.g., State Members of the European Union)
Host	The maintainer	A standardization body
Content	Minimal and simple	Structured and complex

[2] http://www.normes-donnees-tc.org/

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Process	Fast and flexible	Slow, controlled and rigid process
Interested parties	Public and private actors	Public and private actors
Type of data	Open data (most of the time)	Private and open data

2.2.2. Sector-specific standards and specifications

Standards can be specific or common to different sectors. In the case of vertical standards, they are specific to an activity sector, application or product. In the mobility and transport sector, this is the case of TRANSMODEL, NeTEx and SIRI which were covered in D.2.4 and are still under development.

Table 2: Vertical standards and specifications

Categories	Standard	Specification
Public transport	TRANSMODEL, NeTEx, SIRI, DCV	GTFS, GTFS-RT, NTFS
Journey planning	OJP	
Road traffic	DATEX II	
Ticketing	OSTP, CIPURSE, Calypso (CAN)	CDS-M
New mobility	NeTEx and SIRI extensions	GBFS, MDS
Other vehicle related		OCPI, CDS

2.3. Application to MobiDataLab

In the following sections, when we will be covering the “Application to MobiDataLab” we will refer to the standard suitability assessment and its application to the MobiDataLab transport cloud tools (e.g. data catalogue), or the living labs challenges or the use cases.

MobiDataLab partners made sure that the different standards identified were either integrated into the solution implementation (the MobiDataLab transport cloud) or in solutions that will be used in this context (e.g., GeoServer with WFS, HERE Real-Time Traffic API with DATEX II, GTFS with Navitia, etc.).

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2.4. Developments and support for implementation

To follow the advancement of the new mobility standards, the Task 2.3 partners attended webinars, conferences and events organized by the relevant standardisation stakeholders (either in mobility and transport or in more generic domains).

The best way to follow and contribute to the evolution of standards is to be part of the working groups for the different standards, as behind the development of standards there is always a group of experts, producers and users who discuss and arrive at an agreement on a common way to address a specific problem.

Available reports published by relevant organisations such as W3C[3], ISO[4], OGC[5], CEN-CENELEC[6], Data4PT[7], MobilityData[8], NAPCORE[9], the Data Spaces Support Center (DSSC)[10], la *Fabrique des Mobilités*[11], DG MOVE[12], ADEME[13], and others allowed us to evaluate the degree of adoption, adequation to needs of the community, durability of the standard, but also the diversity of the community and the positive externalities (acculturation and cooperation that come with it) of different mobility standards.

[3] https://www.w3.org/
[4] https://www.iso.org/
[5] https://www.ogc.org/
[6] https://www.cencenelec.eu/
[7] https://data4pt-project.eu/
[8] https://mobilitydata.org/
[9] https://napcore.eu
[10] https://dssc.eu/
[11] https://lafabriquedesmobilites.fr/
[12] https://commission.europa.eu/about-european-commission/departments-and-executive-agencies/mobility-and-transport_en
[13] https://www.ademe.fr/

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3. Mobility standards

The purpose of this section is to provide an overview and update about the standards implemented in the MobiDataLab project and discussed in D.2.4, the standardization bodies behind them, and their current level of adoption.

Standards in the mobility sector have been developed to respond to and improve travel needs and access, but they also have been prioritized and imposed by the European Commission as of 2020 for certain types of data and services (API) in the National Access Points (NAPs) of the European Member states. Among these standards, we can find NeTEx, DATEX II and SIRI which are mobility and traffic data standards.

Standardization facilitates data exchange and sharing across sectors and organizations, and they promote adaptable solutions for different purposes (MobilityData, 2022). The next section will cover the principal differences between them.

3.1. Public transport

3.1.1. Multimodal data

Multimodal data refers to the integration and combination of data from multiple modes of mobility sources. It involves the collection and analysis of data related to various transportation modes, such as public transport, shared mobility services and micro-mobility options. The aim is to provide a comprehensive understanding of travel patterns, mobility behaviours and transportation networks by considering the interactions and interdependencies between different modes of transportation.
This data can be used consequently to inform decision-making, optimize transportation networks, improve service provision, and promote more efficient and sustainable mobility options.

3.1.1.1. TRANSMODEL – NeTEx – SIRI

As a short reminder of deliverable 2.4, Transmodel[14], formally known as CEN TC278 and Reference Data Model for Public Transport (EN12896), is a complex series of standards for multimodal data concepts and data structures led by the European Committee for Standardization (CEN). It covers a multitude of functionalities and models. It serves as a reference data model specifically designed for the public transport domain. Its purpose is indeed to provide a structured and standardized approach to representing and exchanging data related to public transport operations, including schedules, routes, fares, vehicles, and passenger information.

[14] https://www.transmodel-cen.eu/transmodel-at-a-glance/

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Hence, transport operators and agencies can achieve interoperability, facilitate data integration, and enhance the efficiency of their information systems. By being developed along the Network Timetable Exchange (NeTEx) and the Service Interface for Real-Time Information (SIRI) standards, TRANSMODEL allows interoperability by precisely defining the global concepts and relations across concepts. It is important to recall that Transmodel, NeTEx, and SIRI were developed to answer to the requirements of the Delegated Regulation (EU) 2017/1926 supplementing the EU-wide Multimodal Travel Information Services of the ITS Directive. Other than covering static and dynamic data, Transmodel also covers Real-Time Information Services (RTTI) and Safe and Secure Truck Parking (SSTP). NeTEx is emphasized in static Multi-Modal Travel Information Services (MMTIS) data while SIRI is in dynamic data of MMTIS and RTTI (particularly parking data). NeTEx is used for the periodic exchange of reference data, while SIRI handles real-time data. Since Transmodel functions as a reference standard, individual systems or specifications don't need to adopt the entire Transmodel framework. Same for NeTEx, it uses separate elements for different concepts, making it reusable in various applications. Other standards led by the CEN that interact with Transmodel are Operating Raw Data and Statistics Exchange (OpRa), Open Journey Planning (OJP) and Data Communication on Vehicles (DCV). All these implementations are central components of Transmodel.

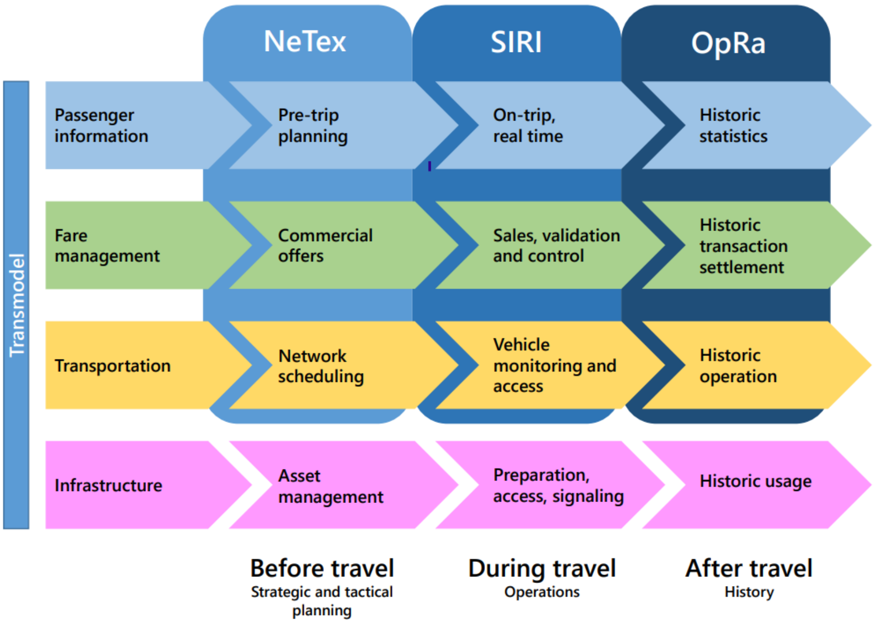

Figure 1: Scope of Transmodel standard (source: Reporting Mobility Data: Good Governance Principles and Practices, 2021)

NeTEx focus on data for the exchange of public transport schedules and information related to it, such as the description of the topology of the public transport network, scheduled timetables, fare information and European passenger information. The aim of NeTEx is to be supported by modern web architectures and to have more extensive coverage of passenger information and operational applications. Its eXtensible Markup Language (XML) format is expected to be efficient and updatable in what concerns the "exchange of complex transport data among distributed systems" (NeTEx, 2023). NeTEx is used in many European countries (particularly for MMTIS) and has been adapted through profiles for different countries (Conceição et al., 2022). However, it seems that it is still important to define the particularities of these profiles in what regards public transportation, as stated by Conceição et al. (2022) in the National Access Point Coordination Organisation for Europe (NAPCORE) report *M2.4 List of gaps and used standards*. The key characteristics of the national profiles have been detailed by DATA4PT on a table which covers the different categories, and it is frequently updated: https://Data4PT.org/w/index.php?title=NeTEx.

While the last fifteen years have focused on harmonizing and systemizing European passenger information data, this work has been extended into the European Passenger Information Accessibility Profile (EPIAP) lately. Furthermore, recently, the group of experts working on NeTEx, as well as the working group on SIRI, have been developing an extension to cover in detailed static data describing the services and the infrastructure offered regarding Alternative Modes (under the Part5 Technical Specification) such as car sharing, cycle sharing, carpooling, car/cycle rental and possibly others. This will be covered in section 3.3.

SIRI is present in counted countries such as Norway, Finland, the Netherlands, France and Cyprus (Conceição et al., 2022). It seems to be a more mature standard, even though it is still growing, as it covers well the different categories of MMTIS and NAPCORE did not identify any gaps within it (Conceição et al., 2022). NeTEx can be considered a widespread standard at a growing phase.

3.1.2. Static multimodal data

Static data is used to exchange information such as the network topology (stops, routes, lines, etc.).

3.1.2.1. GTFS

GTFS (General Transit Feed Specification) is a widely adopted data format for representing public transportation schedules, routes, and stops. It was initially developed by Google to facilitate the integration of public transport information into mapping applications. So, it has become a *de facto* standard and is used by many public transport agencies and applications worldwide. GTFS is considered as widespread speciation at a mature level phase, which is often used in MaaS (Grandjean & Delabie, 2022).

While GTFS is comprehensive in terms of representing schedules and routes, it has limitations. One notable limitation is that GTFS does not cover multimodal fares. It does not provide a standardized way to represent complex fare structures that may involve transfers between different modes of transportation, such as buses, trains, and ferries. However, there are current discussions and propositions about a GTFS Fares v2 extension to help determine and make discoverable the agencies fares products and allow riders to decide based on information such as rider category, fare media and fare capping (MobilityData, n.d.-b). The first proposal regarding fare media (employed to use fare products, for instance, a magnetic card) was already approved and the next discussions will cover "modelling and adopting time variable fares"[15] (MobilityData, n.d.-a).

[15] https://github.com/google/transit/pull/357

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3.1.2.2. GTFS-Flex

GTFS-Flex[16] is a proposed extension to the GTFS Schedule. It introduces concepts like service zones, flexible routing, and on-demand scheduling to support flexible transport models. It provides

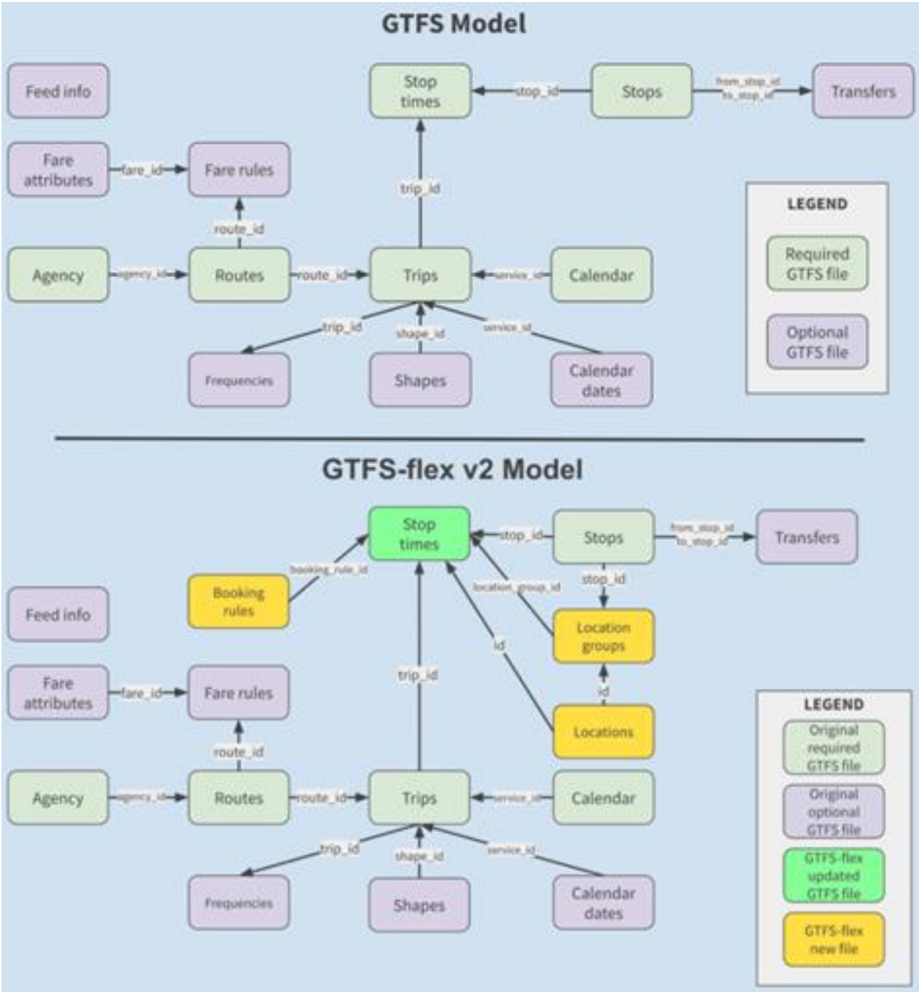

Figure 2: GTFS and GTFS-Flex models (source: MobilityData website).

more flexibility in specifying stops, schedules, and service areas compared to traditional GTFS (see Figure 2 below). It can also handle varying demand patterns and responsive routing based on passenger requests and incorporates real-time data related to flexible transport services, such as vehicle locations and estimated arrival times.

GTFS-Flex adds the capability to model various Demand Responsive Transportation (DRT) services to GTFS, which currently only models fixed-route public transportation. GTFS-Flex is now produced for over 100 transit services and provides flexible transit trip plans through OpenTripPlanner (OTP).

16 https://gtfs.org/extensions/flex/

Discussions and pilot tests have been on the table regarding this extension over the last ten years. However, as of May 2023, work on Discovery Services has begun for this extension (Flex—General Transit Feed Specification, n.d.). For more information about the latest discussions and their adaptation tacker, you can consult: https://gtfs.org/extensions/flex/#adoption-tracker.

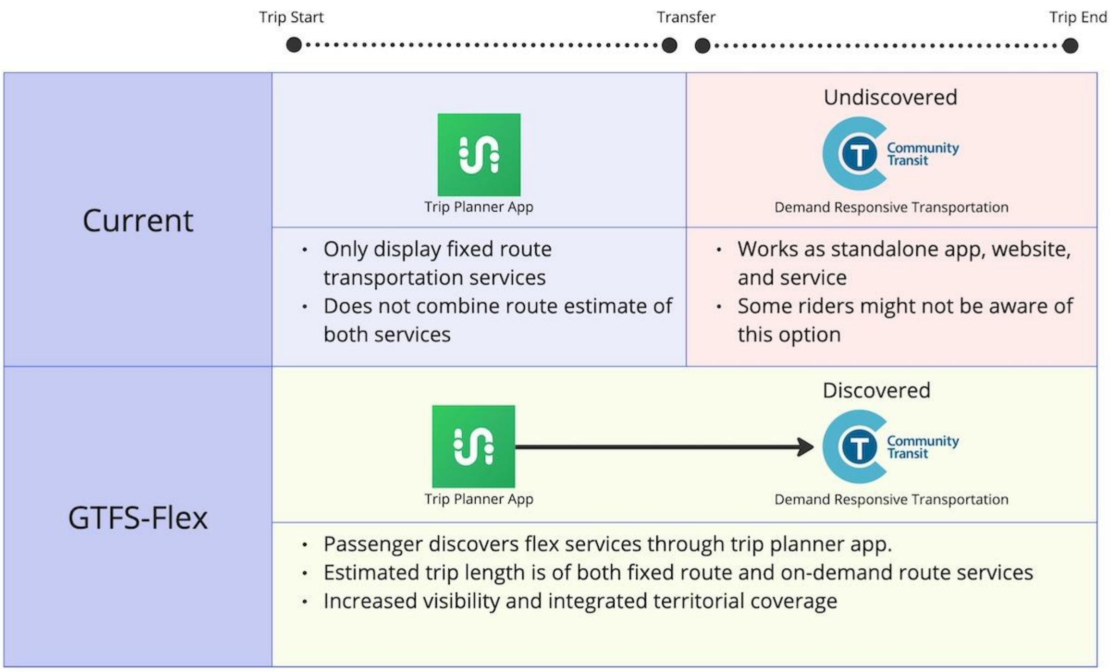

Figure 3: GTFS-Flex (source: GTFS org[17]).

3.1.2.3. GTFS to NeTEx open-source tool

GTFS to NeTEx is an open-source tool that facilitates the conversion of GTFS data into the NeTEx format (*Gtfs2NetexFr, un outil open source intégré au Point d'Accès National!,* 2020). GTFS has become a widely adopted standard for describing public transit schedules and geographic information. However, NeTEx is emerging as a newer standard that provides a more comprehensive and flexible framework. This tool then fills the gap between these two formats, enabling transit agencies and data providers to easily convert their existing GTFS datasets into NeTEx, thus leveraging the enhanced capabilities of the latter. It should streamline the process by automatically mapping the GTFS data elements to their corresponding NeTEx counterparts by considering the nuances and differences between the two formats and ensuring the accurate transformation of data. However, there are multiple NeTEx formats with considerable differences to adapt to the context in which they are used. Currently, there is only one open-source solution known for this purpose, gtfs2NeTExfr, which is a module within the Transit model, a Rust[18] library provided by HOVE to convert GTFS to NeTEx France format.

[17] https://gtfs.org/extensions/flex/
[18] https://www.rust-lang.org/

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This solution was used by the NAP of France (*Gtfs2NetexFr, un outil open source intégré au Point d'Accès National!*, 2020). The way this tool was constructed makes its connectors adaptable and allows to fork the program to employ for other country profiles, for instance, "Gtfs2NetexNL" or the GTFS2NeTEx-converter which is under development for an Italian Profile (*Gtfs2NetexFr, 2020 & NeTEX - DATA4PT Knowledge base*, n.d.).

3.1.2.4. Accessibility

Ensuring the accessibility of static multimodal data is paramount for creating inclusive and user-friendly transportation networks. By providing comprehensive and easily accessible information about schedules, routes, and stops for different modes of transportation, individuals can plan their journeys more effectively and make informed decisions about their travel options. Information accessibility is particularly beneficial for individuals with mobility challenges.

In addition to the MobiDataLab project, The European Union has been actively promoting the accessibility of transportation data through initiatives like the EU Directive on the accessibility of public sector websites and mobile applications. This directive aims to ensure that public sector websites and mobile applications, including those related to transportation, are accessible to all users, including those with disabilities (*Accessibility of public sector websites and mobile apps*, 2021).

In conjunction with regulatory efforts, various European cities and countries have taken steps to make static multimodal data accessible. Many transportation authorities and service providers in Europe publish their static data in open and standardized formats. These datasets are often made available through open data platforms, APIs, or dedicated transportation data portals. Some examples of these open data portals are the French NAP[19], the Lombardy Region portal[20] and the Ile-de-France Mobilites portal[21].

Furthermore, European transport agencies have been actively participating in international data exchange standards and initiatives. Standards like NeTEx and GTFS have been widely adopted in Europe to facilitate the sharing and exchange of static multimodal data. These standards promote interoperability and enable the development of applications and services that leverage transportation data.

It's important to note that the level of accessibility and availability of static multimodal data may vary between different European countries, cities, and transportation operators. However, overall, efforts have been made to improve accessibility and open access to this data.

[19] https://www.data.gouv.fr/fr/datasets/accessibilite-des-equipements-de-la-ville-de-paris-prs/
[20] https://www.dati.lombardia.it/stories/s/Accessibilit-/2jkr-76pb
[21] https://data.iledefrance-mobilites.fr/

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3.1.3. Dynamic multimodal data

3.1.3.1. SIRI vs GTFS-RT

SIRI and GTFS-RT are both used for real-time information exchange in the context of public transportation, although they differ in terms of data coverage, flexibility, complexity, and integration. SIRI offers a broader scope, flexibility, and comprehensive real-time information, while GTFS-RT is more focused on real-time updates related to predefined schedules and routes. The choice between SIRI and GTFS-RT depends on the specific requirements and use cases of the transportation system or application in question.

Table 3: SIRI vs GTFS RT

	SIRI	GTFS-RT
Data coverage and focus	It is a comprehensive standard for exchanging real-time information about public transportation services.	It focuses specifically on real-time updates for public transportation schedules and routes.
Flexibility and Extensibility	It is designed to accommodate a wide range of real-time data requirements. It offers flexibility in terms of the types of data that can be exchanged and allows for extensions to the standard to support specific use cases or additional data elements.	It follows a more structured and predefined format, which limits its extensibility. It primarily focuses on providing real-time updates for the predefined GTFS static schedule and route data.
Integration and Adoption	It has been widely adopted by transportation authorities and service providers globally and is often used for exchanging real-time information across different modes of transportation.	It has gained significant popularity, especially among transport agencies and developers. It is widely used for real-time updates in the context of public transportation, particularly for buses, trains, and trams. GTFS-RT's integration is more focused on specific modes rather than being multimodal by nature.
Data Structure and Complexity	It has a more complex data structure compared to GTFS-RT, allowing for more detailed and diverse real-time information. It supports advanced features like trip updates, vehicle monitoring, and flexible passenger information delivery.	It has a simpler data structure, which makes it relatively easier to implement and consume. It provides real-time updates specifically related to schedules, routes, and service alerts defined in the GTFS static data.
Compatibility and Interoperability	has built-in support for interoperability, allowing for data exchange between different transportation systems and across different regions. It provides mechanisms for translating data into standardized formats and offers compatibility with various communication protocols.	inherits the interoperability and compatibility advantages of the widely adopted GTFS format. It allows for integration with existing GTFS-based applications and services.

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3.1.3.2. Accessibility

The accessibility of real-time/dynamic multimodal data has been prioritized to ensure widespread availability and usability. Open data initiatives encourage transportation agencies to release data in open formats, while standards like SIRI and NeTEx promote consistency and interoperability. Dedicated public transport apps and integration with mapping platforms provide user-friendly access to real-time information. Adherence to accessibility standards ensures that digital platforms and applications are inclusive. These efforts collectively enhance the accessibility of dynamic multimodal data, benefiting users across Europe by facilitating informed decision-making and seamless travel experiences.

3.1.4. Other initiatives to study and control public transport data

Various initiatives[22] [23] [24] and studies have been undertaken by organizations, research institutions, and transportation authorities to explore the vast potential of public transport data. These efforts aim to leverage data-driven insights and innovative technologies to shape the future of transportation.

3.1.5. Application to MobiDataLab

Transmodel, NeTEx and SIRI standards are of high interest for the MobiDataLab project as their goal is to align with the FAIR principles and to be implemented in the European NAPs to cover mainly MMTIS data. In MobiDataLab, we have included these standards by making them available in our Data Catalogues.

However, we have noticed that these datasets are not always present in all the open data catalogues that were able to harvest. For instance, for the Datathon in May, we were able to provide only 20 datasets which we identified as being in the NeTEx format. A good proportion of these datasets were added manually since some portals were not interoperable with our harvesting exchange standards such as DCAT and CSW.

As part of the actions of MobiDataLab regarding the Public Transport standards, it is planned to add information about these standards to our Open Knowledge Base. Another way for MobiDataLab to offer some of these data standards during the Datathon was through access to the Navitia API and datasets. This last one will be covered in the OpenJourneyPlanning section, which offers GTFS, NeTEx, SIRI and Navitia Transit Feed Specification (NTFS) information.

[22] https://www.uitp.org/regions/europe/
[23] https://maas-alliance.eu/
[24] https://www.its-platform.eu/

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3.1.6. Development and support for implementation

As part of this project, there is a follow-up in the updates regarding these standards by attending events and regularly consulting the new documentation regarding them (see Table 3, below).

The purpose of this section is to provide an overview of how standards and specifications are evolving along and adding value to society. It is also about how organisations are implementing them and their current level of adoption and integration.

Table 4: Attended events to follow-up public transport standards

Event name	Type of event	Partner's name	Date	Location
DATA4PT	External event	AKKA	- -21	Online (replay)
DATA4PT Webinar	External event	AKKA	24-11-22	Online
NAPCORE Mobility Data Days	External event	AKKA, POLIS	03-11-22	Paris, France
Transport Research Arena Lisbon 2022	External event	AKKA, POLIS	14-11-22	Lisbon, Portugal
Tomorrow Mobility World Congress	External event		15-11-22	Barcelona, Spain & online
2nd MobiDataLab Webinar	Internal event	F6S, AKKA, POLIS, KISIO, HERE	22-11-22	Online
MobilityData Webinar - Introduction to GTFS and GBFS	External event	AKKODIS	23-11-22	Online
La PAN à côté	External event	AKKODIS	05-12-22	Online
La PAN à côté	External event	AKKODIS	09-11-22	Online
GTFS Components Discussion	External event	AKKODIS	31-05-23	Online

3.1.6.1. Level of services and NAPCORE

In the transportation sector, the Level of service (LoS) is used as a qualitative measure to relate to the quality of motor vehicle traffic service (Wikipedia contributors, 2022). This last has been adapted to evaluate and better understand the needs and experiences that transport users have, but also to harmonize the architecture of the NAP. As part of the agenda of the NAPCORE, there is a working group focused on harmonizing and improving the interoperability of the level of service.

Some of their work consists of extending some of the NAP Common Features and Level of Services categories. For instance, the latter was composed of 5 main features (access, communication, data discovery, update and maintenance and dataset information) and has recently considered adding interoperability, as well as data exchange and operational policy. The idea is to facilitate data sharing and datasets findability, by providing support and best practices to existing and future NAPs.

3.1.6.2. Data4PT (Transmodel)

Data4PT, also known as Data for Public Transport, is an initiative that focuses on promoting the use of data in the planning, management, and improvement of public transportation systems. It aims to harness the power of data to enhance the efficiency, accessibility, and sustainability of public transport services. The initiative emphasizes the importance of open data principles, advocating for the availability of public transport data in standardized and accessible formats.

Data4PT provides NeTEx validation tools. They are designed to assist in verifying the correctness and compliance of their respective standards for interoperability and ensure that the data is structured correctly.

The NeTEx validation tools include features such as:

- **Schema Validation**: The tools perform schema validation to check if the NeTEx data adheres to the specified structure and data types defined in the NeTEx schema. This ensures that the dataset follows the required format and can be properly interpreted by other systems or applications.

- **Syntax Checking**: The tools verify the syntax of the NeTEx data, ensuring that there are no errors or inconsistencies that might hinder the proper interpretation of the data.

- **Rule Compliance**: The tools assess if the NeTEx data comply with specific rules and guidelines set forth by the NeTEx standard. This helps ensure that the data meets the requirements for interoperability and compatibility with other systems.

- **Data Consistency:** The validation tools also verify the consistency of the NeTEx data, checking for any logical or semantic issues within the dataset. This helps identify potential errors or inconsistencies that could affect the accuracy and reliability of the data.

Users can also add their custom configuration based on the following profiles:

- NeTEx - The full NeTEx schema
- NeTEx Light - NeTEx schema without constraint
- EPIP - NeTEx European Passenger Information Profile
- EPIP Light - NeTEx European Passenger Information Profile

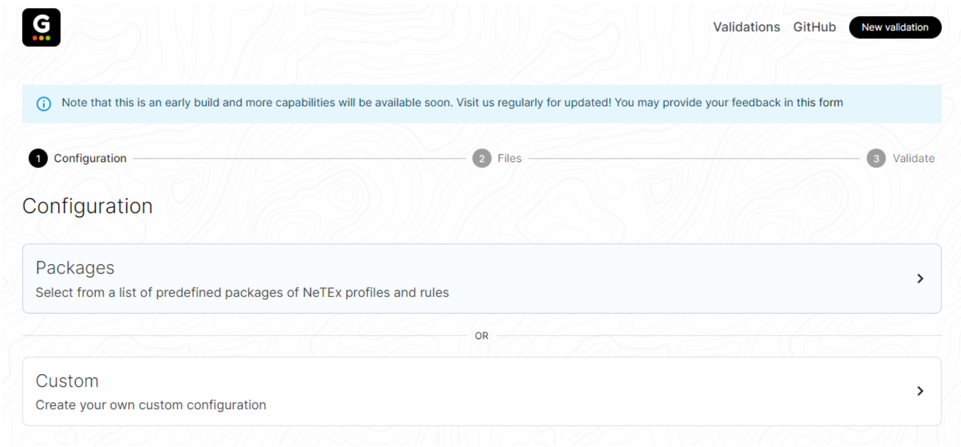

Figure 4: NeTEx validation tools (source: DATA4PT Tools)

The different tools are accessible also in github https://github.com/ITxPT/DATA4PTTools

3.1.6.3. MobilityData (GTFS)

Mobility Data is an initiative that recognizes the potential of data in improving transportation systems, enabling informed decision-making, and fostering innovation in the mobility sector. Hence, it focuses on promoting an efficient and responsible sharing of mobility-related data through the development of tools and data-driven projects. Two examples are:

- GTFS schedule validator maintained with the help of the GTFS community: https://gtfs.org/schedule/validate/
- International Mobility database: https://database.mobilitydata.org/

MobiDataLab has been using the Mobility database to identify and trace new mobility datasets, some of these not being possible to harvest through data portals.

MobilityData plays a crucial role in the development and maintenance of GTFS. It acts as a central authority for these specifications by providing resources, guidance, and support to transport agencies, technology providers, and other stakeholders involved in their implementation.

Since GTFS is becoming more complex, MobilityData has started discussions to work on defining existing GTFS components. The idea behind this is to propose a more precise definition of GTFS itself. Components help to integrate new functionalities into GTFS extensions such as GTFS-Flex (Cripotos & Robert, 2023). They also allow to have access to key information, further collaboration and ease the pathway to access and know about the support provided and the implementation of a particular functionality or feature of GTFS (Cripotos & Robert, 2023).

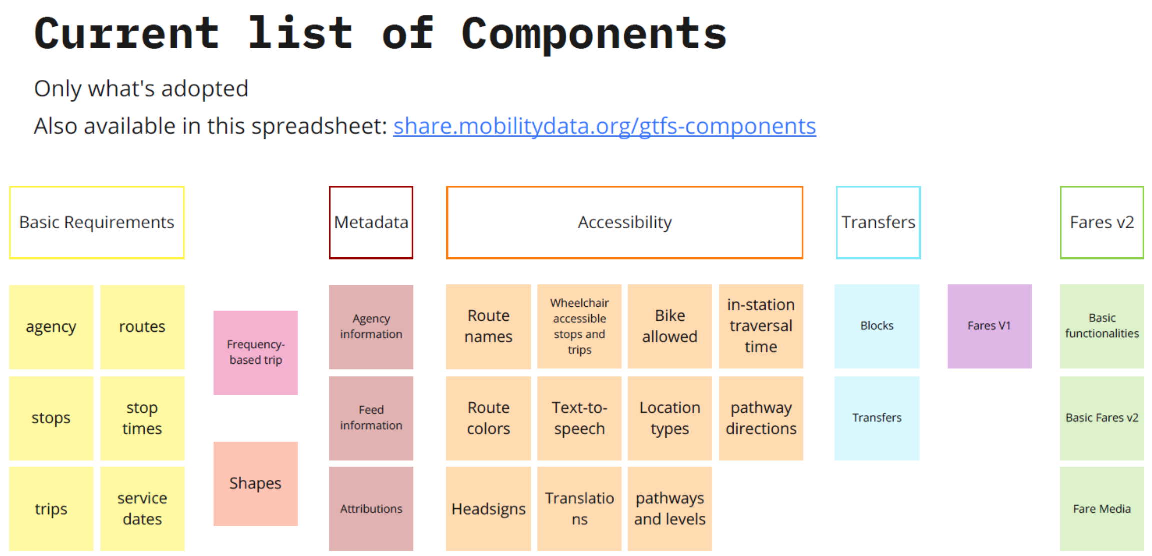

Figure 5: GTFS components (source: MobilityData Webinar)

3.2. Micro-mobility and shared mobility

In shared mobility, data-sharing standards - specifications are mainly designed to encompass a broader range of services. Among other reasons, platforms of shared mobility focus on facilitating the exchange of data between users, drivers, and operators to optimize services, enabling real-time tracking and enhancing operational efficiency. However, user privacy remains a consideration when dealing with localisation data of micro-mobility and shared mobility services as data anonymization is often leveraged to derive insights, improve route planning, and offer personalized experiences. This will be covered in section 3.5.5.

Likewise, micro-mobility data standards also enable data sharing. However, it tends to be more restricted due to privacy concerns and regulatory requirements. Hence, data providers often prioritize user anonymity and implement stringent data protection measures.

Here are a few examples of data-sharing standard's types:

- **Trip Data Standards:** focus on the exchange of information related to individual trips, including origin and destination points, travel times, modes of transportation used, and other trip-specific details. Examples include GTFS and Mobility Data Specification (MDS).

- **Geospatial Data Standards:** are concerned with location-based information, such as mapping, routing, and infrastructure data. These standards ensure interoperability and compatibility when sharing geospatial data across different mobility applications. Examples include OpenStreetMap (OSM) and City Geography Markup Language (CityGML).

- **Schedule Data Standards:** are used for sharing information about public transport schedules, routes, and service frequencies. They enable the integration and synchronization of transport data across various platforms. GTFS and NeTEx are common standards in this category.

- **Real-Time Data Standards:** designed for the exchange of up-to-date information regarding the status of transportation services, such as vehicle positions, delays, and service disruptions. Standards like SIRI and GTFS-RT fall into this category.

- **Operational Data Standards:** facilitates the exchange of data related to fleet management, maintenance, and performance monitoring within the respective mobility services.

- **Multimodal Data Standards:** are relevant to both micro-mobility and shared mobility, enabling the integration and coordination of different transportation modes for journeys

Each type serves a specific purpose and contributes to the overall interoperability and efficiency of data exchange within the mobility ecosystem. Most of these standards are analysed in this deliverable or were covered in version 1[25] of this deliverable.

[25] https://mobidatalab.eu/wp-content/uploads/2023/01/MobiDataLab-D2.4-StateOfTheArtOnMobilityDataSharingStandards-v2.1.pdf

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3.2.1. Static multimodal data

3.2.1.1. GBFS

In the micro-mobility and shared mobility context, it is essential to have an overview of the infrastructure and the offer of transport services.

GBFS (General Bikeshare Feed Specification) is a standardized data format specifically designed to describe traveller-facing information and for sharing real-time information about bike-share systems. It provides a consistent structure and format for exchanging data related to bike-share stations, availability of bikes and docks, and other relevant information. GBFS is used by consumer-facing applications, and it is available to the public (Grandjean & Delabie, 2022).

Overall, GBFS offers significant advantages by standardizing bike-share data and facilitating real-time information exchange. It enhances accessibility, encourages innovation, and improves the user experience for bike-share systems. However, it may have limitations in terms of scope and data quality, which should be considered when utilizing GBFS for bike-share-related applications.

Some advantages of this standard are that it has a simple data format which is most of the time available as open data (MobilityData Webinar –Introduction to GTFS and GBFS, 2022). Furthermore, this solution prevents vendor lock-in (MobilityData Webinar –Introduction to GTFS and GBFS, 2022). However, it is limited in terms of options for alternative mobility modes.

3.2.1.2. Canonical mapping with GBFS

After the release of a Canonical GBFS Validator in 2021, by the collaborative work of MobilityData and Fluctuo, aiming to improve the quality of mobility data, in 2022 the high-level mapping of GBFS to NeTEx & SIRI was released. This came after the NeTEx extension for new modes as a collaborative work of Datat4PT and MobilityData.

The goal is to foster shared mobility and interoperability since this should help to tackle current issues regarding the discoverability of trip planning services.

The idea is to be able to represent the components of GBFS in NeTEx to create effective passenger information services.

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3.2.1.3. NeTEx extension for New Modes of Transport and Operation

As previously mentioned, NeTEx provides a standardized format for exchanging data related to public transport networks, including new modes of transportation and operation[26]. The NeTEx extension for New Modes focuses on developing a data exchange format specifically for the publication of data related to "Alternative Modes[27]" as required by the EC DR (EU) 2017/1926. This extension, referred to as Net Part 5, primarily covers modes such as car sharing, cycle sharing, carpooling, and car/cycle rental. It focuses on static data, describing the services and infrastructure offered, rather than on real-time information, which is provided by SIRI.

The NeTEx extension builds upon the Transmodel extension for New Modes, with additional input from standards such as GBFS, DATEX II, Open Charge Point Interface protocol (OCPI) and MDS. Many concepts from the existing NeTEx standard already cover the requirements to describe new modes, such as site, location, role, connection, trip, journey, vehicle type, parking, and passing time. The extension primarily adds a few attributes and concepts to these existing ones.

For bicycle sharing, NeTEx enables the exchange of information such as station locations, available bicycles, and their status (e.g., in use, available, out of service). It also allows the representation of pricing information, including fares and any additional fees associated with bicycle rentals.

For scooter sharing, NeTEx facilitates the exchange of scooter station locations, availability of scooters, battery levels, and operational status (e.g., in use, available, under maintenance). It can also include details about scooter types, such as electric or manual, and any restrictions or rules associated with their usage.

In the case of car sharing, NeTEx supports the exchange of car station locations, availability of cars, fuel levels, and reservation information. It can also include details about the types of cars available, their seating capacity, and any specific features or restrictions related to the car-sharing service.

NeTEx ensures that relevant information about the availability, location, and attributes of these new modes of transportation is accurately exchanged and made accessible to transport authorities, operators, and other stakeholders. Overall, the NeTEx extension for New Modes provides an expanded framework within the existing NeTEx standard to accommodate the specific needs and characteristics of alternative modes of transportation, ensuring comprehensive data representation and exchange.

More details can be found on the website of MobilityData: https://mobilitydata.org/Data4PT-and-mobilitydata-are-releasing-a-mapping-between-gbfs-NeTEx-new-modes/

[26] "Transport Modes are enhanced to be able to describe travel by Alternative Modes (bicycle, scooters, etc.). A new concept of Mode of Operation is introduced that allows to distinguish between operation as an alternative mode (Vehicle Pooling, Vehicle Sharing, Rental, and operation as a classical mode (e.g. Scheduled service)." (Data4PT, 2022).
[27] Alternative Mode (services and associated online/mobile access): "Mobility Services are added to cover Vehicle Sharing Services, Pooling Services (including chauffeured car and taxi) and Rental Services. Access and Contact details for support can be described." (Data4PT, 2022).

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3.2.1.4. NeTEx extension for New Modes vs GTFS/GBFS

NeTEx, unlike GTFS and GBFS, introduces several technical enhancements to facilitate the representation of complex transportation data. One notable difference is the use of XML as the data exchange format in NeTEx, whereas GTFS and GBFS primarily rely on CSV (Comma-Separated Values) or JSON (JavaScript Object Notation) formats. CSV is useful when working with simple tabular data. JSON has a simpler syntax and is less redundant than XML and a JSON document is also more readable than a XML document (Singh, n.d.). XLM uses a container[28] to organize data while varied structures are nested within a JSON format (*DATA4PT and MobilityData are releasing a mapping between GBFS & NeTEx 'New modes'*, 2022). XML provides a more flexible and extensible structure for representing intricate transport network information, therefore providing detailed descriptions of routes, stops, timetables, and fares. XML is a more complex format compared to CSV, parsing and querying involves interpreting the XML structure, navigating through nested tags, and extracting data from the markup. However, this aspect can slow down data processing and increase resource utilization, particularly in scenarios with real-time data updates or frequent data exchanges. Also, it is necessary to note that currently, XML does not enforce strict schema validation by default. Although XML Schema Definition (XSD) can be used to define and validate the structure of XML documents, it is not inherent to the XML format itself. This flexibility can lead to data quality issues, as there is no built-in mechanism to ensure that the data adheres to a specific schema or format.

NeTEx incorporates a broader range of data elements and attributes compared to GTFS and GBFS. It offers enhanced support for managing diverse vehicle types, including those with specialized features like wheelchair accessibility or bike-carrying capacity. NeTEx also provides more comprehensive mechanisms for representing complex fare structures, allowing for the representation of different fare types, pricing information (discounted tickets), fare zones, and any associated rules or restrictions (time-dependent fares). This makes NeTEx suitable for capturing the complexity of fare systems in multimodal transportation networks.

Another key aspect where NeTEx stands out is its focus on multimodal journey planning and coordination. It enables the representation of interchanges between different transport modes, such as bus-to-train transfers or bike-to-public transit connections. This level of interoperability goes beyond the capabilities of GTFS and GBFS, which primarily focus on individual mode-specific data (Bourée, 2015).

Overall, NeTEx addresses the technical limitations of GTFS and GBFS by introducing XML as the data exchange format, expanding the range of data elements and attributes, and emphasizing multimodal journey planning. These advancements allow for a more comprehensive and detailed representation of complex transportation networks, accommodating new modes of transport and facilitating integration between different modes for a smoother travel experience.

NeTEx is more widespread than GTFS in Europe (Conceição et al.). Nevertheless, GTFS is the most used standard by multimodal traveller information mobility services.

[28]Data container: "stores and organizes virtual objects (a virtual object is a self-contained entity that consists of both data, and procedures to manipulate the data)." (Foote, 2021)

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It is more embraced than NeTEx as it is simpler to use (it has more compatible tools and is more simple to develop with its tools *(Gtfs2NetexFr, un outil open source intégré au Point d'Accès National !,* 2020).

Table 5: NeTEx extension for New Modes vs GTFS/GBFS

NeTEx extension for New Modes	GTFS/GBFS
Complex representation	Simple representation
Wide-ranging data model	Individual mode-specific data
XML format	CSV / JSON formats
XML flexible and extensible structure for representing intricate transport network information	JSON simpler syntax and readability
Global approach	Iterative approach

3.2.1.5. MDS

Mobility Data Specification is a free and open source emerging *de facto* standard model focused on the management of shared micro-mobility (Grandjean & Delabie, 2022). Since it is a specification, this was structured and adopted rapidly by the community, and it's governed by it. Open Mobility Foundation (OMF) is responsible for MDS's quality and implementation. Its goal is to provide comprehensive information about mobility use to cities' administrators to regulate the public space and to exchange pertinent information between cities and private mobility providers. It is used by some cities, data platforms (such as Deutsche Bahn AG[29] and Vianova[30]) and important private operators in Europe (such as Bolt[31], Dott[32], Helbiz[33], Lime[34], SHARE NOW, Tier[35] and more[36]), but it's mostly used abroad, in the US (Grandjean & Delabie, 2022). It provides a reusable framework that can be used in new markets, which permits unified collaboration. It permits device management; it provides real-time and historic data to help with planning and adaptation to changes (dynamic events). In addition, it supports policies for equitable transportation access, dynamic pricing and safety initiatives[37]. It is important to mention that the produced data is private as it is not meant for public consumption. Therefore, access requires the authentication of city regulators.

[29] https://www.deutschebahn.com/
[30] https://www.vianova.io/
[31] https://www.micromobility.com/
[32] https://ridedott.com/
[33] https://helbiz.com/
[34] https://www.share-now.com/
[35] https://www.tier.app/
[36] https://www.openmobilityfoundation.org/mds-users/
[37] https://www.openmobilityfoundation.org/about-mds/

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This specification has potential as it is flexible and has been adopted relatively quickly (Grandjean & Delabie, 2022). Furthermore, the OMF is trying to facilitate the implication of the European actors to adapt it to the European context (Grandjean & Delabie, 2022).

The following three Application Programming Interfaces (APIs) of this specification support the exchange of data between cities and providers:

- Provider API, it allows:
  - private mobility companies to report data to cities on the number, location, status, and ride history of devices in use.
- Policy API, it allows:
  - cities to set rules for how and where different vehicles can operate, how many can operate, and other high-level policy initiatives.
- Agency API, it allows:
  - real-time updates and collaboration between city officials and providers when complex city transportation problems demand dynamic solutions.

3.2.2. Dynamic multimodal data

3.2.2.1. SIRI extension for New Modes of Transport and Operation

SIRI is primarily focused on real-time information exchange for public transport services, but it can also be extended to handle new modes of transportation. For bicycle sharing, SIRI allows real-time reporting of bicycle availability at stations, including the number of available bikes, the number of free docking spaces, and any changes in station status. This enables users to access up-to-date information about bike availability and make informed decisions about their trips.

Similarly, for scooter sharing, SIRI supports the real-time reporting of scooter availability, including the current location of available scooters, battery levels, and any changes in scooter status (e.g., in use, available, under maintenance). This real-time information can be used by users to locate nearby scooters and plan their journeys accordingly.

In the case of car sharing, SIRI enables the real-time reporting of car availability, including the current location of available cars, their fuel levels, and reservation information. It allows users to access real-time updates on car availability, helping them find and reserve a car when needed.

By using SIRI, the real-time status and availability of these new modes of transportation can be efficiently communicated to users, allowing enhanced planning and decision-making.

3.2.3. Application to MobiDataLab

MobiDataLab has been using the Mobility Database[38] to identify and trace newly available micro-mobility datasets and shared mobility. These datasets have been made available in our CKAN data catalogue: around 20 GBFS datasets are available. Furthermore, MobiDataLab has worked with the reference group municipalities in the context of the living labs' challenges focused on transport alternatives. This is the case of Leuven's "Modal Shift with focus on micro-mobility" Challenge #1[39].

3.2.4. Development and support for implementation

3.2.4.1. Data4PT (New Modes extension)

DATA4PT organized a webinar[40] to present the New Modes extensions of these standards and their integration into the Transmodel environment. The training focused on aspects such as the overall framework, the functional scope and use cases, the technical documentation, as well as on available examples. For instance, some of these examples were: plan an intermodal trip, book a bicycle or book a ride share to carpool. They also tackled some implementation recommendations and provided links to the training material documentation (https://data4pt-project.eu/knowledge-database/training-material/) and to the standards' websites. As reported on their website NeTEx Part 5 for New Modes is already available CEN/TS 16614-5:2022[41].

Table 6: Attended events to micro-mobility and shared mobility standards

Event name	Type of event	Partner's name	Date	Location
DATA4PT Webinar	External event	AKKA	24-11-22	Online
MobilityData Webinar - Introduction to GTFS and GBFS	External event	AKKODIS	23-11-22	Online

3.2.4.2. Open Mobility Foundation - MDS

Open Mobility Foundation (OMF) is a governance structure providing open source to provide mobility solutions that go along open decision processes that include local administrative bodies, public and private stakeholders and technical experts. They guide the MDS community with updates, versioning and follow-ups about its environment.

[38] https://database.mobilitydata.org/
[39] https://labs.mobidatalab.eu/challenge-details/?id=96
[40] https://data4pt-project.eu/webinar-on-netex-and-siri-standards-for-new-modes-recording-now-online/
[41] https://www.en-standard.eu/pd-cen-ts-16614-5-2022-public-transport-network-and-timetable-exchange-netex-alternative-modes-exchange-format/

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They also guide cities and companies who desire to implement MDS and stay compliant with the European Union General Data Protection Regulation (GDPR)[42] through a comprehensive guide[43]. For more information about their work, here is a link towards their website: https://www.openmobilityfoundation.org/about-mds/mds-version-guidance/. On May 10th, 2023, the release of MDS 2.0 was announced[44].

This specification has been simplified for easier implementation within public and private organizations. This version has also been extended to be compatible with alternative and future shared modes, such as car sharing, taxis, delivery by robots and ride-hail. Open Street Map (OSM) has also made changes to its MDS API policy, refining the operations rules allowed by the cities on their vehicles. As for the communications interaction differences between agencies and providers, it has also been simplified and aligned for easier implementation.

3.2.4.3. MobilityData – GBFS

As with GTFS, MobilityData plays a critical role in the development, standardization, adoption, and support of GBFS. Their efforts contribute to the global availability and consistency of open mobility data, fostering innovation and improving the user experience in transport and bike-share systems. They provide support and guidance to the different interested actors, propose introductory sessions about the specification, and discussions about possible improvements and tools. For example:

- The GBFS validation tool is based on the official JSON schemas: https://gbfs-validator.netlify.app/
- The latest project registered in their road map concerning GBFS is the Region ID for Vehicles[45].

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[42] https://gdpr.eu/what-is-gdpr/
[43] https://www.openmobilityfoundation.org/using-mds-under-gdpr/
[44] https://www.openmobilityfoundation.org/mobility-data-specification-mds-2-0/
[45] https://mobilitydata.org/roadmaps/

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3.3. Road traffic data

Road conditions and road traffic data of quality are essential for road network operators to ensure proper traffic management and estimated arrival information, but more importantly to ensure travel safety by getting user information and insights about required road maintenance. Road users, on their side, expect up-to-date information on their vehicle's navigation systems and digital maps. This type of data depends on standards, like the DATEX II and TN-ITS which are covered in this section.

3.3.1. DATEX II

DATEX II is a set of specifications developed in accordance with the ITS Directive for the exchange of traffic and travel information. DATEX II is maintained by the technical committee 278 of the CEN. It provides an electronic language base to road and traffic operators, providers as well as management centres with functionalities comparable to a "grammar" and a "dictionary" to exchange road data. Since it is delivered in an independent way from other languages and presentation formats, it avoids common errors in translations and interpretation. It is presented in an eXtensible Markup Language (XML) format and its tools are modelled within a Unified Modelling Language (UML). It is recommended by NAPCORE as a data standard to be used to harmonize multimodal travel information and to avoid data duplication. The report of NAPCORE *M2.4 List of gaps and used standards*[46] shows that DATEX II is widely present in Europe and it covers many components of the European Commission Delegated Regulations (Safety Related Traffic Information (SRTI), RTTI, MMTIS, SSTP).

DATEX II data model includes various components. For instance, the methodology is described in section 1, while the location (referencing) is component 2. The subdomains cover different types of information that can be exchanged such as the road situation, parking, Urban Vehicle Access Regulations (UVAR) and more (see Figure 6). However, it is important to note that some of these components are under development. This is the case for energy, traffic regulations, facilities and UVAR. This is also the case for the component regarding high precision referencing Global Navigation Satellite Systems (GNSS). Another major component is common data.
To better understand the structure of DATEX II, information can be consulted on the following webpage https://docs.datex2.eu/basics/index.html.

[46] https://napcore.eu/m2-4_list-of-gaps-and-used-standards_final/

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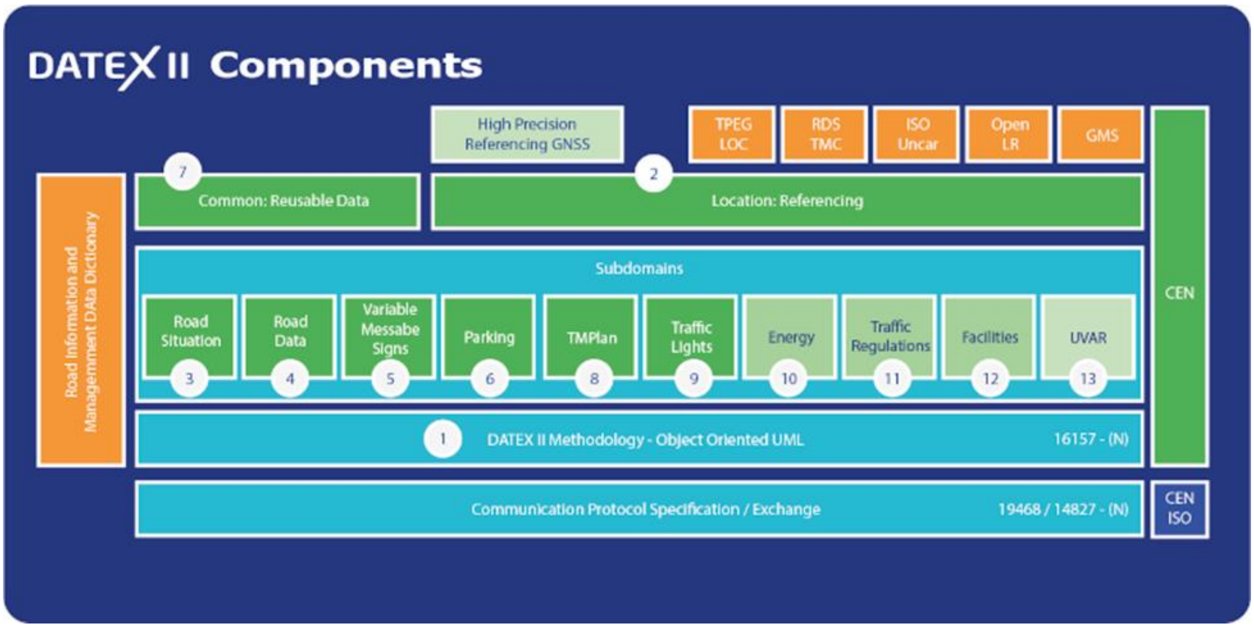

Figure 6: DATEX II components (source: DATEX II website: basic structure[47])

3.3.2. TN-ITS

TN-ITS, CEN TS 17268, is a technical specification maintained by the CEN Road Transport and Traffic Telematics and it focuses on static road data. This last is developed by a technical Intelligent Transport Systems committee identified as 278. TN-ITS describes the way to exchange data concerning road attribute changes. Its goal is to provide precise and up-to-date information for the development of digital maps. Therefore, TN-ITS facilitates and promotes the exchange of ITS-related spatial road data. This exchange format is mandatory in the EU Mobility Data Space (*TN-ITS*, 2022), probably as it has proven to be suitable and easily modelled to be deployed in all countries efficiently with the help of the TN-ITS GO project (*TN-ITS*, 2020). Additionally, it enhances and facilitates the exchange of accurate data between road authorities and data users (including authoritative and regulatory information (*TN-ITS*, 2022). This specification is in use in Belgium (Conceição et al. 2022)

3.3.3. Application to MobiDataLab

DATEX II is of particular interest to MobiDataLab as this information is crucial for Traffic management. This standard can be used in “Analytics & Learning” or “Optimisation of transport flow and ETA” use cases related to traffic incidents. For instance, challenge #1 “Logistics and Traffic Flow Around New Residential Projects” was proposed by the municipality of Eindhoven.

[47] https://docs.datex2.eu/basics/basicstructure.html

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The datasets provided for this challenge came from the Netherlands National Highway Traffic Data Portal[48] that we identified through the NAPCORE website[49]. During the Datathon, we provided data sources and datasets which contained the DATEX II. However, there is a very limited amount of DATEX II datasets in open data portals, at least for the reference group municipalities for which a challenge was proposed.

3.3.4. Development and support for implementation

3.3.4.1. TN-ITS - DATEX II - NAPCORE

The TN-ITS platform provides its support for the NAPCORE project by sharing its expertise and working on the development of the TN-ITS specification.

There is a lot of support given by NAPCORE to DATEX II as it follows many of the current EC delegated regulations, but also because it is present in several European Union countries. DATEX II is a substantial part of the NAPCORE working groups, with a lot of topics to address, related to the new delegated regulations. The interoperability efforts will be challenging with the mobility data spaces coming with their requirements, and the Linked Open Data challenges. Since the 2021 release of D2.4, the first version of this document, new developments are in place. TN-ITS and DATEX II are mentioned as mandatory in the revised Delegated Regulation (DR) on Real-Time Traffic Information (EU RTTI DR 2022/492) for data providers. Both standards are also integrated with the NAPCORE project on the harmonization of National Access Points with the participation of all EU Member States. In this project, it is planned to harmonize and merge TN-ITS and DATEX II into one standard and organisation. This will avoid overlaps in both standards and brings more clarity to road authorities providing road and traffic data.

[48] https://nt.ndw.nu/#/actual-traffic-overview
[49] https://napcore.eu/news-events/

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3.4. Journey planning

In deliverable 2.4, we emphasized the need for accurate and timely information exchange in public transport services and we proposed the adoption of a single Open Journey Planning (OJP) API to support various distributed journey planning systems. Since, despite the use of different architectures, the queries and responses remain fundamentally similar, which can facilitate communication and interoperability between these systems and guarantee the advantage of creating a universal channel for information exchange. Journey planning is applied in MobiDataLab in both the challenges proposed to the participants of the Living Labs and as a use case/service of the MobiDataLab transport cloud prototype.

3.4.1. OJP

OJP[50] initially refers to the CEN/TS 17118's standard, which is the "Open API for Distributed Journey Planning", a protocol required for the Member States of the European Union through DR (EU) 2017/1926. It is a technical framework and a concept that enables the exchange and integration of journey planning. It involves the development and implementation of standardized data models, APIs, and protocols that allow different systems and applications to communicate and share journey planning data effectively.

At its core, OJP utilizes open data formats and standardized XML-based calls in a request/response process. This allows systems to exchange journey planning information in a structured and interoperable manner which ensures compatibility and consistency across different implementations.

To illustrate the technical aspects and implementation examples of OJP, the following should be considered:

- **Data Models:** OJP defines data models that describe the structure and content of journey planning information. For example, it includes entities such as locations, routes, schedules, fares, and real-time updates. These data models provide a common framework for representing and exchanging journey planning data.

- **APIs:** OJP provides a set of APIs that allow developers to access and query journey planning information. These APIs define the endpoints, request parameters, and response formats for retrieving data. For instance, developers can make API calls to obtain route information, departure times, stop locations, and other relevant details.

- **Interoperability:** OJP emphasizes interoperability by promoting open standards and protocols. This enables different journey planning systems to communicate easily. For example, transport agencies can share their data with third-party applications or combine data from multiple sources to provide comprehensive journey planning services to users.

[50] https://opentransportdata.swiss/fr/cookbook/open-journey-planner-ojp/

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- **Real-time Updates:** OJP supports real-time updates by incorporating mechanisms to deliver and consume live information about disruptions, delays, and other relevant events. This ensures that journey plans remain up-to-date and accurate, providing users with the latest information about their trips.

It's important to note that there are specific data standards and requirements for OJP-based APIs to ensure interoperability and consistent data exchange. These standards help facilitate the integration of different journey planning systems and applications. The standard itself provides guidelines and specifications for the structure, format, and content of journey planning data. It defines the data models, attributes, and relationships that should be included in the API responses. However, there may be specific regional or national data standards and regulations that apply to OJP-based APIs. These standards could include requirements for data formats, encoding, localization, and privacy considerations. API providers need to comply with these standards to ensure data consistency, legal compliance, and integration with other systems.

As an implementation example of this standard, OJP also refers to the "Open Journey Planner" backend routing system developed by the Customer Information System Tasks office (SKI) on behalf of the Swiss Federal Office of Transport[51] (FOT). It offers an open and standardized API, based on the TRIAS scheme[52], for accessing and linking various information services known as Linked Services and mainly utilizing standard XML calls in a request/response process.

The three key services provided by OJP are as follows:

1. **TripRequest:** This service handles routing by computing connections between a given start point/origin and a destination. The start point and destination can be specified as coordinates, an address, a point of interest (POI), or a stop. Routing includes public transport-based options that consider current journey times and disruptions. It also incorporates map-based private transport routing using OpenStreetMap (OSM). ModesToCover allows users to request specific modes of transportation, including public transport, walking, cycling, user-driven cars, and vehicle-sharing services (such as bikes, e-scooters and car sharing).

2. **LocationInformationRequest:** By entering a coordinate or address, this service determines the nearest stops and points of interest.

3. **StopEventRequest:** This service provides the next departures/arrivals at a specific stop, enabling the display of real-time information on arrival/departure monitors.

Additionally, as shown in the figure below, an open-source demonstrator that includes a software development kit for the interface can be accessed at https://opentdatach.github.io/ojp-demo-app/.

[51] https://opentransportdata.swiss./
[52] https://www.vdv.de/ojp.aspx

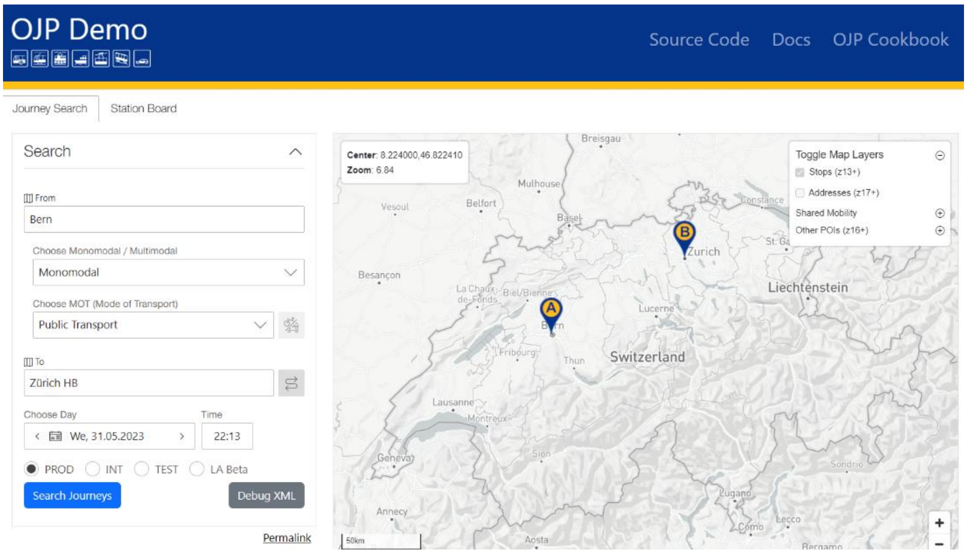

Figure 7: Web demo implementation of OJP (source: OJP Demo, 2023)

Other various implementations of OJP can be found in journey planning applications, systems and APIs such as the Navitia API.

3.4.2. Navitia API

The Navitia API[53] is a comprehensive public transit API provided by Hove. It offers access to a wide range of transit data and services, enabling developers to integrate public transportation information into their applications and services.

Navitia API[54] adheres to several key standards in the public transit domain, ensuring interoperability and compatibility with other systems. Some of the prominent standards supported by Navitia API include GTFS, NeTEx, SIRI and Navitia Transit Feed Specification (NTFS) a specific pivot standard. Its goal is to allow the management of various types of data in a single format (schedules, on-demand transport, etc.). This new format draws heavy inspiration from the GTFS while adapting it to allow for the most comprehensive description of data possible. As such, the format is subject to evolution.

By adhering to these standards, Navitia API ensures compatibility with data sources and standardized systems and integration of transport information from different providers. It provides developers with a unified interface to access and utilize transport data in their applications, making it easier to build transportation-related services and solutions.

[53] https://doc.navitia.io/#getting-started
[54] https://github.com/hove-io/transit_model

3.4.3. OpRA

OpRa, which stands for Operating Raw Data and Statistics Exchange, is an initiative led by CEN aimed at developing a technical specification or European norm. The purpose of OpRa is to support the gathering, exchange, and storage of public transport data, allowing therefore the study and control of public transport services. It primarily focuses on actual and measured data, which provides an accurate representation of public transport operations, including factors like delays and passenger counts.

The initiative builds upon Transmodel's "Operations monitoring and control" and "Management information and statistics" domains. It is specifically designed to facilitate data reporting of individual measurements at specified intervals or in aggregate form (such as statistics). While aggregated and other statistical data have minimal privacy risks, certain forms of raw data representing individual measurements require enhanced data-protection protocols. Data confidentiality and privacy will be briefly discussed in section 3.3.5 of this report since the collection and process of personal or sensitive data linked to the location or mobility of a person in a vehicle require safe treatment and limited access and this can be addressed through strict measures and standards, which play an important role on regulations.

3.4.4. Application to MobiDataLab

Journey planning is one of the main Use Cases proposed by MobiDataLab. During the Datathon, three challenges concerning this use case were proposed by reference group members. The municipality of Eindhoven proposed a challenge for “Assessing the impact of Urban Planning actions at a neighbourhood level”, while the municipality of Leuven proposed one regarding “Modal Shift with focus on micro-mobility” and the municipality of Milan focused on one concerning the “Accessibility (or Transport network adaptation) to large events.

In what concerns proposed solutions, HOVE provided a demonstration and tokens to pass queries through Navitia during the Datathon. This solution will be also available during the next X-thons.

3.5. Ticketing and tariffication data

3.5.1. MaaS

In Mobility as a Service (MaaS) ecosystems, ticketing and tariffication data play a crucial role in facilitating integrated travel experiences across multiple modes of transportation. MaaS aims to provide travellers with a comprehensive and convenient platform for planning, booking, and paying for their entire journey, regardless of the transport modes involved. To achieve this, standardized approaches and data formats are necessary for ticketing and tariffication within the MaaS.

One of the key standards in this regard is the NeTEx (Network Timetable Exchange) specification. As we already mentioned before, it allows the exchange of standardized data related to fare structures, pricing, ticket types, and payment methods across different transport modes and service providers to ensure interoperability and consistency in ticketing and tariffication across their platforms.

Another relevant standard is the GTFS (General Transit Feed Specification) Fare specification. GTFS-Fare complements the GTFS format and enables the representation of fare rules, fare attributes, and fare products for public transportation systems.

Additionally, several initiatives and organizations are working on developing open standards for ticketing and tariffication in MaaS. One notable example is the Smart Ticketing Alliance, which promotes the interoperability of smart ticketing systems across different regions and transport modes. They develop technical standards and guidelines to facilitate the integration of ticketing data within MaaS platforms.

Overall, standardized approaches and data formats for ticketing and tariffication in MaaS are essential for ensuring interoperability, simplifying the user experience, and fostering the integration of various transport modes and operators within MaaS ecosystems.

3.5.2. CDS-M

CDS-M, which stands for Common Data Sharing Model for Mobility, is aimed at creating a standardized data model for sharing mobility data. It is led by the Mobility Open Data Initiative (MODI), a collaboration between transport authorities, operators, and technology providers. The goal of CDS-M is to establish a common framework for data exchange and interoperability among various stakeholders in the mobility ecosystem focusing on data formats and structures standardization. CDS-M is a European adaptation of MDS, and it is in an emerging phase. This standard is used in the Netherlands, and it is closely related to Transport Operator and Mobility Provider (TOMP) and OMF (Grandjean & Delabie, 2022).

The CDS-M model covers a wide range of mobility-related data, including but not limited, to Fare Data. GitHub link: https://github.com/CDSM-WG/CDS-M

3.5.3. TOMP-API

TOMP-API, or Transport Operator and Mobility Provider API, is an open standard application programming interface (API) developed by the Open Transport Initiative (OTI). It aims to facilitate the integration and interoperability of various mobility services within a MaaS ecosystem. It is standard in an emerging phase (Grandjean & Delabie, 2022).

The key features of TOMP-API include:

1. **Trip Planning:** TOMP-API allows users to plan multi-modal trips, considering various transportation modes, routes, schedules, and fare information. It supports journey planning based on different criteria such as time, cost, and preferences.

2. **Booking and Ticketing:** The API enables users to book and purchase tickets for different transportation services within the MaaS ecosystem. It supports ticket issuance, fare calculation, and payment processing across multiple modes and operators.

3. **Real-time Information:** TOMP-API provides access to real-time data, including service disruptions, delays, and availability of transportation options. This allows users to make informed decisions based on up-to-date information during their journey.

4. **User Management:** The API enables user authentication, registration, and management of user profiles within the MaaS ecosystem. It facilitates personalized services, user preferences, and satisfactory user experiences across different platforms and applications.

5. **Data Exchange:** TOMP-API supports data exchange and integration between different systems and service providers, promoting interoperability and collaboration within the MaaS ecosystem. It enables the sharing of relevant data, such as schedules, routes, fare structures, and service availability, to enhance the overall user experience.

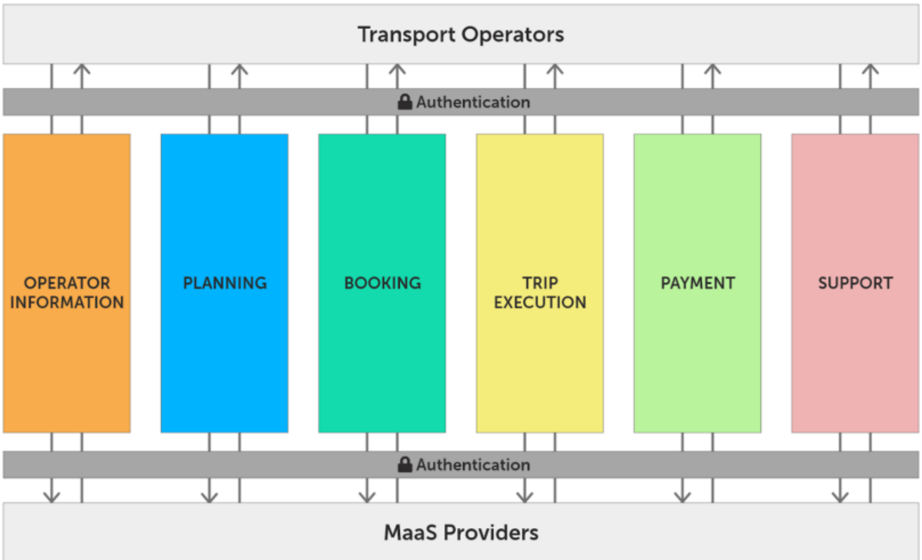

Figure 8: MaaS Providers and Transport Operators ecosystem (Van den Belt & Groen, 2021)

GitHub link of: https://github.com/TOMP-WG/TOMP-API

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3.5.4. OTI

The Open Transport Initiative (OTI) is a collaborative effort that aims to promote open standards in the field of mobility and transportation to facilitate integration and interoperability among different mobility services, systems, and platforms. It is the only initiative that provides a “user management” component to share and standardise personal mobility data (Grandjean & Delabie, 2022). It supports the creation of specifications and guidelines that address key aspects of mobility, including data formats, communication protocols, API design, and interoperability frameworks.

Some examples of the contributions of OTI are the following 2 API standards:

- Customer-account API:

The Customer-account API is standardized for customers to integrate their MaaS or transport provider account data, such as journey history, tickets, and discounts, with other compatible accounts or value-added services. For example, it allows customers to connect their accounts with a Delay Repay provider for handling compensation claims. The API specification can be found at https://app.swaggerhub.com/apis/open-transport/customer-account/.

- Centralized Operator-info API:

The Centralized Operator-info API proposes a design for a centralized API look-up service that helps locate data across different transport operators and MaaS platforms. This innovative technical directory service, inspired by principles of the Internet of Things (IoT), allows one operator's system to automatically discover the latest data URL (e.g., the Customer-account API) provided by another operator, regardless of the transport mode. By providing a centralized information resource, this API facilitates data access and integration among operators and MaaS platforms, promoting efficient collaboration and service delivery. This API specification can be found at https://app.swaggerhub.com/apis/open-transport/operator-info/
https://opentransport.co.uk/

This standard is at an emerging stage and has not been adopted by many actors yet. It requires further structure and financing (Grandjean & Delabie, 2022). However, it might gain popularity in the future as governmental regulations encourage the introduction of smart data initiatives, such as the one in the UK which mentioned OTI (Grandjean & Delabie, 2022).

3.5.5. Data Confidentiality and travel price

Standards play a vital role in ensuring data confidentiality and protecting travel price information within the context of mobility and transportation. By adhering to established standards, organizations can implement robust security measures and best practices to safeguard sensitive data. Generally, standards for data confidentiality may align with established frameworks like ISO/IEC 27001, which provides a comprehensive approach to information security management.

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With regards to privacy and confidentiality of personal information, ISO 24014 relies on the design principles of data minimization, hiding, and separation, that is, to collect as little personal information about customers as strictly necessary, to ensure that only information relating to the service (and not to the customer) is shared between entities, and to ensure that the link between customers and services can only be achieved at the request of the customer. Appropriate data protection measures, such as encryption of data at rest and in transit had to be implemented by all actors. See D2.3 for more information on Privacy by Design strategies. Additionally, industry-specific standards and regulations, such as the GDPR in the European Union, set guidelines for handling personal data and ensuring its confidentiality. More specifically, Travel Price Standardization in travel pricing is essential for transparency and consistency across different transportation modes and service providers.

3.5.6. Application to MobiDataLab

MobiDataLab proposed a generic challenge regarding Mobility as a Service during the Datathon concerning the use case “Analytics & Learning”. For more information about it, please refer to D.5.6 *Report on Datathon.*

3.5.7. Development and support for implementation

3.5.7.1. Use case implementation

ISO 24014, implemented in countries like the United Kingdom, Germany, France and Japan, is a standard that promotes interoperability in fare management systems for public transport. It allows participating companies to implement their strategies while ensuring a seamless journey for customers using a single interface. The standard includes requirements such as data extraction for revenue-sharing, efficient ticketing methods, compliance with data protection laws, fraud prevention, and protection of customer privacy. It also enables the integration of additional services and provides interface definitions for interoperability between different operator networks. The standard remains neutral towards technologies and transport organization structures, providing a flexible framework for commercial agreements. Overall, ISO 24014 aims to enhance efficiency, convenience, and privacy in public transport fare management systems.

3.5.7.2. La Fabrique des Mobilités

La Fabrique des Mobilités (also known as FabMob) is an association that encompasses mobility actors of all levels. Pressed to tackle the current climate crisis, they are acting by contributing to creating projects and giving context to respond to the decarbonization challenge in the transport sector, but also by acting on related matters such as social inclusion and territorial justice.

Based on other works and projects they aim to respond to these challenges by avoiding, shifting and improving transportation habits. They rely on the cooperation of a variety of stakeholders which is the reason why they collaborate with experts, public and private actors and social initiatives. They provide support and information about mobility, look for feedback and insight from the diverse stakeholders and do a retrospective and reflect on the actions and experimentations done. Their objective is to propel the mobility of the general and collective interests. As part of their actions, they propose several online and in-person workshops and webinars to exchange and advance their project advancements and tools. Among other subjects, they often organize discussions about MaaS and sector-specific standards. The table below shows some of the discussions and webinars that FabMob proposed. They also published a Benchmark on *MaaS Standards: Governance & Performance*[55].

Table 7: MaaS standards discussions and webinars followed

Event name	Type of event	Partner's name	Date	Location
Open standards for MaaS of general interest Webinar: *Standards ouverts pour les MaaS d'intérêt général Webinaire*	External event	AKKODIS	05-10-2021	Online (replay)
Ask me anything about ... MaaS standardization!" #1: *Demandez-moi n'importe quoi sur ... la standardisation des MaaS !" #1*	External event	AKKODIS	31-03-22	Online (replay)
Webinaire de présentation du Benchmark sur les démarches de standardisation du MaaS: *Webinaire de présentation du Benchmark sur les démarches de standardisation du MaaS*	External event	AKKODIS	23-05-22	Online (replay)
Ask us anything about ... geographic information in MaaS!: *Demandez-nous n'importe quoi sur ... l'information géographique dans le MaaS !*	External event	AKKODIS	13-11-22	Online (replay)
Ask us anything about ... ticketing in MaaS!: *Demandez-nous n'importe quoi sur ... la billettique dans le MaaS !*	External event	AKKODIS	13-12-22	Online (replay)
Mix and MaaS: Data Architecture for Mobility as a Service - Webinar	External event	AKKODIS	17-05-23	Online (replay)

[55] https://wiki.lafabriquedesmobilites.fr/wiki/Benchmark_%22MaaS_Standards_:_Governance_%26_Performance%22

3.6. Other sector-specific standards

There exist other mobility standards such as Open Charge Point Interface protocol (OCPI) and Curb Data Specification (CDS) which are of interest when talking about modal shift in transportation. OCPI, also known as a charging station network, allows communication between Electric Vehicles (EV) and the management systems (Open Charge Point Protocol, 2023). CDS aims to provide support through tools to understand, manage, measure and improve active curb zones to prevent traffic and safety problems (About CDS | Open Mobility Foundation, 2023). The idea led by OMF is to provide this information to public, private agencies, and non-profit organizations for the development of curb projects and policy innovation.

Another example of a sector-specific *de facto* standard is the Navigation Data Standard (NDS) which is a format for map data in automobile navigation systems. The standard has been developed in a consortium with automotive OEMs and map makers. Its goal is to enhance and make more flexible the exchange of information in a database format. The list of associated members has grown since the setup as a standard in the automotive domain. The development is led by the NDS e.V. organization which has been set up as an independent association to manage the standard. The data itself is stored within an SQLite database. The association provides documentation about the standard. The NDS association also provides tools and documentation to use and integrate NDS data in systems and workflows. The most recent product is NDS.Live. It provides a modular structure, which can integrate and manage complex map data services[56]. Live updates with static and dynamic map data are the core benefit of NDS.Live.

3.6.1. Application to MobiDataLab

During the Datathon, access was provided to the MobiDataLab Service Catalogue[57] and to the CKAN Data Catalogue[58] in which APIs and datasets relating to EV charging points were proposed. Throughout the event a participant presented interest on one of the proposed APIs by HERE: EV Charge Points.

NDS only has an indirect influence on the MobiDataLab project. Data which is being provided in this format is usually directly ingested into the vehicles and is not available via open data initiatives. However, the data is being used by large parts of the mobility ecosystem. Therefore, the data format plays a role in the mobility data ecosystem more from a consuming perspective.

[56] https://www.nds.live
[57] https://labs.MobiDataLab.eu/services/
[58] https://ckan.MobiDataLab.eu/dataset/

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4. Cross-domain data standards

Horizontal standards and specifications are used in more than one sector, as they cover general or basic “principles, concepts and definitions” that can be applied to broad subjects. In what concerns mobility data, some common standards which are often used to obtain mobility data are geospatial data standards (OGC API, OSM, INSPIRE, WMS/WFS), metadata standards (DCAT, CSW DCAT-AP), smart city standards (ETSI NGSI-LD) and semantic interoperability standards (LOD), standards for data exchange in the cloud (AMAZON S3, TOSCA, DATA Exchange), web data exchange (REST, XML, JSON, Open API).

Table 8: Horizontal standards and specifications

Categories	Standard	Specification
Metadata	CSW	DCAT, DCAT-AP
Data exchange in the cloud	AMAZON S3, TOSCA, DATA Exchange	
Semantic interoperability	LOD, RDF, SPARQL, OWL, JSON-LD	
Smart city	ETSI NGSI-LD	
Data on the web	REST, XML, JSON, Open API	
Geospatial data	GeoJSON, WMS/WFS, SOS, OGC API, FGDB, SHP, GeoDCAT-AP, CityGML	OSM

4.1. Metadata exchange

Metadata is a very important element when creating and sharing data. Metadata is a descriptive text file in which a data provider presents a detailed description of the available content and format of the data file provided to the users. A metadata file can be compared to a presentation cover page that describes a whole set of data or it can be seen as the data describing itself. Whenever metadata is incomplete or it is not in a common format, data itself might be not accessible, not sharable, ambiguous and in some cases even obsolete, therefore it is very important to use well-defined standards of metadata.

A metadata catalogue is a standard interface between a service and a user whose role is to query a metadata service to get the list of available metadata, datasets, to query the service and target a precise metadata file to get its content. DCAT is a well-known vocabulary in the mobility world as it eases the exchange between web data catalogues.

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This last was covered in detail in D.2.4. In this version two DCAT-AP extensions will be discussed: one concerning the mobility metadata and another concerning the geospatial metadata (section 5.7). In this section, the Catalogue Service Web (CSW) will be also briefly discussed.

4.1.1. DCAT-AP and mobilityDCAT-AP

DCAT AP is an extension of the DCAT RDF ontology with a cross-border and cross-domain scope whose goal is to meet specific requirements. It is a well know interoperable specification as through semantic equivalents for each attribute and element of data, it allows systems to interact with each other and automatically convert that data (GBFS to NeTEx & SIRI v1.0, 2022). It is a widespread specification in European data portals.

In the search to achieve harmonization across National Access Points, NAPCORE has been working on an extension of the DCAT-AP to create a specific metadata profile for NAPs in the transportation domain. The draft of this last was recently released and named mobilityDCAT-AP. It provides the practices to follow in metadata catalogues.

4.1.2. CSW

As covered in D.2.4, Catalogue Service for the Web (CSW) is a standard for geospatial metadata which is maintained by the Open Geospatial Consortium (OGC). This service allows to publish, modify and search collections of descriptive information (metadata records) of data, services, and related information objects. As with any other catalogue service requirement, it supports the discovery of registered information resources. It is a widespread standard in geographic data catalogues.

4.1.3. CSW – INSPIRE

The INSPIRE Directive (Directive 2007/2/EC) requests to present geodata in a harmonised format that can be viewed and downloaded (*INSPIRE support to Multi-Modal Travel Information Services | Joinup*, 2023). This geodata is often accessible on geoportals via a CSW, often based on a GeoNetwork-base architecture, which enables the harvest of metadata by other data portals. The principal INSPIRE access point is the INSPIRE Geoportal[59] which allows monitoring, access and discovery of datasets and/or services from EU Member States and European Free Trade Association (EFTA) countries according to themes or priority datasets. The INSPIRE geoportal offers a Reference Validator for data providers to verify if their dataset aligns with the recommendations defined by the Directive. The INSPIRE Directive has been used as a support to the MMTIS EC DR (EU) 2017/1926. It is important to mention that within the scope of the INSPIRE Directive, there is a particular theme on Transport Networks[60] to categorize and discover the pertinent datasets.

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[59] https://inspire-geoportal.ec.europa.eu
[60] https://inspire.ec.europa.eu/data-specifications/2892

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4.1.4. Application to MobiDataLab

MobiDataLab integrated the DCAT-AP and CSW solutions by using them to harvest metadata from several data portals into the CKAN and the GeoNetwork catalogues created to be employed during the Living and Virtual Labs of this project.

Some portals were also harvested with the help of the CSW CKAN harvesting extension for INSPIRE records. To achieve this, it was necessary to make an inventory of the different data portals and identify which ones offered this solution to exchange metadata.

Among the different data portals covering, the reference group municipalities' data, twenty-nine offered this service. Below there is a table with some examples of the data portals concerned:

Table 9: Data portal offering a CSW and harvested

Organization (data portal)	Country
Geoportal of the Ministry of Environment and Energy	Greece
Geoportale Nazionale It	Italy
IGN FR	France
National Access Point of Romania	Romania
GeoCatalogueFr	France
IDEE	Spain
IGN ES	Spain
MobiData BW	Germany
PIGMA	France
CEREMA	France
Open Data Vlaanderen	Belgium
NationaalGeoregisterNL	Netherlands
GeoDatiGovIt RNDT	Italy

The INSPIRE themes were also taken into consideration when creating the CKAN metadata groups.

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4.1.5. Development and support for implementation

While CSW and DCAT-AP were some of the most used standards for harvesting data in our CKAN catalogue, it seems relevant to explore in the future how to obtain metadata via the web standards ATOM and RSS feeds, which are often proposed in data portals.

4.1.5.1. NAPCORE

NAPCORE is one of the principal bodies working on metadata[61] harmonization in Europe. There is a particular working group working on the recommendations to improve the quality of metadata to make it more accessible and interoperable. This group has taken mainly as a base the structure of DCAT-AP to conceptualize a cross-border metadata registry that will result in a demonstrator, and it also helped to create the mobilityDCAT-AP draft[62]. NAPCORE made available three reports to answer questions about this specification, which are available on their website:

- Requirements Analysis for a new Metadata Specification[63]
- Approach towards napDCAT-AP specification[64]
- Roadmap to napDCAT-AP[65]

[61] https://napcore.eu/providing-a-baseline-for-a-new-metadata-scheme-for-european-naps/
[62] https://mobilitydcat-ap.github.io/mobilityDCAT-AP/drafts/latest/
[63] https://napcore.eu/wp-content/uploads/2022/08/NAPCORE-4.4.2.1-Requirement-analysis_v1.0.pdf
[64] https://napcore.eu/wp-content/uploads/2022/08/NAPCORE-4.4.2.2-Approach-towards-napDCAT-AP-specification_v1.0-Report.pdf
[65] https://napcore.eu/wp-content/uploads/2022/08/NAPCORE-4.4.2.2-Approach-towards-napDCAT-AP-specification_v1.0-Roadmap.pdf

4.2. Semantic interoperability standards

This section reports on the principles, concepts, standards, ontologies, and languages that have eventually been selected and used in the MobiDataLab project. More specifically, this section reports on those that have been employed during the development of the *semantic enrichment processor*, a key component in the transport cloud architecture whose purpose is to enrich trajectories with several aspects (or semantic dimensions) and that is the focus of Task 4.4.

4.2.1. Linked Data

Linked Data represents a set of design principles for sharing machine-readable interlinked data on the Web. When combined with Open Data, i.e., data that can be freely used and distributed, it is called **Linked Open Data (LOD)**. Linked Data is one of the core pillars of the Semantic Web. The Semantic Web is about making links between datasets that are understandable to both machines and humans. Linked Data provides the best practices to make these links possible. Thus, Linked Data can be seen as a set of design principles to share machine-readable interlinked data on the Web. Linked Open Data is a powerful blend of Linked Data and Open Data, in that it is both linked and using open sources. One example of a LOD set is WikiData[66], while another one is DBpedia[67].

4.2.2. Resource Description Framework and Knowledge Graphs

The **Resource Description Framework (RDF)** is a standard for data interchange that represents prepositional data in *triples* in the form of subject-predicate-object. Triples are *assertions* about a fact and can be used to represent highly interconnected data. Each RDF statement is a three-part structure consisting of resources where every resource is identified by a Uniform Resource Identifier (URI). Representing data in RDF allows information to be easily identified, disambiguated and interconnected. The Protocol and RDF Query Language (SPARQL) is the W3C-standardised language for retrieving and manipulating data stored in RDF format. RDF is the format used in Semantic Web and Linked Open Data.

Knowledge graphs are structured, interconnected representations of real-world entities, their attributes, and relationships. They store data as nodes (entities) and edges (relationships), forming a graph. Knowledge graphs facilitate semantic querying, data integration, and advanced reasoning by capturing information in a machine-readable format. In this context, we note that a *triplestore* is a type of database specifically designed to store and retrieve triples and can therefore be used as a physical storage and retrieval mechanism for knowledge graphs. A popular example of triplestore is GraphDB[68]. Triplestores support SPARQL, a query language for RDF, which is commonly used to retrieve and manipulate data in the knowledge graph.

[66] https://www.wikidata.org/
[67] https://www.dbpedia.org
[68] https://graphdb.ontotext.com/

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More information on SPARQL is provided in one of the next sections.
One can easily see how the RDF standard represents a natural choice for building knowledge graphs, considering its graph-based, triple data model that intuitively represents entities and their relationships.

4.2.3. Ontology Web Language

The **Ontology Web Language** (OWL) defines a semantic web computational logic-based language designed to represent rich and complex knowledge about things and the relations between them. It also provides detailed, consistent and meaningful distinctions between classes, properties, and relationships. By specifying both object classes and relationship properties, as well as their hierarchical order, OWL enriches ontology modelling in semantic graph databases – these are also known as *RDF triplestores*. When used together with a reasoner in such triplestores, OWL enables consistency checks (i.e., finding any logical inconsistencies) and ensures satisfiability checks (i.e., finding whether there are classes that cannot have instances).

4.2.4. Ontologies for multiple aspect trajectories

Ontologies for multiple-aspect trajectories, such as the ones proposed by STEP[69] (Nogueira et al., 2018), and MASTER (Mello et al., 2019), describe the spatiotemporal and semantic dimensions of moving objects by capturing complex relationships and properties. Such ontologies not only formalize concepts such as location, time, and trajectory, but also concepts related to aspects that can enrich trajectories. By providing a structured framework, they enable the integration and analysis of heterogeneous trajectory data, hence facilitating advanced reasoning, analysis, and decision-making in diverse applications, e.g., transportation, human mobility, urban mobility, and tourism.

4.2.5. SPARQL

SPARQL (or SPARQL Protocol and RDF Query Language) is a versatile, standardized query language used to retrieve and manipulate data stored in the Resource Description Framework (RDF) format. Designed for the Semantic Web, SPARQL allows users to express complex queries to extract information from RDF graphs, enabling powerful data integration and analysis. The language supports various query forms, such as SELECT, CONSTRUCT, ASK, and DESCRIBE, to meet diverse querying needs. In its latest revision, i.e., the 1.1 version, the SPARQL language can also be utilized via its protocol for remote data access, making it a critical tool for accessing and working with linked data on the web.

[69] https://github.com/talespaiva/step

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4.2.6. Application to MobiDataLab

All the principles, concepts, standards, languages, and ontologies presented so far have been employed in the context of the MobiDataLab project to develop the semantic enrichment processor, which is a key component in transport cloud architecture. Such a component oversees semantically enriching trajectories with several aspects or semantic dimensions and outputting the resulting datasets in a format that can be understood by popular triplestores such as GraphDB for further querying and analysis.

RDF has been used in the project in conjunction with DCAT to harvest metadata in our CKAN catalogue.

4.2.7. Development and support for implementation

In the following paragraphs, we report on the technologies used to implement the principles, concepts, standards, languages, and ontologies used in the semantic enrichment processor. Overall, the semantic enrichment processor has been implemented with the Python programming language. We report, for each relevant point, the specific Python libraries used.

- **RDF and knowledge graphs:** the semantic enrichment processor generates RDF knowledge graphs containing datasets of multiple aspect trajectories by using the rdflib[70] library and structures the content within the knowledge graphs according to a customized version of the STEP ontology (see below).

- **OWL and ontologies for multiple aspect trajectories**: we considered the STEP ontology, an ontology that models multiple aspect trajectories and that structurally supports the addition of an arbitrary number of aspects and customized it through the Protege' tool[71] to add the aspects that we deemed of interest. This customization has been achieved through the capabilities provided by the OWL.

- **SPARQL and Linked Open Data**: SPARQL v1.1 is employed to conduct movement behaviour analyses on individuals whose multiple aspect trajectories are stored in RDF knowledge graphs. More specifically, SPARQL queries are executed on MAT datasets that are imported into a popular triplestore, i.e., *GraphDB*. Finally, we used SPARQL to access a selected Linked Open Data source, specifically Wikidata, through federated queries. This type of query internally uses the SERVICE construct to access LOD sources' remote SPARQL endpoints.

[70] https://rdflib.readthedocs.io/en/stable/
[71] https://protege.stanford.edu/

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4.2.7.1. Use case implementation

The semantic enrichment processor has been developed according to the requirements established by the research use case study “*Transport data sharing within the Linked Open Data vision*”, which has been detailed in deliverable 2.10. In this study, the goal is to have the processor enrich trajectory data with selected aspects, and then use the resulting dataset to perform analyses of an individual’s mobility behaviours, whereby said analysis is conducted from the perspective of a tourism service provider.

The principles, concepts, standards, languages, and ontologies previously introduced regarded the enrichment part of the processor, and have been considered as follows:

- **RDF and knowledge graphs**: the RDF standard has been used to construct the knowledge graphs containing the datasets of enriched trajectories.

- **OWL and ontologies for multiple aspect trajectories**: we considered the STEP ontology, which we have customized using OWL to add the aspects that we considered relevant for the analyses that have been subsequently done on the enriched datasets in the GraphDB triplestore.

- **SPARQL and Linked Open Data**: the SPARQL v1.1 language has been used to conduct movement behaviour analyses. We also used the same language to access a selected Linked Open Data source, i.e., WikiData, through the concept of federated query, i.e., a SPARQL query that internally uses the SERVICE construct to access remote SPARQL endpoints.

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4.3. Geodata sharing standards

Mobility data is often geospatial data which requires accurate location. Geospatial data can be shared through common geographical standards that depend on the data models for structuring the information (for instance raster or vector data, OpenStreetMap (OSM) data or data models defined by the INSPIRE directive), and the exchange services themselves (for exchanging raster or vector data, object location or features).

4.3.1. OGC: WMS, WFS, WMTS

The Open Geospatial Consortium (OGC) implements several open geospatial/location interoperable information standards. Some of the most widespread standards in the geographic community are the Web Map Service (WMS) for requesting geo-registered map images from one or more distributed geospatial databases and the Web Features Service (WFS) to access geographic information at the feature and feature property level. A standard which has started to be more present in recent years is the interface Web Map Tile Service (WMTS).

4.3.2. OGC GeoPackage or FlatGeobuf as alternatives to shape

GeoPackage is an encoding standard which is being used in more and more frameworks and tools. The OGC released the Version 1.3.1 of the standard, after its approval in 2021[72]. The data format is based on an SQLite database[73], which stores information on:

- vector features
- tile matrix sets of imagery and raster maps at various scales
- attributes (non-spatial Data)
- extensions

The format has been seen as a successor of the proprietary shape format, which has initially been implemented and used by the Environmental Systems Research Institute (ESRI). The GeoPackage is an open format, self-describing and compact. With the possibility to store raster data and its flexibility on attribute names, it extends the typical limitations of shape files and provides more state-of-the-art functionalities to store geospatial data.

FlatGeobuf is an open-source binary geocoding for geographic data based on FlatBuffers[74] (*FlatGeobuf*, n.d.). It aims to store simple features and large volumes of static data, metadata and content in a format permitting easy access and streaming (*FlatGeobuf*, n.d.).

[72] https://www.geopackage.org/spec131/index.html
[73] https://www.geopackage.org/
[74] https://flatbuffers.dev/

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This specification is another alternative to the shape file format. For more information about it, you can consult the following website: https://github.com/flatgeobuf/flatgeobuf.

4.3.3. OGC API – Features and Common

OGC API Features and OGC API Common are multi-part standards which define modular API building blocks. OGC API Features allows to read and access collections of geospatial data on the web (part 1: core, which was approved) and it should also allow to modify, create and query[75]. To bind OGC's Web APIs and Resource Oriented Architectures, the OGC approved the release in 2023 of the OGC API Common[76]. Based on OpenAPI, OGC API Common is used to define common and shared requirements which apply to all OGC Web API Standards to connect to Web APIs[77]. This new modular suite conforms to the principles of Representational State Transfer (REST).

4.3.4. OSM

The OSM data format has not changed since the first version of the Mobility Data Sharing Standards (D2.4). However, there are new activities covered by third parties on OpenStreetMap data to provide validated and curated data sets in digestible data formats.

For instance, Meta provides a Daylight distribution of OSM data, verified in terms of quality and regularity, available in the OSM Protocolbuffer Binary Format (PBF) as well as in Atom feed format (https://daylightmap.org/). In December 2022, the Overture Maps Foundation started with the funding following members: Amazon, Meta, Microsoft and TomTom. Under the umbrella of the Linux Foundation, their goal is to provide a curated map incorporating open data sources and OpenStreetMap data. Their first map versions are available via the Overture Maps website (https://overturemaps.org/).

4.3.5. GeoDCAT-AP and GeoDCAT

GeoDCAT-AP is a DCAT-AP European profile and extension for describing geospatial datasets, dataset series and services. It is used for the discovery of datasets to enable cross-sector and cross-platform sharing and re-use of INSPIRE and general metadata[78]. GeoDCAT-AP is splitting into a new branch which is GeoDCAT a spatio-temporal profile. A Standards Working Group (SWG) of the OGC will be working on the review and maintenance of this new profile, but also on community support.

[75] https://ogcapi.ogc.org/features/
[76] https://docs.ogc.org/is/19-072/19-072.html
[77] https://ogcapi.ogc.org/common/
[78] https://inspire.ec.europa.eu/good-practice/geodcat-ap

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The idea is to address all the requirements identified on the OGC GeoDCAT-AP paper of 2019[79], which were not all necessarily adopted on v3 of DCAT. GeoDCAT will support the FAIR principles, particularly more findable in diverse sectors. By being designed for the web and it is thought to be compatible with the encoding available on API catalogues. While GeoDCAT-AP, GeoDCAT and DCAT might differ, they will remain interoperable.

4.3.6. Application to MobiDataLab

Geodata sharing standards have been used in MobiDataLab to discover geographical metadata, such as digital maps, transport networks, roads, land use information, traffic signs and bus lines, among others, as they often are provided in geodata formats. We have demonstrated and created documentation available in MobiDataLab's github[80] about how to access geographical data and metadata through these standards with Qgis (plugins and connexions to map services), but also with Jupyter Notebooks within the context of the Datathon (see table 8, below).

In addition, we identified one data portal (GeoDatiGovIt RNDT[81]) using the GeoDCAT-AP extension from which it was possible to harvest more than 22 000 datasets.

Table 10: Standards available on MobiDataLab's CKAN and in the access guides of Jupyter notebook or QGIS

Categories	Standard(s)
Table format	CSV, XLS, XLSX
Data exchange	XML, PHP, XSD, ODS, JSON
Text file	TXT
Data on the web	HTML
Public Transport	GTFS
Metadata	CSW
Geographic data	GIS API, GeoJSON, SHP, GPKG, GML, WMS, WMTS, WFS, OGC API, GeoPackage, KML

While we have not had yet the opportunity to use the Daylight distribution, we have provided OSM extracts from GeoFabrik for their use during the Living and Virtual labs of MobiDataLab. These were used to be ingested by Navitia or by other interphases to use and enrich their content.

[79] http://www.opengis.net/doc/dp/GeoDCAT-AP
[80] https://github.com/MobiDataLab
[81] https://geodati.gov.it/geoportale/eng/

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For instance, the geographical enrichment processor as a part of the transport cloud processes, enriches different data formats like NTFS (HOVE), HERE journey planner and GeoJSON, the processor can also convert OSM and GTFS data into a GeoJSON format, then it parses and adds useful data (accessibility, weather, air quality index and more) to the target APIs.

Table 11: Attended events - Geodata

Event name	Type of event	Partner's name	Date	Location
OGC Mobility Data Science Summit Preview Session, Singapore Geospatial Festival 2021	External Event by OGC	HERE	15-09-21	Hybrid (Singapore, online)
HERE GIS Days 2022	HERE internal event	HERE	16-11-22	Online
FOSSGIS 2023	External event	HERE	17-03-23	Berlin, Germany
FOSS4G	External event	HERE	26-06-23	Prizren, Kosovo

4.3.7. Development and support for implementation

The OGC is currently working on the review of the API Roadmap. Regarding OGC API-features, part 3 and part 4 are still in the draft version process.

4.4. Standards and the Mobility Data Spaces

Once there exists harmony among mobility data for exchange, the next common strategy for the EU is to achieve findability, interoperability, accessibility and reusability to develop a European Data Space for Mobility.

Europe is on its way to generate and make use of more data than ever. PrepDSpace4Mobility[82] lays the foundation for a secured and controlled way of pooling and sharing mobility data across Europe.

4.4.1. PrepDSpace4Mobility project

The project aims at contributing to the development of the common European mobility data space by supporting the creation of a technical infrastructure that will facilitate easy, cross-border access to key data for both passengers and freight. Given the enormous potential of data and digital technologies, the project is expected to have a positive impact on European competitiveness, society, and the environment.

The Data Spaces Support Centre[83] explores the needs of data space initiatives, define common requirements, and establish best practices to accelerate the formation of sovereign data spaces as a crucial element of digital transformation in all areas.

The aim of Data Spaces is to provide added value to data through its exchange in a transparent and efficient manner. This allowing autonomy to the data holder and making data of quality discoverable and decentralized. All this following clear ethical norms and rules to use data and with a well-defined business model (see Figure 9).

Figure 9: Open Digitising European Industry (DEI) schema [84] (source: FIWARE, 2023).

[82] https://mobilitydataspace-csa.eu/
[83] https://dssc.eu/
[84] https://www.opendei.eu/

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4.4.2. Building blocks

A building block is an open and reusable digital solution, which can take the shape of a framework, a standard, software, or Software as a Service (SaaS) (source: FIWARE, 2023)[85]. Building blocks can be used in multi-sectorial data spaces which makes them interoperable across sectors.

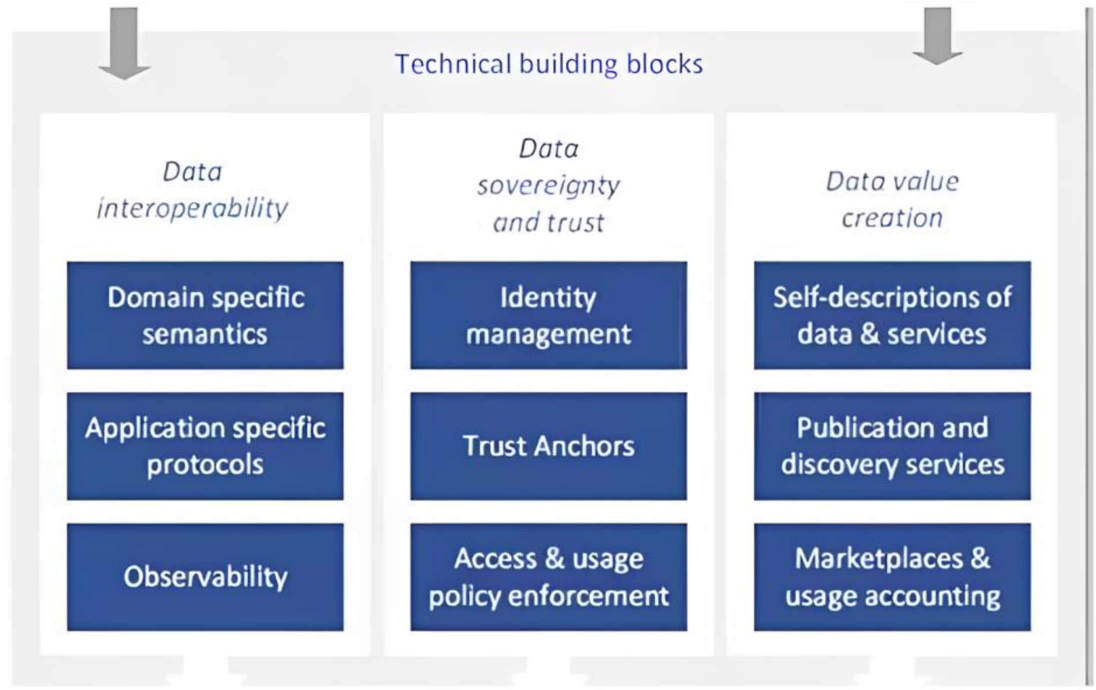

Figure 10: Technical building blocks (source: FIWARE, 2023).

The mobility data space project proposes common building blocks and governance frameworks found in existing data space architectures, by mapping existing data ecosystems, identifying gaps and overlaps within.

[85] https://www.slideshare.net/FI-WARE/prepds4mobilitybuildingblockspptx

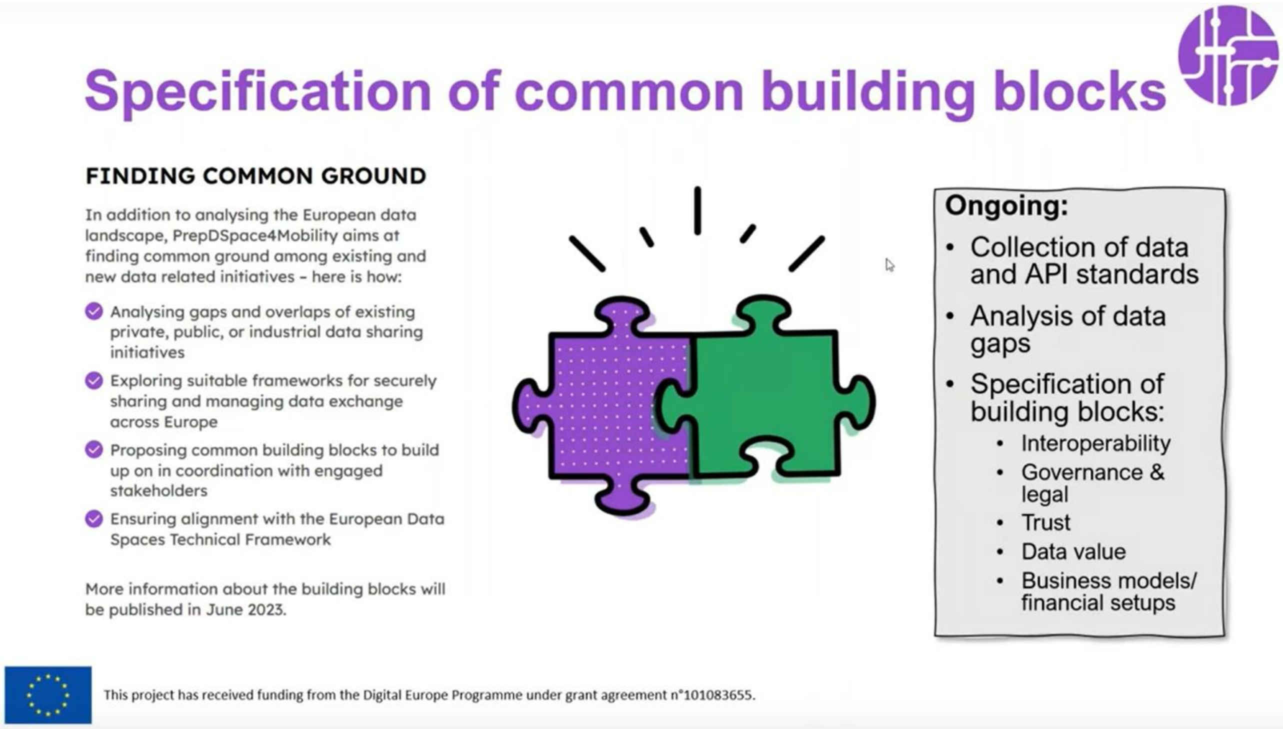

Figure 11: Specification of common building blocks (source: FIWARE, 2023)[86].

4.4.3. Application to MobiDataLab

MobiDataLab uses a building block logic, to develop several components that will be assembled into the transport cloud architecture.

Geographical and Semantic enrichment processors provide an OpenAPI UI and produce standard outputs. An effort has been put into also CKAN data catalogue to make it interoperable with different data formats such as DCAT (RDF/XML, JSON), CSW (Inspire) and WAF.

As already highlighted in deliverable D4.2, the notion of data space within GAIA-X appears to represent a layer within one or multiple inter-connected GAIA-X ecosystems (which, we recall, will make up a multi-cloud federation) whose goal is to provide a specific type of data (e.g., automotive, agricultural, tourism, medical, mobility) via data sharing and data cooperation among multiple participants. Such a layer must implement the FAIR principles, as well as the principles of identity, trust, and sovereignty. This requires implementing the data space layer via several components. Among these, we report the data space connector[87], which is a key component that provides several fundamental capabilities to data space layers such as communication protocols, discovering, connecting, automated contract negotiation, policy enforcement, and auditing processes. Data space connectors must be able to communicate with each other.

[86] https://www.youtube.com/watch?v=nVSddaRqEpM
[87] https://github.com/eclipse-dataspaceconnector/DataSpaceConnector

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4.4.4. Development and support for implementation

Table 12: Attended events - Mobility Data Spaces

Event name	Type of event	Partner's name	Date	Location
First expert workshop: Preparatory action for a common European mobility data space	External Event by FIWARE Foundation	AKKODIS	31-01-23	Online
Third expert workshop: Preparatory action for a common European mobility data space	External Event by FIWARE Foundation	AKKODIS	31-05-23	Online
Second Public Stakeholder Forum	External event by EIT Urban Mobility	AKKODIS	27-05-23	Online
Data Week Leipzig 2023	External event	AKKODIS	26-06-23	Online

4.4.4.1. Use case implementation

The geographical enrichment processor[88] has been developed to support the conversion and enrichment of various mobility data formats such as GeoJSON, GTFS and OpenStreetMap, and produces GeoJSON standard.

The processor's API can be used to enrich the mobility data APIs that produce JSON representation, using JSON path regular expressions.

[88] https://MobiDataLab.eu/wp-content/uploads/2023/01/MobiDataLab-D4.7-DataEnrichmentProcessorsV1_v1.1.pdf

5. Conclusions

Throughout this document we discussed about standards used to deal with shared mobility data. The aim of the deliverable was to show how some of them have evolved since the redaction of the deliverable 2.4 and how MobiDataLab has been using them, by following a precise methodology, as suggestions to be adopted for improved FAIR mobility data sharing. The methodology consisted of the identification of standards and their context in relation to use cases, their application in the different stages of MobiDataLab and on their evolution and related support for implementation.

These standards are of interest to MobiDataLab as they promote data sharing in the mobility and transport field that can allow us to diversify the data content and value. Several of these standards make data more accessible, findable and linkable at local, regional and national levels.

Organizations such as MobilityData and FabMob promote cooperation to improve and maintain these standards. It is important to follow these types of activities and organizations to be informed about the latest changes on standards, collaborate and learn how to implement them.

MobiDataLab has used these standards in the cloud architecture, the uses cases, the data catalogue, the demonstration tools, and it has also participated in standard related events. Furthermore, MobiDataLab has invited experts in the mobility and transport standardization field to collaborate, provide insights into our actions and be part of our events. For instance, Timo Hoffmann (General Secretary of NAPCORE) was invited to present NAPCORE during the MobiDataLab Datathon and Tu-Tho Thai (ex. Director at MobilityData and present Projects and Partnerships Manager at ITxPT) was invited as a jury member.

While fast development and implementation of standards are praised by some, it can come to the detriment of a reduced point of view. Therefore, thinking about the long run remains important and working with the open support from a dynamic community is important throughout the whole process of development of standards.

It is important to consider that promotion (proper presentation) and support for implementation are keys for a standard to prevail. Open development by the technical community might ease the work of developers, and it might provide visibility to transport operators for them to follow the standardization process.

Always-evolving standards can be evaluated by how findable, accessible, interoperable and reusable they are, but also by the quality of their content since empty or incomplete harmonised metadata is often obsolete. Metadata must be shareable, structured, detailed and understandable. It must be also discoverable, so it can be exploited.

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The level of implementation of these standards changes according to countries and the administrative level of the data portals and uses cases. A more extensive analysis is required to answer this question. Nevertheless, we included a table in the annex to provide a small recapitulation of the phase, level of implementation and data categories covered by the standards and specifications covered in this deliverable.

Although every single community, sector and administrative entity might have very specific needs to represent the context of their data, it is important to define and develop profiles for the particularities of each of them and at the same time it is crucial to restrain the number of standards to enjoy the benefits of standardizing which are the ability to exchange and integrate data from different sources to develop an efficient sharing environment.

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7. Annexes

This table is a recapitulation of the development, level of implementation and categories of the data-sharing standards and specifications covered in this deliverable. However, it is limited to the information that we gathered on the subject.

As mentioned previously, a more detailed analysis might be pertinent to confirm the information on the table below.

Table 13: Recap phase and category standards/specifications

Standard	Phase	Implementation	Category
CDS	Emerging		Shared mobility
CDS-M	Emerging		MaaS
CSW	Mature	Widespread	Metadata
CSW INSPIRE	Mature	Partially available	Metadata and MMTIS
DATEX II	Mature	Widespread	Traffic, parking, road information, road operator information and individual transport, SRTI, RTTI, MMTIS and SSTP
FlatGeobuf	Development		Geodata sharing
GBFS	Development	Available	MaaS, micro-mobility and shared mobility
GeoDCAT	Under development		Geodata sharing
GeoDCAT-AP	Under development	Limited	Geodata sharing
GTFS	Mature	Widespread	MaaS, public transport, MMTIS
JSON-LD		Widespread	Semantic interoperability
LOD	Development	Widespread	Semantic interoperability
MDS	Development	Partially available	MaaS, RTTI, micro-mobility and shared mobility
NeTEx	Development - Mature	Widespread	Public Transport, MaaS, micro-mobility, shared mobility and rail information

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NDS	Development - Mature	Widespread	Navigation data, map data
OCPI	Development	Widespread	MaaS, multimodal mobility (including parking, EV & charging)
OGC API	Development	Widespread	Geodata sharing
OGC GeoPackage	Development	Available	Geodata sharing
OJP	Development	Available	Journey planning, individual transport, rail information and MMTIS
OpRA			Public transport, ticketing and journey planning
OSM	Mature	Widespread	Geodata sharing and MMTIS
OTI	Emerging	Limited	MaaS and mobility account
OWL		Widespread	Semantic interoperability
RDF	Development	Widespread	Semantic interoperability
SIRI	Development - Mature	Limited	Public transport, MMTIS, RTTI and rail information
SPARQL	Mature	Widespread	Semantic interoperability
TN ITS	Mature	Limited	Traffic and road operator information
TOMP-API	Emerging - Development	Available	MaaS
Transmodel	Development - Mature		RTTI, MMTIS, MaaS and rail information
WMS, WFS	Mature	Widespread	Geodata sharing, RTTI and MaaS
WMTS	Mature	Widespread	Geodata sharing and RTTI

MobiDataLab consortium

The consortium of MobiDataLab consists of 10 partners with multidisciplinary and complementary competencies. This includes leading universities, networks and industry sector specialists.

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