International Mobility as a Service (MaaS) Ecosystems and Governance Frameworks

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Executive Summary

This report, created under the MaaS4IRL project with support from the Sustainable Energy Authority of Ireland (SEAI) and the Department of Transport, offers an in-depth exploration of Mobility as a Service (MaaS), Mobility Data Spaces (MDS), and their governance frameworks. It evaluates the feasibility of developing robust data-sharing infrastructures within Ireland's mobility sector while aligning with the European Union's (EU) broader data strategy and sustainability objectives.

MaaS represents a transformative approach to transportation, providing users with seamless access to diverse travel options through integrated platforms that combine journey planning, booking, payment, and real-time updates. This concept aims to encourage the use of public and shared transport modes, reducing reliance on private vehicles, alleviating congestion, and supporting sustainable urban development. At its core, MaaS relies on MDS, which provides the secure, interoperable, and standardized data-sharing architecture necessary for effective collaboration among public agencies, private operators, and technology providers.

The report identifies global best practices as key references for Ireland's mobility transformation. Platforms like Jelbi in Germany and Whim in Finland demonstrate the potential of MaaS to reduce emissions, improve urban mobility, and offer user-friendly transport solutions. These case studies underscore the critical role of governance models, data standardization, and advanced technologies, including e-payment systems, GPS integration, and real-time data exchange. Importantly, they highlight the value of public-private partnerships in fostering innovation, optimizing resources, and delivering customer-centric mobility services.

A central theme in the report is the significance of governance and regulatory frameworks in facilitating MaaS and MDS ecosystems. EU directives, such as the Data Governance Act (DGA) and General Data Protection Regulation (GDPR), ensure the ethical use of data and encourage interoperability. National policies, including Ireland's Data Sharing and Governance Act (DSGA), further support data-sharing agreements while aligning with EU standards. The choice of governance model significantly impacts the design and implementation of MaaS systems. For instance, the commercial integrator model fosters innovation but may risk misalignment with public policy objectives, while the transport-as-integrator model ensures alignment with public goals but is perceived as less innovative. The intermediate open platform model offers a balanced approach, combining innovation with public oversight.

The report also identifies challenges facing the implementation of MaaS and MDS in Ireland. Fragmented governance structures, lack of standardized data protocols, and gaps in digital infrastructure pose significant barriers. Public resistance to data sharing, driven by concerns over privacy and complexity, further underscores the need for clear communication and engagement strategies. Comprehensive awareness campaigns, user education, and transparent governance are essential to overcoming these obstacles and building trust in MaaS platforms.

Looking to the future, the report envisions advancements in MaaS features, including incentive-driven modal shifts, guaranteed travel continuity during disruptions, interoperable services across regions, and the integration of non-mobility-related services into MaaS packages. These enhancements can expand the functionality of MaaS platforms, making them more attractive and practical for a wider range of users.

The findings in this report highlight the transformative potential of MaaS and MDS for Ireland's mobility landscape. By learning from international best practices and addressing local challenges, Ireland can leverage MaaS and MDS to build a modern, efficient, and sustainable mobility system. This system has the potential to reduce environmental impacts, enhance public transport networks, and deliver a superior user experience, positioning Ireland as a leader in innovative mobility solutions within the EU and beyond.

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Acronym and Abbreviation Glossary

Abbreviation / Term	Description
MDS	Mobility Data Space
EC	European Commission
EU	European Union
IoT	Internet of Things
DSSC	Data Space Support Centre
CSA	Coordination Support and Action
AI	Artificial Intelligence
MaaS	Mobility as a Service
TFI	Transport For Ireland
ICT	Information and Communication Technology
B2C	Business to Consumer
B2B	Business to Business
PPP	Public-Private Partnership
GDPR	General Data Protection
SLAs	Service Level Agreements
BI	business intelligence
MSPs	Mobility Service Providers
DSA	Data Sharing Agreement
MMTIS	Multimodal Travel Information Services
VBB	Verkehrsverbund Berlin-Brandenburg
SMEs	small and medium-sized enterprises
GMDS	German Mobility Data Space
EDC	Eclipse Dataspace Components
CaaS	Connector-as-a-Service
DSA	Digital Service Act
DMA	Digital Markets Act
ITS	Intelligent Transportation Systems
MDMS	Multimodal Digital Mobility Services
EMDS	European Mobility Data Space
eIDAS	Electronic Identification, Authentication, and Trust Services Regulation

LMS	London Mobility Survey
NFC	Near Field Communication
SWOT	Strengths, Weaknesses, Opportunities, Threats
IDA	International Data Spaces
EDC	Eclipse Dataspace Components
JMDS	Japan Mobility Data Space
APIs	application programming interfaces
OMF	Open Mobility Foundation
EV	electric vehicles
ICV	Intelligent Connected Vehicle
V2X	Vehicle-to-everything
V2V	Vehicle-to-Vehicle
V2I	Vehicle-to-Infrastructure
V2N	Vehicle-to-Network
DSRC	Dedicated Short-Range Communications
C-V2X	Cellular Vehicle-to-Everything
SMDS	Stockholm Mobility Data Space
IDSA	International Data Spaces Association
LTA	Land Transport Authority
NTA	National Transportation Authority
CSO	Central Statistics Office
RMO	Road Management Office
GTFS	General Transit Feed Specification
GBFS	General Bikeshare Feed Specification
TIDES	Transit ITS Data Exchange
TODS	The Transit Operational Data Standard
NAPCORE	National Access Point Coordination Organization for Europe
TS	Technical Specification
EN	European Norm
OJP	Open Journey Planning
NeTEx	Network Timetable Exchange
SOA	Oriented Architecture
SIRI	Service Interface for Real-time Information
TN-ITS	Transport Network ITS Spatial Data Deployment
OpRa	Operating Raw Data and Statistics Exchange

UML	Unified Modeling Language
SIRI	Service Interface for Real-time Information
MDS	Mobility Data Specification
RDF	Resource Description Framework
DGA	Data Governance Act
DSGA	Data Sharing and Governance Act
PSBs	Public Service Bodies
DSA	Data Sharing Agreement
DPO	Data Protection Officer
DMA	Digital Markets Act
DSA	Digital Services Act
DAMA-DMBOK	Data Management Body of Knowledge

1 Introduction

While vast amounts of data are generated daily, many sectors, including mobility, still struggle to access the high-quality data needed to drive innovation. For example, advanced Mobility as a Service (MaaS) applications rely heavily on quality data for operational optimisation and customer experience. Data sharing offers a promising solution to address this "data starvation" challenge.

In April 2022, the European Union (EU) Parliament adopted the **Data Governance Act**[1], a framework aimed at enhancing data sharing across the EU. Its primary goal is to ensure that companies and start-ups have access to more data, enabling the creation of innovative products and services. Building on this, the Parliament introduced the **Data Act**[2] in November 2023, designed to unlock access to vast quantities of high-quality industrial data, particularly from sources like the Internet of Things (IoT). Together, the Data Governance Act and the Data Act form key pillars of the **European Data Strategy**[3], which aims to promote data sharing across Europe's regions, sectors, and businesses—regardless of their size—creating a unified market for the free flow of data between providers and recipients.

At the core of this data-sharing initiative lies the concept of Data Spaces, a pioneering solution for secure and multi-party data sharing within trusted ecosystems. According to the Data Space Support Centre (DSSC)[4], a data space is an interoperable framework based on shared governance principles, standards, practices, and enabling services, facilitating trusted data exchanges among participants. The European Union (EU) envisions establishing Common European Data Spaces across various sectors, including mobility, manufacturing, languages, skills, media, agriculture, health, and sustainability.

The mobility data spaces (MDSs) provide a secure and trusted environment where participants—such as data providers, recipients, and governance authorities—and intermediaries, such as MaaS solution providers, collaborate to develop applications that effectively address end-user needs.

The **MaaS4IRL project**, funded by the SEAI and the Department of Transport, aims to conduct a comprehensive feasibility study exploring the challenges, opportunities, and technologies required to establish efficient data-sharing frameworks for the mobility sector in Ireland. Since data spaces represent not only a promising solution but are also closely aligned with the EU's data strategy, the project places special emphasis on investigating this technology to assess its feasibility for implementation in Ireland's mobility ecosystem.

1.1 Document Scope

The MaaS4IRL project is set to deliver four key outcomes, each geared towards achieving the project's main goals. First, it will conduct an in-depth study of MDSs, MaaS, and governance frameworks, considering both international examples and the Irish context. Secondly, it will develop practical guidelines for optimising MaaS, which will rely on a high-performance, scalable, decentralised, trusted, and interoperable MDS. Thirdly, the project will identify the key areas within the transport sector where

[1] https://digital-strategy.ec.europa.eu/en/policies/data-governance-act
[2] https://digital-strategy.ec.europa.eu/en/policies/data-act
[3] https://commission.europa.eu/strategy-and-policy/priorities-2019-2024/europe-fit-digital-age/european-data-strategy_en
[4] https://dssc.eu

improved data sharing could offer the greatest return on investment, particularly in sectors like Electric Vehicle Charging Systems, which also have the potential to significantly reduce emissions.

This deliverable addresses the first objective. It offers a comprehensive review of existing MDSs and MaaS, investigating both European and global contexts, including their technologies, applications, capabilities, and governance structures. MDS is designed to facilitate trusted data sharing and promote interoperability among diverse mobility services and stakeholders. MaaS, on the other hand, seeks to bridge the gap between the public and private sectors by integrating fragmented tools and services that travellers rely on for journey planning, booking, access to real-time information, payment, and ticketing [1].

This document is organised into three interconnected sections. First, it presents a conceptual model focusing on mobility, with a particular emphasis on MaaS. Secondly, it provides a thorough review of Irish and international MaaS initiatives, data sharing frameworks, and the related governance and regulatory frameworks. Finally, it studies the synergies between MDS and MaaS, aiming to demonstrate how these systems can enhance the efficient use of mobility data and services.

Our review of MDS was based on publicly available reports. We identified the key technologies and architectures in use, mapped out the stakeholders involved, and studied the regulatory frameworks that guide data sharing and mobility services. This analysis enabled us to draw a comparative overview of the current MDSs within the EU. For MaaS, our review was informed by a wide range of sources, including articles, reports, online information, and partnerships such as the MaaS Alliance, both within Europe and internationally. As MaaS is the central focus of this deliverable, we took particular care to highlight 'good practices' across Europe, where these practices reflect a range of approaches, partnerships, technological innovations, and capacity-building efforts. We also explored the governance frameworks shaping MaaS, including relevant legislation, codes of conduct, and agreement frameworks.

All these findings have been consolidated into a single report that provides a detailed understanding of MaaS, MDS, and governance frameworks. The overarching goal is to clarify the roles each of these concepts plays within the broader mobility ecosystem, their interactions, and the critical actions required to support these relationships. This report offers valuable insights into the infrastructure for data sharing and the governance mechanisms that underpin these mobility services.

1.2 Methodology

This deliverable presents the findings from an extensive literature review and analysis of the MDS and MaaS ecosystem. The review had two main goals: first, to establish a conceptual foundation for MaaS, considering the role of MDS within it, and second, to provide an overview of the current state of the MaaS and MDS ecosystem. This will serve as a strong starting point for future research and development in the same field in Ireland. A systematic approach was followed to conduct the literature review.

Database Selection: To ensure a robust scientific basis for the work, our research primarily focused on peer-reviewed general databases like *Scopus*[5] and *Web of Science*[6]. However, given the emerging nature

[5]https://www.sciencedirect.com/topics/biochemistry-genetics-and-molecular-biology/scopus
[6]https://access.clarivate.com/login?app=wos&alternative=true&shibShireURL=https:%2F%2Fwww.webofknowledge.com%2F%3Fauth%3DShibboleth&shibReturnURL=https:%2F%2Fwww.webofknowledge.com%2F&roaming=true

and practical focus of the topic, the scope was expanded to include other sources that cover grey literature as well.

Keyword Specification: The literature search was defined by a combination of key terms, including "mobility data spaces," "mobility-data-spaces," "mobility as a service," "mobility-as-a-service," "intermodal mobility," "inter-modal mobility," "multimodal mobility," "multi-modal mobility," and "ecosystem." For example, one search string used was: ("mobility as a service" OR "mobility-as-a-service" OR "intermodal mobility" OR "inter-modal mobility" OR "multi-modal mobility" OR "multimodal mobility") AND ("architecture" OR "ecosystem" OR "system architecture" OR "technical architecture").

Selection Criteria

The selection process for sources was based on three main factors:

1. **Subject Relevance**: Only publications related to the transportation or mobility sectors were selected, including reports, project deliverables, and book chapters, with websites and blogs excluded.
2. **Publication Date**: Only sources published from 2020 onwards were considered, ensuring that the analysis reflects the most recent developments.
3. **Accessibility**: Only open access sources were reviewed, to ensure the research remains widely available.

Further, the review was limited to English-language sources and focused primarily on the European context, as the research is aligned with the MaaS4IRL project.

In total, 75 sources were selected for detailed review, each of which was individually analysed with a focus on identifying clear examples of MaaS applications and ecosystems. Throughout the process, additional relevant sources were identified and incorporated into the review.

2 A Conceptual Framework for MaaS

Key Takeaways from this Section

- Gain insights into various conceptual frameworks and approaches for MaaS, highlighting their stakeholders, transport and mobility modes, travel functionalities, operational model, data sharing, service federation, and infrastructure.

The literature identified eight conceptual categories for MaaS: 1) Modes of transport [2][3][4], 2) Functions covered by the MaaS [3][5][6]; 3) Information or data required by MaaS [5][2]; 4) Stakeholders considered within MaaS [7][8]; 5) service federation [9]; 6) Operational model [5]; 7) Type of infrastructure [10]; 8) User service [9]. Table 1 presents the consolidated conceptual Framework for MaaS.

Table 1 A Consolidated MaaS Conceptual Framework

A Consolidated MaaS Conceptual Framework	
Stakeholders	A **transport service provider**, whether commercial or public, is responsible for delivering transportation services to the public. This can include both public sector transport (like buses and trains) and privately-owned services. For example, **Transport For Ireland's** (TFI) Leap Card is a prepaid travel card that gives users

	convenient access to a range of public transport across Ireland, including buses, trams (Luas), and trains (DART and commuter services). The MaaS operator is an entity that manages and operates the software behind MaaS platforms, offering mobility services in a machine-readable format for seamless integration. Regulators, such as public transport associations and standardisation bodies, work with government authorities to support the development of public transport services. They are responsible for publicising and enforcing national policies and regulations in the transport industry. Government authorities play a key role in drafting, approving, and implementing transport laws, regulations, and policies. At the heart of the system are the end users—MaaS consumers, research institutions, and other stakeholders who directly benefit from these services. Beyond these core roles, other important participants include data providers, technical backend and IT providers, ICT infrastructure specialists, insurance firms, regulatory bodies, as well as universities and research institutes, all of whom contribute to the wider mobility ecosystem.
Transport and mobility modes	This approach aims to achieve seamless, multimodal mobility by integrating various transport options. It includes both public transport and shared mobility services, as well as taxi and car rental options. Shared mobility encompasses services like ride-sourcing, ridesharing, and bike-sharing, while public transport covers options such as the metro, trains, and buses. The goal is to provide users with a flexible, interconnected system that simplifies journeys across different modes of transport.
Travel Functionalities	Core travel functionalities include essential services such as journey planning, booking, payment, trip execution support, real-time tracking, and notifications. Additionally, users can track their carbon footprint and access usage statistics. Other features, though secondary, include route calculation and comparison, as well as personalised travel options tailored to individual preferences. These functions work together to provide a seamless and efficient travel experience.
Operational model	MaaS relies on data sharing between Mobility Service Providers, allowing it to function under both Business to Consumer (B2C) and Business to Business (B2B) models. In addition, it can operate through a Public-Private Partnership (PPP) model, which involves collaboration between private companies, municipalities, and transport operators. An example of this approach is UbiGo[7], which brings together different stakeholders to offer integrated, multimodal transport services to the public. This cooperative model helps ensure efficient service delivery and innovation across mobility networks.
Information/ Data sharing & Governance and Regulatory frameworks	MaaS relies heavily on data sharing from mobility operators or service providers. The category of information provided ranges from basic services that publish raw data, such as timetables or the real-time location of vehicles, to more advanced services that process this data to generate new insights, such as predicting bus delays. For a multimodal MaaS product to function effectively, it must integrate

[7]https://www.ubigo.co/

	information from various sources so that this data can be used across different services. The first step in making MaaS a reality is to establish legislation that supports data sharing and open data initiatives, enabling the digital economy and connecting MaaS to a broader context. The data involved can be divided into two categories: real-time and static data. • **Real-time data**: This includes contextual information (e.g., environmental conditions), infrastructure data (e.g., network status), and object-related data (e.g., vehicle features, locations, availability, and prices). • **Static data**: This encompasses geographic context (e.g., maps), infrastructure information (e.g., transport networks), and object-related data such as routes and timetables. By enabling the sharing and integration of both real-time and static data, MaaS platforms can create a seamless and responsive mobility experience for users. **Governance and regulatory frameworks** are essential that organizations use to manage data effectively, ensure regulatory compliance, and build trust in data sharing ecosystems specifically data spaces. These frameworks establish the policies, standards, roles, and responsibilities for managing data throughout its lifecycle, while ensuring that data usage complies with legal and ethical standards such as General Data Protection (GDPR)[8], Data Governance Act, Data Act, and AI Act[9].
Service federation	In a federated and integrated MaaS system, the services of one mobility operator are seamlessly combined with those of others. Each MaaS operator presents information and transit services from different operators as part of their own offering. These services include clearing, roaming, access control, Service Level Agreements (SLAs), and business intelligence (BI). The roaming concept refers to the interoperability between different operators, enabling ticketing systems to work seamlessly across various transport providers and their respective zones. Clearing involves the redistribution of profits among transport operators to ensure fair revenue sharing. An SLA is a contract that defines the level of service usage or frequency of invocation, while access control governs the quality and range of services or data provided. Finally, business intelligence services focus on managing shared data, analysing statistics, and administering services among operators, ensuring smooth cooperation and data-driven decision-making.
Infrastructure	**Transport flow infrastructure** refers to the physical infrastructure that supports mobility and related services, such as public transport, car-sharing, bike-sharing, and innovative services like autonomous vehicles. It includes various types of transport services: public transit, on-demand services, and innovative options like

[8]https://gdpr-info.eu/
[9]https://www.europarl.europa.eu/topics/en/article/20230601STO93804/eu-ai-act-first-regulation-on-artificial-intelligence

	electric cars. It also encompasses supportive facilities such as parking spaces, which are essential for smooth transport flow. **Information-flow infrastructure** is necessary for the efficient collection, management, and use of data generated by these services. It forms the backbone of MaaS, bridging the gap between physical and virtual infrastructure. This infrastructure pulls information from different services and regulates access for further use. Key components include data producers like sensors, IoT devices, and ICT systems; data usage tools such as data and API standards; data storage facilities that ensure secure and legally compliant access; and payment systems, including integrated or third-party online payments. Lastly, **computing-flow infrastructure** is the virtual component of MaaS, responsible for intelligent computation, such as route planning and transport management. It relies on the information-flow infrastructure to optimise and enhance the efficiency of the transport-flow infrastructure. This includes systems like a **smart transport brain**[10], which uses AI algorithms for route planning and transport optimisation, and transport simulators that model mobility patterns, preferences, and agent-based simulations to improve MaaS performance.
User	This includes **User Profiling** and **Management**. User profiling is not required to create services for mobility, but it has become essential to ensure usability, to provide user assistance, and to even anticipate and plan for the next movements of the user. Data Theft as the most obvious threat is the possibility of stealing information derived from the profile dataset, such as preferences, recordings of movements, orders and payments; and Countermeasures to empower the User with control over his/her profile and the related access policies.

3 Mobility as a Service Ecosystems

Key Takeaways from this Section

- Understand how MaaS bridges public and private transportation by integrating services like trip planning, booking, payment, and real-time updates into a single platform.
- Gain knowledge about MaaS projects that address goals like reducing congestion, improving air quality, supporting climate change efforts, and boosting tourism.
- Understand the range of transport options supported by international and Irish MaaS initiatives, from public transport to shared mobility and on-demand services, and how integration levels vary among projects.
- Gain insights into the technological platforms used by international and Irish MaaS initiatives, including mobile apps and smart cards, and their functionalities, such as trip planning, payment, and real-time monitoring.
- Understand the role of data portals and APIs in enabling seamless integration, supporting real-time updates, and enhancing MaaS services.

[10]https://ai-for-sdgs.academy/case/343

3.1 MaaS in International Context

The concept behind MaaS aims to bridge the gap between the public and private sectors by integrating the various tools and services travellers need for their journeys—such as planning, booking, real-time information, payment, and ticketing. The goal is to create a single app that allows users to pay for all forms of transportation, whether within a city or beyond. The app would present different transport options so users can choose what suits them best. This concept has become feasible thanks to the widespread use of smartphones, social media, and constant internet connectivity [7].

Many cities across Europe are already rolling out MaaS initiatives. After reviewing the latest developments and considering a list provided by the MaaS Alliance, we've identified 20 initiatives, mostly within Europe. This list is far from exhaustive, as MaaS is a rapidly growing field, with new projects launching worldwide at a fast pace.

When evaluating these initiatives, we considered their main goals, transport modes, hosting platforms, operational models, travel functionalities, payment options, and the availability of data through portals and APIs. Table 2 summarises the key objectives of these initiatives. Most of them aim to enhance mobility and reduce congestion, while initiatives like Jelbi[11], Moovizy[12], Whim[13], HSL[14], and MaaSMadrid[15] are also focused on improving air quality and contributing to climate change plans. AMT, on the other hand, has a goal of boosting tourism.

Table 3 highlights the transport modes, platforms, and operational models. Most of the initiatives offer a range of options, including public transport (train, bus, metro), shared vehicles (car, bicycle, peer-to-peer sharing), and in some cases, on-demand services (taxi, ride-hailing, minibuses). MaaSMadrid, Smile, and Whim provide a comprehensive range of transport modes, including public transport, shared mobility, and taxi/car rental services. Meanwhile, WienMobil[16] and Mobilitätsshop[17] have lower levels of integration, offering direct access to public transport with ticket purchasing but only integrating route planning for other travel modes.

In terms of technology, most initiatives support both iOS and Android apps, although two rely on a smart card system pre-loaded with credit, which can be used for various modes of transport. Table 4 details the functionalities, payment options, and data availability. Most initiatives offer features such as trip planning, booking, payment, ticketing, and real-time monitoring. Some go further by providing services like parking, charging stations, discount schemes, and automatic driving licence verification. Whim stands out as the only initiative offering both pay-per-use and monthly/annual subscription payment options.

[11]https://www.jelbi.de/en/home/
[12]https://maasification.com/applications/by-application/moovizy/
[13]https://www.transdev.com/en/solutions/whim-maas/
[14]https://sales-api.hsl.fi/
[15]https://urban-mobility-observatory.transport.ec.europa.eu/news-events/news/maas-madrid-new-mobile-application-shared-mobility-2018-04-04_en?prefLang=ro
[16]https://www.wienmobil.at/en/monitor/PT
[17]https://shop.gvh.de/

Table 2: MaaS Initiative Goals

Initiative name	Goal					
	Improving mobility	Reducing congestion in the city	Best-in-class application	Improve tourism	Improve Air Quality and achieve Climate Change Plan	Support for Innovation Project/Business ideas
Jelbi	x	x			x	
Moovizy	x	x	x	x	x	
Floya	x	x				
Breeze	x					
Whim	x	x			x	
HSL	x	x			x	
Rejsekort & Rejseplanen	x					
Entur	x					
Ruter, Kolumbus, Skyss, ATB	x	x				
Uber & Lyft13	x					
BIP for MaaS	x	x		x		
CityTrips	x	x		x		
MaaSMadrid	x				x	
AMT	x	x		x		
Smile	x					
SHIFT	x			x		
UbiGo	x	x		x		
WienMobil	x					
Mobilitätsshop	x					

A2D2[18]	x					x
NuScenes[19]	x					x
AppolloScape[20]	x					x
ONCE[21]	x					x
Waymo Open[22]	x					x
KITTI-360°[23]	x					x

Table 3 MaaS initiative modes of transport, platform, and operational model

Initiative name	Modes of transport				Platform					Operational model	
	Public Transport	Shared Mobility	On-demand Taxi/car rental	Private Cars?	IOS	Android	Windows	Card/ budget	Web	Public	Private & B2B
Jelbi	x	x			x	x		x		x	x
Moovizy	x	x			x	x					
Floya	x	x								x	
Breeze	x									x	
Whim	x	x	x		x	x					x
HSL	x				x	x	x	x	x	x	
Rejsekort & Rejseplanen	x									x	
Entur	x					x				x	

[18]https://a2d2.audi/a2d2/en.html
[19]https://www.nuscenes.org/
[20]https://apolloscape.auto/
[21]https://once-for-auto-driving.github.io/
[22]https://waymo.com/open/
[23]https://www.cvlibs.net/datasets/kitti-360/

Ruter, Kolumbus, Skyss, ATB	x									x	
Uber & Lyft13 (California)		x	x		x	x	x				x
BIP for MaaS	x	x								x	
CityTrips	x	x								x	
MaaSMadrid	x	x	x							x	
AMT	x									x	
Smile	x	x	x		x	x					
SHIFT		x	x		x	x					
UbiGo					x	x					
WienMobil	x	x								x	
Mobilitätsshop	x	x				x				x	
A2D2[24]				x					x		x
NuScenes[25]				x					x		x
AppolloScape[26]				x					x		x
ONCE[27]				x					x		x
Waymo Open[28]				x					x		x
KITTI-360°[29]				x					x		x

[24]https://a2d2.audi/a2d2/en.html
[25]https://www.nuscenes.org/
[26]https://apolloscape.auto/
[27]https://once-for-auto-driving.github.io/
[28]https://waymo.com/open/
[29]https://www.cvlibs.net/datasets/kitti-360/

Table 4 MaaS initiative functionalities, payment options, and data availability

Initiative name	Travel Functionality									Travel Package/payment options		Data/API availability		
	Planning	Booking	Integrated / in-app Payment	Ticketing	Charging	Service alerts	Discount schemes	Parking lot	Automated driver's license ID verification	Package (Subscription)	pay-as-you-go	Open Data	Data Sharing Agreement	API
Jelbi	x	x	x	x	x	x		x		x				
Moovizy	x	x	x	x							x			
Floya	x	x		x					x		x		x	
Breeze	x	x	x	x	x					x			x	
Whim	x	x	x	x				x		x	x			
HSL	x										x	x	x	x
Rejsekort & Rejseplanen	x						x				x	x		
Entur	x										x	x		x
Ruter, Kolumbus, Skyss, ATB	x										x	x		x
Uber & Lyft13 (California)		x	x			x					x			
BIP for MaaS	x	x									x			
CityTrips	x										x			
MaaSMadrid	x	x							x		x		x	
AMT	x	x	x	x			x	x			x		x	
Smile	x	x	x	x		x					x			
SHIFT	x	x	x	x										
UbiGo												x	x	x
WienMobil	x		x	x						x	x		x	

Mobilitätsshop	x		x	x							x		x	

Breeze and Jelbi platforms allow users to bundle ticketing options from Mobility Service Providers (MSPs) in ways that best match their journey plans and preferences [11]. For example, Mobilitätsshop lets users buy a single public transport ticket via the app, while WienMobil offers a broader range of public transport tickets and subscriptions, though not annual passes. A key advantage of Breeze is that transactions can be completed entirely within the app (referred to as Level 2 ticketing integration), and users can manage all services through a single account (Level 3), ensuring a seamless experience with no need to switch to external apps.

When it comes to data ownership and sharing, Jelbi maintains exclusive ownership of the data generated by its MaaS platform. Breeze, on the other hand, is working on a Data Sharing Agreement (DSA) between local authority delivery partners. For example, HSE data and APIs are accessible via Digitransit.fi and ITS Factory DeveloperWiki, a portal supporting data and API access. In Denmark, Rejseplanen provides access to public transport information such as timetables, prices, traffic updates, and travel itineraries through the National Access Point (du.vd.dk) and Rejseplanen LAB.

Entur in Norway is responsible for providing Multimodal Travel Information Services (MMTIS), as per EU regulation EU 2017/1926, which governs open mobility data for both scheduled and on-demand transport modes. Entur's data portal offers free access to route information, although travel demand data remains unavailable. More detailed information can be found at www.transportportal.no and developer.entur.org.

Table 5 provides a deeper analysis of the key success factors of these initiatives, offering valuable insights into what has driven their achievements in the MaaS landscape.

Table 5 MaaS initiative success factors and takeaway message

Initiative name	Success Factors
Jelbi	Quality and Rich Open Data: Jelbi is based on the data of the *Verkehrsverbund Berlin-Brandenburg* (VBB) that are made freely available on the Open-Data-Portal of the State of Berlin for commercial use. Interactive map as the first screen, on which users can find all its offer. More than 30,000 vehicles from eight mobility partners: this offers a convenient alternative to using one's own car. A single interface and single user account to find, compare and use public transport and shared mobility. A single registration unlocks most of Berlin's shared mobility seamlessly and enables users to choose what suits best for any given situation, rather than what a particular service provider has to offer. Jelbi Mobility Hubs to embed the idea of shared mobility into the physical landscape of the city. Jelbi Corporate Mobility Budget offers a solution for employers who aim to encourage their teams to use a sustainable alternative to the company car.

Moovizy	Interactive map as the first screen, on which users can find all its offer. Focus on the UX design of the application. Governed by the model "integrator by transport" managed by STAS (the transport public of the Saint-Etienne agglomeration), a strategic choice because in 2016 the STAS network registered about 73,000 customers per day. By entrusting the MaaS project to STAS, Moovizy could easily access to the distribution systems of the MaaS application.
Floya	Awareness of the limitations of public procurement, including budget and timeline constraints in the MaaS planning. Open communication with transparent processes, ensuring coherence in expectations and mutual understanding. Clearly defined, distinct roles and responsibilities between the client and supplier, providing the diverse expertise needed for success on both sides.
Breeze	Significant income generation and/or external funding. Extensive modelling of the combination of differing levels of market share for Breeze, and different commercial/income generation options. A large and complex range of relationships and governance with over 30 partners, MSPs, and other third parties and stakeholders has been established to implement Breeze.
Whim	Constant market research. Modelling the user segments and testing the models in real market. Analysis of user data. Occasional focused research into the lives and attitudes of the users. Interactive map as the first screen, on which users can find all its offer. Taking societal objectives into account (by public policies, incentives, etc.).
HSL	Service integration and private sector involvement: The service catalogue includes a total of 3354 services, the production of which involves a total of 5652 companies or organisations.
Entur	Entur operates the railway's ticketing system, sales facilities at stations and customer centres on behalf of all the train operators in Norway. The main products included in the delivery consist of the Google-certified rugged smartphone Point Mobile PM45 and a new payment terminal from Verifone, the V400m. Together with the programs and apps owned by Entur, these two products constitute a complete point-of-sale solution for ticket sales, among other things. The terminal is also used for ticket checking and the verification of previously purchased tickets. The PM45 is part of Google 's Android Enterprise Recommended program and runs on Android 9. As a rugged smartphone, it is IP67 certified and withstands drops from 1.2m on concrete (MIL-STD 810G). The large 5" screen with FHD resolution is daylight readable and is protected against scratches and impacts by Corning Gorilla glass [12].

Smile	A single platform door-to-door mobility alternative to the private car by integrating a broad range of mobility services with public transport, with the possibility to immediately book and pay for these services. The SMILE platform gathered all relevant and available data for real-time information, bookings, ticketing and payment through standardised interfaces to the different mobility providers.
UbiGo	Flexibility and autonomy. Flexibility involves the option of adapting travel behaviour if personal circumstances so dictate, regardless of the time of day and the location. Autonomy pertains to independence of others in taking decisions regarding mobility. A wide range of transport services offered via a single integrated platform and diverse fleet of cars available to them; range of vehicles on offer (e.g., an electric city car or family car).
WienMobil	In cases when service operators not wanting to integrate MaaS, technical difficulties in integrating these services within MaaS, or the MaaS operator wanting to limit the diversity of accessible services or not to include competing services within the same offer; WienMobil links to the car-sharing and bike-sharing service applications for booking and payment and offers to call to the taxi company.
Mobilitätsshop	Links to the car-sharing and bike-sharing service applications for booking and payment and offers to call to the taxi company.

3.1.1 MaaS Good Practices

As we have observed through several initiatives, here we will see a summary of the good practices derived from existing developments. Table 6 summarises a list of national MaaS good practices.

Table 6 List of national MaaS good practices

Finland	
Operational	Fixed plans for several sociodemographic groups (families, students etc.).
Operational	MaaS Global also includes some more innovative ideas, such as ‘guaranteed 15-min pick up by taxi’, ‘child seats provided in cars’, and the inclusion of shared taxis. These concepts indicate that tailoring mobility plans is a much more holistic idea and should comprises of more than just changing the amount of the transport modes in each plan (e.g. miles of taxi or hours of car sharing).

Operational	For Whim, the new subscription options are not segmented according to sociodemographic groups, but rather by the size of each plan. All of them have local public transport as their core, and then have a certain number of points that can be used freely among other modes (taxi and car sharing).
Operational	Pay as you go option where there is complete flexibility.
Engagement	The “pay-as-you-go” bundle offers unlimited urban transport and reduced taxi fares for a monthly fee of 49 euros. The Whim Unlimited bundle, at 499 euros a month, is presented as a “modern alternative for owning a car. For the price of car ownership, users will have unlimited access to public transport, taxis, or [shared use] cars based on your daily needs.”

Austria	
Data	All relevant and available data for real-time information, bookings, ticketing and payment are gathered through standardised interfaces to the different mobility providers.
Collaboration	Collaboration between (major) transport providers and parties such as software engineers and environmental protection organisations.

UK	
Behavioural	The London Mobility Survey (LMS) gather in-depth data on travel behaviour and new mobility services.

Germany	
Smart predictions	IVU. suite uses a sophisticated algorithms and uses completed trips to make detailed predictions of how many trips and passengers to expect on a particular day. IVU.fleet and IVU.real-time are already using real-time data from public buses to calculate anticipated arrival and departure times to ensure that connections link up properly and passengers are kept informed.
Integrated Planning System	MaaS L.A.B.S. (user-centric mobility as-a-service platform) funded by the German Federal Ministry of Education and Research. It is looking to combine flexible and demand-based public transport with automated on-call micro-buses and car, bike and ridesharing services. MaaS L.A.B.S. is testing the relevant technologies, combining them all in a multi-manufacturer app and developing the requisite background systems.
Integrated system architecture	This is a groundbreaking project launched by the Bremen/Lower **Saxony transport association (VBN)**. This project enables the members of the association to complete all their timetable planning, vehicle scheduling and duty scheduling as independent operators in a central planning system created based on IVU.suite. At the customer experience level, one thing that all service providers (both public and private) share is a commitment to the idea of getting passengers to their destinations safely, quickly, and easily.

Awareness	Competition for storefronts with bicycle-themed decorations.

Spain	
Collaboration	City of Madrid concentrates the largest number of shared-mobility operators worldwide, with 29 (public and private) companies and an approximate fleet of 30 thousand vehicles.
Policy	In 2015 the local government established an air-quality protocol to respond to high NO_2 pollution episodes. This protocol implemented restrictions on the use of private vehicles, on-street parking and an odd–even license plate control scheme.
Personalized and on-demand service	A single digital interface to provide travellers with personalized recommendations that respond to their needs on-demand.
Mobility pattern	It is aligned with individuals' mobility patterns, since multimodality is associated with a favourable attitude towards public transport and new mobility services.
Living Lab	The Municipality of Milan creates an "open-private model", open to one or more MaaS operators, to guarantee market competitiveness and gain leverage to apply "public policies" to guarantee transparency while allowing the public administration to avoid committing to significant technological costs (in investments and operations) in a market subject to strong competition and technological evolution.
Awareness	Activity #AskYourQuestios to the councillor responsible for mobility.
Awareness	Develop environmental awareness campaigns.
Awareness	A full week's worth of events, including a fair, the debut of new infrastructure, movies, conferences, and more. During Car-Free Day, public transportation was used by 21% more individuals.
Worldwide study	The Sustainable Mobility Plan incorporates well-structured programmes designed by drawing on the best global practices, input from renowned professionals in relevant fields, and the key principles of traffic and transport management: prioritizing public transport, promoting healthy mobility, and ensuring effective traffic planning and road safety.

Portugal	
Integrated ticketing system	Lisbon was amongst the first large mobility area to evolve to a fully multimodal NFC (Near Field Communication)[30] based integrated ticketing system [14].
Contactless cards	Most public transport trips take place using contactless cards based on CALYPSO[31].
Data	Most relevant data is made available through open data platforms.
Awareness	Portugal held a series of in-person regional seminars that were broadcast live across the whole nation, hitting both established campaign cities and some newcomers. The topics covered in these seminars were chosen based on the requirements of the attendees.
Awareness	Eco-driving demonstrations for local employees in Delphi (Greece): Air quality measurements before, during and after the week.

Poland	
Awareness and engagement	Thanks to the workshops held in the various areas, Poland experienced a notable growth in the number of participating towns and communities. Estonia: The state broadcaster and the Estonian coordinator have signed a contract allowing for the nationwide television airing of the campaign film.
Public Consultation	Consultation on public bike-sharing scheme, and promotion of shared mobility and MaaS.

Budapest	
Operational	Alerts when there are problems with the selected route.
Operational	Recommendations to switch to another available plan that better fits the user's needs.
Operational	The personalized support function towards the selection of MaaS plans that suit users' needs and mobility habits.

Sweden	
Operational	Public transport, car sharing, taxi, bike sharing and car rentals were offered to users as subscription plans. Households subscribed for monthly plans including a personalised combination of—and credit for—the various travel services.
Institutional	A mobility broker handled everything for the users to make it a seamless experience.

[30]NFC is a modular technology for wireless radio communication between electronic devices at a very short distance (up to 4 cm) with the approach of the devices.
[31] Calypso cards are microprocessor based contactless and dual interface smart cards which offer both speed of transaction and a high level of security.

Experimental-Behavioural and Attitude	Prior to the commencement of the UbiGo pilot in Sweden, potential UbiGo participants were encouraged to give up (one of) their car(s) during the process, in exchange for financial compensation.
Operational	Bundles are tailored to the wishes of individual customers. This played a fundamental role in changing mobility behaviour.

Italy	
Awareness	People were encouraged to participate in the many activities during the campaign via a treasure hunt.
Awareness	There are initiatives to provide citizens free bus trips or pedal-assisted bicycles as alternatives to driving.
Awareness	Vintage bus exhibition, and new sharing systems and e-bikes.

Greece	
Awareness	Greece has established a network of campaign-participating villages and cities, with year-round interactions between them. At an awards event, the Ministry in charge of organizing the campaign nationally acknowledged the achievements of the top 12 cities.

Austria	
Operational	Architecture blueprint for a SMILE MaaS solution is developed to provide standardized and easy to integrate connectors that enable even smaller partners to use the full range of high-quality services offered in the MaaS environment.
Data	For the users, the data was selected and combined to provide the most suitable options for the requested trip (including the actual price) and then users had the chance to choose an option to book the entire trip—even with several mobility providers—without changing between different apps.

3.1.2 SWOT Analysis of MaaS Framework Models

National and Local level: MaaS continues to gain traction around the world, regulatory bodies are beginning to develop or adopt frameworks to govern this new form of transportation. These regulatory frameworks can take many different forms, from national laws to regional initiatives to city-level programs. Some of these frameworks include Act of transport services in Finland; MaaS Code of Conduct[32] in UK; Flemish MaaS agreement[33] framework in Belgium; TOMP-API and an OpenWheels model contract [71] for transport operators and MaaS providers in the Netherlands; and the Smart Ways to Antwerp (Belgium) which is a coordinated and open ecosystem approach to governance of MaaS in Antwerp encouraging mobility providers to integrate with multiple MaaS platforms and share data through APIs.

MaaS level - UITP[34] identifies three main organizational and governance methods in the MaaS approach, in which the authorities are involved to varying degrees. The examples of the presented MaaS initiatives in this deliverable show contrasting governance principles following the UITP method.

Commercial integrator model (See Table 7), in this model the MaaS operator signs bilateral agreements with the various transport operators. The MaaS is set up in an open competitive framework, with minimal investment by the authorities.

Table 7 SWOT analysis of the Commercial integrator model

Commercial integrator model	SWOT
Investment by the authorities	Low
Ability to innovate and provide customer-oriented offers	**O** Assumed to be high by private MaaS operators
Ability to integrate different mobility services	**O** Assumed to be high
Presentation of mobility offers	**T** Risk of favouring the commercial interests of the MaaS operator
Contribution to public policy	**T** Risk of favouring the commercial interests of the MaaS operator
Customer relationship	**T** Risk of losing the customer relationship by the local authority
Control of data	**T** Risk of losing control of data for the local authority
Competition between MaaS operators	Possible competition between several MaaS operators

Intermediate Open back-end platform model (See Table 8), in this model the local authority sets up a platform into which data from the various mobility services (timetables, route calculation, booking, ticketing, pricing, etc.) are integrated. MaaS operators then use this platform to build their MaaS solution, allowing competition between different MaaS services.

Table 8 SWOT analysis of the open back-end platform model

Intermediate open back-end platform model	SWOT
Investment by the authorities	Average
Ability to innovate and provide customer-oriented offers	**O** Left to the initiative of MaaS operators
Ability to integrate different mobility services	-

[32]https://www.gov.uk/government/publications/mobility-as-a-service-maas-code-of-practice/mobility-as-a-service-code-of-practice
[33]https://www.polisnetwork.eu/news/governing-maas-the-flemish-maas-agreement-framework/
[34] https://www.uitp.org/

Presentation of mobility offers	O Possibility of imposing fair and non-discriminatory rules
Contribution to public policy	-
Customer relationship	-
Control of data	O T Control of supply data, risk of losing control of usage data
Competition between MaaS operators	Competition facilitated, as part of the investment is paid for by the public authorities

Transport as the integrator model (See Table 9), it is the urban transport network operator that develops the service and seeks to attract other mobility service operators to its MaaS solution.

Table 9 SWOT analysis of the transport as the integrator model

Transport as the integrator model	SWOT
Investment by the authorities	High
Ability to innovate and provide customer-oriented offers	T Assumed to be more limited by the transport operator
Ability to integrate different mobility services	T Risk of focusing on the transport operator's historical partners
Presentation of mobility offers	O Possibility of imposing fair and non-discriminatory rules
Contribution to public policy	S Alignment with public policies
Customer relationship	S Control of customer relations by the local authority
Control of data	S Control of data by the local authority
Competition between MaaS operators	Monopoly of the authority (except in the case of an offer created by a commercial integrator)

A fourth model may be considered, in which the authority awards a contract to select a MaaS integrator, which may be the transport operator or another company.

3.2 MaaS in Ireland

We conducted a comprehensive desk-based study to examine the current state of MaaS initiatives in Ireland. The research began with an in-depth exploration of Ireland's mobility services, encompassing public and private transport systems, as well as shared and sustainable mobility options. To provide a holistic perspective on the country's transport ecosystem, the study also included an analysis of maritime and aviation services.

Building on this foundation, our focus shifted to the evaluation of MaaS initiatives in Ireland. These initiatives aim to integrate various transport modes into a seamless and unified platform, designed to enhance user accessibility, optimise resource efficiency, and promote multimodal transportation solutions. The study culminates in an assessment of the progress and current status of MaaS initiatives in Ireland. The findings of this analysis are detailed in the following sections.

3.2.1 Transport Services

The Irish mobility ecosystem comprises a diverse range of transportation modes, each playing a vital role in fostering a connected and sustainable network. These modes collectively contribute to Ireland's overarching mobility goals, including accessibility, efficiency, and environmental sustainability.

The key categories within the ecosystem include public transport, private transport, maritime services, aviation services, sustainable mobility, and shared mobility. A summary of each category is provided below to highlight their individual contributions and interconnected roles within Ireland's transport landscape.

Public Transport Services

Ireland's public transport network, encompassing heavy rail, trams (LUAS), and bus services, constitutes the cornerstone of the nation's mobility infrastructure. Public transit, which recorded over 308 million passenger journeys in 2023, is progressively evolving into a more sustainable and appealing option. Under the Climate Action Plan, all public buses are to be electrified by 2035—Dublin Bus has already taken steps toward this goal with new hybrid and electric buses as part of its emission reduction efforts [19].

The National Development Plan and Project Ireland 2040 further support expanding and electrifying rail services, like the DART+ program, alongside investment in LUAS light rail extensions, all geared to meet rising demand [20]. Public transport has also benefitted from a focus on accessibility, better serving a broader range of users, including those with disabilities. Multimodal connectivity is improving through initiatives like integrated bus, rail, and light rail ticketing with the Leap Card, along with MaaS solutions.

With these improvements, Ireland's public transport network is evolving to be a more sustainable, accessible, and attractive alternative to private vehicle use. Ongoing investments in electric fleets, rail expansion, and integrated services prepare the network to meet Ireland's climate and mobility goals by reducing emissions, easing urban congestion, and fostering a connected, equitable transit ecosystem.

Private Transport Services

The private transport sector in Ireland is an integral part of the country's transportation ecosystem, providing essential services to fill gaps left by public transit and facilitating flexible mobility for residents, business executives, and tourists alike. It comprises vital services like taxis and private intercity buses catering to specific travel needs. Taxis continue to play an important role for on-demand, door-to-door service in urban and rural areas, albeit with challenges around price transparency and consistency. Ireland is also home to highly efficient intercity private bus services like Aircoach, Citylink, and GoBus, which connect many of the main cities and towns across the country reliably and affordably.

The private transport providers are investing in greater fuel efficiency and cleaner fleets, including electric vehicles, while raising service standards with digital innovations like online booking, integrated payment solutions, and live tracking as Ireland moves toward a more sustainable, inclusive, and modern transport network. Ireland's private transport services play an important role in achieving wider mobility and environmental objectives by providing necessary connectivity and complementing the public transport network.

As the country expands and upgrades its transportation infrastructure, the private sector's commitment to agility in operations, customer service, and sustainable practices will be significant in building a well-rounded, efficient, and green national transport ecosystem. By aligning public and private services under a shared vision, Ireland will be able to deliver a seamless, inclusive, and sustainable transport network that meets the current and future needs of its residents and visitors.

Maritime Services

Ireland connects with global markets through its maritime sector, with a network of efficient ports supporting trade in goods and passenger movement. Dublin, Cork, and Shannon Foynes are Ireland's main ports, playing critical roles in international trade, backed by infrastructure upgrades that allow them to handle larger cargo volumes and prioritize advanced safety measures. Key trends show steady growth in containerized and bulk cargo traffic, especially for imported consumer goods and fuels, as well as exported pharmaceuticals and

food products. Passenger traffic across the Irish Sea to Britain and between mainland Europe and Ireland primarily rely on ferries.

The Irish Maritime Administration ensures adherence to international standards on maritime safety and environmental protection, maintaining high levels of maritime safety in Ireland [21. Sustainability initiatives, including emissions reductions and waste management, are prioritized, with efforts underway to adopt cleaner fuels and eco-friendly port practices. Technologies like digital logistics management, sustainable port development, and climate adaptation are set to shape the sector's future. Through ongoing improvements, Ireland's maritime sector aims to sustain economic growth while supporting environmental sustainability.

Aviation Services

Ireland has a strong aviation industry, with major international airports in Dublin, Shannon, and Cork serving as critical hubs that connect the country to global destinations. Infrastructure at key facilities, such as Dublin Airport, which handles most of the international traffic, has been significantly enhanced through recent capacity expansions. While passenger volumes have risen, they continue to fluctuate in response to global tourism and business travel trends. Aviation freight is essential for supporting Ireland's key industries, including pharmaceuticals and technology, by enabling the transport of high-value, time-sensitive goods. Dublin Airport acts as the primary freight gateway, featuring purpose-built facilities for efficient cargo handling. Current sector trends emphasise sustainability initiatives aimed at achieving net-zero emissions and leveraging technological advancements to improve both passenger and cargo experiences.

Sustainable Mobility Services

Several operators in Ireland, including JCDecaux [22], Uber [23], Free Now [24], and Bolt [25], are enhancing urban mobility through shared bike and e-scooter services, offering eco-friendly travel solutions to urban dwellers, particularly in Dublin. These services operate on dockless systems, allowing users to locate, reserve, and unlock vehicles via mobile apps, which increases flexibility and convenience for short trips. This approach promotes active travel, helps alleviate traffic congestion, and reduces urban emissions, directly supporting both Ireland's National Sustainable Mobility Policy [26] and the EU's Sustainable and Smart Mobility Strategy [27]. These policies emphasize the importance of integrating low-emission and active transportation options into urban mobility networks to achieve climate neutrality by 2050 [28].

Shared Mobility Services

Shared mobility in Ireland, including public transport, micromobility (bike and scooter-sharing), and car-based options (car-sharing, carpooling, short-term leasing), is reshaping urban transportation by providing eco-friendly alternatives to private car use. The concept of a "mobility hub" is closely tied to the growth of shared mobility services. A mobility hub is a key location that integrates various shared mobility options, such as bikes, cargo bikes, and electric vehicles, while offering additional amenities, services, and information to enhance the user experience. These hubs can include a range of micromobility modes—like bikes, e-bikes, e-scooters, and e-cargo bikes—as well as electric vehicles from car-sharing clubs. They may also bring together services from multiple providers and be managed by different operators. Companies offer convenient, app-based services that reduce congestion, lower emissions, and encourage active travel. Shared mobility impacts travel behaviour by encouraging alternatives to car ownership, improves urban space by reducing parking demand, and offers users economic benefits through cost savings.

3.2.2 MaaS Initiatives

In recent years, the Irish government has taken significant strides toward integrating diverse transport services under the **Mobility-as-a-Service (MaaS)** framework. This initiative aims to enhance urban mobility, promote sustainable travel behaviours, and support healthier communities. MaaS aligns closely with Ireland's strategic objectives and the broader goals of the European Union, offering tangible social, environmental, and economic benefits by fostering a multimodal and user-centric approach to transportation.

To advance these objectives, MaaS has been implemented through various platforms with substantial support from public and semi-public organisations, including the **Department of Transport**, the **NTA**, and **TFI**. These organisations play a pivotal role in shaping the MaaS ecosystem, ensuring its alignment with policy objectives and facilitating its practical implementation.

Table 10 below provides an overview of key initiatives driving the adoption and development of MaaS in Ireland, showcasing the progress made and the strategies employed to create a cohesive and sustainable mobility network.

Table 10 The MaaS initiatives in Ireland

MaaS Initiatives	Description	Organization Involved	Key Functions
Journey Planner	A MaaS solution which enables end-users to plan journeys using different modes of transport—connected seamlessly from origin to destination.	TFI	Multi-modal journey planning.
Next Generation Ticketing	The Next Generation Ticketing (NGT) program, part of a project by the National Transport Authority (NTA), is aimed at upgrading ticketing infrastructure through account-based payment. It is built to prioritize mobile-first ticketing, enable flexible payment mechanisms, and centralize validation in the cloud for added convenience and accessibility.	NTA	Enables a nationwide multimodal Account Based Ticketing (ABT).
Automatic Vehicle Location	This NTA project involved a technology upgrade to provide real-time information, helping passengers access accurate and timely live updates about bus locations.	NTA	Locating vehicles.
Leap Card Top-Up	The TFI Leap Card is a contactless smart card operated by Transport for Ireland (TFI) for the automated collection of fares on various transit services. Launched in 2011 for the Greater Dublin area, it allows seamless integration between Luas, DART, Iarnród Éireann, and Dublin Bus services.	TFI	Subscription based payment for multimodal transportation services.

Real Time Passenger Information	Developed by Transport for Ireland, the TFI Live App allows users to access live departure information and plan journeys across the entire TFI network, informing them about how they can travel from A to B.	TFI	• Access real-time departure information for Bus Éireann, Dublin Bus, Go Ahead Ireland, Luas and Iarnród Éireann Irish Rail services. • Find the best route for your journey. • Search for timetables and maps. • Save your favourite journeys, departures and timetables.
Bleeperbike	Bleeper offers dockerless bike hiring system which is an automated solution enabled via smartphone apps and GPS technology that allows users to rent a bike from anywhere in Dublin.	Bleeper	Bike reservation.
DublinBikes	DublinBikes is a publicly available self-service bike rental scheme, allowing anyone to access bikes from numerous stations located throughout Dublin's city centre for optimal convenience. The platform offers various subscription models, including monthly and yearly plans, as well as daily and 3-day ticket options.	AltairApps	Bike reservation.
Moovit	Moovit is a public transit app providing an interactive map of Ireland's entire transportation network, including light rail, train, and bus routes and stops, making navigation and planning easy.	Moovit	interactive map.
ParkingTag	Parking Tag is a parking payment solution offering flexibility and convenience, allowing users to pay via multiple methods including the Parking Tag app, SMS, Charge to Mobile, IVR (phone call), or in person at a Payzone store.	Payzone	Payment processing for parking.
NextBusDublin	Next Bus Dublin harnesses the real-time information from the Dublin Bus system to give accurate arrival times, so users know exactly when their bus will arrive. This service adds convenience and	Stephen McBride	Provides real-time information about the arrival time of Dublin Bus.

	reduces wait times by providing real-time updates for Dublin Bus passengers.		
GoCar	GoCar is a return-to-base, pay-as-you-go car-sharing service that charges by the hour. Members can reserve vehicles online or via the GoCar app, unlock them with their phone or GoCard, enter a PIN to access the keys, and start their journey. It's an ideal alternative for those who need occasional access to a car without the commitment of ownership, offering a flexible and convenient service.	Go Car	Pay as you go car sharing service.
Googlemaps	Google Maps serves as a comprehensive navigation and mapping tool. It integrates data from multiple transportation providers allowing users compare.	Google	Journey planning.
Free Now	FREENOW is Europe's largest multimobility app, spanning nine European countries, including Ireland. Through the app, users can directly book transport options like black cabs, private hire vehicles, and e-scooters and e-bikes from partners such as TIER, Voi, and Dott. Users can also rent cars via the app, making it an all-in-one tool for diverse mobility needs.	Free Now	Booking Taxi, Bike reservation, Payment.
Uber	Uber is a worldwide ride-hailing service connecting passengers with drivers through its mobile app. Available in over 70 countries and thousands of cities, including Dublin, Ireland, Uber enables users to book rides quickly and conveniently at competitive prices. The app offers various transportation options to meet diverse needs and preferences.	Uber	Booking taxi, bike reservation, payment processing.
LUAS App	Luas, Dublin's tram system, operates on two major branches called the Green Line and Red Line. Managed by Transdev under a contract with Transport Infrastructure Ireland, the system was originally overseen by the Railway Procurement Agency (RPA). LUAS App gives you all the information you need to make use of Luas direct from Luas.	Transdev and TII	Individual Journey, Planning, Ticketing, and payment processing.

Irish Rail Website and App	Irish Rail operates the national railway network in Ireland, providing passenger and freight services across the country. Irish rail provides Web applications and mobile apps for the passengers to plan journey, make reservation, and process payment.	Iarnród Éireann	Individual Journey, Planning, Ticketing, and Payment.
TFI Live App	The TFI Live App is a comprehensive tool designed to enhance your travel experience across Ireland's public transport network. It provides real-time departure information and journey planning for services including Bus Éireann, Dublin Bus, Go-Ahead Ireland, Luas, and Iarnród Éireann Irish Rail.	TFI	• Real-time departure information for Bus Éireann, Dublin Bus, Go Ahead Ireland, Luas and Iarnród Éireann Irish Rail services. • Journey planning.

3.2.3 Summary of Findings

Ireland's MaaS initiatives represent significant progress in integrating diverse transport services to create a user-centric and sustainable mobility ecosystem. However, despite these advancements, several limitations hinder their full potential. This section analyses the key challenges based on evidence from national transport reports, and international comparisons.

Insufficient Data Sharing Frameworks

Effective MaaS platforms require extensive data sharing among transport operators, service providers, and regulatory bodies. However, a report by the National Transport Authority indicates that only 62% of private operators are willing to share real-time data due to concerns about privacy and ownership. This lack of standardized data-sharing agreements undermines the availability of real-time information and hampers the integration of multimodal services.

Regulatory and Policy Barriers

Ireland's regulatory framework does not yet fully accommodate emerging mobility modes or their integration into MaaS platforms. The OECD Transport Policy Review (2022) notes gaps in regulations for services like e-scooters and ridesharing, which complicate their inclusion in MaaS solutions. Additionally, policy frameworks often fail to align public and private sector interests, slowing down MaaS implementation.

Limited Digital Infrastructure

A robust MaaS ecosystem depends on advanced digital infrastructure, including real-time data sharing and widespread broadband access. However, the Digital Economy and Society Index (DESI 2023) ranks Ireland below the EU average for rural broadband penetration. This digital divide limits the ability of MaaS platforms to provide real-time updates and services, particularly in rural regions, thereby perpetuating inequities in access to transport solutions.

Fragmented Transport Infrastructure

The integration of various transport modes is impeded by fragmented infrastructure and insufficient coordination between service providers. According to the Transport Infrastructure Ireland Report (2023), regional transport networks often lack seamless connections with national services, leading to inefficiencies

in multimodal travel options. For example, rural areas frequently experience gaps in service coverage, reducing the feasibility of MaaS platforms that rely on integrated transitions between modes.

Accessibility and Inclusion Gaps

MaaS initiatives often fail to provide equitable access for rural communities and individuals with limited digital literacy. According to the Central Statistics Office (CSO), 35% of rural households lack regular access to public transport. This restricts the reach of MaaS platforms, which rely on digital connectivity and multimodal options to be effective. Additionally, the reliance on app-based platforms excludes individuals without smartphones or adequate digital skills.

Low Adoption of Sustainable Mobility

While MaaS aims to promote sustainable transport options, adoption rates remain low. The 2022 Climate Action Plan Progress Report reveals that only 15% of commuter journeys in Ireland are made using sustainable modes, such as cycling or electric vehicles (EVs). Contributing factors include insufficient infrastructure, such as EV charging stations, which are concentrated in urban areas and fail to meet demand elsewhere (Transport Infrastructure Ireland, 2023).

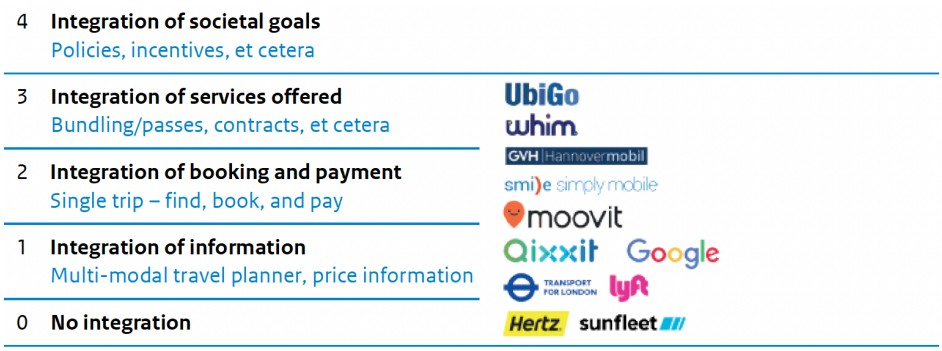
Public Awareness and Behavioural Resistance

Limited public awareness about MaaS and resistance to changing travel behaviours hinder adoption. A 2021 Public Transport User Survey found that only 28% of respondents were familiar with MaaS platforms, and many preferred private cars use due to perceptions of convenience. These findings indicate the need for stronger public engagement and incentive programmes to encourage users to switch to MaaS solutions.

Lack of Integration

Integration is essential as it forms the cornerstone of MaaS, enabling seamless and efficient multimodal transportation systems, as highlighted by Hietanen [17]. Sochor et al. [18] have proposed a typology that categorises MaaS into four distinct levels of integration, alongside a basic level that represents the absence of integration. This framework, illustrated in Figure 1 (sourced from the MaaS Alliance), provides a clear understanding of the progression required to achieve a fully integrated MaaS system.

Figure 1:Typology of MaaS with levels and examples



We mapped this typology to the current Irish MaaS initiatives (r with specific reference to integration levels discussed in this report). The mapping reveals that integration is still largely absent in these initiatives (See Table 11), highlighting a significant barrier to unlocking their full potential. This lack of integration undermines the seamless and user-centric mobility solutions that MaaS aspires to deliver, underscoring the need for strategic efforts to address this critical gap.

Table 11: The integration level of MaaS initiatives in Ireland

SL#	MaaS Initiatives	Mobility Integration Level
01	Journey Planner	Level 1
02	Next Generation Ticketing	Level 1
03	Automatic Vehicle Location	Level 1
04	Leap Card Top-Up	Level 0
05	Real Time Passenger Information	Level 1
06	Bleeperbike	Level 0
07	DublinBikes	Level 0
08	Moovit	Level 1
09	ParkingTag	Level 0
10	NextBusDublin	Level 0
11	GoCar	Level 2
12	Googlemaps	Level 1
13	Free Now	Level2
14	Uber	Level 2
15	LUAS App	Level 2
16	Irish Rail Website and App	Level 2
17	TFI Live App	Level 1

4 Mobility Data

Key Takeaways from this Section

- Diverse Mobility Data: Insights are provided into various types of mobility data, including real-time traffic updates, public transport schedules, vehicle tracking information, and environmental data like emissions and noise levels.
- Sources of Mobility Data: Mobility data is derived from multiple entities such as public transport operators, private mobility providers, IoT sensor networks, and user-generated inputs from mobile apps and other devices.
- Data Standards and Frameworks: The importance of standardized frameworks, including MobilityDCAT-AP and GDPR-compliant metadata practices, is highlighted to ensure data interoperability, accuracy, and reliability.

Mobility data is a cornerstone of modern transportation systems, playing a critical role in enabling user-centric, efficient, and sustainable mobility solutions. These data underpin informed decision-making, support advanced analytics, and foster innovation in areas such as MaaS, public transport optimization, and sustainable urban planning. By providing comprehensive and reliable information, mobility data allows stakeholders to design integrated systems that meet the needs of diverse user groups while advancing environmental and economic objectives.

This section presents the findings of an investigation into global mobility data sources and the standards that guide their use. The analysis focuses on identifying key repositories, their functionalities, and the data standards that ensure interoperability, accuracy, and accessibility in the mobility ecosystem.

4.1 Mobility Data Sources

There are different types of mobility data. Each has specific use in building efficient applications such as travellers behaviour analytics, mobility usage patterns, infrastructure planning etc. Table 12 shows a list of primary mobility data types, categorized for clarity.

Table 12: Types and categories of mobility data

SL#	Category	Type	Description
01	Public Transport Data	Schedules	Timetables for buses, trains, ferries, and trams.
		Real-Time Data:	Vehicle locations, delays, cancellations, and service disruptions.
		Ridership Data	Passenger volumes, boarding/alighting counts, and peak usage patterns.
		Accessibility Information	Details on wheelchair access, lifts, and other accessibility features.
02	Private Transport Data	Fleet Data	Information on taxi, ride-hailing, and car-sharing services, including vehicle types, availability, and locations.
		Usage Data	Trip start and end times, distances, and routes.
		Fare Information	Pricing structures, surge pricing details, and payment methods.
		Operational Data	Driver availability, vehicle maintenance schedules, and service quality metrics.
03	Shared Mobility Data	Vehicle Availability	Locations and availability of shared bicycles, e-scooters, and cars.
		Docking Station Data	Status of shared mobility docks (e.g., number of bikes available).
		User Data	Frequency of use, trip durations, and common routes.
		Safety Data	Reports of accidents, incidents, and safety compliance.
04	Sustainable Mobility Data	Cycling Infrastructure:	Locations of bike lanes, shared paths, and parking facilities.
		Pedestrian Data	Foot traffic volumes, crosswalk usage, and pedestrian zones.
		EV Infrastructure	Locations of charging stations, charging capacity, and real-time availability.
		Emission Data	CO2 emissions per mode of transport, impact of electrification, and air quality measurements.
05	Traffic and Road Data	Traffic Flow	Real-time and historical traffic volumes on roads and highways.
		Congestion Data	Real-time and historical traffic volumes on roads and highways.
		Incident Reports	Bottleneck locations, peak congestion times, and duration of delays.
		Speed Data	Accidents, road closures, and construction zones.
06	Multimodal Integration Data	Journey Planning Data:	Average travel speeds on different road segments.
		Intermodal Connectivity	Schedules and connectivity between buses, trains, and other modes.

		Fare Integration	Unified fare structures and payment systems for multiple modes.
07	Maritime Transport Data	Schedules	Ferry and cargo ship departure and arrival times.
		Port Data	Real-time dock availability, cargo volumes, and passenger data.
		Weather Data	Maritime weather conditions affecting operations.
		Emission Data	Pollution levels from shipping activities.
08	Aviation Data	Flight Schedules	Departure and arrival times, delays, and cancellations.
		Passenger Data	Boarding numbers, load factors, and peak periods.
		Operational Data	Airport taxiway congestion, luggage handling metrics, and gate usage.
		Emission Data	CO2 emissions per flight and airport operations.
09	User Behavior and Preferences	Travel Patterns	Common origins and destinations, preferred travel times.
		Mode Choices	Distribution of users across transport modes.
		User Feedback	Surveys, complaints, and satisfaction ratings.
10	Environmental Data	Weather Conditions:	Temperature, precipitation, wind speed, and visibility affecting transport operations.
		Air Quality Data	Pollution levels, including CO2, NOx, and particulate matter concentrations.
		Noise Pollution	Noise levels from traffic and transport hubs.
11	Policy and Governance Data	Regulations	Policies governing transport operations, emissions, and safety.
		Subsidies and Incentives	Data on public funding for sustainable transport.
		Urban Planning	Zoning data, land use patterns, and mobility hubs.
12	Revenue and Economic Data	Ticket Sales	Revenue generated by public transport, ride-hailing, and shared mobility services.
		Subsidy Utilisation	Funding allocated to transport services and infrastructure.
		Economic Impact	Contributions of the mobility sector to GDP, job creation, and indirect economic effects.
13	Safety and Incident Data	Accident Reports	Details on accidents involving public and private transport modes.
		Incident Response Times	Efficiency of emergency services.
		Compliance Data	Adherence to safety regulations and standards
14	Infrastructure Data	Road Networks	Geospatial data on highways, arterial roads, and local streets.
		Parking Facilities	Locations, availability, and usage of parking spaces.
		Public Transport Infrastructure	Stations, stops, terminals, and maintenance facilities.
		Energy Infrastructure	Availability of fuel stations, EV chargers, and hydrogen refuelling stations.
15	Emerging Technology Data	Autonomous Vehicles	Routes, test results, and operational metrics.
		Blockchain Data	Records of smart contracts for MaaS and mobility services.

		IoT Sensor Data	Data from smart infrastructure, such as traffic lights and connected vehicles.

A diverse range of mobility data sources is available globally, catering to different purposes and user groups. However, it is important to note that not all types of data outlined in Table 12 are universally accessible. This limitation arises because not all mobility providers share their data, often due to privacy concerns, proprietary interests, or technical constraints. Table 13 presents a carefully curated list of notable repositories that offer accessible and reliable mobility data, ensuring usability for a variety of stakeholders.

Table 13: A curated list of mobility data sources

SL#	Category	Data Sources	Location (Country/Region)	Descriptions
01	Public Transport Data Platforms	**O**pen Data Portal	Ireland	Offers schedules, real-time positions, and accessibility data for Irish public transport.
		National Public Transport Data Repository (NPTDR), UK	United Kingdom	Annual snapshots of schedules across the UK.
		National Transit Database (NTD)	United States	Financial, operational, and ridership data for public transport in the US.
		Transport.data.gouv.fr	France	Comprehensive transport datasets covering public systems.
02	General Transit Feed Specification (GTFS) Repositories	Mobility Database	Online	A global repository offering over 2,000 GTFS feeds.
		OpenMobilityData (formerly TransitFeeds)	Online	Extensive archive of GTFS and GTFS-realtime feeds.
03	Shared Mobility and Micromobility Data Sources	Moovit	Online	Provides public transit and shared mobility data for city authorities.
		CycleNetXChange, UK	UK	Data exchange format for cycling infrastructure.
		Citylines.co	Online	Maps global transit systems, emphasizing historical evolution.
04	Geospatial and Mapping Data Sources	OpenStreetMap (OSM)	Online	A collaborative map with detailed transport and routing data.
				Offers geospatial data in formats such as GeoJSON and CSV.

05	Environmental and Sustainability Data	Data4COVID19 Mobility Repository	Online	Mobility data supporting COVID-19-related decision-making.
		Breadcrumbs Mobility Dataset	Online	Tracks mobility patterns for sustainable planning.
06	National and Regional Data Portals	All national data repositories that serve as central platforms for mobility and related datasets.	Online	All mobility data available in the national data portals. The list can be found here.
Uncategorised Data Sources				
SL#	**Data Source**		**Location (Country/Region)**	**Description**
01	NaPTAN		UK	NaPTAN is a dataset of all public transport access points, i.e. anywhere you can get on or off public transport (including bus, rail, tram, metro, underground, air and ferry services).
02	National Public Transport Gazetteer		UK and Ireland. Each country has their own datasets.	Provides a topographic database of towns and settlements in the UK.
04	Smart Transport Mobility Solutions Repository		EU	Provide repositories of mobility data, and best practices to support sustainable and intelligent transportation systems across Europe.
06	German Mobility Data Space		Germany	Hosts a diverse array of datasets, including but not limited to Traffic Information, hazard warning, infrastructure data, vehicle master data etc.
07	European Data Portal		EU	Serving as the unified access point for open data from EU institutions, agencies, and member states.
08	Asian Transport Data Repository		Asia	Serves as a comprehensive

			repository of transport data and policy information for the Asia-Pacific region.

4.2 Mobility Data Standards

Mobility data standards are frameworks and protocols that ensure interoperability, accuracy, and consistency in the exchange of data across diverse transportation systems and services. These standards are crucial for integrating multimodal transport networks, facilitating MaaS, and enabling real-time data sharing. Adherence to well-defined standards allows for seamless communication between public and private mobility providers, application developers, and end-users, ultimately enhancing the efficiency and user-friendliness of transportation systems.

General Transit Feed Specification (GTFS)

The GTFS format, widely adopted by transit agencies, is used to publish nodes and bus stop location data. It encourages the app developers to create applications that provide similar services in diverse environments. GTFS focuses on timetable information, organizing it into structured text files within a ZIP archive, typically including data on routes, schedules, and bus stop locations.

The structure of GTFS files contains information about transport modes represented by specific lines, timetables that specify when these modes operate, and details about stops where passengers board or alight. It can also include information on restricted locations and trips along specific routes. By standardizing public transportation data, the GTFS system simplifies the management and use of traffic information, enabling the development of essential tools such as journey planning, real-time notifications, and mapping systems.

General Bikeshare Feed Specification (GBFS)

The GBFS is designed to provide data from all shared mobility service operators, ensuring that travellers receive real-time updates. GBFS primarily focuses on user interactions across a wide range of mobility modes, including bicycles, scooters, mopeds, and cars. It includes information on availability, pricing, and service catalogue details.

In terms of operational data, GBFS provides standardized details about vehicle and station locations, dock availability, and station attributes such as form factor, power type, and travel range. It also covers service-specific features like pricing and rental terms. Additionally, GBFS incorporates geofenced zones that regulate operations, such as speed limits, parking, and restricted areas, to enhance public safety and ensure compliance with regional laws.

GBFS also facilitates planning for casual trips using shared mobility vehicles for short distances, such as one or two miles, between various origin and destination points. Public GBFS APIs enable shared mobility providers to integrate seamlessly with public transportation systems, improving connectivity and user experience.

Furthermore, GBFS serves as a valuable platform for cities and institutions to aggregate, analyse, and evaluate data collected from shared mobility services. This supports the implementation of effective and targeted interventions in urban transportation systems, promoting efficiency and sustainability within metropolitan areas.

Transit Integrated Data Exchange (TIDES)

TIDES is a data standard used in the field of transit operations, covering areas such as vehicle location, passenger fare collection, and passenger counts. TIDES helps organize and manage diverse data by enabling integration across different systems. This capability is leveraged by transit agencies, consultants, vendors, and other stakeholders, allowing subway services to achieve the desired performance and capacity within their operational areas.

For the benefit of transit agencies, TIDES simplifies the extraction of data from improved data repositories while providing tools that align with best practices in the transportation industry. Contractors, academic institutions, and other stakeholders working with transit agencies can also benefit from standardized agency data, which offers broader coverage and helps generate consistent reports and tools that can be used across various system environments. Vendors developing ITS systems understand the demand levels from their users and can focus on providing dynamic data accordingly.

By utilizing operational and performance data from public transport services, TIDES transforms raw data into actionable information, such as ridership statistics, passenger load, fare revenue, vehicle speeds, driver delays, and service reliability. This capability in public transportation allows management to make data-driven decisions aimed at improving passenger flow and operations, ensuring equitable service delivery.

Transit Operational Data Standard (TODS)

TODS is a publicly available standard designed to streamline the scheduling of public transport services across multiple software applications and organizations. It builds upon the General Transit Feed Specification (GTFS)—a common solution for schedule interoperability among transit agencies—by incorporating additional layers of operational data.

TODS is an operational standard that includes valuable information such as job titles, timetables, and work orders for staff, as well as details on non-revenue activities. This may include tasks like maintenance or driver training, often referred to as "deadhead" service (when buses are not carrying passengers). By integrating this data with other operational systems, such as scheduling tools and CAD/AVL-enabled vehicles, TODS enhances the overall management of transit operations.

The application of this standardized approach will enable more efficient work processes, reducing tensions between public transportation agencies and software providers. Ultimately, this will result in a more consistent and adaptable data storage structure.

DATEX II

Introduced by the Commission of the European Communities, DATEX II is the backbone of the traffic information systems used by its member states. It is an XML-based format for documents that describe traffic events, service characteristics, and static geographical data to be exchanged. DATEX II is primarily used over the internet for real-time traffic and travel information.

The DATEX II model supports a wide variety of traffic and travel information, such as traffic flow, traffic management measures, roadworks, accidents, and parking, among others. Most of this information contributes directly to advanced traveller information services. Additionally, DATEX II aims to enhance the first two levels of traveller information by providing more and better-quality data. These enhancements can be applied at any level of the traffic data framework and are fully compatible with the default Level A data model, which allows data sharing and extension at this level. Much of the work involved in the specification

and development of DATEX focuses on defining different extensions at various levels of the data model. Extensions within Level B are particularly important when a more focused data set or an in-depth traffic management approach is needed, such as in the case of detailed incident reporting or traffic control.

Transport Network ITS Spatial Data Deployment

TN-ITS is an ERTICO Innovation Platform, established at an Inaugural General Assembly held on June 5, 2013, in Dublin, Ireland during ITS European Congress. The primary objective of the platform is to enhance, road safety and efficiency through increased data exchange especially, regarding static road information such as speed limits. Road authorities, who are responsible for these changes, can provide accurate and up-to-date information to mapmakers and other service providers.

This creates an obligation for different parties to ensure that the information provided is current and received promptly from the proper source. TN-ITS is supporting the NAPCORE project through SWG 4.2, contributing its expertise in road data sharing and working on the definition and further development of the TN-ITS standard.

Operating Raw Data and statistics exchange (OpRa)

The OpRa-CEN initiative focuses on identifying unprocessed data related to public transportation that needs to be shared, collected, and maintained during the development and supervision of public transportation services. The initiative involves the preparation of the CEN Technical Report, which will explain the investigations conducted and the results achieved. The goal of the report is to clearly outline the framework within which the requirements for developing the Technical Specification (TS) or European Norm (EN) must be met. One key challenge under scrutiny in such projects is raw data, particularly in the case of actual and measured information—data that has not been altered in the past and will remain unchanged in the future.

Open Journey Planning (OJP)

This repository contains the schema notation of “Open API for Distributed Journey Planning”, along with examples and diagrams from the publication “CEN/TS 17118:2017: Intelligent Transport Systems - Public Transport – Open API for Distributed Journey Planning”. It also features the “Open Journey Planner” (OJP) routing backend system, which processes service directions for public transport, pedestrian movement, and other modes of mobility. The OJP interface, which is aligned with the OJP interoperability code, allows systems adhering to this XML-based standard to communicate with each other through a simple request/response mechanism. Additionally, a document will be prepared in Switzerland detailing which areas are covered by this standard profile and which are not.

The principle architecture outlined in CEN/TS 17118:2017 focus on various ITS areas such as data, transaction and networks. The standard OJP interface includes structures for ‘distributive order planning.’ This concept helps avoid the need for multiple systems to achieve the same result, as each system is typically designed to address specific tasks without a common framework in mind. OJP was developed to meet the needs of the FOTs. Its objectives are for a non-discriminatory, intermodal path routing system, implemented through the standard OJP compliant ACCESS-API.

Transmodel

The purpose of Transmodel is to provide an abstract view of common public transportation systems and concepts. It serves as the foundation for many software information systems that support various aspects of public transportation. It is particularly relevant in public transport network management, timetable creation,

vehicle scheduling, ticket sales control, operation monitoring, route and passenger journey organization, and the management of driving staff.

Designed to support multiple modes of travel, Transmodel covers both traditional services, such as scheduled and demand-responsive transport, as well as innovative modes like car-sharing and taxi services. Currently, it supports various types of land transport, including buses, trams, light rail, metros, and local ferries, as well as distance-based services like moving bars. It also addresses services for cars, bikes, and scooters, provided they are used within the framework of leasing or right-to-use agreements rather than for personal purposes. Additionally, Transmodel includes modes of public transport that are not land-based, such as waterside transport (e.g., maritime coastal shipping) and aerial transport (e.g., airplanes).

Network Timetable Exchange (NeTEx)

NeTEx or Network Timetable Exchange is a transfer standard from CEN that intends to effectively transmit the set of public transport services and elements associated with them.

An interesting specification as it allows passenger information data such as stops, routes, schedule, and prices, and related key performance data to be shared across many computer systems. It allows the collection and integration of data from varied consumers and allows reintegration where the data has been modified in previous versions. For several reasons, a Unix application whose interface is text rather than graphics is not cost-effective for this purpose. Its architecture, NetEx, is not only general-purpose XML format but also an efficient and easily extensible way to exchange transport data between distributed systems, thereby aligning with the Service Oriented Architecture (SOA) concept. These structures serve user and operational applications for passenger information and operations.

While there are several standards for timetable data, NeTEx is the first systematically developed standard that also covers multimodal fares. The NeTEx schema is freely available under a GPL license, and its development is governed by the CEN standardization process.

Service Interface for Real-time Information (SIRI)

SIRI (the European Standard for Services Interface Real Time Information) is a standard designed for sharing of real-time public transportation data between systems. It is widely used by, public transport operators, traffic management authorities, and travel information service providers. SIRI was declared a European standard in October 2006 and is a standardized document and a Technical Instruction within CEN. It enables interconnected server systems to exchange structured real-time information related to schedules, vehicle positions, connections, and general operational characteristics. SIRI naturally complements NeTEx, which handles scheduled information, while SIRI deals with real-time passenger transport data. Both standards are built around a common conceptual model, known as Transmodel.

Mobility Data Specification

MDS, or Mobility Data Specification, is a digital standard that assists cities manage transportation within public spaces more efficiently. This technology standardizes communication and data-sharing between cities and private transportation services, like e-scooter and bike sharing services. The digital infrastructure enables local governments to design, implement, and control policies more effectively, promoting the use of these vehicles while fostering socially beneficial practices that improve outcomes for both vehicles and residents. Furthermore, MDS provides a common framework for mobility service providers to expand into new locations, fostering harmonized relationships and reducing both travel and operating costs.

From a technological perspective, MDS consists of several Application Programming Interfaces (APIs) that facilitate data exchange between cities and mobility providers. The key secure API interfaces include:

- **Provider API** – This API enables private mobility companies to share data with the city, such as the number of devices, their locations, statuses, and ride records.
- **Policy API**- This API allows cities to set operational constraints, such as geographic areas and vehicle deployment numbers, providing high-level policy control.
- **Agency API** - This API addresses the limitations of the Policy API by enabling closer and more ad hoc collaboration among in-city administrators, consultants, and operators to address transportation challenges.

The introduction of such methodology's fosters the development of effective evidence-based strategies for providing transportation services at the urban level.

mobilityDCAT-AP

mobilityDCAT-AP is an extension of DCAT-AP designed for describing mobility datasets, dataset series, and services. It provides an RDF syntax binding that unifies metadata elements defined by National Access Points across Europe. Its primary use case is to enhance the searchability of mobility datasets, data series, and services on general data portals, improving access to mobility information across borders and sectors. mobilityDCAT-AP is an initiative by NAPCORE (National Access Point Coordination Organisation for Europe), an organization established to coordinate and harmonize over 30 mobility data platforms across Europe.

Table 14 summarises the mobility data standards based on their name, core functionalities, and potential use cases.

Table 14 Mobility data standards

Name	Core Functionalities	Technical Format	Data Types Covered	Licensing/Access	Potential Use Cases
General Transit Feed Specification (GTFS)	Provides a standard format for publishing transit agency data, including schedules, routes, stops, and services, in structured text files within a ZIP archive.	CSV files in a ZIP archive	Static data: schedules, routes, stops	Open, freely available	Journey planning, real-time notifications, and transit mapping for app developers and users.
General Bikeshare Feed Specification (GBFS)	Presents data on shared mobility services, including real-time vehicle locations, dock availability, pricing, rental terms, and operational zones for user safety.	JSON	Real-time data: availability, pricing, geofenced zones	Open, freely available	Supports shared mobility service integration with public transport, facilitates trip planning for short-distance travels, and allows cities to evaluate mobility patterns.

Transit ITS Data Exchange Specification (TIDES)	Standardizes transit operational data for vehicles, passenger counts, revenue, and service performance, enabling effective transit operations and reporting.	Varies (often XML or JSON)	Operational data: passenger load, revenue, reliability	Restricted, proprietary in many cases	Operational data sharing for transit agencies, analysis of transit performance (e.g., ridership, revenue), and ITS vendor applications.
Transit Operational Data Standard (TODS)	Builds on GTFS to include transit operations data (e.g., schedules, job titles, and vehicle work orders) across multiple systems.	XML	Operational data: scheduling, timetables, staff tasks	Open, freely available	Integrated operations data management across transit agencies, facilitating efficient workforce and resource allocation in transit services.
DATEX II	Provides an XML-based data exchange format for real-time traffic and travel information, such as traffic flow, incidents, and roadworks.	XML-based format	Real-time data: traffic flow, incidents, roadwork	Open, some restrictions	Supports traveller information systems, enables real-time traffic updates, and facilitates traffic management interventions by agencies across EU member states.
Transport Network ITS Spatial Data Deployment (TN-ITS)	Standard for road safety and efficiency data, focusing on static road data (e.g., speed limits) for use by authorities and map providers.	XML	Static data: road features, restrictions	Open, governed by ERTICO	Provides up-to-date road data to mapping services, enabling safe navigation, real-time road updates, and compliance with road authority regulations.
Operating Raw Data and Statistics Exchange (OpRa)	Framework for sharing, collecting, and storing raw public transport operational data, promoting consistent data	CSV, XML	Raw data: ridership, operational stats	Open, under CEN initiative	Development of public transportation services, production of transit performance reports, and analysis for

	handling across systems.				planning and management of transit resources.
Open Journey Planning (OJP)	XML-based standard for journey planning across multimodal transportation, with API-based data exchange for distributed systems.	XML, Open API	Static & real-time: routes, timetables, availability	Open, European Standard	Enables intermodal journey planning across transit systems, promoting seamless connectivity between different transportation services.
Transmodel	Abstract data model for public transport systems covering operations such as scheduling, ticketing, route management, and staff allocation.	UML (Unified Modelling Language)	Static & operational data: timetables, vehicle schedules, routes	Open, widely used in Europe	Creates standardized data systems across various public transport services (bus, tram, etc.), aiding in route planning and service scheduling.
Network Timetable Exchange (NeTEx)	XML-based format for sharing public transport data (e.g., schedules, routes, prices), promoting multimodal fare integration.	XML (CEN standard)	Static data: schedules, stops, pricing	Open, GPL license	Used for passenger information systems, enables integration across transit networks, and supports multimodal fare coordination and timetabling.
Service Interface for Real-time Information (SIRI)	Provides real-time public transportation data exchange, covering vehicle locations, schedules, and service reliability.	XML (CEN standard)	Real-time data: schedules, vehicle locations	Open, freely available	Real-time updates for transit systems, integration with passenger information services, and coordination with traffic management for smoother operations.
Mobility Data Specification (MDS)	A digital standard for cities to manage and share data with private mobility	JSON with multiple API interfaces	Real-time & static: vehicle location, policies	Open, city-controlled	Assists cities in monitoring mobility services (e.g., e-scooters), enforces

	services, featuring APIs for reporting, policy setting, and real-time agency coordination.				operational policies, and fosters collaboration between cities and private mobility providers.
mobilityDCAT-AP	Extension of DCAT-AP for describing mobility datasets, making them searchable across general data portals with standardized metadata.	RDF (Resource Description Framework)	Metadata: dataset descriptors	Open, European standard	Cross-border mobility data integration, enhancing data accessibility across EU data portals, and promoting harmonized data sharing for public mobility projects.

4.3 Summary of Findings

The findings emphasize that mobility data is not merely a collection of information but a strategic asset that drives innovation and efficiency in transportation systems. Addressing the challenges of data accessibility and standardization, while leveraging the strengths of existing repositories and standards, will be key to unlocking the full potential of mobility data in advancing sustainable, efficient, and user-centric transport ecosystems globally. We summarise our findings related to mobility data as follows:

- **Diverse Data Types with Specialized Applications**: Mobility data encompasses a broad range of types, including public transport schedules, shared mobility statistics, environmental data, and traffic flow patterns. These datasets serve distinct yet interconnected roles in creating user-centric, efficient, and sustainable transportation solutions. For instance, real-time public transport data improves operational efficiency, while EV infrastructure data supports sustainable mobility initiatives.
- **Fragmented Data Accessibility**: While a variety of mobility data repositories exist globally, not all data types are universally accessible. Many mobility providers do not share data due to privacy concerns, proprietary interests, or technical constraints. This lack of accessibility limits the potential for creating fully integrated transport solutions.
- **Availability of Comprehensive Repositories**: Table 13 lists notable repositories like the Mobility Database, OpenStreetMap, and regional platforms such as the National Public Transport Data Repository (UK) and Transport.data.gouv.fr (France). These repositories offer extensive datasets but vary in scope, coverage, and technical implementation.
- **Emerging Challenges and Opportunities**: While standards like DATEX II and mobilityDCAT-AP promote data integration and accessibility, challenges remain, including the harmonization of standards across regions, data privacy concerns, and the need for stakeholder collaboration. Opportunities lie in leveraging these standards to address these challenges, promoting sustainable and user-friendly transportation systems.

5 Data Sharing Frameworks in the Mobility Sector

Key takeaways from this section

- Gain knowledge about the widely used state of the art frameworks for sharing data in the mobility sector.
- Understand the advanced technologies behind data sharing frameworks, including IDS architecture, decentralised storage, Eclipse, which enable secure and seamless data exchange.
- Gain clarity on how data sharing solutions aligns with regulations.
- Recognize the challenges the data sharing frameworks face, including digital sovereignty, interoperability, and efficient data management, and how these impact its operations.

5.1 Mobility Data Spaces

Mobility data holds immense potential to drive innovation and efficiency while reducing environmental impact and enhancing the quality of life. By effectively harnessing this data, we can create smarter, more resilient transport infrastructure and services. This would lead to smoother traffic flows, facilitate cross-border travel, strengthen logistics chains, and simplify reporting for small and medium-sized enterprises (SMEs). Yet, the key challenge goes beyond mere data collection. It lies in enabling easier, secure, and controlled data sharing, and in transforming that data into actionable insights capable of driving meaningful change.

Data spaces are central to the EU's strategy for fostering innovation and collaboration in the mobility sector, particularly by addressing issues such as data sovereignty and interoperability. MDSs, a specialised type of data space, incorporate various architectural frameworks and technological infrastructures that support secure, efficient, and interoperable data exchange between stakeholders.

In this section, we explore the mobility data spaces, reviewing their architectures, the technologies they employ, the stakeholders involved, and the regulatory frameworks that oversee them. We also explore the open-source tools they utilise, the methods they adopt to ensure data sovereignty and secure exchanges, and how they implement data catalogues to manage and organise data effectively.

5.1.1 German Mobility Data Space (GMDS)

The GMDS is an open platform designed to provide access to both real-time traffic information and sensitive mobility data, ensuring secure exchange while connecting existing data platforms. In the future, this will enable the provision of comprehensive, national-level mobility data, offering a more seamless and integrated approach to transport information.

The GMDS offers an ecosystem where data providers can define and control the conditions under which third parties may use their data. This approach fosters both data sovereignty and trust, ensuring that users can rely on the origin and quality of the data. By bringing together data from both public and private sectors through regional and national platforms, the MDSs will evolve into a digital hub for data-driven business models, unlocking entirely new possibilities for data acquisition, integration, and utilisation.

- **Technology & Approach**: To foster secure and sovereign data exchange within the mobility sector, GMDS employs the International Data Spaces (IDS) reference architecture, decentralised data storage, Eclipse Dataspace Components (EDC), and Connector-as-a-Service (CaaS). These technologies uphold privacy and legal standards while enabling seamless integration, resilience, and interoperability across various systems.
- **Data Catalogue**: GMDS utilises EDC as its data catalogue to enhance data governance and interoperability within the mobility sector.
- **Incentives for Data Sharing**: GMDS is committed to encouraging data sharing while safeguarding the security and sovereignty of the shared information. By providing a secure platform for data exchange, GMDS motivates stakeholders in the mobility sector to share their data more openly, thereby fostering innovation and collaboration in the development of mobility services.
- **Regulatory Framework**: MDSs comply with antitrust legislation and the European GDPR as well as the European directives and conceptual thinking on the Data Governance Act, Digital Service Act (DSA)[35] and Digital Markets Act (DMA)[36].
- **Capacity and Capability**: Capacity and capability refer to the ability and readiness of an organisation, system, or initiative to effectively accomplish specific tasks or activities, encompassing both technical and non-technical factors. On the technical side, the focus is on secure data exchange and interoperability, ensuring that data is transferred safely and efficiently throughout the mobility sector. Non-technical factors include policy enforcement to uphold data governance standards and community support to encourage stakeholder collaboration and involvement.
- **Opportunities**: Data exchange within GMDS creates opportunities for enhancing safety and sustainability in mobility services. Access to real-time data on traffic patterns, vehicle statuses, and environmental conditions allows stakeholders to improve transportation systems, prevent accidents, and reduce their environmental impact.
- **Challenges**: GMDS encounters challenges related to digital sovereignty, interoperability, and data consumption, all of which affect efficient data management.

5.1.2 deployEMDS

The deployEMDS promotes EU coverage priorities by means of organising a technical infrastructure for an operational statistics area within the mobility area. It supports the European Data Strategy's objective of permitting records access, integration, and sharing. This initiative additionally aligns with the European Green Deal's imaginative and prescient to power sustainable and smart mobility, assisting in the reduction of transport emissions.

In addition, it supports the Sustainable Smart Mobility Strategy, the ITS Guidelines, and the MDMS initiative. Fifteen implementation cases have been delivered by peer groups in nine European cities and regions to create and set up a working media agency with an integrated technology infrastructure. By ensuring that data is available in machine-readable forms, the project enables continuous improvement of services and packages and promotes the creation of a European shared travel record ecosystem encouraged.

- **Technology & Approach**: deployEMDS is an open framework that relies on different data space technology infrastructure. The European Mobility Data Space (EMDS) utilizes a cloud-based,

[35]https://commission.europa.eu/strategy-and-policy/priorities-2019-2024/europe-fit-digital-age/digital-services-act_en
[36]https://digital-markets-act.ec.europa.eu/index_en

federated data architecture, enabling seamless integration across multiple regions and mobility providers. For deployment, the EMDS may leverage a range of technologies. deployEMDS is a pilot project exploring the deployment of MDS, incorporating technologies such as FIWARE, Gaia-X, and EONA-X.

- **Data Catalogue**: The European mobility data spaces used EDC to develop the catalogue. MobilityDCAT-AP is used to describe metadata standards will promote discoverability, allowing stakeholders to easily identify and utilize relevant datasets.
- **Incentives for Data Sharing**: Different EMDSs use open and paid subscription incentive models. By combining open and subscription-based models, the EMDSs create a balanced approach that drives revenue, encourages participation, and supports a variety of stakeholders in the mobility ecosystem. This hybrid scheme aligns with European goals for digital and mobility integration, fostering innovation and sustainable development.
- **Regulatory Framework**: deployEMDS is implemented in different jurisdiction of European countries. Therefore, different regulatory frameworks are adopted in deployEMDS including eIDAS, GDPR, static road traffic regulation, Multimodal Travel Information Services (MMTIS) Commission Delegated Regulation (EU) 2017/1926[37].
- **Capacity and Capability**: The core capabilities of deployEMDS are primarily technical. These include ID binding, authentication and authorisation, onboarding and participation, support cross cutting legal frameworks, access and usage policies enforcement, data and data service offering description, publication and discovery, interoperability, marketplace, data intermediaries. From non-technical standpoint, deployEMDS promotes collaboration between different actors such as shared mobility operators and data owners.
- **Opportunities**: deployEMDS fosters various opportunities primarily including improving the provision of mobility services, fostering a more accessible data ecosystem, enabling the creation of MaaS solutions, and mapping and characterising critical public transport route paths.
- **Challenges**: Collaboration between public and private actors in data sharing can be challenging, as different priorities, conflicting interests and organizational constraints often impede effective collaboration.

5.1.3 Japan Mobility Data Space

The Japan Mobility Data Space (JMDS)[38] is a state-of-the-art project to move forward the data mobility sharing, which focuses on the consolidation of all the necessary information to create intelligent, safe and more efficient transportation. The fully patent-free Open-source technology, being created under the collaboration of the intra public and private sector, is enabling this visionary arrangement. This platform is specially designed to connect different partners collaborating Japan's mobility ecosystem and facilitate the introduction of data-driven services.

Some of the top objectives for JMDS are improving urban mobility, reducing traffic congestion, and assisting custom mobility applications. Using in-depth real-time and historical traffic data, Toyota has employed JMDS for MaaS solutions that suggest highly efficient routes and methods of transport to the traveller according to individual needs. The customization of mobility not only meets users' needs but also aids urban infrastructure by managing congestion and enhancing service efficiency.

[37]https://eur-lex.europa.eu/eli/reg_del/2017/1926/oj
[38]https://mobility-data-space.jp/

- **Technology & Approaches**: Highly advanced technologies of AI and IoT are used in JMDS to amalgamate different data sources of mobility; gaining access to information from public transport schedules, traffic data, and real-time vehicle details. They are critical for the ability to process the data in real time and provide rich analytic capabilities that powers personalized mobility services and urban traffic management in an integrated manner.
- **Data Catalogue**: The platform features an advanced data catalogue that curates and offers access to diverse data assets. This allows users to find and consume these assets via an AI-driven conversational interface which enables natural interaction with the data and helps developers to build new applications and services.
- **Incentive for Data Sharing**: GMDS provides incentives for Information providers including opportunities to monetize Information and develop partnerships that could lead to service Improvements and market expansion.
- **Regulatory Framework**: Aligned with international data standards like the International Data Spaces (IDS), JMDS incorporates strong data privacy protections and regulatory compliance to manage data sharing securely. This framework ensures that participants can trust the system while supporting interoperability, making data exchange safe and consistent with global standards.
- **Capacity and Capability**: The platform features an advanced data catalogue that curates and offers access to diverse data assets. This allows users to find and consume these assets via an AI-driven conversational interface which enables natural interaction with the data and helps developers to build new applications and services.
- **Opportunities**: The potential for traffic management, congestion reduction, and Mobility-as-a-Service (MaaS) business models are enormous on the platform. GMDS not only acts as a sturdy data-sharing foundation, but also empowers stakeholders to innovate on top of that foundation and create mobility experiences at scale — ones that individualize address challenges of different urban population segments.
- **Challenges**: Challenges involve ensuring that different data sources can work together and keeping data private and secure. Also, getting private companies to share data can be hard without clear rules and good reasons to do so. The process can be slowed down by different groups trying to agree on data rules.

5.1.4 Stockholm Mobility Data Space (SMDS)

SMDS is a is part of the EU-funded deployEMDS project. Mobility and environmental data providers, including sources of traffic counts, air quality metrics, and noise levels—both within and outside the City of Stockholm—will contribute their data to the SMDS. This shared data will be aggregated to support evidence-based analysis of the city's zero-emission zone, using tools and methods developed specifically for the project. Within SMDS, the City of Stockholm will serve as both a data provider and consumer.

- **Technology & Approaches**: SMDS uses the International Data Spaces Association (IDSA) Reference Architecture Model, which provides the backbone for data interoperability, security, and compliance within the data space. This architecture enables the City of Stockholm and other participants to engage in standardized, protocol-driven data exchanges that support data privacy and protect participant data.
- **Data Catalogue**: SMDS implements a **centralized data catalogue**, which serves as a searchable database for data assets within the MDS. This design choice simplifies data access for participants,

especially smaller entities that may lack the resources for complex infrastructure. A centralized catalogue lowers the entry barrier, enabling easy discovery of available datasets related to traffic, environmental conditions, and more. Additionally, this catalogue aligns with the broader objectives of the European Mobility Data Space initiative to foster regional collaboration through accessible data assets.

- **Incentives for data sharing**: Participants benefit from shared infrastructure and trust frameworks, minimizing the need for each entity to build its own secure data-sharing systems. Participation in SMDS supports the city's ambitious goal of reducing car traffic by 30% by 2030, contributing to a cleaner and more sustainable urban environment.
- **Regulatory Framework**: SMDS is structured around several regulatory frameworks to ensure data privacy, security, and compliance with both local and European standards. Key regulatory frameworks and guidelines that SMDS adheres to include: GDPR, Data Governance Act, and local and EU-wide environmental objectives, such as the European Green Deal and Clean Air Policies.
- **Opportunities**: As part of a larger European initiative, SMDS connects Stockholm with other cities like Barcelona and Tampere, fostering shared insights and solutions across regional boundaries. SMDS encourages the development of new solutions for traffic management, emission reduction, and sustainable mobility. The centralized catalogue simplifies entry for smaller entities, encouraging diverse participants to contribute data and access valuable information that would otherwise be hard to obtain.
- **Challenges:** Aligning with IDSA protocols requires consistent application of data standards, which can be challenging across diverse participants. Also, While the centralized data catalogue lowers barriers, some potential participants may still find it challenging to meet technical requirements, highlighting the need for ongoing support and infrastructure development.

5.2 Mobility Data Specifications

Originally created in 2018 to address micromobility needs, MDS is an open-source, global standard that helps cities manage shared mobility within public transport rights-of-way. MDS standardizes communication and data exchange between government agencies and private mobility providers, giving cities the tools they need to improve safety, equity, and quality of service on their roads. At the same time, it provides a coherent playbook for mobility providers. At its core, MDS is a set of APIs (application programming interfaces), which are protocols that allow data to flow securely between cities and providers. Three main APIs allow cities and providers to communicate in different ways: the provider allows private mobility companies to report data to cities about the number, location, status, and trip history of devices used.

The policy allows cities to set rules regarding where and how different vehicles can travel, how many vehicles can travel, and other high-level policy initiatives. The agency provides real-time updates and collaboration between city officials and vendors when complex urban transportation problems require dynamic solutions.

- **Technology & Approaches**: MDS relies on RESTful APIs for real-time data interchange, allowing seamless communication between cities and providers. The data format is usually in JSON, enabling easy integration and standardization. Given the high volume of real-time data exchanged, MDS implementations often utilize cloud infrastructure for storage and processing, which ensures scalability and efficient resource management.
- **Data Catalogue**: MDS does not include a formal **data catalogue** in the traditional sense, like a comprehensive, browsable library of datasets or metadata records.

- **Incentive for Data Sharing**: MDS is developed by the Open Mobility Foundation (OMF). Therefore, MDS does not include financial incentives. The MDS offerings are designed to promote collaboration and ensure that data sharing yields mutual benefits for both parties. By sharing data through MDS, providers can optimize their fleet operations and resource allocation. Cities often require mobility providers to share data as part of their operating agreements. Furthermore, sharing data contributes to a better user experience by enabling seamless integration of various mobility services.
- **Regulatory Framework**: To protect sensitive information, MDS incorporates data encryption and user privacy protocols, aligning with global privacy regulations like GDPR to secure vehicle location and trip data.
- **Capacity and Capability**: For cities, MDS facilitates sharing real-time data on vehicle locations, status, and trips, which helps them monitor and respond to congestion. Also, it enables cities to enforce operational restrictions in real time.
- **Opportunities**: MDS creates the following opportunities for mobility data sharing: real-time and historic data allows better planning and program management; digital management greatly reduces operating costs and staff time spent monitoring mobility programs and service providers; allows real-time policy changes to be made to adapt to planned events and emergencies; and supports policies that allow dynamic pricing, equitable access, and safety initiatives.
- **Challenges**: Not all cities or mobility providers are equipped with the necessary infrastructure to integrate MDS efficiently. Another critical challenge is different cities may require customized policies and data fields, making universal adoption and interoperability challenging. Furthermore, protecting user data while sharing real-time vehicle information presents a complex challenge, especially with increasingly strict global privacy regulations like GDPR.

5.3 Intelligent Connected Vehicles

China is actively integrating national data to develop smart cities and intelligent transportation systems, as demonstrated in cities like Shenzhen and Guangzhou. These efforts encompass real-time tourism data, public transportation, and electric vehicles (EVs). A key initiative is the development of the Intelligent Connected Vehicle (ICV) [15] pilot zone, which establishes a regulatory framework and facilitates information sharing between autonomous vehicles and public transportation systems.

This zone allows for practical tests and encourages collaborations between the government, car manufacturers, and technology companies, who are working on international standards for data interchange, to guarantee joint interests and security in urban transportation development. Recent advances in China are inclusive of the most sophisticated AI and 5G technologies for enabling people, i.e. enhancing transportation services and performance. They also address the enhancement of autonomous driving capabilities and reduction of traffic congestion through public and private sectors exchanging data in a better manner than they have done previously, namely, through the operation of improved technologies.

- **Technology & Approach:** The ICV Pilot Zone leverages advanced 5G networks, artificial intelligence (AI), and IoT integration to enable real-time information sharing among vehicles, infrastructure, and control systems. These technologies support seamless vehicle operations and effective communication across diverse transport modes. The pilot zone also incorporates roadside sensors and digital infrastructure to facilitate vehicle-to-everything (V2X) communication, enhancing safety and navigation capabilities.

- **Data Catalogue:** Data in the ICV Pilot Zone is systematically catalogued to manage vast and diverse datasets produced by autonomous vehicles, sensors, and digital road infrastructure. This process involves organizing and categorizing information types such as vehicle diagnostics, route conditions, and traffic flow.
- **Standards and Protocols**: The system uses Vehicle-to-Everything (V2X) communication standards to enable interaction between vehicles and their environment, including other vehicles (V2V), infrastructure (V2I), and networks (V2N). The primary protocols include *Dedicated Short-Range Communications (DSRC)* for low-latency communication between vehicles and roadside units, and *Cellular Vehicle-to-Everything (C-V2X)* protocol which leverages cellular networks, including 4G and 5G, to provide broader range and enhanced communication capabilities.
- **Regulatory Framework**: The regulatory framework for the ICV pilot sector includes strict data privacy laws and security protocols to protect personal data and operations. The regulations emphasize data sovereignty and define the roles of data controllers and processors.
    - They ensure that all participants comply with China's information security laws and policies on public-private cooperation.
    - They promote collaboration among technology companies, car manufacturers, and government agencies to drive innovation while maintaining stringent security standards.
- **Capacity and Capability**: The system supports high-speed, real-time data exchange using advanced communication technologies such as 5G networks. The Vehicle to Infrastructure (V2I) communication enables vehicles to share information with road infrastructure to improve traffic management and safety. It also facilitates the integration of various data sources, including vehicle telemetry, sensor data from infrastructure (such as traffic lights and road sensors), and external data feeds (such as weather and traffic reports).
- **Opportunities**: Real-time data sharing can lead to quicker responses to road hazards and improved accident prevention. Autonomous vehicle data contributes to traffic optimization, reducing congestion. Also, optimized traffic flow and electrification of vehicles contribute to lower emissions and improved air quality.
- **Challenges**: Despite significant progress, the ICV initiative faces challenges, particularly in safeguarding personal data and ensuring the privacy of vehicle owners. As the volume of sensitive data generated and transferred grows, maintaining privacy becomes increasingly complex.

5.4 National Transport Data Sharing Programme

As a part of the Smart Nation initiative, Singapore has developed the National Transport Data Sharing Programme allows different transport companies to share information about traffic, public transportation, and pedestrian activity with government departments. This program helps in making quick decisions for improving city transportation and infrastructure. It also gives useful information about how people travel, which helps in designing better public transport routes.

- **Technology and Data Catalogue**: Singapore’s transport data-sharing program leverages cutting-edge technology to enable real-time data collection and integration. It provides access to a catalogue of datasets through the *DataMall*, a platform run by Singapore's Land Transport Authority (LTA). DataMall includes a vast range of transport-related data, such as live traffic conditions, public transport schedules, and geolocation data. Through API access, this data is available for developers to integrate into new applications, supporting innovations such as route optimization and predictive analytics.

- **Incentives for data sharing**: The program incentivizes data sharing by supporting companies and researchers in developing and testing mobility solutions within a controlled environment. Singapore's *Data Innovation Programme Office* facilitates collaborations between government and private sectors, which include sandbox environments and frameworks that protect proprietary data while promoting innovation.
- **Capacities and Capabilities**: Singapore's National Transport Data Sharing Program enables capabilities like real-time traffic management, improved public transportation services, and vehicle-to-infrastructure communication.
- **Opportunities**: By supporting the development of autonomous vehicles and intelligent transport systems, Singapore seeks to stay at the forefront of mobility innovation, which can reduce road congestion, enhance commuter experiences, and promote sustainable transport solutions.
- **Challenges**: Despite these advancements, the program faces challenges related to data privacy concerns, integration complexities with legacy systems, and the need for ongoing collaboration among diverse stakeholders to ensure the effectiveness of shared data. Additionally, balancing public interest with private sector competition remains a delicate issue, especially in data access and usage.

5.5 Blockchain for Data Sharing

There is an increasing trend of cooperation between the national sector and the private and public sectors for the greater good of breaking information barriers as it comes with a phenomenon known as data sharing. Traditionally, one way that addressed this issue was through central government data sharing which was put into one data centre that required a lot of resources to be constructed and maintained. This method also lacked other parameters like sectoral aims, supervision of duties, professional information protection and the tracking of information history which made it difficult towards government and department data sharing. As a data centre is a centralized organization, there are risks such as data loss and data tampering. In addition, various countries have also issued a series of policies on data security issues, such as the GDPR implemented by the European Union in 2018.

Responding to such problems, the solution of blockchain technology is extremely advantageous. Blockchain comprises of several aspects such as a journal with dispersed documentations, smart contracts, reliable data handling among others including transparency. It can be observed that such characteristics of blockchain amongst others, are useful in governing the security and efficiency in governmental data sharing. It is put forward the following problem solution - the creation of a government data sharing system on the basis of blockchain technology with a concept of a single data sharing platform together with the possibilities for autonomous administration. The concept is aimed at enabling smooth and secure decentralized government big data sharing, and bringing about cooperation among various sectors yet ensuring all measures as the concern transparency and responsibility of data usage and access.

An argument in favour of blockchain-based models emphasizes that their advantages are primarily in increasing transparency and security and enhancement of traceability and trust without centralized controlling body. Also, distributed type of architecture enables more community oriented models of sharing (peer-to-peer or multi-level). Nevertheless, there is a flipside to these points. As in restraining barriers ones, such design may not be very effective or productive in large and busy places and localize the problem between the lines.

5.6 Mobility Data Hub

Some countries including Ireland have developed what can be referred to as **national mobility data hubs**, considering how important mobility data is for data management and regulatory oversight. These data hubs are usually maintained by the government, which puts emphasis on the consolidation of data collection and access for public consumption. For instance, the mobility data hubs in Ireland are managed and maintained by the Open Data Portal Data.Gov.IE[39]. The key primary data providers include National Transportation Authority (NTA)[40], Central Statistics Office (CSO)[41], Department of Transport[42], Dublin City Council[43], Road Management Office (RMO)[44], and County Council. In doing so the optimal compliance of policies and standards is ensured, which particularly relevant for countries having exhaustive legal frameworks on the privacy, security and use of data at the global level.

The usefulness of these national data interoperability centres lies in more than just utility. Such providers usually render the data accessible to the government and transport establishments for the purpose of performing operational functions in the river, established legislation and policies, and the transportation behaviour of the society moving from one region to another. When the national hub is established in the best interest of the government authorities, effective checks and balances can be implemented to control the data set covered, ensuring all data and information comply with the prevailing legal requirements. Furthermore, national data hubs are generally included into the overall country's infrastructure development planning enhancing the ambitions of urban development, digitalization and transportation.

National hubs can be very instrumental in creating data-driven views within different sectors of mobility including public transport and infrastructure planning. These data hubs allow regional and city government aids to appreciate the demand and diversion of any extra resources helping to optimize transportation in the region. Moreover, they improve the control of various situations such as, shifting the operation of public buses during poor weather conditions or even ensuring the safe control of vehicular traffic where there is a heavy traffic build up in a short period amongst other incidents.

However, drawbacks persist despite the merits of national data hubs. One of the major setbacks associated with the centralized approach of a national data hub is the risk of data silos in the presence of interoperability linked particularly to other systems and platforms. Interoperability being an issue, creates isolation within which stakeholder groups such as commercial entities, local governments at sub-national levels, and even civil society organizations may feel restricted to work in ways that avail shared benefits.

Moreover, the highly centralized nature of the data hub may reduce the opportunities for creative abilities of the private sector and enhance also geographical imbalances and development since there may be less incentive for regional interrelationships. For instance, it is possible that private transport companies could face problems when trying to include their original statistics, or development of new services, when the hub employs exclusionary standards and protocol. However inconvenient, despite said approach, various national data hubs remain a constructive method for those countries which want to carry out comprehensive regulation of access to data. These hubs create space where data can be shared in a controlled and safe way,

[39]https://data.gov.ie/
[40]https://www.nationaltransport.ie/contact-us/
[41]https://www.cso.ie/en/index.html
[42]https://www.gov.ie/en/organisation/department-of-transport/
[43]https://www.dublincity.ie/residential
[44]https://www.rmo.ie

streamlining how data related to mobility is managed locally. Therefore, in the environment of very rapid development of information technology, such information centres are in a rather appropriate role, since they provide the necessary stability for the new periods and corresponding patterns of behaviour without disregarding the interests of the public and the state regulatory practice.

5.7 MaaS Platform with Integrated Data Sharing

MaaS platforms, which offer integrated trip planning and ticketing end-to-end, have emerged as a natural mediator for mobility data exchange. These platforms offer multiple transit modes for connection, including buses, bikes, and ride-sharing; integrate multimodal mobility data to provide personalized user experience — tailored recommendations of all possible ways to complete a given trip.

The design of MaaS platforms is such that they are user-centric and will provide a seamless integration with consumer-facing applications for a last mile travel solution. They promote a cooperative relationship between public and private mobility providers, enabling a smooth multimodal trip through real-time data for efficiency purposes.

But these platforms are usually in metropolitan areas or on private platforms. Moreover, as MaaS is only sustainable and scalable with a large amount of data collected to enable the functions of such services, many privacy concerns might arise if proper regulations or protections are not put in place. Furthermore, MaaS platforms handle data from multiple providers and must thus guarantee strong security and privacy protections for users. When exchanging data between private and public entities, neutrality of the network is not enough to prevent privacy regulation violations such as the GDPR in force within the EU. With multiple providers using different systems, integration can be a challenge because there is no standardization of the data formats. Highly successful MaaS platforms are built on good partnerships of public transit, private mobility providers, and local governments. And there are complexities in aligning goals and expectations across these entities, as well as ensuring that issues like ownership of the data are addressed through clear agreements and governance models.

5.8 Summary of Findings

Mobility data has transformative potential to drive innovation, enhance efficiency, and promote sustainability. By leveraging secure and interoperable data-sharing ecosystems, stakeholders can address urban mobility challenges, optimize transportation systems, and enable data-driven decision-making. Key initiatives, such as MDSs, blockchain for data sharing, and MaaS platforms, demonstrate how strategic integration of technologies and frameworks can unlock these benefits.

Key Findings

- **Opportunities:** Mobility data initiatives enhance traffic management, foster innovation, and support sustainable urban development. Platforms like MaaS offer seamless multimodal solutions tailored to user needs.
- **Challenges:** Interoperability, data privacy, and collaboration across diverse stakeholders remain critical hurdles. Centralized hubs risk creating data silos, while fragmented regulations hinder seamless adoption.
- **Technological Solutions:** Advanced frameworks such as International Data Spaces (IDS), blockchain, AI, and IoT facilitate secure, scalable, and standardized data sharing.

- **Governance and Compliance:** Strong adherence to regulatory frameworks like GDPR and the Data Governance Act ensures lawful and ethical data exchange, fostering trust and transparency.

Strategic Implications

To fully realize the potential of mobility data, stakeholders must prioritize collaboration, standardization, and the integration of advanced technologies. These efforts will pave the way for more intelligent, resilient, and user-focused transportation systems globally.

6 Governance and Regulatory Frameworks

Key takeaways from this section

- Gain a clear understanding of the governance structures that support the effective implementation and management of MaaS.
- Gain insights into global regulatory standards and frameworks shaping the mobility sector, providing a broader perspective on compliance and best practices.
- Develop a detailed understanding of Ireland's specific governance structures and regulatory policies impacting the mobility sector, including their alignment with international standards.

6.1 MaaS Governance Model

Governance models form the foundation of MaaS regulatory frameworks, typically implemented alongside relevant policy instruments to achieve the specific goals of each regulatory scheme. MaaS governance models encompass various ownership structures that define the role of the MaaS operator. There are two extreme types of governance models that a MaaS system can adopt [16]:

- **Broker Model**: The model involves a MaaS operator functioning as a single entity and acting as a broker, meaning it purchases capacity and resells it in MaaS packages—known as the broker model. In this setup, the MaaS operator assumes full risk and responsibility for its activities. This model is structured as a principal-agent relationship, where bilateral agreements are essential to ensure effective data exchange, interface compatibility, service availability, and fare pricing.
- **Partner Model**: The model involves a MaaS operator functioning as a partnership of multiple organizations within the MaaS scheme. Here, the MaaS operator acts as a coordinator, often referred to as the "MaaS coordinator" (partnership model), overseeing the activities of partners to form an alliance within the MaaS ecosystem. This alliance is based on multilateral agreements and faces challenges related to revenue allocation. Operating costs are distributed across the entire "MaaS partnership," while revenues are allocated to participating partners. Both the MaaS coordinator and the partners share the associated risks.

The other governance models offer varying characteristics and may be more suitable for specific contexts. First, there is a mixed model that combines elements of both broker and partnership models. Second, a model where the MaaS operator leverages in-house resources to deliver MaaS solutions. Third, a model where the MaaS operator outsources all responsibilities except for certain critical functions, such as managing financial transactions.

6.2 International Regulatory Frameworks Relevant to Mobility Sector

This section presents regulations relevant to MaaS drawn from various EU projects and secondary sources. A total of 25 pertinent regulations have been identified and included in this deliverable, covering areas such as data, MaaS, micromobility, shared mobility, and other related categories. The review reveals a notable scarcity of MaaS-specific regulations. To expedite the development and implementation of MaaS, it is essential to consider applicable regulations from related categories.

Table 15 provides an exhaustive list of these regulations, detailing their categories, types, implementation status, and relevant countries and cities.

Table 15 A summary of the international regulatory framework relevant to mobility

Regulation Category	Regulation Name	Type of Regulation	Implementation Status	Country Level	Description
Data	Directive EU 2019/1024 [29]	EU Directive / Regulation	Implemented	EU	Open data and re-use of public sector information. The Commission emphasized the need for Union-level action to address barriers to reusing public sector and funded information, update legislative frameworks, and stimulate digital innovation, particularly in artificial intelligence.
Data	Regulation 886/2013 [30]	EU Directive / Regulation	Implemented	EU	The Commission enacted Regulation (EU) No 886/2013 on 15 May 2013, enhancing Directive 2010/40/EU on providing road safety-related minimum universal traffic information free of charge to users.
Data	Data Regulation 2015/962 [31]	EU Directive / Regulation	Implemented	EU	Commission Delegated Regulation (EU) 2015/962 of 18 December 2014 supplementing Directive 2010/40/EU of the European Parliament and of the Council regarding the provision of EU-wide real-time traffic information services.
Data	Regulation 2015/962 [32]	EU Directive / Regulation	Implemented	EU	The Commission enacted Regulation 2015/962 on 18 December 2014, supplementing Directive 2010/40/EU, pertaining to real-time traffic information services across the EU.
Data	Regulation 2017/1926[33]	EU Directive / Regulation	Implemented	EU	Commission Delegated Regulation (EU) 2017/1926 of 31 May 2017 supplementing Directive 2010/40/EU of the European Parliament and of the Council regarding the provision of EU-wide multimodal travel information services.
Data	Directive EU 2019/1024 [34]	EU Directive / Regulation	Implemented	EU	The Directive on open data and the re-use of public sector information provides a common legal framework for a European market for government-held data.
Data	Directive EU	EU Directive /	Implemented	EU	The European Parliament and Council's Regulation (EU) 2019/1150 aims to promote fairness and transparency for online intermediation services

	2019/1150 [35]	Regulation			users. It emphasizes the importance of trust in these services for businesses to fully benefit from the online platform economy and engage in commercial relationships.
Data	The Re-use of Public Sector Information Regulations 2015 [36]	National / Regional / Local law	Implemented	United Kingdom	This regulation allows the re-use of information from public sector entities.
Data	Federal Open Data Act of 18 May 2017 [37]	National / Regional / Local law	Implemented	Germany	This regulation establishes a central support agency for open data. German Government has their open data publicly available.
Data	Personal Data Protection Act 2012 [38]	National / Regional / Local law	Implemented	Singapore	This regulation governs the collection, use and disclosure of personal data by organisations.
Data	Digital Government Agenda [39]	Agenda	Implemented	Netherlands	This agenda is part of the Dutch Digitalisation strategy and contains rules on how governments deal digitally with citizens, the application of which may be desirable for the MaaS programme.
MaaS	Shared Mobility, MaaS and the Regulatory Challenges [40]	Recommendation	Implemented	EU Level	MaaS can combine traditional and new mobility services, reducing disutility from switching from private cars to public or active transport. However, issues arise regarding data, platforms, apps, and regulation of traditional and new modes of transport. This report addresses these questions and proposes answers and policy recommendations to address these challenges.
MaaS	Mobility as a Service and Sustainable Urban Mobility Planning [41]	Recommendation	Implemented	EU Level	MaaS can assist city decision-makers and planners in achieving mobility goals by offering a multimodal, user-centric alternative to private car use and promoting sustainable transport modes and efficient use of transport networks.

MaaS	MaaS Services and Business Opportunities [42]	Recommendation	Implemented	Finland	This recommendation assesses emerging traffic service markets in Finland, analysing MaaS impacts and business opportunities, emphasizing organizing and platform services as key elements in MaaS development.
MaaS	Framework Agreement for the implementation of 7 regional, Nationally Scalable MaaS Pilots [43]	Recommendation	Implemented	Netherlands	The Ministry of Infrastructure and Water Management has issued a framework agreement for the implementation of seven regional, nationally scalable MaaS pilots, aiming to create experimentation space, remove obstacles, and facilitate cooperation between Service Providers and Transport Providers.
MaaS	Programme Of Requirements as part of the Framework Agreement for the implementation of 7 Regional, Nationally Scalable MaaS Pilots	Programme Of Requirements	Implemented	Netherlands	This Programme of Requirements is part of the tender dossier and the MaaS Framework Agreement (Framework Agreement).
Micromobility	Road Traffic Act 1988 [44]	National / Regional / Local law	Implemented	United Kingdom	The UK's reluctance to adopt e-scooters highlights the global need for more proactive and flexible solutions to address the rapidly evolving mobility challenges.
Micromobility	Car-sharing Policy [45]	National / Regional / Local law	Implemented	Australia	The objectives of this car-sharing policy are to increase car-sharing usage and to ensure that the city's car-sharing program is well-governed and transparent.
Shared Mobility	Greater London Dockless Vehicle Hire Bylaws [46]	National / Regional / Local law	Will be implemented	United Kingdom	This is a proposed legal text – a guidance document.

Shared Mobility	Ordinance on the Operation of Motor Vehicles in Passenger Transport [47]	National / Regional / Local law	Implemented	Germany	Regulations are similar for taxis and private hire vehicles, with the main difference being that private hire vehicle drivers are required to return to their company's headquarters after each trip.
Shared Mobility	Act on the Priority of Carsharing [48]	National / Regional / Local law	Implemented	Germany	This Act enables measures to prioritize car-sharing to promote its use within station-independent and station-based service models, aiming to reduce the environmental and climate impact of motorized private transport.
Shared Mobility	Subsidy Scheme for One-way Electric Shared Vehicles	Subsidies and incentives	Implemented	Netherlands	A subsidy is available for parking permits for fully electric shared cars that can be used throughout the city. This subsidy is valid from October 1, 2017, to June 1, 2021.
Shared Mobility	Parking Permit for Car Sharing without a Stand with 100% electric vehicles.	Subsidies and Incentives	Implemented	Netherlands	Car-sharing organizations can apply for city-wide parking permits for their free-floating services using 100% electric vehicles. A maximum of 750 permits is available, with up to 350 permits granted per provider. This program began on March 31, 2020, as a trial, ending on March 31, 2020. If an organization wishes to continue using city-wide parking permits for shared cars after this date, they must reapply for the permits.
Other	170/2017. (VI. 29.): Government Decree on Electric Car Charging Services [49]	National / Regional / Local law	Implemented	Hungary	The Government Decree on certain public tasks related to promoting electromobility in Hungary covers areas such as electric vehicle charging, alternative fuel labelling, and greenhouse gas emissions regulations. This decree also amends the 2012 regulations, allowing certain transport fuel suppliers to claim credits for reductions in greenhouse gas emissions from fuel production, known as upstream emissions, to help meet emissions reduction targets set for 2019.
Other	243/2019. (X. 22.): Government Decree on Electro-	National / Regional / Local law	Implemented	Hungary	Same as the previous one.

	mobility Services: Electric Charging Devices and Stations, Tasks of the Electro mobility Provider, Pricing [50]				

The study provides a detailed and structured overview of regulations, recommendations, and programs governing mobility systems. The breadth of the regulations listed in the above table reflects the growing importance of regulatory frameworks in addressing the challenges of sustainable and efficient transportation systems. By encompassing international, regional, and national perspectives, the table highlights the diverse approaches to mobility governance and offers valuable insights into global trends.

One notable aspect is the emphasis on data regulations, particularly at the EU level. Directives such as EU 2019/1024 and Regulations 2017/1926 demonstrate the critical role of data sharing and interoperability in enabling advanced mobility solutions, including multimodal travel information services and real-time traffic management. These regulations underpin many mobility innovations and highlight the strategic importance of fostering secure, open, and standardized data ecosystems to drive digital transformation in transport.

The focus on MaaS recommendations is another significant feature. Policies such as Finland's exploration of MaaS business opportunities and the EU-level guidance on integrating MaaS into sustainable urban mobility planning underscore the potential of user-centric, multimodal systems to reduce private vehicle dependency. These initiatives align closely with broader sustainability goals, emphasizing the importance of equitable access, efficient resource utilization, and reduced environmental impact.

In contrast, the micromobility category reveals a more cautious regulatory approach, as seen in the UK's reluctance to embrace e-scooters under the Road Traffic Act 1988. This hesitance contrasts with the proactive measures in MaaS and shared mobility, suggesting that certain modes of transport face greater regulatory and societal barriers to adoption.

Geographically, the study reveals disparities in regulatory ambition and scope. While the EU consistently emphasizes harmonized, forward-thinking policies, some national-level approaches, such as those in Hungary and Australia, focus on narrower or region-specific objectives. This divergence highlights the importance of balancing localized priorities with broader international frameworks to ensure cohesive and scalable mobility solution.

6.3 Irish Governance and Regulatory Frameworks Relevant to Transport Sector

To shape and regulate transportation services, the governance and legal frameworks in the transportation industry are essential. Ireland has several governance and legal frameworks related to the transportation sector that are designed to promote accessible, sustainable, and effective modes of transportation. Several government authorities, including the Department of Transport, the National Transport Authority, Transport Infrastructure Ireland, the Commission for Railway Regulation, and the Road Safety Authority, often take responsibility for these frameworks, creating strategic directives and regulations that expedite mobility projects.

To ensure compliance with laws and safety standards, and guide operational aspects of transport services, the regulatory frameworks of these authorities are issued. We have listed the governance and legal frameworks in the Irish mobility sector in Table 16, which highlights key governance and regulatory frameworks, their type, and the primary authority responsible. Table 16 provides a summary of Irish governance and regulatory frameworks relevant to transportation sector.

***Table 16**: Governance and regulatory frameworks for Irish transportation sector*

Frameworks	Authority	Description
Transport Appraisal Framework	Department of Transport	The Transport Appraisal Framework offers comprehensive guidance for appraising and implementing transport investments. It is designed to promote projects that address societal needs, align with strategic policy objectives, and ensure value for money. By adhering to a standardized approach outlined in the Infrastructure Guidelines (IG), the TAF supports consistent and effective decision-making for transport investment.
National Sustainable Mobility Policy	Department of Transport	The National Sustainable Mobility Policy establishes a strategic framework through 2030 to promote active travel, such as walking and cycling, and public transport use, supporting Ireland's efforts to meet its climate commitments.

National Roads 2040 (NR2040)	Transport Infrastructure Ireland	National Roads 2040 (NR2040) is Transport Infrastructure Ireland's strategic framework designed to support the implementation of Project Ireland 2040. It aligns with the Department of Transport's National Investment Framework for Transport in Ireland and adapts to evolving national policies to ensure the development of a sustainable and efficient road network.
Dublin Transport Authority Act Public Transport Regulation Act (2009)	National Transport Authority	The principal functions of the Authority involve undertaking strategic transport planning, promoting the development of an integrated and accessible public transport network, and regulating public transport fares to ensure fairness and efficiency.
Road Traffic Acts	Department of Transport, Transport Infrastructure Ireland and An Garda Síochána	These acts encompass various regulations governing road usage, vehicle standards, and driver behaviour, enforced by the Department of Transport to ensure road safety and compliance.
Taxi Regulation Act (2013)	National Transport Authority	Also overseen by the NTA, this legislation governs the operation of small public service vehicles, setting standards for safety, accessibility, and fare structures.
Railway Safety Act 2005	Commission for Railway Regulation	Enforced by the Commission for Railway Regulation, this act focuses on maintaining high safety standards within Ireland's railway operations.
Air Navigation and Transport Act (2022)	Department of Transport	This act provides the regulatory framework for civil aviation, ensuring safety, security, and efficient air transport services, under the Department of Transport's jurisdiction.
Public Transport Regulation Act (2009)	National Transport Authority	Administered by the National Transport Authority (NTA), this act regulates public transport services, including licensing and service standards, to maintain an integrated and accessible network.
Road Safety Strategy	Road Safety Authority, Department of Transport, and An Garda Síochána	It aims to reduce road traffic collisions, fatalities, and injuries through targeted initiatives such as public awareness campaigns, infrastructure improvements, enforcement of traffic laws, and promotion of safer driving behaviours.
Public Passengers Transport Services Bye-laws 2019	National Transport Authority	Regulates the operation and use of public passenger transport services, ensuring compliance with service standards, passenger safety, and operational efficiency.

Small Public Service Vehicle (SPSV) Regulations	National Transport Authority	Governs the licensing, operation, and standards for vehicles such as taxis, hackneys, and limousines.
Roads Act 1993	Transport Infrastructure Ireland	Key provisions include the designation of national, regional, and local roads; the regulation of road-related activities; and the framework for compulsory land acquisition for road development projects. The Act supports the efficient operation of Ireland's road network, ensuring it meets the needs of users while aligning with national and regional development goals.
Traffic Signs Manual	Department of Transport	The manual supports compliance with the **Road Traffic Acts** and aligns with international standards, enabling safe and efficient navigation for all road users.

Governance and regulatory frameworks play a crucial role in enforcing standards and ensuring operational integrity across various transport domains. Table 16 shows that, the National Transport Authority is a key regulatory authority, overseeing critical acts like the Public Transport Regulation Act and Taxi Regulation Act, while the Department of Transport enforces broader regulatory mandates, including the Road Traffic Acts and Air Navigation and Transport Act. Specialized agencies such as Transport Infrastructure Ireland (TII) and the Commission for Railway Regulation further contribute by managing infrastructure and safety-specific regulations.

The frameworks reflect a strong alignment with national and EU sustainability goals, focusing on urban mobility enhancements, public safety, and infrastructure development. However, the involvement of multiple authorities highlights the need for effective coordination to ensure seamless implementation and avoid overlapping responsibilities. Adapting these frameworks to address emerging challenges, such as shared mobility, MaaS platforms, and data-driven decision-making, will be crucial for Ireland’s evolving transport ecosystem.

6.4 Governance and Regulatory Frameworks for Data Sharing

The governance and regulatory frameworks for data sharing span global, regional, and national levels, emphasizing transparency, ethical use, privacy, and interoperability. These frameworks address critical challenges associated with data sharing, offering structured guidance to foster trust, innovation, and cross-sector collaboration. Data sharing requires a strong commitment to compliance of the regulatory frameworks. By balancing regulatory oversight with innovation-friendly policies, the regulatory frameworks enable secure, ethical, and transparent data use, driving both societal benefits and economic growth. Data sharing initiatives can leverage these frameworks to craft tailored data governance strategies that align with their operational goals while ensuring compliance. Table 17 lists and describes some well-known governance and regulatory frameworks used in data sharing ecosystem such as data spaces.

Table 17 Data governance and regulatory Frameworks

Governance/Regulatory Frameworks	Level	Description
European Data Governance Act (DGA [51]	EU Level	The European Data Governance Act (DGA) establishes a framework to promote data sharing across the European Union by creating data intermediaries and fostering a European data market. The DGA aims to encourage voluntary data sharing while protecting data privacy and ensuring data is used ethically. It includes provisions for "data altruism" where individuals and organizations can share data for the public good and mandates strict privacy requirements to ensure data security.
AI Act [52]	EU Level	The dataset covering the following subjects was enforced on 2 August 2024, also known as the EU Artificial Intelligence (AI) Act. The regulation applies to activities carried out within the EU and is already in effect. The main objective is to provide exceptionally high levels of protection for public health, safety, and citizens' rights, while also enabling the development of human-centric AI. The regulation applies to AI systems implemented or used within the EU, with provisions that apply to both the public and private sectors. However, there are exemptions for specific AI applications related to national defence and security, scientific research, AI systems and data models in research, open-source models, and, last but not least, the use of apps for personal use.
Data Act [53]	EU Level	The Regulation establishing the Data Act came into force on 11 January 2024. This law is one of the most integrative in the European data strategy, helping to achieve the Digital Decade objective on the contemporary technology. For further details, this Act is explained in the document titled *Data Act Explained.* The provisions of the Data Act build on the first milestone of the European data strategy, the Data Governance Act, which came into force in September 2023. The Data Governance Act primarily focuses on creating processes and structures for enabling voluntary data sharing, while the Data Act addresses data exploitation and its regular use. Together, these two acts will ensure the availability of data across critical areas of economic and public concern, without access restrictions. Additionally, they will drive the development of a single data market across Europe, benefiting both economic welfare and society throughout the EU.

SITRA Rule Book [54]	EU Level	Sitra's Rule-book for Data Economy aims at creating an environment for transparent and honest data sharing while respecting data ownership The rule-book includes a set of contractual templates, tools and policy documents in the areas of the law, economics, technology, management and other related fields. These resources are useful for businesses that deal with data ethically. The rulebook contains several key components, such as contractual templates, a set of audit benchmark questions, and a proposed code of conduct, which can help create a tailored framework for a specific data network. For example, from the perspective of the Sitra Rulebook, predictive control methods can solve critical problems in managing projects, such as those related to the concept of a data space. It also facilitates the growth of data-sharing networks within organizations, ensuring they implement the right policies and standards. Using the rulebook, participants can develop a data-sharing network built on trust, with a shared mission, vision, and set of values. Finally, the rulebook outlines the obligations of data providers and users under existing statutes and agreements. It also offers guidance on how to adopt applications that promote data usage while ensuring that associated risks are fully managed.
IDSA Rulebook [55]	EU Level	The IDSA Framework is essential for the day-to-day management of data sharing and data spaces, with the main goal of distinguishing mandatory rules from those that are merely recommendations. Inclusively, this governance structure constitutes various avenues such as business, technological, operational and legal. It includes the best practices for functions of the Business Entity, applicable procedures and services, and how to implement or use technology artifacts enforced by IDSA. In addition, the rulebook provides for cooperation in the field of data services and offers a legal SAFE to assist in ensuring compliance with the legislation. Encouraging trust and security within the data space is also achieved through the above aspects.
Traffic Data Ecosystem Rulebook [56]	National Level, Finland	Inspired by Sitra's Fair Data Economy Rulebook, The Rulebook is a service agreement prepared to encourage the traffic sector stakeholders to exchange data in good faith. The information traffic over the internet is conceptualized as a distributed data system or network open to all individuals and/or corporate bodies who can become members by agreeing to the terms of the Rulebook.
Data Sharing Governance Framework by the UK Government [57]	National, United Kingdom	Developed by the UK government, this framework offers guidance on establishing governance structures, policies, and processes to facilitate responsible and secure data sharing across government departments, agencies, and organizations. Central to this framework is the Data Sharing and Governance Act 2019 (the Act), which was enacted in March 2019. This Act extends the provisions of the General Data Protection Regulation 2018 (GDPR) and the Data

		Protection Act 2018. It provides specific clarification on the regulations and exceptions regarding the sharing of citizens' personal data between public entities. Additionally, it furnishes assurance and legal clarity to entities intending to engage in the disclosure or reception of data.
Data Sharing Governance Act 2019 [58]	National, Ireland	The Data Sharing and Governance Act (DSGA) serves as enabling legislation, offering a statutory foundation for public bodies to share personal data within the realm of delivering public services. It guarantees the secure management of such data by implementing a suitable governance framework and enhances transparency regarding the data sharing agreements established. The governance framework for data sharing under the DSGA consists of several components that are briefly described below: o The DSGA Data Sharing Playbook serves as a visual guide, resembling a flowchart, that outlines the various stages of data sharing, including delineating roles and responsibilities. o The **Data Sharing Guidelines** offer comprehensive insights into the regulations, methodologies, and protocols governing the sharing of data, providing detailed information on rules, processes, and procedures. o As part of the data sharing governance processes, it is now mandatory to complete a new **Data Sharing Agreement** (DSA) template. This DSA template is designed to guarantee adherence to all applicable data protection legislation. Each section of the DSA template must remain intact and cannot be removed; however, there is flexibility to add new sections as needed. o Ideally, all Public Service Bodies (PSBs) participating in the data sharing arrangement should sign the Data Sharing Agreement (DSA) upon its execution. In cases where signing on the execution date isn't feasible, an **Accession Agreement** can be generated, but it will only apply to the original DSA. If there is a need for different terms, a separate DSA must be created.
Australian Government Data Sharing Principles [59]	National, Australia	The data sharing principles serve as the central risk management framework within the DATA Scheme, assisting data custodians in determining the safety of data sharing. Developed by the Australian government, these principles provide guidance on sharing government data with other agencies, organizations, and the public while safeguarding privacy, confidentiality, and security through consent, transparency, and accountability mechanisms.
General Data Protection Regulation [60]	EU Level	The General Data Protection Regulation (GDPR) of the European Union is considered the most robust framework of privacy and security. It modernises values of the Data Protection Directive adopted in 1995. The Council of the European Union adopted this regulation in the year 2016 and was enforced on 25th of May 2018.

		The GDPR focuses on the rights of individuals in the age of information technology, outlining the duties of data processors, methods for ensuring compliance, and penalties for breaches of the law. Furthermore, the GDPR spells out the basic obligations of both data controllers and data processors (entities processing personal data on behalf of controllers). It includes the ledger entry of appropriate risk-based security controls in the processing of data by an entity. In certain instances, the data controller must inform individuals about personal data protection in the event of a breach. Additionally, all entities including public bodies and companies that process personal data of operations that carry high risk are obliged to appoint a Data Protection Officer (DPO).
Interoperable Europe Act [61]	EU Level	The Interoperable Europe Act is set to revolutionize the sharing of information in the public sector among the member states at an accelerated pace, to achieve the EU's public procurement transformation objective. It includes a plan for the public boxes with different aims across the Union, facilitating data traffic between regions, and providing interinstitutional support services. This plan also realizes the urgency of having agreed and adopted EU-wide digital solutions including open-source solutions, standards, guidelines, templates, and ICT tools that are interoperable and reusable. Through this action, the Act incentivizes connection-building rather than merely creating an obligation to act.
Digital Service Act [62]	EU Level	The Digital Services Act (DSA) is a law that defines the scope of activities of online intermediaries and information society services. This includes nearly all segments of online environment such as marketplaces, social networking sites, video sharing platform, app stores and online travel and accommodation services. The main aim of the directive is the regulation of illegal and negative phenomena in the electronic network, particularly the dissemination of false information. The Act, authored by the European Union, takes fulsome measures regarding cybercrimes, thus ensuring maximum protection to the public, maintenance of the citizens' rights and a dignified model for the operation of online platforms. The DSA takes care of the concerns of the consumer with the help of very clear and appropriate rules. It not only backs growth and encourage entrepreneurial activity but is also attuned to the needs of smaller platforms and new start-ups. Finally, DSA makes sure all perspectives and roles are taken into consideration, within the values of the European society and the public's interest particularly the citizens.
Digital Markets Act (DMA) [63]	EU Level	Digital Markets Act (DMA) is an initiative taken by the European Union to address digital market fairness and competition issues within the digital sector. This act is laid down with the aim of finding and establishing objectively, large digital platforms whose activity needs to be "watched and possibly regulated" which in this context is described as 'gatekeeping'.

		A gatekeeper's role under the DMA is twofold: it includes both positive measures, or "do's," to promote desirable objectives, and negative measures, or "don'ts," to restrict certain conduct. The DMA is one of the first legal frameworks to address the issue of digital platforms' gatekeeping power. As such, it works in conjunction with the competition rules applicable within the European Union, which remain essential for the full implementation of this Regulation.
Data Governance Framework by DAMA [64]	International	The Data Management Body of Knowledge (DAMA-DMBOK) by DAMA International is an exhaustive framework for data management. Developed by DAMA International, a non-profit organization committed to advancing data management concepts and practices, it serves as a cornerstone resource in the field. While primarily focused on data management, DAMA's framework includes guidelines for data governance, including data sharing, data stewardship, and data quality management, to ensure effective and responsible use of data assets.
OECD Recommendation on Enhancing Access to and Sharing of Data [65]	International	The OECD provides evidence-based analysis and recommendations to help governments manage policy tensions and unlock the full benefits of data for economic growth and societal well-being, while also protecting the rights and interests of individuals and organizations. The OECD Recommendation on Enhancing Access to and Sharing of Data is the first internationally agreed set of principles and policy guidance on how governments can maximize the cross-sectoral benefits of all types of data while safeguarding these rights.
US Federal Government Data Sharing Frameworks [66]	National, United States of America	The US government has established frameworks and guidelines for sharing government data, such as the Data.gov initiative, Federal Data Strategy, and various agency-specific data sharing policies, to promote data-driven decision-making, innovation, and collaboration across government agencies and with external stakeholders. The above frameworks provide guidance and best practices for establishing governance structures, policies, and processes to enable responsible, secure, and effective sharing of data across different sectors, domains, and jurisdictions. Organizations can leverage these frameworks to develop customized data sharing governance strategies aligned with their specific needs, objectives, and regulatory requirements.

The table highlights that the EU-level frameworks, including the Data Governance Act (DGA), Data Act, and AI Act, form a comprehensive data ecosystem. The DGA establishes processes to encourage voluntary data sharing and "data altruism," while the Data Act focuses on data exploitation and regular use to ensure equitable access across the EU. The AI Act sets stringent regulations for AI systems, balancing innovation with public safety and citizens' rights. Supporting initiatives like the SITRA Rule Book and IDSA Rulebook provide operational tools, templates, and compliance guidelines, fostering trust and enabling ethical data use in data spaces.

Additionally, EU regulations, such as the General Data Protection Regulation and the Digital Services Act (DSA), ensure robust privacy protections and safeguard against misinformation and cybercrimes. The Digital Markets Act (DMA) focuses on regulating gatekeeping behaviours in digital platforms to promote competition.

National frameworks, such as Ireland's Data Sharing and Governance Act (DSGA) and the UK's Data Sharing Governance Framework, provide country-specific guidelines for managing personal data securely and responsibly. The DSGA emphasizes transparency through mandatory Data Sharing Agreements (DSAs), while the UK's framework extends GDPR provisions to ensure compliance and mitigate risks in inter-agency data sharing.

The Finnish **Traffic Data Ecosystem Rulebook** adopts principles from the SITRA Rule Book, fostering stakeholder collaboration in the traffic sector. Similarly, Australia's **Data Sharing Principles** and the US **Federal Data Strategy** aim to ensure privacy and security while encouraging cross-sectoral data sharing for innovation and decision-making.

The table also shows that global frameworks like the **OECD Recommendation on Enhancing Access to and Sharing of Data** and DAMA's **Data Governance Framework** provide universal principles for responsible data management. These emphasize maximizing data's societal benefits while safeguarding rights, offering cross-sectoral guidance adaptable to diverse regulatory environments.

6.5 Data Governance Authority

Data governance authorities operate across international, regional, and national levels, each tailored to address the unique challenges of their jurisdiction. These authorities are tasked with implementing frameworks that promote transparency, enforce compliance with data protection laws, and facilitate the responsible sharing of data across sectors. Prominent examples include the European Data Protection Board (EDPB), which enforces GDPR across the European Union; the Office of the National Data Commissioner (ONDC) in Australia, which governs ethical data sharing; and Ireland's Data Governance Board, which ensures secure data handling in public services.

In this section, we study the roles, functions, and frameworks of widely recognized data governance authorities, highlighting their contributions to creating a secure and interoperable global data ecosystem. By analysing their governance models and operational principles, we seek to understand how these authorities address the complex interplay between data innovation, security, and compliance in a rapidly evolving digital landscape. Table 18 shows the list data governance authorities.

Table 18 Data governance authorities

Name of Authority	Roles	Location (Country/Region)	Functions
Data Governance Board (Ireland)	Oversee data sharing under the Data Sharing and Governance Act (2019).	Ireland	Promotes transparent data-sharing agreements, ensures GDPR compliance, and monitors public data usage.
European Data Protection Board (EDPB)	Enforces GDPR across EU member states.	Europe	Oversees cross-border data protection issues, provides guidance on GDPR compliance, imposes penalties.
Office of the National Data Commissioner (ONDC, Australia)	Regulates data sharing under the Data Availability and Transparency Act (2022).	Australia	Ensures ethical data sharing, fosters innovation, and protects privacy and confidentiality.
International Data Spaces Association (IDSA)	Sets standards for secure and compliant data spaces.	International	Develops frameworks for interoperability, trust, and secure data exchange in data ecosystems.
Sitra (Finland)	Promotes ethical and fair data-sharing practices.	Finland	Provides contractual templates, governance tools, and guidance for creating fair data-sharing networks.
National Institute of Standards and Technology (NIST, USA)	Develops standards for information management.	USA	Creates data governance models, including privacy frameworks, to enhance data security and resilience.
Data Protection Commission (DPC, Ireland)	Enforces GDPR compliance in Ireland.	Ireland	Investigates breaches, provides guidance, and imposes sanctions for non-compliance.
Data Governance Agency (France)	Oversees data sharing and management within public and private sectors.	France	Implements the National Data Strategy, promotes interoperability, and ensures data quality.
UK Information Commissioner's Office (ICO)	Ensures compliance with Data Protection Act 2018 and GDPR.	United Kingdom	Provides guidance, investigates breaches, enforces penalties, and supports public awareness.
OECD Data Governance Working Group	Develops international guidelines for data governance.	International	Provides policy recommendations, best practices, and analytical frameworks for data governance.
Open Data Governance Board (ODGB)	Provides strategic leadership for open data governance.	Ireland	Enhances public bodies' capacity to implement open data, identifies opportunities for maximizing public sector data, and advises the government on strategies for economic, social, and democratic benefits.

The table highlights the diverse roles and functions of key data governance authorities across global, regional, and national levels. These entities collectively demonstrate the critical importance of robust governance structures in managing data ethically, securely, and effectively.

Authorities like the **European Data Protection Board (EDPB)** and the **OECD Data Governance Working Group** set international and regional standards for data governance. Their focus on harmonized regulations, such as GDPR, ensures consistency across borders, promoting trust and compliance in an interconnected digital

landscape. The presence of entities like the **International Data Spaces Association (IDSA)** underscores the need for interoperability and secure data sharing frameworks in cross-border data ecosystems.

National-level authorities, including Ireland's **Data Governance Board** and the **Open Data Governance Board (ODGB)**, emphasize tailored approaches to address country-specific needs. For instance, ODGB focuses on leveraging open data for economic and social benefits, while the **Office of the National Data Commissioner (ONDC)** in Australia ensures ethical data sharing in public services. These bodies demonstrate how national governance can align with broader international principles while addressing localized challenges. Specialized authorities, such as Finland's **Sitra** and the **National Institute of Standards and Technology (NIST)** in the USA, provide targeted tools and frameworks for specific sectors. Their focus on ethical data sharing and security standards supports innovation while ensuring compliance with privacy and data protection laws.

Across all levels, a common theme is the prioritization of privacy, transparency, and ethical data use. However, challenges such as achieving interoperability, fostering collaboration across jurisdictions, and balancing innovation with regulation remain central concerns.

7 Synergies Between MDS and MaaS

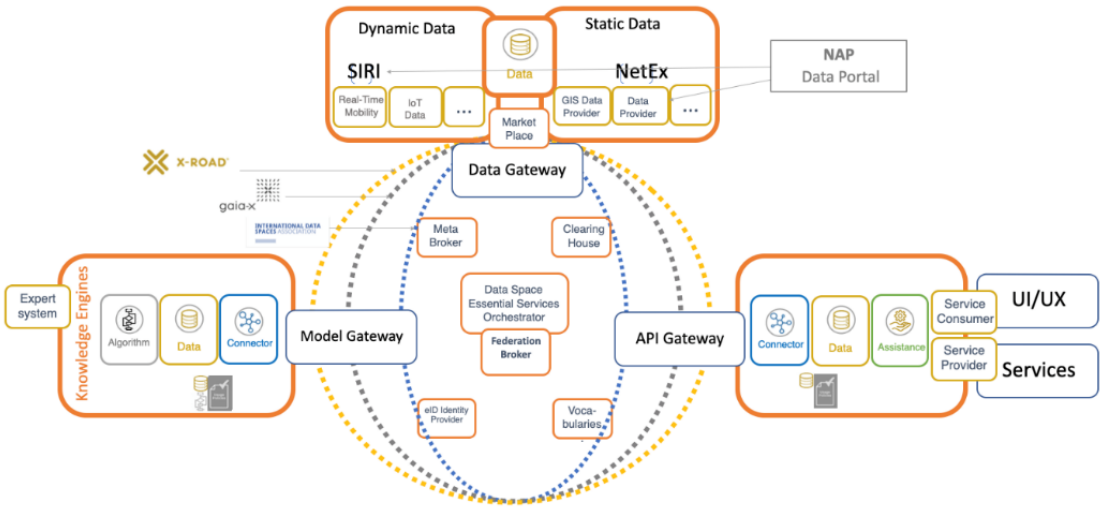
Key takeaways from this section

- Learn how mobility data spaces function as integrated solutions to facilitate secure data sharing and enhance the efficiency and interoperability of the MaaS ecosystem.
- Explore the advanced technologies, such as decentralized storage, data cataloguing, and secure data exchange protocols, that are foundational to building effective mobility data spaces.

7.1 MDS Powered MaaS – An Integrated Solution

MDS is emerging technology for sharing data within the evolving data ecosystem, playing a crucial role in the sustainable expansion of MaaS. By offering a decentralized infrastructure, MDS facilitate equitable and trustworthy data-sharing models, which are essential for addressing the pressing challenges in today's mobility landscape.

Figure 2 Topology overview of Mobility Data Spaces



One of the key challenges MDS addresses is ensuring interoperability across various systems, including data formats, protocols, and connectivity. This is vital for creating a seamless user experience, allowing different mobility platforms to communicate and operate cohesively. Furthermore, MDS aim to establish clear governance and legal frameworks that define the agreements necessary for implementation. This clarity is fundamental for all stakeholders involved, providing the legal backbone that fosters collaboration and innovation. The figure below shows a generic topology of how an MDS empowers the mobility services [67].

The depicted topology of a standard MDS, as illustrated in Figure 2 (Source: Olaf-Gerd Gemein, truzzt Alliance, 2022 Dublin), embodies the primary design principle of a Data Space acting as a trusted federator or aggregator of data and data services. This fundamentally distinguishes a data space from data platforms, portals, warehouses, hubs, or lakes. At its essence, the Data Space serves as a service orchestrator, encompassing core functions such as meta-brokering, acting as a clearing house, providing identity, and offering vocabulary services.

MDS enable a unified framework for seamless data exchange and integration across diverse MaaS platforms. This harmonization is essential for ensuring that data flows freely between systems, facilitating real-time updates and responsiveness to user needs [68]. It enhances data accessibility. By improving access to MaaS-related data, MDS ensure that stakeholders—including mobility providers, planners, and researchers—can derive valuable insights to inform decision-making processes. This accessibility not only supports operational efficiency but also enhances the ability to innovate new services and improve existing ones.

Standardizing data formats and structures is vital for enabling seamless communication between different systems. By ensuring that data is presented in a consistent manner, MDS promote coherence and compatibility across the mobility ecosystem, allowing for easier integration of new services. Establishing trust is the unique value of MDS. Trust is a crucial element in data-sharing arrangements. MDS can cultivate trust within the MaaS ecosystem by providing standardized templates for defining and negotiating business terms related to data sharing. This streamlining reduces friction in partnerships and encourages collaboration among diverse stakeholders.

Furthermore, the robustness of MDS frameworks and protocols ensures that MaaS services are not only replicable but also reliable. By promoting consistent implementations across different regions and service providers, MDS enhance the dependability of mobility services, which is vital for user satisfaction [69].

Moreover, MDS encompass a diverse array of stakeholders. The stakeholders involved in MDS includes travellers, mobility providers, data aggregators, and facilitators. Each group has distinct requirements and expectations, and MDS must address these to foster a functional ecosystem. Importantly, competition among mobility providers can drive down costs for consumers, enhancing the attractiveness of MaaS offerings [72]. An intriguing aspect of MDS is their potential to enable **geographic roaming** features, akin to mobile phone contracts. This functionality would allow travellers to utilize their preferred mobility services seamlessly across different regions, thereby improving the overall user experience and convenience [70].

7.2 Key Technologies of Mobility Data Spaces

Data spaces amalgamate governance and infrastructure to facilitate the pooling and sharing of data in a controlled and secure manner. The MDS establishes the benchmark for data sharing. It seamlessly connects data providers and data consumers of mobility data while establishing a framework for collaboration rooted in trust.

Leading MDS technologies typically adhere to a set of established design principles, including interoperability, data sovereignty and trust, data value, and governance. These technologies universally incorporate three fundamental features: enabling seamless data access, facilitating data sharing among participants within the data space, and augmenting the overall value of the data assets. Table 19 outlines some best technologies include data sharing platform, data space connector, clearing house, and broker.

Table 19 Mobility data sharing technologies

Technology	Type	Description
iSHARE [45]	Platform	An integrated set of agreements for identification, authentication, and authorization, facilitates seamless data access between organizations. Originally pioneered by the Dutch transport and logistics sector, this framework is now expanding its reach into new sectors and even crossing international borders.
IDSA Data Space Protocol[46]	Protocol	The IDSA Dataspace Protocol comprises a series of specifications meticulously crafted to streamline interoperable data sharing among entities. Governed by usage control and grounded in web technologies, these specifications delineate the schemas and protocols necessary for entities to publish data, negotiate usage agreements, and access data within a federation of technical systems, collectively termed a dataspace.
Gaia-X[47]	Infrastructure	Gaia-X stands as a European initiative committed to constructing a federated and highly secure data infrastructure, with the primary objectives of advancing data sovereignty, interoperability, and innovation. At its core, Gaia-X aims to establish a robust and transparent digital ecosystem, empowering individuals, enterprises, and governmental bodies to securely and meticulously share and harness data resource.
FIWARE[48]	Platform	FIWARE is an open-source platform engineered to drive the development of intelligent solutions and applications for the digital economy. Its core mission is to provide developers, companies, and cities with a comprehensive framework and a suite of standardized technologies. This empowers them to efficiently build and deploy innovative digital solutions while reducing costs.
EONA-X[49]	Platform	EONA-X, the global data space for Mobility, Transport, and Tourism, is designed to facilitate data exchange, ultimately enhancing the safety, planning, sustainability, comfort, resilience, accessibility, and enjoyment of all related activities. This initiative opens opportunities for economic growth and improved service quality, both nationally and internationally. When it comes to tourism, it is worth noting that the sector consists of

[45]https://ishare.eu/
[46]https://internationaldataspaces.org/offers/dataspace-protocol/
[47]https://gaia-x.eu/
[48]https://www.fiware.org/
[49]https://eona-x.eu/

		many players, particularly SMEs, who often have limited capacity for digital investment.
Catena-X[50]	Platform	Catena-X is the first open, collaborative, and decentralised data ecosystem for the automotive industry, built on common standards and shared principles. The Catena-X data ecosystem consists of three areas: the Catena-X Automotive Network e.g., the development environment, and the operating environment.

8 A Consolidated Observation of MaaS, MDS, and Governance and Regulatory Frameworks

Data sharing lies at the heart of modern innovation ecosystems, enabling organizations, governments, and individuals to collaborate effectively and unlock new possibilities. The ability to securely and efficiently share data drives advancements across sectors, including mobility, healthcare, energy, and beyond. In the context of transportation, data sharing is more than a technical necessity—it is a foundational element for creating integrated, user-centric, and sustainable systems.

MaaS exemplifies how data sharing can transform urban mobility. By integrating journey planning, ticketing, and payment systems across various transport modes, MaaS provides seamless, personalized travel experiences. This vision, however, cannot be realized without robust frameworks for data sharing, which ensure interoperability, real-time collaboration, and the secure exchange of information among diverse stakeholders. Successful MaaS initiatives rely on open, standardized, and well-governed data sharing ecosystems, where public and private entities contribute and utilize data to optimize transportation networks.

Mobility Data Spaces emerge as the technological and operational response to this imperative. MDS are structured environments that facilitate secure, interoperable, and standardized data sharing between stakeholders, acting as enablers for MaaS systems. They offer a cohesive framework to harmonize data from public agencies, private operators, and third-party developers. MDS allows real-time and historical data to converge, enabling transport operators to manage congestion, improve service efficiency, and enhance user experiences. International examples such as the German Mobility Data Space (GMDS) illustrate the potential of MDS to serve as the digital backbone of mobility ecosystems, fostering innovation and collaboration.

Governance and regulatory frameworks are indispensable for achieving secure and ethical data sharing. Frameworks like the European Union's Data Governance Act (DGA) and General Data Protection Regulation (GDPR) set clear rules for how data can be accessed, shared, and utilized. These regulations protect individual privacy while promoting interoperability and innovation, balancing the dual goals of safeguarding rights and fostering economic development. On a national level, Ireland's Data Sharing and Governance Act (DSGA) exemplifies how countries can align local policies with international standards to create a robust and transparent data-sharing environment. Such frameworks establish trust, ensuring that data sharing serves societal, economic, and technological interests.

[50]https://catena-x.net/en/1

The challenges of implementing data sharing frameworks are significant but surmountable. Fragmented governance structures, the absence of standardized data protocols, and technical gaps in digital infrastructure hinder seamless integration and collaboration. Moreover, public resistance to data sharing, often rooted in concerns over privacy and misuse, highlights the importance of transparent governance and effective communication strategies. Addressing these challenges requires investments in technology, infrastructure, and public education, as well as a collaborative approach that brings together policymakers, industry leaders, and civil society.

Public-private partnerships play a pivotal role in bridging these gaps. Collaboration between governments, private mobility providers, and technology developers ensures that data sharing initiatives are aligned with both public interest and market innovation. Examples from Finland and the Netherlands demonstrate how partnerships can foster operational efficiencies, create user-centric solutions, and drive sustainable mobility innovations. These cases underline the need for shared goals, mutual trust, and a common commitment to ethical data practices.

Ireland stands at a promising juncture in adopting advanced data sharing frameworks to enhance its mobility sector. With strong alignment to the EU's Digital Decade strategy and a growing emphasis on sustainable transport solutions, the country is well-positioned to harness the potential of MaaS and MDS. However, achieving this vision requires a concerted effort to address governance, technical, and public engagement challenges. Learning from international best practices and fostering an inclusive approach will be critical for Ireland to build a mobility system that is not only efficient and sustainable but also resilient and future ready.

Ultimately, data sharing is not merely a technical capability but a strategic enabler of economic, societal, and environmental progress. Its effective implementation requires robust governance, collaborative partnerships, and an unwavering commitment to transparency and trust. By embedding these principles into its data sharing frameworks, Ireland and other nations can lay the foundation for transformative, inclusive, and enduring mobility ecosystems.

9 Conclusion

This deliverable provides a comprehensive review of the current state of play in Mobility Data Spaces and MaaS, offering critical insights into their deployment and operational dynamics. MaaS applications are predominantly implemented at the local or town level, where robust and attractive alternatives to private car usage exist. The integration of pre-existing transportation offerings in each area is a key determinant of what MaaS can successfully provide, underscoring the importance of leveraging existing infrastructure and services.

The analysis reveals that while MaaS schemes exhibit diverse attributes such as personalization, customization, and flexible tariff options, certain commonalities emerge. These include the modes of transport incorporated into MaaS platforms, the core functionalities offered—such as real-time information, trip planning, booking, and ticketing—and the technologies employed, including e-payment systems, GPS, e-tickets, and real-time data integration. However, operationalizing MaaS in an urban setting requires critical components such as reliable public transportation services, diversified and efficient mobility modes, open data, a robust data exchange infrastructure, and integrated e-ticketing and payment systems.

Data sharing serves as the linchpin of contemporary mobility systems, facilitating a seamless and user-centric experience while driving innovation and efficiency. The comprehensive review in this document highlights the critical role of Mobility Data Spaces in operationalizing data sharing, which is essential for the success of MaaS. By providing secure, interoperable environments for data exchange, MDS enables stakeholders to collaborate effectively, creating the foundation for integrated mobility ecosystems. The examines how MaaS leverages MDS technologies to offer services like real-time journey planning, ticketing, and payment, integrating diverse transport modes into a cohesive system. This integration is particularly crucial in urban areas, where efficient, multimodal mobility can alleviate congestion, reduce emissions, and enhance user convenience.

The report further outlines the indispensable role of governance and regulatory frameworks in shaping the landscape of MaaS and MDS. These frameworks ensure compliance with data protection laws, such as GDPR and the Data Governance Act, while fostering an environment that balances innovation with public oversight. The analysis underscores the necessity of governance models that accommodate both public policy objectives and the flexibility required for private sector innovation. Examples include the commercial integrator model, the open platform approach, and the transport-as-integrator model, each offering unique advantages and challenges.

The review also discusses the critical role of public awareness and effective communication strategies in MaaS implementation and adoption. The complexity of the MaaS concept can create barriers to passenger understanding and acceptance. Clear communication, including detailed explanations of packages and step-by-step guidance on usage, is essential to mitigate public reluctance. Continuous engagement through awareness campaigns and targeted communication methods is vital, not only during the initial launch but also in sustaining long-term adoption and trust.

The report also sheds light on the challenges facing MaaS implementation, such as fragmented transport infrastructures, data-sharing reluctance, and insufficient integration. The report identifies critical enablers, including comprehensive digital infrastructure, open data policies, and user-centric designs, to overcome these barriers.

In envisioning the future, the review anticipates advancements in MaaS features, such as incentive-driven modal shifts, guaranteed service continuity, and interoperability across urban regions. These developments could transform MaaS from a local initiative into a scalable, international framework, aligning with broader sustainability and mobility goals.

In conclusion, the document argues convincingly that data sharing, enabled by MDS, is the backbone of MaaS and modern mobility solutions. By integrating robust governance models, advanced technologies, and strategic partnerships, MaaS can become a catalyst for sustainable, efficient, and inclusive transportation systems. The insights provided offer a roadmap for leveraging MDS to realize the full potential of MaaS, underscoring the transformative impact of data sharing on the future of mobility.

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