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Unlocking
the Future of Mobility
with European Data Spaces

Urban Mobility
Next 10

November 2023

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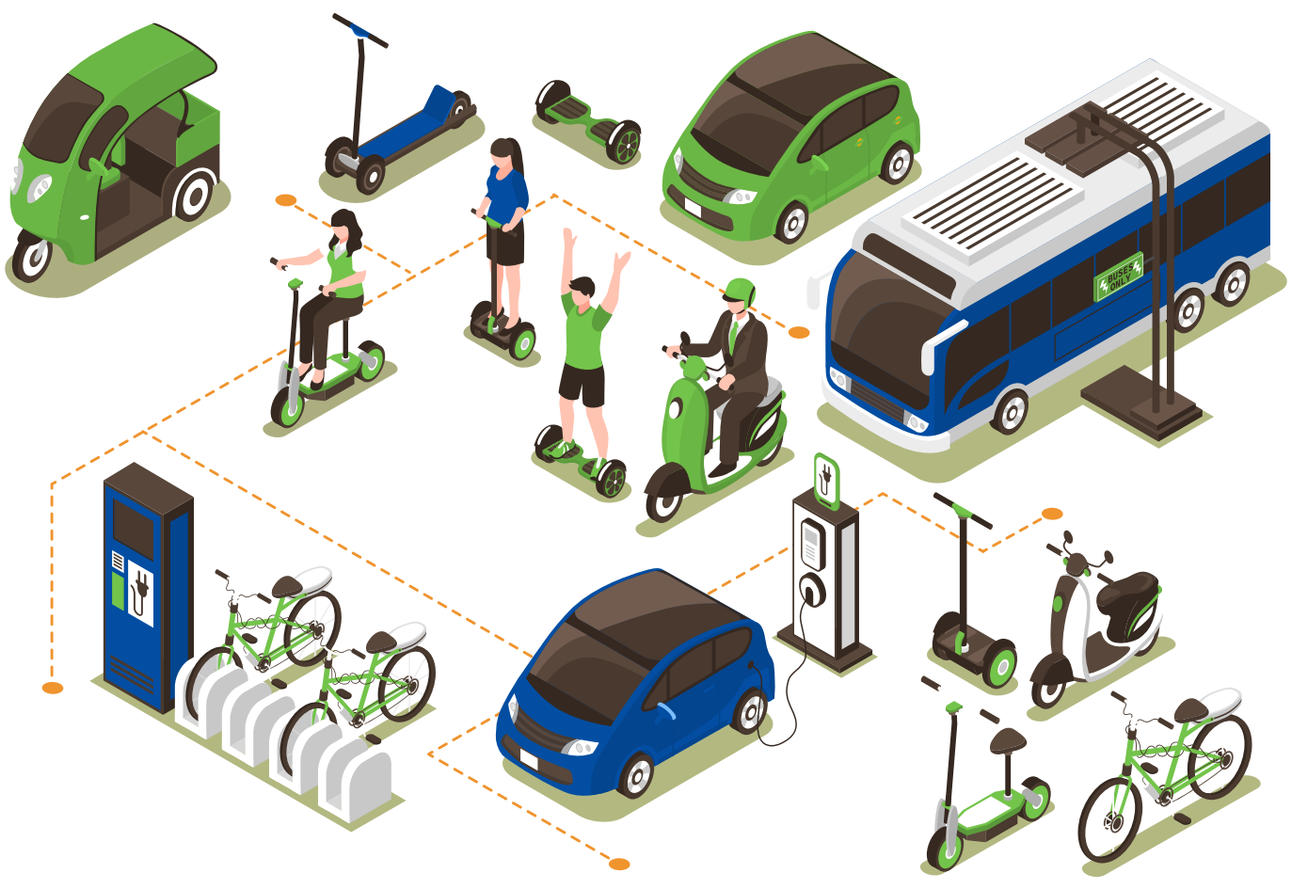

EIT Urban Mobility

November 2023

EIT KIC Urban Mobility S.L.

Torre Glories, Diagonal 211

08018 Barcelona

Spain

Contact

Yoann Le Petit

Thought Leadership Manager

yoann.lepetit@eiturbanmobility.eu

Karma Islam

SIG Officer

karma.islam@eiturbanmobility.eu

eiturbanmobility.eu

Co-funded by the European Union

Authors of the study

FACTUAL

Josep Laborda
Eglantina Dani
Luke Bates

i2cat

Jim Ahtes
Rizkallah Touma

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Additional references from events, reports and shared insights included in the appendix.

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Executive Summary

Data is a key strategic asset in the framework of the European Strategy for Sustainable and Smart Mobility. Leveraging it will support priorities such as improving road safety, promoting alternative or complementary modes to private cars, mitigating the negative externalities of transport, as well as boosting advanced and personalised mobility services based on digitalisation, such as demand-responsive transport or the application of algorithms based on artificial intelligence.

To move towards this vision, it is essential to prioritise greater availability and accessibility to data, and to promote trusted environments for secure data sharing.

With this in mind, the European Commission's European Data Strategy backs the nascent concept of data spaces that complements a new generation of regulation that will facilitate these goals. Data spaces are ecosystems that facilitate the voluntary, sovereign and secure sharing of data. Both in mobility and in other strategic sectors (tourism, energy, health, agri-food, etc.), data spaces promise to enable new public and commercial business models and services by unlocking access and availability to existing data while respecting usage control and privacy for data owners.

The 'hype' around this novel concept is therefore understandable, with analysts already placing mobility data spaces on the renowned Gartner Hype Cycle curve.[1] This is representative of the increasing awareness and understanding of mobility data spaces, but more importantly it suggests that this technology is still in the early innovation phase and is expected to evolve rapidly in the next 10 years.

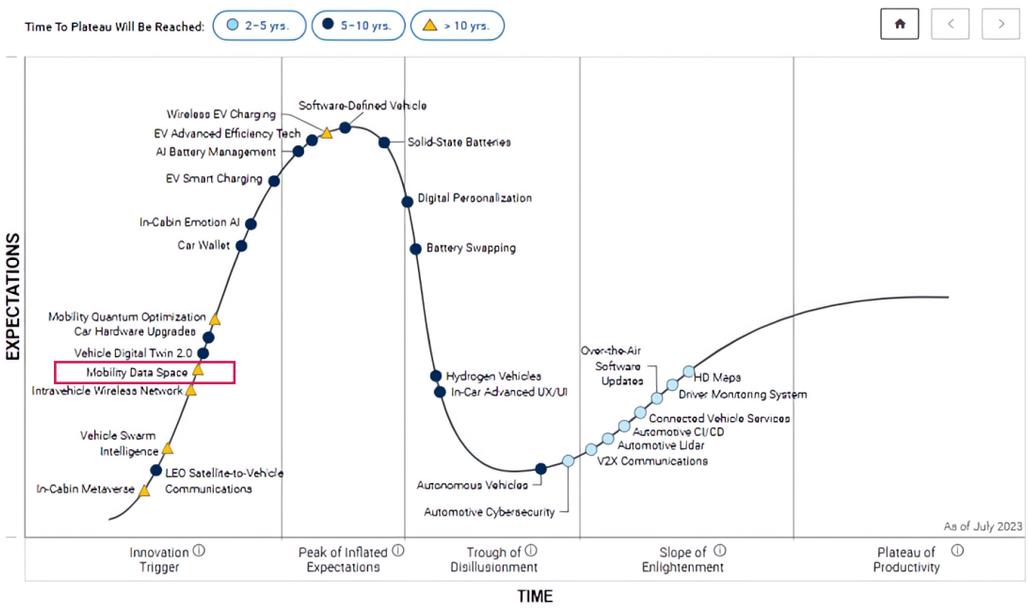


Figure 1: Mobility data spaces presented as an Innovation Trigger for automotive technologies on the Gartner Hype Cycle curve (July 2023)

That said, it is true that transformative technologies rarely follow such a common trajectory and in reality it is much harder to assess the rate of mass adoption. What this iteration of the Gartner Hype Cycle does show, however, is that mobility data spaces are not going unnoticed, and that it is fair to question whether all of their promised potential will be reached. This is why this study explores the foreseen challenges in developing, deploying and operating mobility data spaces in more detail, analysing the commercialisation aspects of transitioning from conceptual design, to piloted innovation, to sustainable, in-production service model. The technology itself is homegrown in Europe through various initiatives, forums and standardisation groups. It is now in an accelerated development and convergence phase between complementary and overlapping visions, coupled with the piloting of new governance models that are key to a data space's operation encompassing public and private sector actors in mobility value chains.

As with most technological advances, this stage in product development is where attracting private sector interest and investment is the most critical. From MaaS solution providers to freight operators to large OEMs, businesses in the mobility sector are generating and aggregating increasingly large volumes of proprietary data. In these new trusted environments that data space can provide, win-win business models with clear incentives will have to be defined to help overcome resistance to change in a historically conservative and data-protective industry culture, as well as provide a sufficiently attractive 'carrot' - the ROI (economic and strategic) to warrant such investment.

It is also important to remember the role of the 'stick' - in this case, regulation. The European Commission has taken an ambitious approach to a future data economy and has already introduced important transversal regulation such as the Data Governance Act and Data Act, providing an urgent and potentially costly adaptation of platforms, services and business models towards compliance (and one that data spaces can help facilitate). Meanwhile, delegated regulations under the Intelligent Transport Systems (ITS) Directive aim to drive the development of high quality mobility data at a national level through a network of interoperable National Access Points (NAPs). However, the full potential of NAPs has a long way to go, with significantly different levels of maturity between Member States in their current form. Data spaces stand to play an important role in supporting their development, especially in terms of data quality and traceability.

To summarise, mobility data spaces are a concept backed by the European Union to have the potential to positively disrupt the mobility sector towards a more efficient, sustainable and safe transport system. But will more local public and private sector actors buy into this vision? And will mobility data spaces live up to the hype? This report addresses these questions and provides a set of key recommendations for cities and businesses to assess the application of data spaces for their respective needs.

Introduction

Objectives and Methodology

This study explores the potential of mobility data spaces to transform the way people and goods move in European countries and cities thereof. This report is framed within the European vision for a data-led mobility future facilitated by data spaces to address common challenges in achieving sustainable mobility milestones.

The report's findings are primarily intended for businesses and cities looking to invest and participate in mobility data spaces, focusing on the commercial aspects of deploying impactful use cases from the ground up to sustain European mobility data spaces.

This study has the following objectives:

- Explain how a data space works, its basic components and its value proposition for cities and businesses.
- Analyse the regulatory environment relevant to mobility data spaces and assess its effectiveness in furthering the European Strategy for Sustainable and Smart Mobility.
- Explore the value chain and key stakeholders involved in shaping, setting up, and participating in mobility data spaces across different market segments, alongside their respective data sharing challenges and opportunities.
- Present a commercial assessment framework for use cases and identify business model opportunities that can unlock public-private investment to accelerate the development and adoption of mobility data spaces.
- Provide key recommendations that structure further research and future work streams on mobility data spaces.

The study has combined comprehensive desk research consisting of the review of reports, articles (scientific and media), results of events and workshops, and other resources related to various initiatives around mobility data and the emerging concept of data spaces.

Alongside this, primary research methods included a workshop with EIT Urban Mobility's Special Interest Group (SIG)* on mobility data spaces held in Köln to assess the challenges and use cases in the mobility ecosystem, an analysis of the results gathered from a comprehensive online survey, and interviews with experts who provided diverse and complementary perspectives based on their respective experiences.

*EIT Urban Mobility's Special Interest Groups (SIGs) are thematic-focused groups bringing thought leaders across disciplines together to discuss key urban mobility trends and get deeper insights on best practices and use cases that can address mobility challenges in European cities.

The online survey (Annex: survey results) was shared publicly and within the SIG member network, and received a total of 76 responses from a variety of stakeholder groups such as start-ups, public transport authorities, research organisations, etc.

Background and context: future mobility is driven by data

We live in the age of data. In Europe, more than 80% of the population already have access to mobile Internet on their smartphone, and data consumption is forecast to triple by 2028,[2] an exponential increase driven by more and more data-intensive applications and services. The possibilities provided by millions of people connected through mobile devices with unprecedented data processing and storage capacity are limitless. Disruptive technologies such as Big Data, Artificial Intelligence (AI), the Internet of Things (IoT), ultra high-speed mobile networks, nanotechnology, 3D printing and cloud-edge computing are transforming all economic sectors.

These include mobility and transportation: highly autonomous vehicles governed by AI algorithms, capable of interpreting dynamic situations on the road and making driving decisions in real time, while learning and becoming increasingly intelligent; Mobility as a Service (MaaS) ecosystems that require constant data exchange between diverse public and private sector actors; advanced remote condition monitoring and predictive maintenance systems that prolong vehicle life, increase safety and reduce disruption to rail and road freight. Technologies that generate and consume massive amounts of data. And software. Software that depends on the availability of data. Unfortunately, however, much of this data is still stored in silos and is not easily accessible, both in terms of availability as well as the diversity and lack of standardisation of methods for its acquisition, characterisation and integration. Other market and regulatory factors come into play: companies recognise the value of their data and are protective of it (yet uncertain of how to calculate its value), and EU regulation is evolving quickly but has yet to catch up to the sheer volumes of data and its complex processing. The resulting reality is a lack of transparency over data governance between organisations and control over its use.

Data is a resource that only has value if it is transformed: in the case of data, into information. But that in itself is a challenge. Raw data must be “refined”, or pre-processed, before it can be used by any algorithm or software. The data may contain inconsistent, inaccurate or incomplete information, or may not be encoded according to a standard format, not to mention data containing traces of personal information, which must be aggregated or anonymised before exploitation by any algorithm in order to preserve user privacy. Data requires an infrastructure consisting of software and hardware for its collection, processing, storage and, ideally, sharing.

These technologies can range from data centres, to databases and data lakes managed by cloud services. Data, in the vast majority of cases, is centralised: here lies one of the biggest challenges for efficient and massive data sharing in a manner that is consistent with new European regulation that protects the roles and rights of data owners, providers, intermediaries and consumers.

Data spaces, alternatively, propose a paradigm shift in the sense of decentralising data governance, providing a system that will guarantee security and control of access, management and use by data owners and providers, thus preserving "data sovereignty", a term that reflects the importance of this transformation. This, in turn, will foster an environment of trust between the various data producers and consumers, which will democratise access to more data and enable new, innovative services. But more data does not always mean better mobility applications and services. It is also essential to create an appropriate legal framework and promote an innovative and ethical data culture aligned with the needs of the economic sectors that stand to benefit.

Innovation in mobility is a 'must' considering the urgency found in strategic agendas across Europe, such as the net zero imperative, road safety and seamless multimodal travel. The effectiveness and potential impact of these innovations is underpinned by the diagnosis and evolution of current transport systems, which can only be achieved with access to larger amounts of high-quality mobility data and its secure, sovereign sharing. data spaces can provide renewed opportunity for a more informed, intelligent and sustainable mobility for Europe.

1. Primer on data spaces

1.1 What is a data space?

A data space is a federated data and service ecosystem enabling the voluntary, sovereign and secure sharing of data between different entities, such as industry, SMEs and public administrations*. The concept applies to various sectors, such as manufacturing, energy, tourism, health, and of course, the focus of this study: mobility and freight.

These data providers and data consumers participate in the data space because of mutual benefits, such as unlocking innovative data-driven services; cost savings and efficiency gains in a value chain; or working towards a common strategic goal such as decarbonisation or sustainable mobility.

But what differentiates a data space from today's data sharing approaches is that they are realised on the basis of a decentralised infrastructure following common governance, organisational, regulatory and technical mechanisms.[3][4] The result facilitates the search, access, controlled sharing and reuse of the data offered to support the data-driven services that generate added value for all participants, while lowering the risks associated in inter-organisational data sharing.

*Although the data space vision is evolving, this definition is consistent with the pioneering work on data space design in Europe, such as from the International Data Space Association and Gaia-X, as well as initial EU projects on the topic like OpenDEI (all of which are referenced in the report).

As such, data spaces form an important pillar of the EU's European Data Strategy,[5] complementing new regulation such as the Data Governance Act and Data Act as a means to evolve the ideal data economy in line with core European values around data, such as clear ownership, privacy and security.

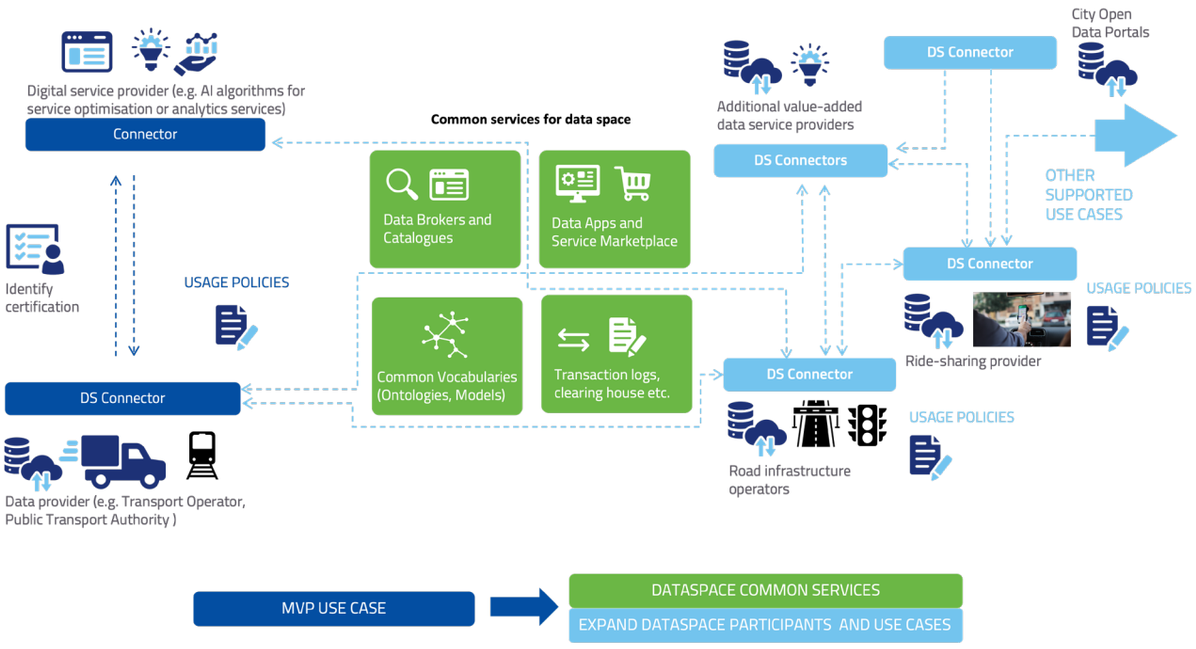


Figure 2: A conceptual visualisation of an evolving data space for mobility

From a technical point of view, the data space model can be considered an evolution of conventional data sharing and integrated solutions. Unlike conventional models that rely on a centralised data platform to facilitate data sharing, a data space has a highly decentralised and federated infrastructure, where participants can communicate directly with each other, without relying on a central node as an intermediary for all data provision and consumption. This ensures that data never leaves the provider's domain unless for a specific use that is in accordance with a pre-defined usage policy.

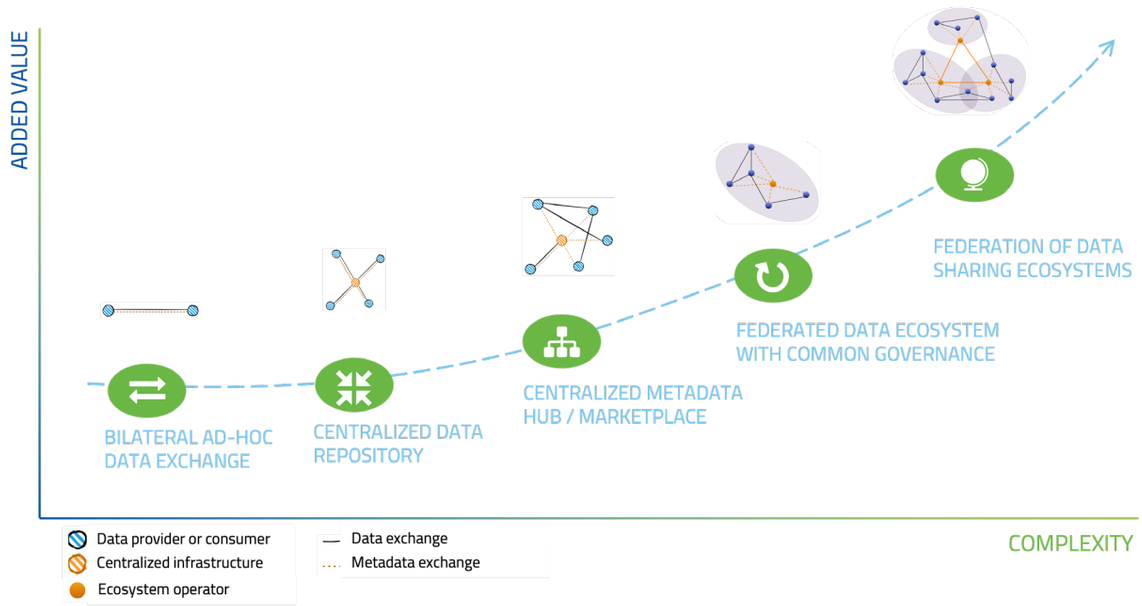


Figure 3: Evolution of data spaces towards a federated data sharing approach*

This direct communication is made possible through the use of standardised techniques and solutions, where the various participants in the data space can connect with each other through interoperable components. In addition, within the data space infrastructure, supporting actors are included to facilitate governance and ensure the trust and security of data exchange through intermediary components that are independent of any participant. Finally, this federated and fully decentralised model allows connections to be established between different data spaces to build what is known as an "ecosystem of ecosystems".

In 2021, one of the initial EU conceptual projects on data spaces, Open DEI, laid out four fundamental design principles:[6]

- **Data security and sovereignty:** data sharing security is guaranteed by means of certification processes, schemes and homologation of the participants. Likewise, each participant maintains sovereignty over the data it makes available to the different participants by defining mandatory use, access and reuse policies. In an extensive ecosystem behind a shared mobility service, for example, each data provider has control over how its data is used in an aggregated service offering.

- **A level playing field in the data economy:** a data space facilitates the entry of new players into a given sector, making available to them all the data offered by the various participants, while respecting their respective conditions and usage policies of use. This, in turn, generates incentives for new participants, allowing them to focus their efforts on the development and innovation of new digital solutions based on the available data.

*Based on an earlier version from the Spanish Government's Data Office.

For example, a start-up developing a journey planner has visibility of the data sources needed for their service, with a clear view of availability, quality, and terms of exploiting them, in fair and competitive conditions.

- **Decentralised "soft" infrastructure:** the infrastructure of a data space is not a monolithic infrastructure, but a collection of standards, reference models and software solutions that meet predefined technical, legal and economic requirements to establish secure data exchange. This reduces dependence on large monopolistic platforms as intermediaries in the mobility sector.

- **Participatory governance:** the essence of a data space is the representation of the needs and conditions of all stakeholders, both private and public, for the creation of value. From the public transport authority to the private sector ecosystem of MaaS services. This governance fosters the fluidity of the ecosystem and the development of a community around the data space.

To ensure compliance with these principles, data space design is a framework of several building blocks, covering not just the technical aspects, but the business, governance and legal, as well. The latest iteration of this common framework at the time of the report publication is the work done by the Data Space Support Centre (DSSC), as seen in the diagram below.

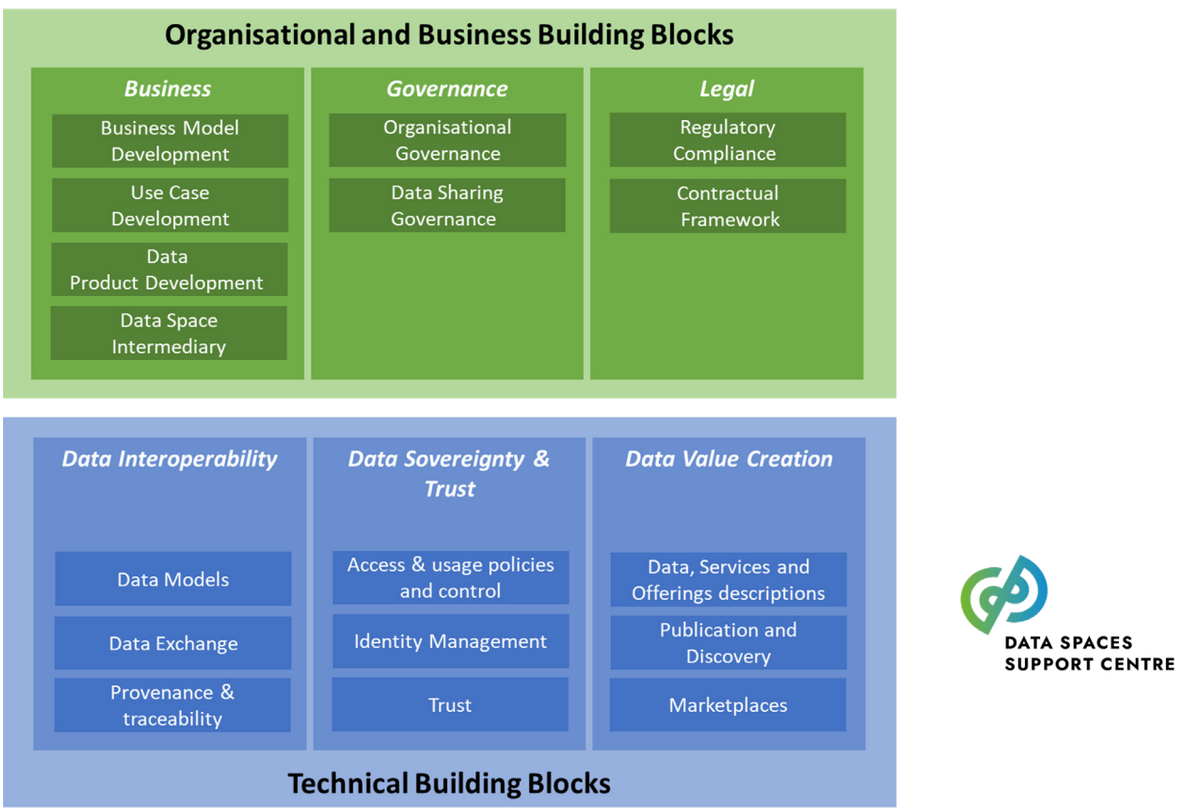


Figure 4: Data space "building blocks" framework, as part of an identification exercise by the Data Space Support Centre (DSSC)[7]
This has evolved from the original design principles for data spaces from the Open DEI initiative.

Confronting the business, governance, legal and technical aspects when developing and operating a data space is covered in more detail between Section 4 and 5.

1.2 The value proposition of data spaces

The European vision of data spaces is a nascent concept, including its application to the mobility sector. Only broad forecasts of their value potential can be made on a microeconomic (business benefits) and macroeconomic scale (national and European mobility sectors). Furthermore, the impact and return on investment (ROI) of implementing and participating in a mobility data space will vary significantly depending on the use case, participating actors, integration of legacy systems, etc.

As the first generations of pilots of European mobility data spaces are deployed, the easier it will be to assess real use cases, refine their offer and operation, and measure their respective impact on cities and businesses. Section 5 delves into the commercial challenges in more detail, and presents strategies to overcome these.

A use case connects two or more actors together for a data sharing scenario that is mutually beneficial (business and/or strategic) under specific conditions, following the decentralised approach and properties presented in the previous section. Generally, the value proposition of mobility data spaces and its use cases can be summarised into the following categories of incentives:*

- **Cost savings and operational gains:** participation in the data space leads to optimised operational and efficiency costs for the participating entity. For example, a public transport provider connecting with analytics services or other operators for multimodal integration scenarios. This also applies to logistics and supply chain cases, where pooling data in certain scenarios can provide streamlined operations across the value chain. According to the survey results collected in this study, this ranks highly as one of the common incentives across SMEs, large enterprises, the public sector and RTOs.

- **Enable new services and innovation:** participants, such as a service provider or niche solution startup, leverage the improved availability and governance of data exchange to create new services and solutions not previously available. This is especially valued by SMEs and the private sector, but also RTOs as reflected in this study's survey results. Innovation value ranks higher than monetary value across all stakeholder groups, pointing to the potential of new mobility and digital services derived from the increased access to high-quality data but also the difficulty in calculating the monetary value of data.

- **Strategic challenge:** participants in the data space share a common government-driven strategic challenge, for example, to stimulate the deployment of more sustainable mobility services, or better monitoring of related metrics (e.g. the next iteration of the EC's Sustainable Urban Mobility Indicators (SUMI) or similar in objective).

*Extended from original Data Space Support Centre topology of incentive types.

- **Regulatory compliance:** to support participants in data spaces to use established governance tools and standards to ensure that they comply with the regulatory framework. It is relevant for both a National Access Point (Intelligent Transport Systems Directive) and a service provider (Data Act). The survey results show that all stakeholder groups consistently rank regulatory compliance and meeting strategic goals as one of the most important incentives, second only to innovation value.

- **Establish and access a marketplace:** participants, for example data and MaaS service providers, connect to a data ecosystem in order to deliver their value in a more efficient, cost-effective and automated way.

The above will be relevant in different degrees depending on the specific actor of the mobility data space, but they are underlying factors that, when contrasted with the investment and costs needed, make up the incentives for setting up, operating and participating in a data space.

Mobility data spaces and digital twins: synergies and benefits for cities

In the context of urban mobility, cities and municipalities play a central role in their public-private ecosystem of mobility services.

A priority for cities is to improve the accessibility, safety, energy efficiency and environmental sustainability of the transport system. In order to achieve this, they need better visibility and information on their respective mobility systems.

By implementing and operating mobility data spaces, cities can benefit from increased access to higher-quality data from a wider range of sources. This complements the development of advanced digital twins of 'smart cities' with the capability to run predictive models and algorithms based on different scenarios that could impact the urban mobility system. For example, the potential impact of a planned construction and maintenance project on a busy central road could be modelled prior in the digital twin to optimise the duration, work schedule and scale of the activity which in turn optimises budget and costs. Furthermore, during and upon completion of such a project, data can be channelled and updated through the data space to refine the digital twin and predictive models following a circular data flow that drives continuous improvement in the accuracy of digital infrastructures of cities. The interfaces of a data space connect the simulated world of the digital twin with the data sources and data-consuming services of the real world.

Beyond this, an effective mobility data space brings structure and transparency in understanding mobility service users' behaviour and needs, which form the foundation for more efficient mobility models such as Mobility as a Service (MaaS) and smart logistics, which have so far seen their progress inhibited by fragmented data sharing between value chain actors in the mobility sector. The role of mobility data spaces in these mobility value chains is discussed in the next section on market analysis.

The direct value to cities is difficult to measure because it cannot be attributed to a mobility data space alone, rather its enabling value in complementing digital twins, and improving mobility services (including new innovative services) and supporting infrastructure, as shown in the graphic below. This argument is also echoed by the EC's Preparatory Action for a Data Space for Smart and Sustainable Cities and Communities (DS4SSCC) launched in October 2022 and the Data Space Support Centre (DSSC).[9]

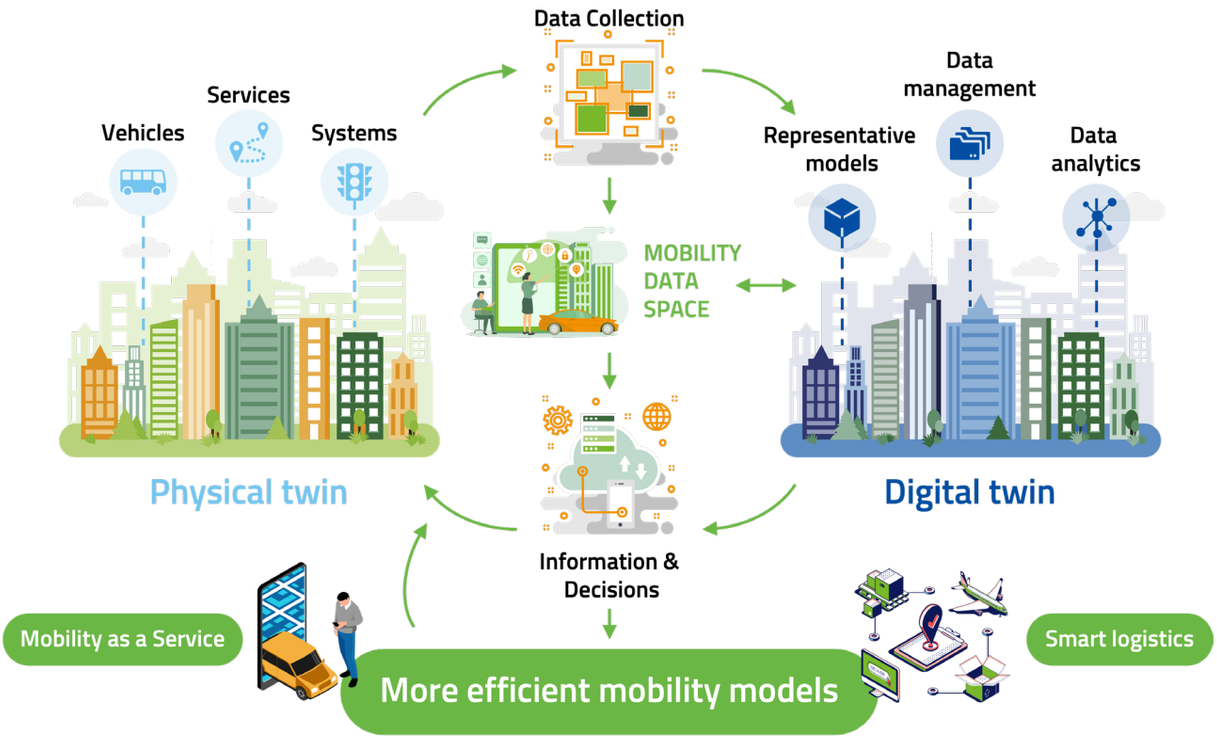


Figure 5: Conceptual model of a 'Smart City mobility data space'

Regional case study: Flanders

Flanders is one of the leading examples in Europe taking a joint approach to regional digitalisation through data spaces and digital twins. Key regional examples include the Digital Urban European Twins (DUET) and the Flemish Smart data space, which link within the Flemish government's ambition to position Flanders as a European reference in smart cities and digitalisation.[10] The DUET project in Flanders is especially relevant to this report as it is one of the digital twin pilots that focuses on smart mobility and its impact on the environment (air quality, noise levels, etc.), with integration of real-time Linked Data Event Streams (LDES) to enrich the digital twin with new data sources. Such an approach supports city planners in decision making and long-term policy development that is more effective and reliable.[11] Flanders and its local ecosystem of stakeholders are continuously evolving digital twins in the cities of Bruges, Ghent, Antwerp, Mechelen, Leuven and Roeselare.

1.3 Resolving data sharing challenges

When it comes to sharing data in a sector as complex as mobility, several challenges must be taken into account that can hinder the sharing process. These challenges can come from the nature of the data itself, both at the technical and conceptual level, and also from the context and environment in which the data is being shared. This creates demand for data spaces as a solution, as their approach and value proposition are highly applicable in addressing these challenges.

For example, the volume of data or the speed of its generation may impose difficulties at the technical level if real-time data sharing is required. Other examples of challenges related to the nature of the data would be the interoperability and standardisation of the data models used. There is also a large demand for approaches to improve data quality, as well as facilitate integration, with a growing market of data transformation and harmonisation solutions.

Such technical complexities are met also with organisational and legal challenges, especially at the level of the organisation or company providing the data, most notably as trust in sharing proprietary data or incorporating data sharing into the internal data management cycle.[12] While access control is a commonly addressed issue, better techniques are needed to ensure control over the use of data once it is shared. New EU data regulation, covered in the following Section 2, present significant new compliance requirements that cover the governance and legal aspects of these challenges.

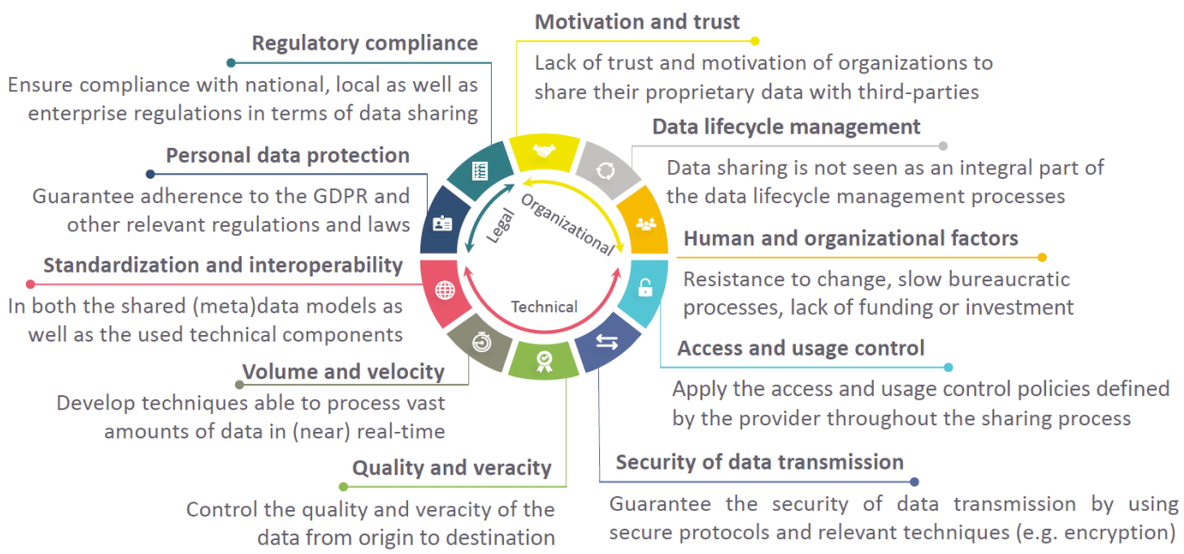


Figure 6: Technical, organisational and legal challenges around data governance

The survey carried out to support this study asked participants to rate the importance of different challenges that the data space concept can facilitate, including increased data privacy, security, trust, availability, utility, regulatory compliance, interoperability, portability and other data characterisation aspects, such as fidelity, diversity and quality. The below points summarise the survey results:

- **Privacy, security and trust** were consistently rated higher than the others ("high" or "very high" by over 85% of respondents across profiles), reflecting a strong recognition of the value of data and the need for clear guarantees for participating in such ecosystems. It is also in line with the priority core functionality of data space technology and standards discussed in Section 4.

- **Interoperability and portability** were rated with a relatively lower priority (although still with over 60% responding "high" to "very high"). Interoperability is relevant for compatibility with legacy systems as well as in the future tense, where investments on a next generation of data infrastructure needs to be one based on accepted standards. This unlocks the "big picture" of the data space vision, such as long-term scalability and integration with other data space ecosystems - undisputed requirements for the long-term European Data Strategy discussed in Section 2. Portability, the ability to migrate data assets from one platform to another, was rated in parity with interoperability.

- **Data quality** (e.g. structured) and **veracity** (e.g. reliability) were consistently rated higher than other data characterisation factors, including challenges in data volume and latency. This reflects transversal challenges across use cases, whereas latency, for example, can be highly important for some use cases (e.g. connected vehicles), while irrelevant for others (e.g. transportation schedules).

Further results are presented in the Annex.

1.4 Analysis of current European lighthouse projects developing mobility data spaces

Early-mover data spaces exist today, generally in the form of pilots of various degrees of size and maturity, including those focused on mobility and logistics. A simplified categorisation includes:

- **Lighthouse data spaces:** these are a few first generation of newly implemented data spaces operating in the pilot stage, with a decentralised architecture that follows today's developing European technical standards (Section 4). rich ecosystem of public and private sector actors providing and consuming data, an operational governance model, and multiple pilot use cases to serve as demonstrators.

- **Existing data ecosystems evolving towards a data space vision:** with various levels of ambition to adapt to the data space vision as presented in Section 1.1. Several city-based examples are following this path, such as the aforementioned Flanders initiative, as well as others such as Fintraffic,[13] an advanced data exchange initiative which has also integrated the Finnish NAP.

- **Individual use case "Minimum Viable Data Space" (MVDS):** these are individual use case implementations, often following an "MVDS" approach,[14] a term of the International Data Space Association (IDSA) a first implementation step of a data space (described further in Section 4). This can then scale to a more extensive data space.

As a guide, the IDSA Data Space Radar is a great visualisation tool that shows some of the current data space and use cases across different sectors including mobility and automotive, but also other sectors of the European economy, such as manufacturing, logistics and energy.[15]

To provide a more complete picture on the advanced lighthouse examples of the first category, four examples in the mobility sector with different approaches are presented below:

- *Mobility Data Space* (Germany) which focuses on sustainable, multimodal and safe urban mobility.
- Catena-X (Germany) that focuses on connecting supply chains in the automotive industry.
- Eona-X (France) which focuses on mobility, intercity travel and tourism.
- Rail data space (Europe) which enables and accelerates the digitalisation of the European rail system, including the integration of rail services into multimodal mobility systems for both passengers and freight.

These examples are by no means a complete catalogue. Other prominent initiatives exist, including in neighbouring sectors such as manufacturing (e.g. Industrie 4.0, an industrial data sharing network in Germany)[16] and logistics (e.g. the Smart Connected Supplier Network (SCSN) that defines a standard for communication and data sharing in the logistics sector in the Netherlands.)[17]

Mobility Data Space - Germany [18]

In November 2019, the "Concerted Action on Mobility" committee of the German federal government decided to develop its *Mobility Data Space*.* It is built from standard approaches developed in Europe, such as the International Data Space (IDS) Reference Architecture and the Eclipse Dataspace Components (see Section 4).

Its development was funded by the Federal Ministry of Digital Affairs and Transport (BMDV) and designed and coordinated by Acatech, supported by additional technical partners. Its operation has since been transferred to the non-profit DRM Datenraum Mobilität as part of its long-term commercial plan.

The *Mobility Data Space* is a growing ecosystem, with partners that include important national and international mobility stakeholders such as BMW, Deutsche Bahn, the Volkswagen Group, Mercedes-Benz and FREE NOW, as well as the regional authorities of the states of North Rhine-Westphalia and Baden-Württemberg. Initial use case pilots include smart parking, road safety and travel planning, among others, each integrating data from different sources to provide optimised services.

*When written in italics, *"Mobility Data Space"* refers to the German initiative, to distinguish it from the general "mobility data space" concept.

More recently, the German National Access Point (NAP) Mobilithek has been connected to the *Mobility Data Space,* initially providing static data such as multimodal accessibility of major German cities among other offerings. This is a very significant development for the German *Mobility Data Space,* as NAPs manage a high quantity of rich public sector mobility data that is crucial to data spaces for mobility. A NAP's integration into an operational data space is an evolution from a data aggregator and open data provider, and can improve traceability of its use, as well as support its role in consolidating data from diverse sources.

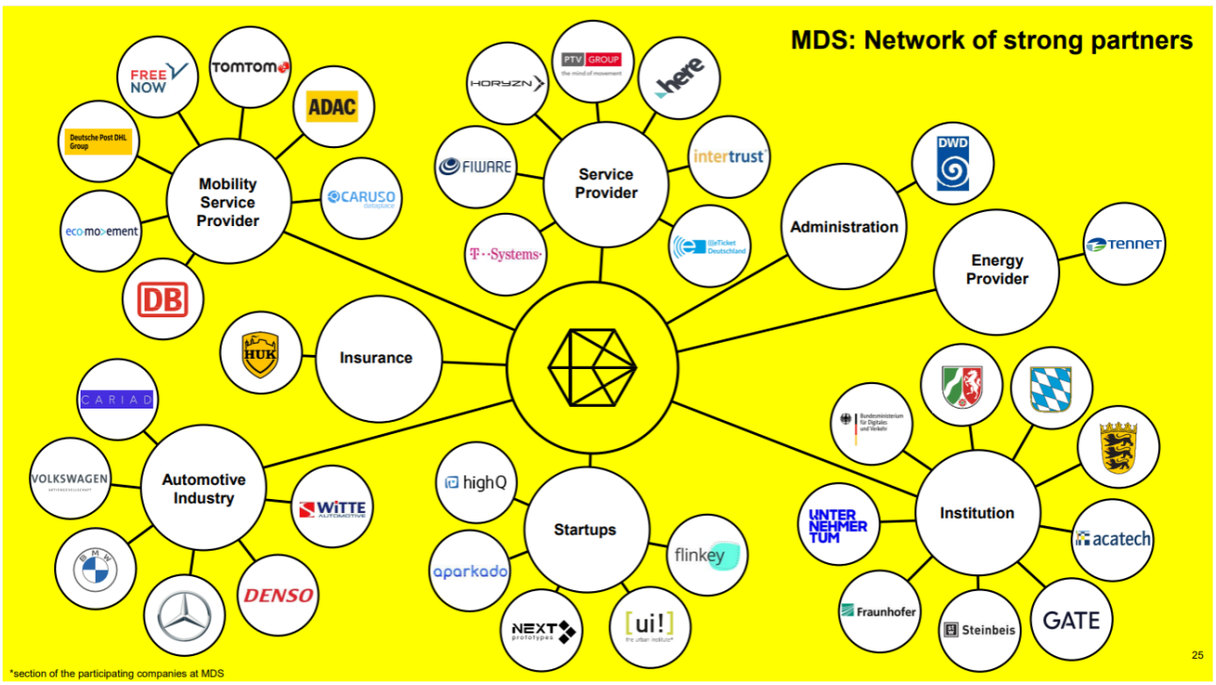


Figure 7: Example participants of the German *Mobility Data Space* (as of September 2023)[19]

The goal of the German *Mobility Data Space* is to drive innovative, environmentally sustainable and user-friendly mobility solutions by providing all users with equal and transparent access to various relevant datasets that help them derive added value from their solutions. This data space catalogue currently includes metadata on weather and infrastructure conditions, traffic and road safety data, public transport and shared mobility data among other metadata.

Currently this *Mobility Data Space* operates a "freemium" model where current and prospective participants can opt for a basic connection for free (until 2024) or a more advanced integration with a premium subscription service.

Catena-X - Germany [20]

Catena-X is a data space that aims to connect actors along the automotive supply chain in a collaborative, open and secure data ecosystem. All actors are connected in a value network, where partners are on equal footing, have sovereign control over their data and no lock-in effects occur, providing a sustainable solution for the digitisation of supply chains, especially for medium and small companies, and supporting the cooperation and collaboration of market participants and competitors.

Currently, the development around Catena-X is focused on an initial set of use cases across the supply chain, in areas such as traceability, circular economy, quality management and digital twins. These use cases address various current issues in the automotive industry, such as sustainability, simulation and traceability, and guide the development of the technical components of Catena-X.

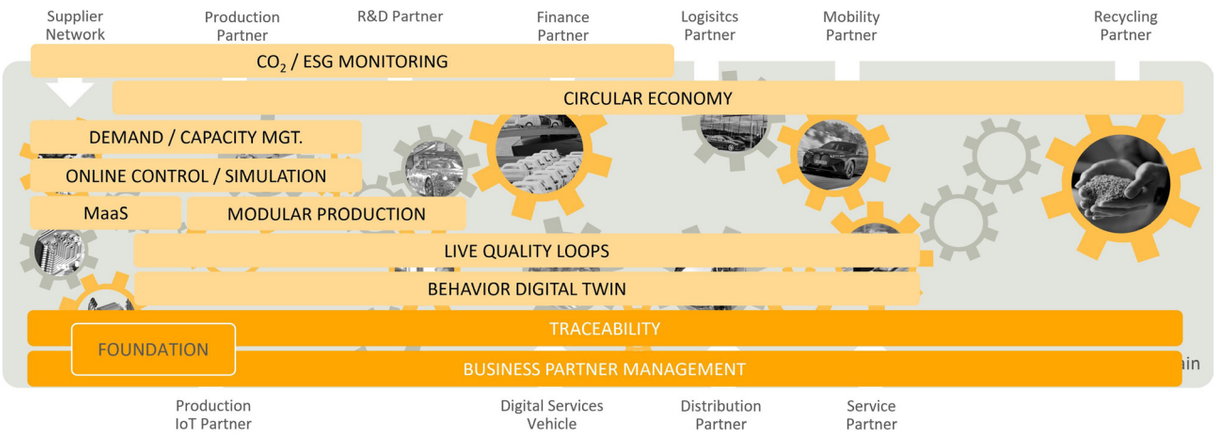


Figure 8: Initial Catena-X use cases [21]

Cofinity-X, a new joint venture, plans to bring its marketplace and onboarding services live in October 2023 to support the Catena-X network.[22]

Eona-X - France [23]

Eona-X is a data space focused on mobility, transportation and tourism data. It aims to facilitate the exchange of data in a secure and standardised environment to improve travel services, intermodal and multimodal transport, and the sustainability of its partners. With a focus on multimodal travel and intercity transport, the initiative was launched by Amadeus in France in early 2021, and already has several members from the sectors mentioned above (Air France/KLM group, SNCF, Marseille-Provence Airport (AMP), the Paris Airports group (ADP), the Renault Group and APIDAE).

Rail Data Space - Europe [24]

This is a European-wide dataspace of stakeholders in the European Rail System designed to enable and accelerate the digitalisation of rail operations in multiple domains, from energy management, assets maintenance, engineering, traffic management and more. It is in the early stages of development in Europe's Rail Joint Undertaking (EU-Rail) private-public partnership of the Horizon Europe programme, as part of EU-Rail's Motional project.

The rail system is also sought to also be a potential participant of multiple European sectoral data spaces, including energy, manufacturing, tourism and other mobility data spaces. The Rail Data Space is therefore being developed according to guidelines and leveraging building blocks common to other lighthouse projects in view of its future federation with other similar initiatives.

2. European vision and regulation for a data-driven future of mobility

2.1 Alignment with the European Strategy for Sustainable and Smart Mobility

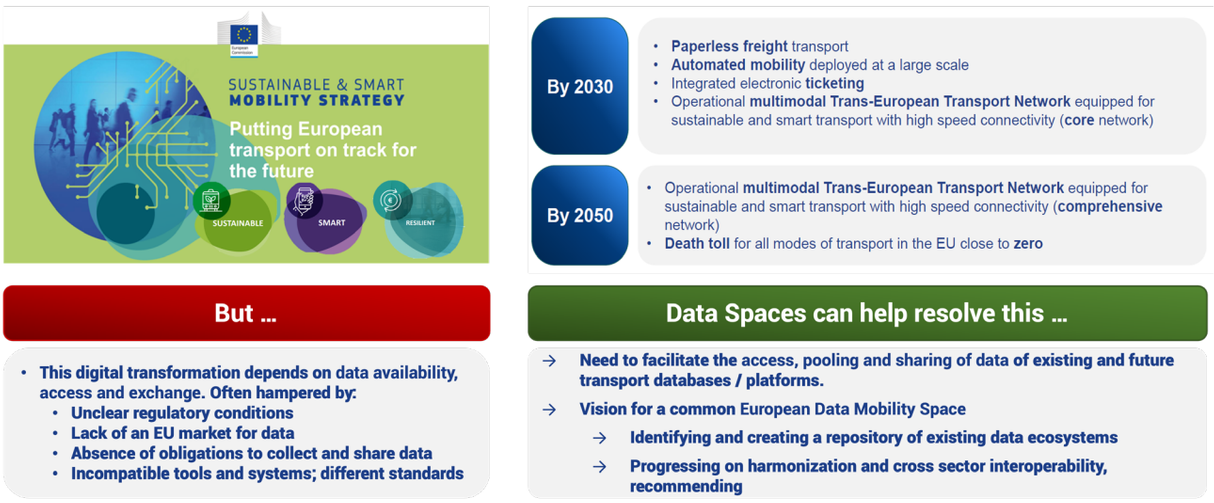


Figure 9: Data space potential to resolve challenges identified in European Strategy for Sustainable and Smart Mobility[25][26]

In the context of the **European Strategy for Sustainable and Smart Mobility,**[27] the European Commission (EC) highlights that progress towards its objectives depends to a large extent on the availability, access and exchange of relevant and high-quality data. This is currently inhibited by the ambiguity and redundancy of regulations on data use and reuse, the lack of an advanced data market in Europe, the absence of obligation on data collection and sharing, and the incompatibility between data systems, tools and standards used in different member states and initiatives related to data sharing.

Data spaces have the potential to be an effective solution to address these challenges. Specifically, mobility data spaces can bring together the different initiatives, ecosystems and actors in the sector under common standards and objectives, ensuring the availability of relevant and high-quality data for use in the economy and society, while helping companies and data generators to maintain control over their data.

This aligns with the challenges identified in the European mobility strategy under its set of actions for "Innovation, Data and AI for smarter mobility", where the EC recognises that data availability, access and exchange are key to driving digital transformation in transport and mobility.

"Currently, they are often hampered due to unclear regulatory conditions, a lack of an EU market for data provision, the absence of an obligation to collect and share data, incompatible tools and systems for data collection and sharing, different standards, or data sovereignty concerns. The availability of data and statistics is also essential, in particular real time data, as it enables better services to citizens or transparency of supply chains in freight transport." [27]

Since mobility is not only a strategic sector but also a vector that connects other economic sectors of activity (e.g. manufacturing, logistics, etc.), the relevance and potential of data spaces for mobility is even greater. This interdependency became even more visible during the various confinements and restrictions to mobility experienced during the coronavirus pandemic. Therefore, the deployment of data spaces and their interconnection has the potential to trigger a multiplier effect, as it will allow cross-referencing mobility data with data from different sectors, enabling the generation of high value-added information, as well as the development of new services and the training of AI-based systems.

In short, the creation of interoperable mobility data spaces at the European level will boost the data economy in the mobility sector, a crucial fact to achieve the objectives set by the European Strategy for Sustainable and Intelligent Mobility.

2.2 Data-related European regulation

The European Data Strategy[28] is underpinned by two key regulatory pillars: the Data Governance Act and the Data Act. While the Data Governance Act focuses on the processes and structure to facilitate data availability, the Data Act clarifies who can create value from data and under what conditions.[29] Their main objective is to make Europe a leader in the data economy by harnessing the potential of the growing amount of industrial data to benefit the European economy and society.

Data spaces are the technical approach and governance framework to facilitate the implementation of such regulations at an operational level for the public and private sector alike. This is in line with one of the principal roles attributed to mobility data spaces in progressing the European Strategy for Sustainable and Smart Mobility.

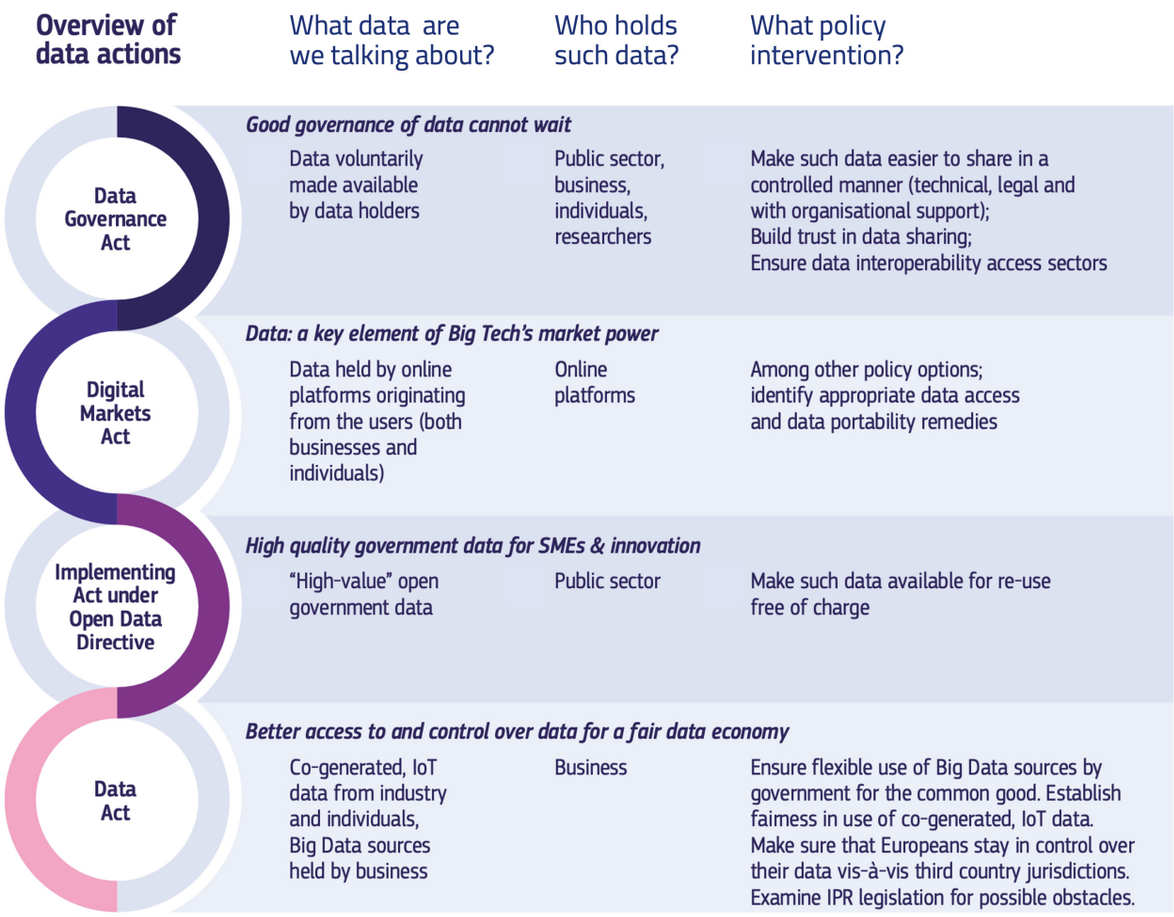


Figure 10: Overview of the legislative framework for the implementation of the European strategy for data[30]

Data Governance Act

As part of its data strategy, the EC proposed a **European Data Governance Act.**[31] This new regulation will play a key role in ensuring EU leadership in Europe's **"data economy",** fostering trust in data sharing (within and also across data spaces), reinforcing mechanisms to increase data availability and overcoming technical limitations for data reuse. Specifically, it will do so by implementing:

1. Mechanisms to facilitate the reuse of certain data sources that currently cannot be shared as open data.

2. Measures to ensure that data intermediaries function as trusted agents in the context of European data spaces.

3. Measures to make it easier for citizens and companies to make their data accessible for the benefit of society.

4. Measures to facilitate data sharing, both within and across the different strategic sectors, while ensuring that the appropriate and necessary data for each application or service is available.

The regulation was adopted on June 23, 2022 and, after a 15-month grace period, will become mandatory in late 2023.

European Data Act

Another key pillar of the EC's data strategy is the **European Data Act (Data Act),**[29] which the European Parliament and the Council of the EU recently approved on the 28th June 2023.[32] The Data Act's main objectives are to unlock industrial data and set rules on who can access what data and for what purposes they can use it across all economic sectors in the EU, ensuring fairness in the allocation of value from data, stimulating a data market in Europe, open opportunities for data-driven innovation and make more data accessible to all.[33] The new rules are expected to generate €270 billion of additional GDP for EU Member States by 2028 by addressing the legal, economic and technical issues that cause data to be underutilised.[28]

With more information, consumers and users will be in a position to make better decisions, such as acquiring higher quality or more sustainable mobility services. Greater choice among mobility service providers to process and create value from a user's data will open up the market and stimulate competition and innovation.

2.3 Mobility-specific regulations

Intelligent Transportation Systems (ITS) Directive and National Access Points (NAPs) in Europe

An important lynchpin of mobility regulation in Europe is the Intelligent Transport Systems Directive (ITS Directive 2010/40/EU),[34] which was recently revised in June 2023.[35]

A key challenge is to make urban-level traffic and travel information available and accessible in a machine-readable format to facilitate the processing and flow of data for transportation and mobility services. To facilitate this, there are four supplementary regulations in the ITS Directive:

- Delegated Regulation (EU) 2017/1926 - Multimodal travel information services (MMTIS).
- Delegated Regulation (EU) 2022/670 (substitutes 2015/962) - Real-time traffic information services (RTTI).
- Delegated Regulation (EU) 886/2013 - Safety-related traffic information (universal minimum) (SRTI).
- Delegated Regulation (EU) 885/2013 - Safe and secure parking places for trucks (SSTP).

This recent ITS Directive revision will mainly impact the RTTI[36] and take into account technological developments since 2010, such as connected and autonomous mobility (CAM), on-demand mobility applications and multimodal transport. It also aims to improve the trust, availability and interoperability of the digital data that feeds these services, a key requirement in the development of mobility data spaces.[37]

Of note, the geographical scope of the ITS Directive will be extended beyond the Trans-European Transport Network (TEN-T) to cover the entire publicly accessible road network in the EU. This will be phased in in stages, and with different timelines for specific Delegated Regulations.

This directive aims to encourage collaboration between transport operators and MaaS operators by defining the principles of standardisation and sharing of transport data, and is complemented by Commission Delegated Regulation (EU) 2017/1926 on means of access to data which provides for the creation of a framework for sharing multimodal transport service information, thus opening the door to the development of MaaS solutions. In particular, the objective is the creation of a digital architecture that allows the availability of open standards and interfaces, making both static and dynamic travel information available to all (businesses and citizens) through the creation of National Access Points (NAPs).

At Member State level, these NAPs are a requirement under the ITS Directive 2010/40/EU and its Delegated Regulations. NAPs are ensuring the implementation of standards and interfaces to enable access, easy exchange and reuse of transport-related data to help support the provision of EU-wide intermodal travel and traffic information services to end users.[38] At present, there are more than 30 operational National Access Points in almost all of the EU Member States and in other European countries.

To assist in this coordination of the various NAPs at the European level, there are projects such as NAPCORE,[39] which is co-financed under the EC's Connecting Europe Facility (CEF). NAPCORE is driving harmonisation across the NAP mobility data exchanges with a focus on interoperability based on common mobility data standards, namely: DATEX II, TN-ITS, multimodal data, metadata. This cross-border interoperability is one of the most important aspects related to the potential impact of the ITS Directive on mobility data spaces.

Impact of the ITS Directive and NAPs on European mobility data spaces

It is important to remember that NAPs, in their most basic form, are centralised mobility and infrastructure data repositories (essentially databases). As such, they can only be participants of a mobility data space. In Germany for example, the Mobilithek NAP platform[40] is already connected to the existing German *Mobility Data Space* initiative, an approach that will likely be followed by other Member States. This integration is an important catalyst for developing the MVP of a national mobility data space and the 'buy in' of new participants.

However, a recent report by the Maas Alliance suggests that some NAPs could evolve into National mobility data spaces, beyond being a data provider connected to one.[41] This might happen in cases where the population and implementation of the NAP is more advanced than any independent mobility data space plans, leading to a NAP-led mobility data space. However, so far the effectiveness of the ITS Directive in populating NAPs with high quality mobility datasets has been very limited relative to initial expectations, especially in the case of MMTIS. This can be attributed to:

1. **No sanctions incurred for non-compliance:** the 2020 Annual NAP Report,[42] showed that data providers into the NAP are mostly from the public sector data providers such as public transport authorities. Only Germany, the Netherlands and Spain had substantial contributions from private sector data providers out of the almost 30 NAPs at the time. The report also highlights that the quality and standardisation of data for multimodal travel information services (MMTIS) is quite divergent across different NAPs. Furthermore, according to the expert interviews carried out within this study, there is currently no sense of urgency or concern from cities in general to meet the impending requirements from December 2023. In fact, the data processing and upload to meet NAP requirements is often outsourced to third parties and, in some cases, even the published NAP data is not of sufficient quality so it has to be processed further before being used by its data consumers. While this argument may not apply to all Member State NAPs, this general lack of motivation to meet the data provision requirements is very likely linked to the fact that currently no penalties are imposed if NAPs fail to comply with the Directive.[43]

2. **Providing dynamic data has so far been optional:** in the case of MaaS for example, the Delegated Regulation (EU) 2017/1926 for MMTIS stipulates that all mobility services such as rail, taxi, on-demand bus, carpooling and bicycle rental have to upload all their static data (e.g. timetables) to the NAP of the country in which they operate through open digital channels before 2023. However, dynamic data (e.g. availability of shared vehicles), which underpins the model of any MaaS app, is only mandatory from December 2023 onwards. There is the risk that making this mandatory with the current centralised architecture of most NAPs only makes costs mandatory and unaffordable, particularly for smaller organisations. However, more advanced NAPs like the Mobilithek are preparing for this requirement by connecting to decentralised architectures like the German *Mobility Data Space* to facilitate dynamic data exchange.

3. **Open ticketing to third parties is currently not in scope:** specifically related to the MMTIS regulation, the ticketing re-sale and booking service contracts between mobility operators and third parties such as MaaS providers currently lack the appropriate legal and market frameworks. This is an important part of the "equation" that forms the basis of a MaaS business model, and the concern is especially related to longer-distance multimodal travel. To this end, the European Commission is currently finalising a regulation based on the proposed revision to the MMTIS regulation and ITS Directive from the initiative on Multimodal Digital Mobility Services (MDMS) led by DG MOVE. The regulation proposed has the main objective of increasing the transparency in- and standardising a framework for "commercial agreements for services re-selling mobility products", as well as for "agreements on journey continuation".[44] The former is especially important in improving the confidence mobility service operators have in opening their ticketing re-sale to third parties, as currently there is very limited transparency on how tickets are resold and other legal aspects such as liability. The latter refers more specifically to the rail sector, where services that offer combined rail offers and continuous cross-border tickets are currently seeing a very limited uptake among rail operators.

4. **Poor visibility on how NAP data is used:** on the other hand, it could also be an issue of the disconnect between the NAP data providers and the data usage phase in terms of visibility. This can lead to questions over the justification for financing data collection and management at a municipality level for example. While the objectives of NAPs are similar to that of mobility data spaces, in practice they follow very different approaches to data sharing. In the NAPs there is no data-sovereignty or automated digitally enforced governance of the exchanges (which makes data providers reluctant to comply), and there is no standard open-source or commercially available software such as the data space connector for federating proprietary legacy operators systems to the NAPs (which makes it costly). With this regard, NAPs can stand to benefit significantly from the increased transparency that connecting to a mobility data space offers in terms of visibility of the who, how, where and for what purpose their data is used. This improved connection with the 'data consumer' can help data providers within the NAP justify more concretely the reason for providing their data in a given format, time frame, among other aspects beyond the minimum requirements established within the ITS Directive and NAPCORE project.

In summary, while the potential synergies between NAPs and mobility data spaces are clear in theory, in reality the complementary impacts are currently not being realised because in most Member States these structures are emerging in parallel and not converging enough. However, it is expected that as the technology and regulation that underpins these matures, we will start to see a more joined-up approach where NAPs are federated participants in data spaces.

Electronic Freight Transport Information Regulation and e-CMR

The international transport of goods is regulated by the United Nations convention known as CMR (Convention relative au contrat de transport international de Marchandises par Route). The e-CMR is an international initiative to replace the paper CMR with a secure, digital version that is accepted by shippers, carriers and consignees in the logistics chain in any country in Europe. This system is fully valid in 30 European countries and it is expected that all countries adhering to the original CMR convention will ratify its electronic version.

According to the Data Sharing Coalition, adoption of the e-CMR system is expected to increase with the introduction of the new European regulation for the use of electronic freight transport information (eFTI).[45] This is because public authorities in EU member states (e.g. customs) will have to accept e-CMRs by the end of 2025. In fact, there is significant overlap between the eFTI and e-CMR data requirements. In some cases the data used for the e-CMR will be the same as the required information for competent EU authorities within the eFTI regulatory framework,[46] so there is clear potential to have a universal electronic waybills platform that can be used in both e-CMR and eFTI.

The eFTI Regulation was published by the EC in 2020, and will be directly applicable in its entirety in each Member State from December 2025. This regulation "establishes a [harmonised] legal framework for the electronic communication of regulatory information between the economic operators concerned and competent authorities in relation to the transport of goods on the territory of the Union".[47] This will involve integrating detailed shipment data into unique shipment identifiers with a vision to use QR codes. The regulation's main objectives are to greatly improve uniformity and interoperability between the competent authorities across EU member states to streamline European freight and reduce the administrative and operational costs associated with the current paper-based systems.

Impact of eFTI Regulation and e-CMR on European freight data spaces

Today, less than 1% of freight transport operations within the EU are completely paperless.[47] This means that shipment information exchange is currently highly centralised and shared in silos within each organisation's logistics chain leading to self-contained data cycles that have largely been undisrupted for years. Now the momentum is shifting, and the DTLF plays a crucial role in the freight sector's transition to increasingly digitised systems.

Within its remit, the DTLF is tasked with educating and preparing the European freight industry to meet the eFTI Regulation. Interestingly, this forum is also directly involved with the development and implementation of a European 'Freight Data Space' through the establishment of digital corridor information and management systems. This work stream is logically highly interconnected to the eFTI Regulation.

The eFTI Regulation is expected to harmonise standards and facilitate interoperability across Member States when it comes to sharing regulatory data on freight. Like the role of NAPs connected to mobility data spaces, this approach would create the initial data foundation for a decentralised data sharing infrastructure where freight data can be accessed by stakeholders to generate use cases. Conversely, through its fundamentals a data space architecture also enables the secure, sovereign and federated data sharing ecosystem required for the eFTI Regulation to be implemented as quickly and successfully at a European regional level.

The eFTI Regulation also offers an opportunity to standardise the exchange and re-use of e-CMR data, which is already being collected by freight actors and is therefore an existing datapool that could be leveraged. In the case of insurance for example, e-CMR providers have different ways of presenting their data, and insurance companies also set different requirements leading to siloed centralised data exchanges with bespoke connections. This in turn inhibits economies of scale and can dissuade the use of paperless systems for insurance. Therefore, a more regulated approach to freight data sharing through the eFTI can potentially unlock more value from e-CMR and facilitate its integration into a freight data space.

3. Market analysis: mobility value chains and the potential for data spaces

Digitalisation and data are the necessary thread for the promotion and deployment of new services, better mobility planning and management policies, thus contributing to the achievement of the sustainability, efficiency and equity impact objectives set by the European Commission.

This section analyses the current mobility value chains and the relevant market opportunities for mobility data spaces in 3 different, but overlapping segments. These include: the mobility of people and complementarity with new shared or on-demand mobility services, particularly under the MaaS paradigm; connected infrastructure and vehicle and the challenges faced by the automotive sector in particular; and freight. This way the rail sector is cross-cutting across all three markets, reflecting the increasingly composite mobility and freight services that incorporate different modes.

3.1 MaaS & Public Transport

Current state and evolution (MaaS & Public Transport)

Mobility as a Service (MaaS) can be defined as *"the integration and access to various mobility services (public and private) through a digital application, bringing certain advantages to the end user: use of a single application to access multimodal mobility on demand and the possibility of making a single payment instead of several transactions with each transport operator".*[48]

MaaS encompasses the full spectrum of mobility from fixed route, mass transit services such as rail, tram and metro to on-demand services like micromobility, buses and ride-hailing. In the scope of this report we do not cover air or sea travel in detail but appreciate the connection to interurban journeys.

Applications based on the MaaS concept are emerging in more and more cities thanks to the technological advances (IoT, Big Data, ticketing, etc.) and the widespread usage of smartphones, as well as changes in user consumption habits, which increasingly prioritise access (to mobility) over ownership (of vehicles). In short, data and interoperability between the different systems involved in any MaaS scheme are crucial for the development of this new mobility management paradigm and new business model.

A successful MaaS service also brings new business models and ways to organise and operate the various transport options, with advantages for PTOs including access to improved user and demand information and new opportunities to serve an unmet need. MaaS aims to provide cheaper and more sustainable alternatives to using the private car -that can be just as convenient (if not more)- to reduce congestion and inefficiencies in the transport system.

The common thread that guarantees the different levels of MaaS integration is the availability of high-quality data, as well as the standardisation of these and of the business processes that ensure interoperability between heterogeneous systems. This guarantees that the planning, reservation, payment, ticketing, digital identity and security subsystems work in a harmonised way, under a robust, data-driven governance structure that ensures trust between actors with very different priorities and objectives. MaaS aims to offer the best value proposition for users, societies, and the environment.

Importance and use of data (MaaS & Public Transport)

Access to different levels and types of data is necessary in forming any MaaS scheme. The level of technical complexity and difficulty in accessing the data needed to achieve the four levels of MaaS integration is increasing, with the higher levels being those where the transformation potential is more evident and the relevance of the data more critical:

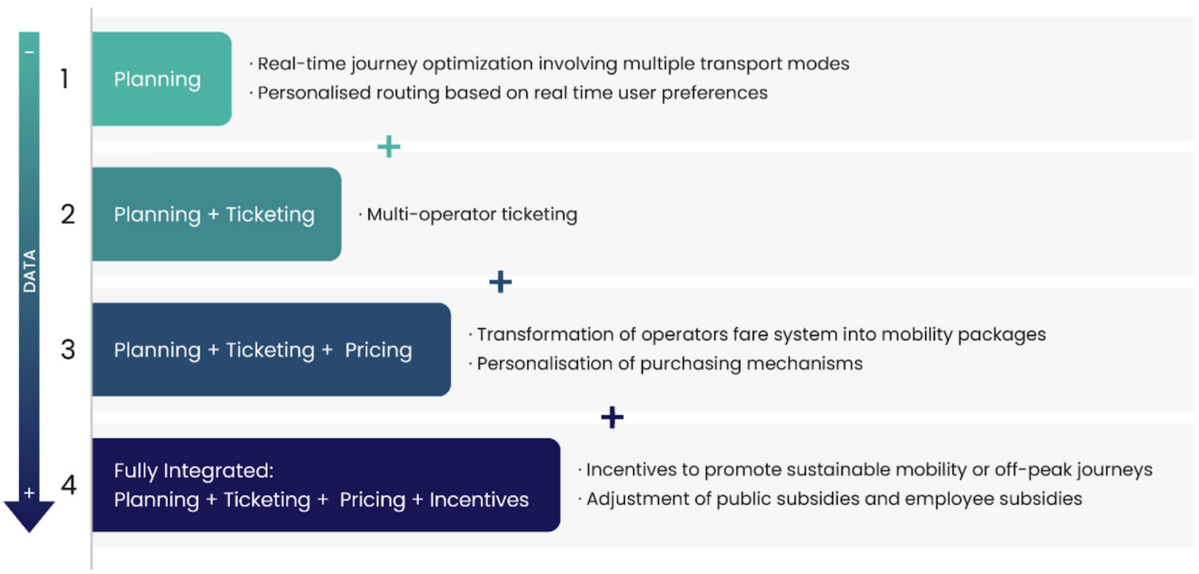


Figure 11: Classification of MaaS integration levels through data[48][49]

User management is a cross-cutting functionality at all levels of integration (some MaaS applications allow the use of level 1, information and planning, without identifying the user). A single verification of the user's digital identity and information is essential from integration level 2 onwards for access to any mobility service included in a MaaS offer.

Examples of data types (MaaS & Public Transport)

- **Public transport data:** typically includes data on stop locations, routes and schedules, service disruptions (such as possible delays, breakdowns, etc.), occupancy levels, expected connection times, as well as ticketing information, etc. Being a public service, providers of these modes of transport usually share this data through open data portals completely free of charge.

- **Shared, on-demand and multimodal transportation data:** this category of data is very diverse and includes any type of data collected by ridesharing and multimodal transportation providers (bicycles, motorcycles, electric scooters, cars, etc.). They usually include data on users' frequent routes, location data and vehicle availability, and are often combined with external data such as traffic, weather or public transport data to better serve users.

Other types of data that also apply to other sectors outside of mobility include **personal user data** and **supplementary data (such as mapping, demographic, meteorological, air quality, traffic, etc.)**

Value chain: data providers and consumers (MaaS & Public Transport)

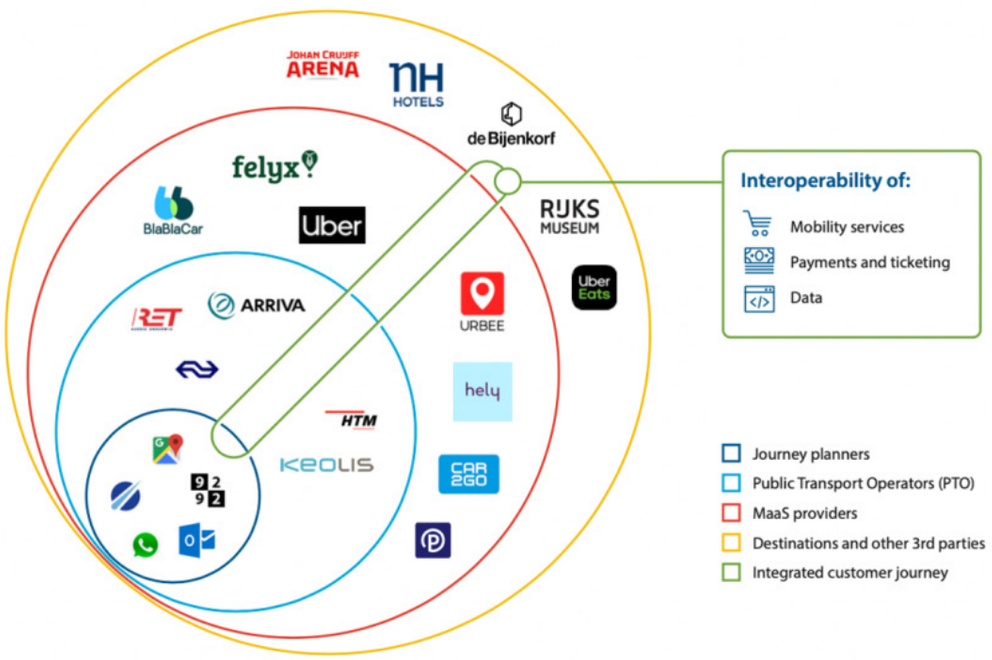


Figure 12: A non-exhaustive example of a Dutch MaaS ecosystem[50]

The data providers and consumers in any MaaS scheme are typically as follows:

- **Routing software providers:** They provide and update the digital map infrastructure that underpins MaaS apps. Route mapping and optimal routing is led by geospatial data but is also increasingly influenced and refined by 'in-the-field' mobility user data.

- **Public transport authorities and operators:** Public transport authorities (PTAs) manage ticketing data for the purchase and use of transport tickets. There is a growing trend among public transport agencies to provide third parties with static data (timetables, stops, etc.), and increasingly also dynamic data (passing time of the next bus, train or streetcar, etc.). Unfortunately, most of this data is still highly fragmented and much of it is not accessible. Within this stakeholder group, we also include:

  - **Mobility planners and managers:** Cities have the responsibility and challenge of managing mobility and the use of public space. To this end, access to data on the availability and use of different modes of transport is key, both by public transport operators (PTOs) and shared mobility services.

- **MaaS operators:** They receive high-value information from anonymised user data (on travel patterns, preferred modes of transport, etc.) collected in the course of each transaction with the different mobility service providers included in the MaaS offer. Within this category we also find:

  - **Operators of shared mobility services:** Access to or availability of dynamic vehicle data (geolocation, acceleration and speed, load level, etc.) is crucial for their operation and for integrating all this information into a MaaS platform. The end users of car sharing and MaaS applications are the consumers of the vehicle data. In addition to the location information, the operator also provides the locking and unlocking functionalities.

- **Users:** They interact with mobile applications that help them plan and manage their mobility based on criteria of time, cost, sustainability, accessibility or transport mode preferences. Their smartphones generate a huge amount of data about their trips which, duly anonymised, allow them to obtain information about people flows and mobility preferences (modes of transport used), and to cross-reference this data with other data sources to infer mobility patterns and apply mobility management measures better adapted to users.

Opportunities for data spaces (MaaS & Public Transport)

Mobility data spaces will accelerate multimodal integration projects and MaaS platforms by encouraging the sharing of more and better data, essential and strategic to achieve higher levels of integration (from level 1 to 4). These platforms are currently collecting and sharing data in silos, contributing to the fragmentation of the MaaS ecosystem and inhibiting the flow of data between different subsystems and producer/consumer agents, both public and private. These subsystems, typically heterogeneous in the technologies and standards they use, will be able to advertise and share (through standardised and open source connectors) their data with third parties in a standardised and secure way. This will reduce the necessary investment and technical risk, ultimately favouring interoperability, one of the main challenges for the development of MaaS. All this, while giving confidence to the different agents participating in the MaaS ecosystem through robust business processes (in terms of security and privacy) and allowing efficient, transparent and flexible control of access and use of data in the different sub-processes (information, planning, booking, ticketing, payment and management of subsidies and incentives).

Data spaces will also facilitate the monetisation of data, which adds validity to the business models of new mobility services (and therefore MaaS schemes) that still raise many doubts about their viability at an economic level.

Examples of use cases (MaaS & Public Transport)

MaaS applications provide significant, high-impact use cases for future data spaces, leveraging the accessibility to quality data and common governance to facilitate the development and operation of new services across the value chain. A number of more advanced MaaS apps (mostly Level 2) are already offered across Europe, such as: Urbi, Jelbi (Berlin), Hoppin, Floya and Gaiyo.

The example use cases outlined below are of initial pilots integrating MaaS projects into mobility data spaces*:*

AI-based optimisation of mobility offerings[51]

- **Description:** the highQ MobilitySuite app (mytraQ)[52] obtains weather data from the German *Mobility Data Space* (which in turn is linked to data from mobility services and infrastructure) and, through an integrated incentive system, motivates users to change their mobility behaviour towards more sustainable options.
- **Stakeholders involved:** highQ, German Meteorological Service (DWD), Stadtwerke Münster (SWMS), LOOPmünster, TIER
- **Maturity level*:** Pilot, expected Live in 2024. HighQ is currently implementing their mytraQ platform for Stadtwerke Münster, integrating local car-sharing service "LOOPmünster" and TIER's e-scooter and bicycle rental services with a view to adding more service providers from 2024. [53]

RealLab Hamburg [54]

- **Description:** An intermodal mobility app integrates competing mobility providers into one app by addressing data sovereignty and data sharing. This MaaS app promotes and facilitates increased public transport use by creating personalised transport recommendations based on anonymised mobility user data. [55]
- **Stakeholders involved:** National Platform Future of Mobility, RealLab Hamburg, Deutsche Telekom, Urban Software Institute, International data space Association
- **Maturity level:** Pilot

*Based on the IDSA's definition for levels of maturity

3.2 Infrastructure and vehicle connectivity

Current state and evolution (Infrastructure and vehicle connectivity)

Technological advances are changing the way vehicles are designed, produced, marketed and sold, while also raising customer expectations, especially in the automotive sector. Cars still play the traditional role of transporting people from point 'A' to point 'B', but at the same time they are rapidly transforming into complex digital products where software is becoming more important than hardware.

The data generated by connected vehicles is used to provide services customised to the user's needs with the aim of improving the overall experience through improved comfort, information and safety. This opens up a very broad field for the monetisation of data as a catalyst for new services and business models. Improving connectivity in vehicles and infrastructure also enables autonomous mobility, which is seen as a key solution to improve the safety and efficiency of the transport system.

Importance and use of data (Infrastructure and vehicle connectivity)

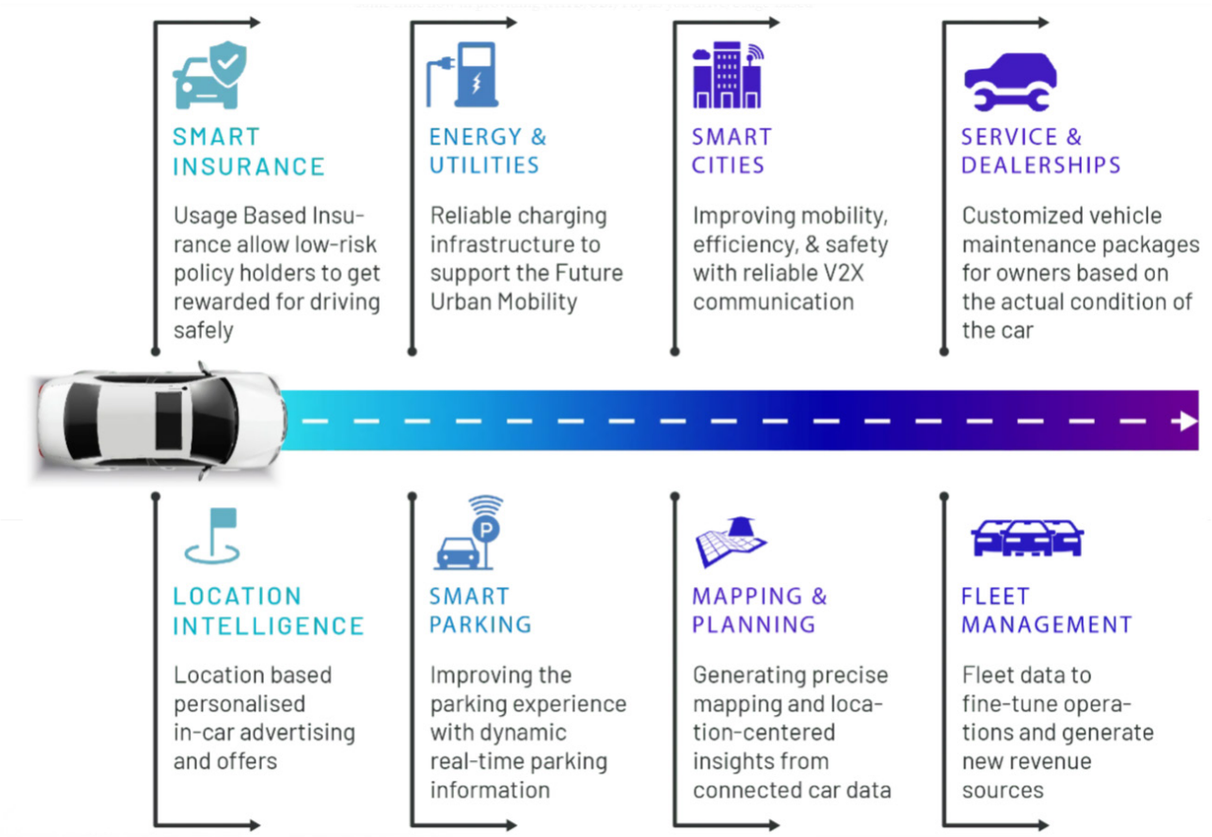


Figure 13: Data-driven connected car services[56]

Here are some cross-sector examples of how connectivity creates data usage opportunities:

- **Preventive maintenance:** data from connected vehicles is a valuable source for predicting future breakdowns and anticipating preventive maintenance, improving driver safety and extending vehicle and infrastructure life, a parameter especially relevant in the railway sector as identified by the European Motional project.[24]

- **Geolocation-based services:** vehicle data (such as Floating Car Data) can be exploited, aggregated with data from other vehicles and complementary data sources, to infer traffic conditions (both real-time and predictive). This helps inform users on the estimated time of arrival at the destination programmed in the navigation system, as well as warnings of possible incidents on the route, such as road works or accidents on the rail infrastructure.

Examples of data types (Infrastructure and vehicle connectivity)

- **Private transportation data:** mostly from passenger cars and other private vehicles, is necessary to better understand user habits and develop more relevant services for them. It typically includes data on frequent routes, travel times, parking availability, etc.

- **Connected and Autonomous Vehicle Data (V2X):** this type of data refers to raw data collected directly by sensors in connected vehicles. This data is often characterised by its high generation speed, large volume, and the need for privacy and transfer security to guarantee the safe operation of vehicles. These characteristics impose technical challenges when sharing this data. Sometimes the owners of this data are not the car manufacturers directly, but the suppliers of the sensors and applications that collect the data inside the cars, which further complicates the sharing process.

- **Traffic flow and intensity data, and incidents in infrastructures:** they include intensities, instantaneous and average speeds, infrastructure accidents and other incidents. This data is often available through multiple sources, such as open data portals, mobile phone driving aid applications, or geographic positioning systems. The most significant challenges in sharing this data is the high volume and velocity of its generation and the frequent updates that often occur. They do not usually contain personal data, as they are aggregated data, although some sources rely on citizen-generated data to provide them.

Value chain: data providers and consumers

The key suppliers and consumers of data in the connected vehicle sector are:

- **Vehicle manufacturers (OEMs):** the urgent need to decarbonise mobility has driven the development of electric vehicles that, by design, are connected and data-intensive. Highly automated vehicles and cybersecurity are currently considered state of the art in the automotive and rail sectors. Automotive OEMs are increasingly software-oriented in efforts to leverage the value from connected services.

- **Component suppliers:** the business model of the main Tier 1 suppliers (Siemens, Bosch, Continental, Denso, ZF, Valeo, Magna, etc.) has clearly evolved towards the areas of connected electric vehicle and mobility services, in tune with the evolution of the sector driven by digitalisation and changes in vehicle usage parameters.

- **Infrastructure operators and traffic managers:** they operate linear infrastructures, such as roads or railways*, both physically and digitally. Public administrations and concessionaires in charge of infrastructure management and maintenance obtain and monitor data on the infrastructure and the state of traffic flow and possible incidents. They do this through data obtained from sensors deployed in the infrastructure itself and through traffic information providers.

- **Users (drivers):** the interaction between the driver and the connected vehicle is rapidly evolving beyond the mere driving task, especially with the growing adoption of increasingly sophisticated ADAS driving assistance systems and infotainment systems based on AI.

Those that are more specific to the automotive sector include:

- **Connected service providers:** V2X connectivity makes it possible to offer information services such as real-time and predictive traffic information. In the case of cars, services can provide parking information and reservations, information on the availability of electric charging points, etc. - and infotainment, as well as secure and integrated payment of services to the driver from the user interface in the car known as in-car payments or in-vehicle commerce.

- **Fleet managers:** company cars; traditional (daily) and flexible (car-sharing) rental; ride-hailing; leasing and renting; subscription services. All of them use fleet management systems based on IoT technology and generate and use large amounts of data. The services they offer include real-time information on vehicle location, routes, speed, acceleration, all data that can be used to infer driving profiles and propose measures to improve safety, as well as driving efficiency (ecodriving).

- **Insurance companies:** innovation based on connected car data goes through telematics insurance, which makes it possible to reduce the risk of fraud and customise insurance to the driver's profile, while increasing driving safety and efficiency through personalised recommendations to the driver. Manufacturers (such as Tesla) are also entering this sector, where the challenge depends not only on data, but also on updating the legal framework.

*Rail operators are included in the MaaS and freight transport value chains

Opportunities for data spaces (Infrastructure and vehicle connectivity)

Mobility data spaces will act as a lever to drive R&D projects to validate different technologies for connected and autonomous vehicles before their commercial launch*. The need for access to massive amounts of data poses the challenge of having an adequate data network infrastructure (e.g., to implement traffic sign recognition systems for autonomous cars), including storage, network bandwidth, and computing capacity needs.

Connected car applications pose in a particularly critical way the challenge of access, use and ownership of data, aspects efficiently addressed by data spaces and crucial not only to preserve the rights of consumers (drivers) and ensure the competitiveness of the sector. Under the Data Act, which promotes data portability, drivers will be able to decide which service provider (e.g., roadside assistance or maintenance) to give access to the data generated by their connected car.

Data spaces also have great potential to transform the rail sector away from the current fragmentation at a national or regional level towards a future European railway system that is highly digitalised and interoperable across borders. This is arguably the market sector with the greatest need and potential in achieving a unified European mobility data space. It is also important to highlight the opportunity to integrate a more demand-responsive railway system in the urban mobility tissue of cities to complement services such as MaaS and last mile operations. Furthermore, data spaces will unlock the potential for the creation of assets like advanced digital twins of the European railway network, enabling new value streams from legacy and developing assets.

Examples of use cases (Infrastructure and vehicle connectivity)

A variety of use cases have already been identified throughout Europe in the domains of autonomous driving, vehicle testing, road infrastructure, rail operations and more. Such cases could involve two actors, such as an OEM connecting to vehicle testing or V2X simulation service, or more complex multi-actor IoT and data ecosystems connecting digital twin providers, road infrastructure operators and traffic authorities to optimise traffic flows in a city.

Below are some initial examples of infrastructure and vehicle connectivity use cases being implemented and supported by a mobility data space:

Smart Parking (OptiPark)[51]

- **Description:** solutions such as "OptiPark" (from Urban Mobility Innovations), "Smart Parking" (from FIWARE) or "Parking Monitoring" (from Mercedes Benz) capture and share data on available parking spaces, facilitating navigation to the closest free space to the destination and thus helping to reduce cars driving around looking for parking. Parking monitoring data is shared with cities to enable more efficient parking space management and planning.

*A widely accepted framework used in many CCAM-related R&D projects is the Data Sharing Framework

The German *Mobility Data Space* enables secure data transmission between all actors involved in each use case and offers the opportunity to extend the solution by easily including additional data from various providers, such as data on access barriers to parking zones or Park & Ride in the case of "OptiPark".

- **Stakeholders involved:** Urban Mobility Innovations, City of Füssen
- **Maturity level:** Pilot

Gaia-X 4 Product Life Cycle - Across Automated Driving (PLC-AAD)[57]

- **Description:** one of several examples of the Gaia-X 4 Future Mobility portfolio of R&D projects, Gaia-X 4 PLC-AAD is building an open and distributed data ecosystem to support the product life cycle of automated driving functions. It is also a case whereas a digital twin is integrated into the Gaia-X framework.
- **Stakeholders involved:** 20+ partners including OEMs, digital solution providers and more. Coordinated by msg systems AG.
- **Maturity level:** In Development

Condition based maintenance in the Rail Data Space[24]

- **Description:** one of the first use cases of the European Rail Data Space focuses on developing a vehicle and rail network predictive maintenance model through greater latency and access to rail and network operator condition monitoring data. Interoperable, secure and sovereign data exchange is a challenge in the rail sector as there is still significant heterogeneity between the actors involved. This use case will test the technical feasibility of addressing these within a data space architecture. The ultimate goal is to reduce capital, operational and disruption costs by leveraging AI, digital twins and the data space as part of the FP1 Motional project aforementioned in the previous section. This use case is applicable to all 3 market segments identified in this report.
- **Stakeholders involved:** Knorr Bremse, SAP, msg
- **Maturity level:** Case Committed, technical feasibility study with IDSA ongoing.

3.3 Freight and logistics

Current state and evolution (Freight and logistics)

Fleet management technology based on connectivity, IoT systems and data will play an increasingly important role for the competitiveness of companies and a more efficient and sustainable management in terms of environmental impact. Significantly, around 80% of the just over 900,000 passenger and freight transport operators in the European Union are small and medium-sized companies with between one and ten vehicles in their fleet.[58]

For these companies, digitisation and data-driven management requires significant investment to equip them with digital tools and training in their use.

Data, whether generated manually or preferably obtained in an automated way by specialised applications running on cell phones, telematics units onboard vehicles or the embedded connectivity system of the coach or truck itself, are essential for the decarbonisation of the sector and the improvement of the supply chain. According to a study by the Coalition for Reimagined Mobility (ReMo) conducted in cooperation with the International Transport Forum (ITF), up to 22% of supply chain emissions can be reduced by 2050, or 2.5 billion barrels of oil, with the adoption of a standardised open data exchange system for freight transport.[59]

In recent years, we must highlight the exponential growth of e-commerce, which has generated traffic flows that did not exist before, and in too many cases, inefficient or congestion-generating movements, especially in the last mile.

Importance and use of data (Freight and logistics)

Freight transportation companies have systems for fleet management, logistics operations and route planning, generating a large volume of data on vehicles, drivers and logistics activity. Let's take a look at some examples of efficient logistics through data:

- **Intelligent transportation forecasting and planning:** accurate estimation of travel times for each leg or route can help reduce waiting time at the terminal or distribution centre. This makes it possible to optimise planning at the terminal using traffic density data combined with weather data.

- **Planning of truck or cargo train arrival times:** real-time data on truck arrival time estimates can be used to optimise the costs and efficiency of logistics processes. Similarly, real-time data on cargo train location and speed helps to improve the planning of trains approaching the station and the expected arrival times at the end destination.

- **Traffic control:** real-time data on traffic density in or around the city and the reasons for travel (e.g. delivery of goods) facilitate the implementation of appropriate measures. This can result in alternative routes, different travel times or restrictions for specific groups instead of a total road closure.

- **Predictive maintenance:** advanced analytics systems are used to determine driving habits, such as speeding and driving time. In addition, fleet condition data helps to perform maintenance in advance, resulting in fewer delays due to vehicle breakdowns.

Value chain: data providers and consumers (Freight and logistics)

The providers and consumers of data in freight and logistics are:

- **Logistics Service Providers (LSP):** they provide supply chain management services, including transportation, storage and distribution of packages and goods. LSPs generate a large amount of data related to the origin and destination of shipments, package typology and geolocation, among others.

- **Transport operators:** the category includes road transport operators and rail transport operators, and can overlap with passenger mobility. For example, Renfe is a public company that provides passenger and freight transport services.

- **Fleet operators:** this category includes fleet managers of freight vehicles (last mile, medium and long distance), as well as fleet managers of High Speed and long-distance trains (such as GMV). These managers can be public or private, and have access to real-time data on vehicle geolocation, routes, speed, acceleration, driving patterns, etc.

- **Infrastructure operators and traffic managers:** They operate and maintain the physical and digital infrastructures used by intercity freight transport service operators (see description in section 3.2).

- **Users:** customers of freight and logistics services (end users, companies). Better knowledge of users through data-driven profiling is a source of innovation, service optimisation and new sources of revenue.

Examples of data types (Freight and logistics)

- **Freight data**: freight transport, whether by rail or road, is a unique sector within mobility because of its special characteristics, conditions and restrictions. The data collected includes, for example, the volume of materials transported, restrictions on their transport (fragile, refrigerated, hazardous materials, etc.), vehicle routes or estimated delivery times, etc. Two main subtypes of freight transport can be distinguished: long distance freight and last mile transport. In general, the most important challenges for this type of data tend to be availability and lack of standardisation, along with resistance to sharing by some actors.

- **Transport infrastructure data (roads and railroads):** transport infrastructure data includes maps of roads, railways, ports and airports, and other related data. These are data that are usually made available to citizens by the relevant public authorities on open data portals and free of charge. Moreover, they are static data in general, except for occasional updates that do not generate technical challenges when consuming them.

Opportunities for data spaces (Freight and logistics)

Mobility data spaces will accelerate the digitisation of freight transport, making its management more efficient, flexible and sustainable through standardised access, use and exchange of data, facilitating data to flow between the different producing and consuming agents in a secure way and complying with all privacy standards, as well as governance recommendations at European level. All this on a common architecture and data standards that allow interoperability between systems, while giving confidence to the agents involved in the logistics supply chain to undertake the necessary investments to adapt their systems, reducing as much as possible the dependence on proprietary systems.

The freight and logistics sector is facing a multitude of new challenges, but decarbonisation and supply chain transparency are arguably the most critical. The European Commission is increasingly focused on regulating the transparency of supply chains when it comes to life cycle emissions, which impacts the whole freight and logistics value chain. For example, from 2027 electric vehicle manufacturers in the EU will have to provide and make publicly accessible a digital battery passport that will contain detailed information on the carbon footprint, material provenance, recycled content and other aspects such as the State of Health (SoH). The 'Battery Pass' lighthouse project has formed a consortium (including data space actors Fiware and Acatech) that will define the technical specifications and implementation plan of this tool by 2025, and it is not surprising that it has already identified the need to align this work with the European Union's Digital Transition and Data Spaces plans. This is because data spaces will promote and facilitate the harmonisation and standardisation of access to data, and in turn make compliance across multiple supply chain actors much more cost and time effective for all.

Data spaces are supported by the updating of the legal framework at European level (through the Data Act) to protect transport operators in terms of control of access and use of data. In a mobility data space, transport operators will be able to securely monetise their own data related to the operation of the services they provide, duly anonymised, aggregated and preserving the competitiveness of the companies, while allowing them to consume third party data to improve their own operations, such as real-time traffic data to feed their navigation systems.

Since transport operators will have to upgrade their technological infrastructure to, among other objectives, enable interoperability with third-party systems, such as eFTI and e-CRM, data spaces have great potential to facilitate this digital transition. The DTLF's freight data space project is well underway and looks to provide clarity on how this sector can leverage its benefits.

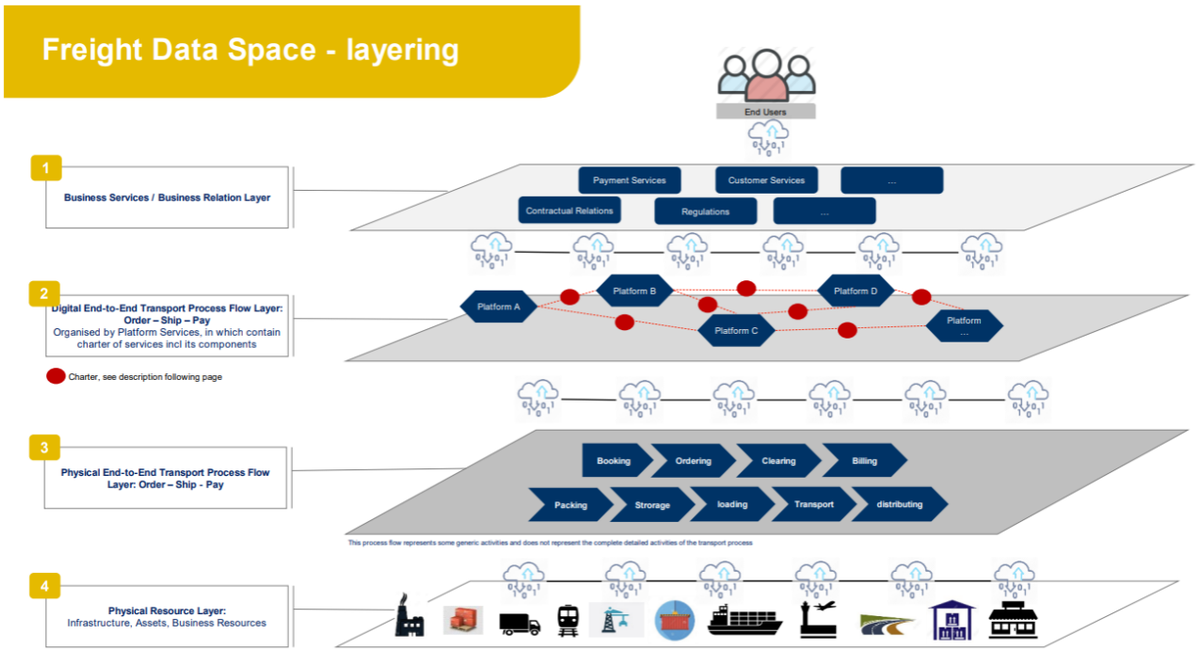


Figure 14: DTLF vision for a Freight data space[60]

Examples of use cases (Freight and logistics)

The freight sector has a wealth of potential use cases that are not yet facilitated by data spaces, such as payload and capacity optimisation across different fleet operators to improve the total cost of ownership and reduce the emissions of logistics.

The use cases outlined below are examples of freight and logistics use cases that are currently exploring the connection to a mobility data space.

Dynamic collaborative planning[61]

- **Description:** cities have to maintain a balance between economic growth and sustainability while logistics companies have to respond to customer expectations. The idea of dynamic collaborative planning is based on the adjustment of logistics processes, such as interaction or contact points, as well as the alignment of intralogistics and external transports. New technologies in urban distribution must be included and facilitated for these collaborative concepts. For this, a greater amount of information has to be exchanged, almost in real time, as the alignment of processes is time sensitive. For this reason, a virtual logistics data space that can be easily accessed is required.

- **Stakeholders involved:** Volker Kraft, Fraunhofer IML, IDSA

- **Maturity level:** Case Committed

Sharing of freight data with insurers to improve processes and risk management[62]

- **Description:** structured data according to the e-CRM standard is shared by logistics companies to insurers. An authorisation record maintained by a neutral actor is used in interactions to maintain traceability of access authorisations to specific data points. The use case actors comply with iSHARE recommendations that ensure the authenticity and control of the data by its owner so that it is shared only with trusted actors. In this way, data is opened to insurers in a controlled manner to improve process efficiency and develop new products and services on top of it.
- **Stakeholders involved:** iSHARE, Verbond van Verzekeraars (VvV), SUTC (logistics IT industry standards), TransFollow, Collect + Go, insurers like SIVI (insurer industry standard organisation), TJIP (platform software for insurers) and multiple insurers.
- **Maturity level:** Case Committed

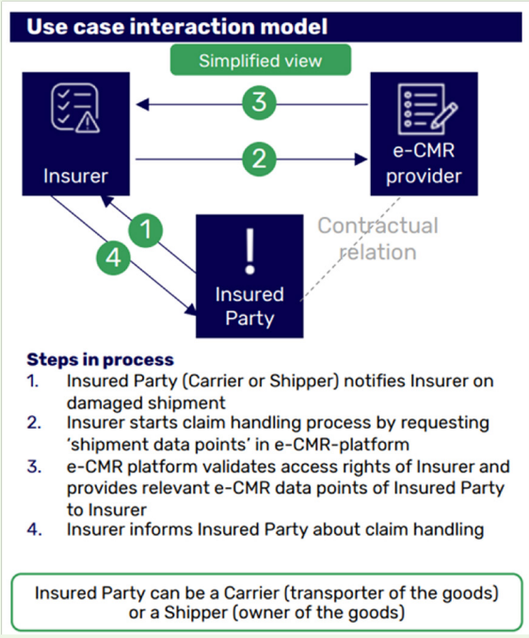


Figure 15: Use case interaction model (iSHARE)[63]

4. How data spaces are implemented

Implementing a data space is an integration of technical and organisational (business, governance, legal) "building blocks", a term of the Data Space Support Centre (DSSC).[7] Much of the preparation, and arguably the greatest challenge, is the non-technical. For example, the multi-sided business model behind the data space, with a focus on the use cases that will drive the supply/demand of data and data-driven services, and the benefits and ROI that can be achieved (business, economic, strategic, etc.). There are also the governance and legal aspects ranging from decision-making in a multi-stakeholder ecosystem, defining roles and common rules, to developing a contractual framework. This holistic vision of "building blocks" can be found in the DSSC diagram of Section 1.1.

4.1 Roles in a mobility data space

The roles and models adopted will vary between each data space. But in general, the following roles will be present:

- **Data owners and providers:** legal owners of the data, and in the cases where they differ, those that provide the data to the data space. For example a public transit authority providing transport data for a multimodal use case, or a logistics operator providing freight data downstream. Each data provider conforms to the norms established by the data space, ranging from organisational requirements to standards in data quality. Each provider has full control over the sharing and use of its data, through defined usage policies and transversal components amongst participants to enforce them.

- **Data consumers:** those entities consuming data, often to provide a service themselves. Following the above examples, this could be a Demand-responsive Transport (DRT) operator exploiting transportation operational data to optimise its own service, or a freight road transport service using a logistics operators' data to optimise the end-to-end delivery. They discover data via common metadata catalogues, and use additional data spaces service to arrive at an agreement. It is also recognised that in many cases an entity can be both a data provider and consumer, reflecting the dynamic nature of a data and service ecosystem.

- **Data space solution providers:** an abstracted term for the purpose of this document, this refers to the service providers, system integrators, etc. that provide the technical components and services to run the decentralised data space, such as individual connectors, catalogues, clearing houses and more. These are not mobility stakeholders, but IT service providers.

- **Data space operator:** an entity or group of entities that maintain the governance of the data space and take a role of a common authority. The ambiguity of this term is by design - it could be a city municipality, a public-private partnership, a consortium of companies in a common supply chain, an independent neutral entity, etc. Like the technical standards, optimal models for governing a data space are quickly evolving today, and will be refined through pilots.

The stakeholders behind driving a data space are varied. For example, a public administration of a region or city (e.g. public transit authority, port authority, city government, etc.) looking to stimulate the market conditions for the surrounding private sector of mobility and digital services. Or a consortium of companies in a value chain building upon an initial use case (such as the examples of Section 3). In this sense, the momentum can be top-down or bottom-up, and potential models are discussed further in Section 5.

4.2 The technology and governance frameworks being developed for data spaces

Europe is accelerating the development of the technology to enable and operate data spaces, advancing the design, architectures and components needed. However, the above topology stresses that the implementation of data spaces is much wider than a technical solution. Inter-organisational governance within the data space ecosystem involved is a complex framework of roles, responsibilities and processes. As such, several of the leading European groups that design the technical standards for data spaces also incorporate components for an accompanying governance framework:

- The **International Data Spaces Association** reference architecture (IDS-RAM)[64] defines all the necessary and complementary components to implement a data space, respecting the principles of interoperability, sovereignty, trust and intermediation. This is complemented by the IDSA Rulebook, which also covers governance aspects, such as organisational agreements and legal dimensions.[65] The architecture was the founding model for Germany*'s Mobility Data Space.*

- The **Gaia-X** architecture[66] envisages the creation of federated services to provide an interoperability layer between different infrastructure providers, allowing the creation of data spaces on top of that federation. This is complimented by the Gaia-X Trust Framework among other specifications.[67] An example project closely linked to Gaia-X is Catena-X, presented in Section 1.3.

- The **FIWARE architecture**[68] includes a context broker, which acts as an interoperability layer to collect data from heterogeneous sources and deliver it to a services layer. FIWARE has used its platform to make significant progress in the smart city domain, among others.

- The **iSHARE** architecture and trust framework[69] is a European standard for sharing international commercial data in a sovereign manner, governed by the requirements and guarantees.

- The forthcoming **SIMPL middleware**[85] will help enable cloud-to-edge federations for EU data spaces. It will be procured by the EC (currently in process at the time of this report), with a roadmap that includes an open source software stack to power data space implementations, as well as an experimentation and demonstration environment for data spaces in various levels of development maturity.

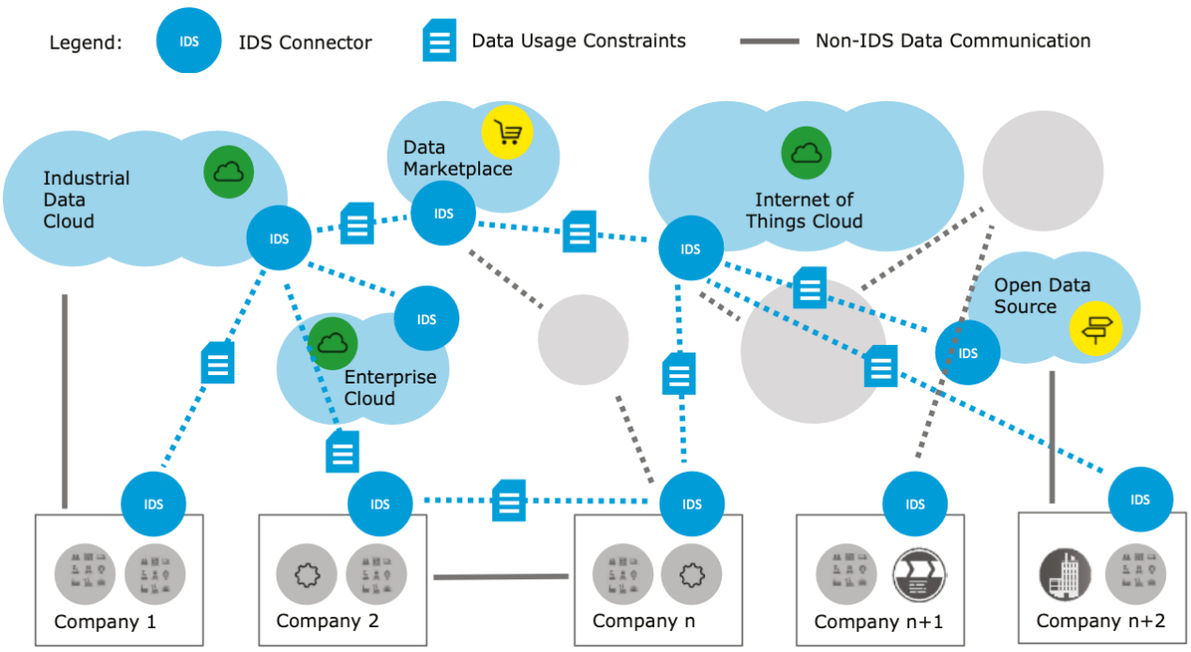


Figure 16: Conceptual data space implementation, using IDS-RAM[64]

Although these solutions have been created independently, work has already begun on collaborating between the different models to ensure greater interoperability between them. Key examples:

- **Technical convergence for interoperability:** The Data Space Business Alliance (DSBA)[70] is a collaboration between IDSA, Gaia-X, FIWARE and BDVA, and the results of their technical convergence line of activity can be seen in a series of reports that they release regularly.[71] The vision is to arrive at a "Minimal Viable Framework", that provides differentiated choice in solutions, yet interoperable.

- **Common blueprint and building blocks:** The aforementioned Data Space Support Centre (DSSC)[8] is another umbrella initiative, sponsored by the European Commission. It is delivering a variety of resources to help organisations build data spaces, such as a starter kit that covers business, legal, governance and technical aspects; a common data space glossary to harmonise relevant terms; and a conceptual model that serves as a starting point for new governance models. Its key result will be a common blueprint, which consolidates the conceptual model, compatible building blocks, and a recommended selection of standards, specifications and reference implementations for data spaces.

- **Growing market of connectors:** A key component of several data space approaches is the "Connector", essentially what plugs an organisation into a data space and manages the main functionality of secure sharing data while providing them full usage control and data sovereignty. IDSA has an ongoing activity to track the functionality and maturity of different connector implementations, in their Data Space Connector Report.[72] An important example with momentum is the Eclipse Dataspace Components project (EDC).[86]

The above efforts involve many of the same actors and are complementary. They progress based on previous work on interoperability, such as between IDS-RAM components and Gaia-X services,[73] between the FIWARE architecture and IDS-RAM,[74] and between FIWARE and iSHARE.[75]

5. Navigating the commercial challenges in deploying mobility data spaces and use cases

While data spaces have a lot of potential to generate value for cities and businesses in addressing key market challenges, this study identifies that these key stakeholders are increasingly scrutinising the investment case for both the implementation and participation phases. Private sector actors are especially accustomed to services that generate a return on investment, and the commercial value proposition of connecting to data spaces and participating in use cases for mobility is currently ambiguous.

The DSSC distinguishes the business models related to data spaces as follows:[76]

- The business model of the data space as an infrastructure that can support multiple use cases and;
- Business models of the individual data space participants engaged in one or more data space use cases. This is linked to the model for use case development, as defined by the DSSC.

European mobility data spaces are being developed and deployed at different rates across Member States, as seen in section 1 of this report. The approach to this deployment process can vary - this report identifies two main approaches to justify the investment case for a data space or a mobility use case, illustrated in the below graphic:

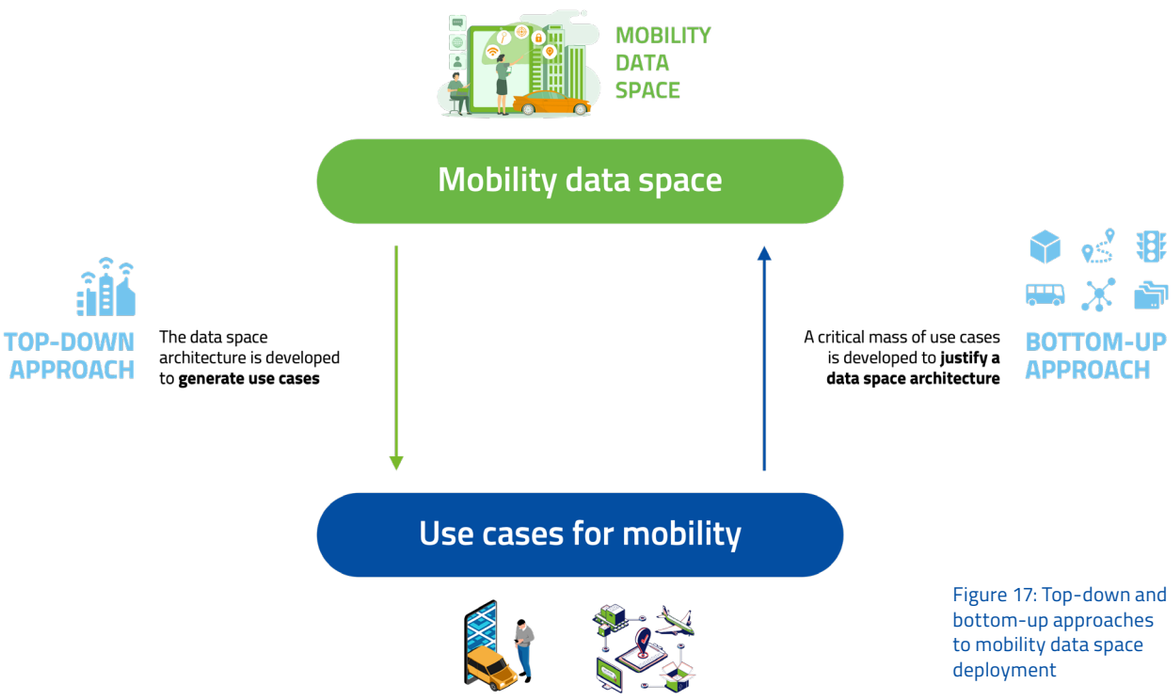


Figure 17: Top-down and bottom-up approaches to mobility data space deployment

Early-mover data spaces have been established via the 'top-down' route, which makes sense as the main objectives have been to test important implementation and operational aspects such as the technological architecture components described in section 4. However, it would be expected that, as the technology, legal and governance frameworks mature, cities and nations start to pivot towards the bottom-up approach where the emphasis is on generating a minimum viable product (MVP) or critical mass of mobility use cases that unlocks investment in deploying a supporting data space. The following subsections look at the business cases for data spaces and mobility use cases in more detail, and propose a framework for impact assessment.

5.1 Marketplace business models

It is important to reiterate that mobility data spaces are a nascent marketplace model, in most cases subsidised by the public sector, and have yet to develop a business model that is financially self-sustaining. This appears to be the case in the pioneering European mobility data spaces such as Catena-X and the German *Mobility Data Space,* which are currently still backed by government funding. While government backing is highly important in the early phases of development for mobility data spaces, experts interviewed in this study caution that the private sector can be dissuaded from sharing their data with an initiative that is part-funded or government-led.

However, data spaces have great potential to be the next-generation model to follow for data and service exchange in the mobility sector, leveraging learnings from existing commercial data marketplaces. Currently, there are the four main types of data sharing marketplaces relevant to mobility: [76]

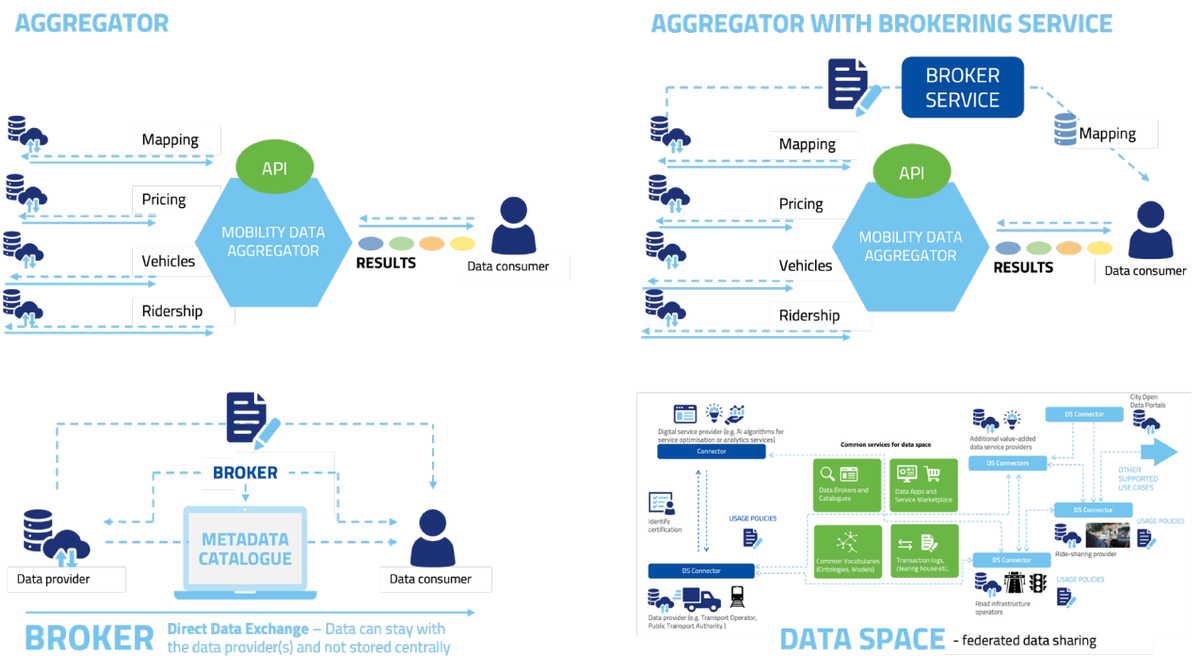


Figure 18: Types of data marketplaces

These data marketplaces all have somewhat different characteristics in terms of structure and operation:

Data marketplace business models

Data marketplace	Ownership	Platform access	Architecture	Pricing mechanism	Price-setter	Typical business model
AGGREGATOR	Private sector entity	Closed	Centralised	Fixed	Marketplace owner	Platform/ data subscription
AGGREGATOR WITH BROKERING SERVICE	Private sector entity/ consortium	Open	Centralised	Fixed	Marketplace owner or data seller	Platform/ data subscription Brokering commission
BROKER	Private sector consortium	Closed	Centralised / Decentralised	Fixed	Data seller	Brokering commission
DATA SPACE	Independent 3rd party	Open	Decentralised	Fixed or dynamic	Data seller	'Freemium'/ non-profit

Figure 19: Data marketplace types and characteristics adapted from R. Bergman et al.[77]

While all four marketplace archetypes trade data (and services thereof), their value proposition differs based on what complementary services are packaged within their respective offerings. For example, aggregators such as Fluctuo[78] and Vianova[79] offer customisable mobility data dashboards, or brokers provide a data quality review service. In the case of mobility data spaces, the focus still appears to be on the operational aspects of facilitating decentralised data exchange, rather than identifying potential synergies with 'data intermediaries' and value-ad services that could be bundled with this offering. This is perhaps as expected because important aspects such as the legal mechanisms and technical architectures required to operate data spaces effectively are still developing. However, more importantly, in some cases it is a critical design-phase decision to not implement value and business logic into the operation of a data space. For example, the internet or www protocols are designed for networking and linking content only, while value-ad services (such as search engines, e-commerce, shipment tracking and a very vast range of other applications) are developed by participants. Therefore, this analogy would suggest that mobility data space operators should focus on providing the underpinning secure, reliable, scalable and interoperable data-sharing and communication mechanisms for businesses to develop value-ad services from mobility use cases.

Nevertheless, this presents a challenge because data itself is an intangible product that is very difficult to price, therefore a data sharing business model is equally as difficult to define and sustain. In other words, only facilitating decentralised data sharing (which is highly complex in itself) is not a sustainable commercial proposition for mobility data spaces, and other solutions must be packaged in an offering to generate and sustain sufficient revenue. For example, the German *Mobility Data Space* operates a 'freemium' subscription model based on a Connector-as-a-Service (CaaS) offering. However, this is the value proposition in its most basic form, and there is potential for new and existing mobility data spaces alike to leverage other services from providers that the latest DSSC blueprint defines as "data space intermediaries".[76]

Some of these services are offered by existing commercial marketplace types, such as:

- Data quality audit service: based on independent assessment and buyer reviews. This would entail creating a model with a common framework of parameters to assess and validate the metadata against a related dataset
- Data usage analytics tool for both sellers and buyers (can also be advertised in catalogue)
- Marketing and metadata description support for increased exposure (especially relevant for SMEs)

As well as other approaches more specific to mobility data spaces such as:

- Knowledge hub: mobility use case feasibility assessment, and 'matchmaking' service for existing and prospective participants
- Dedicated technical and legal support for SMEs: could include connection onboarding, data processing and standardisation
- Impact assessment tool to predict and track environmental and commercial impact of use cases

The role of AI in streamlining the above service offerings (or package thereof) is one of the key technological synergies that data space operators could exploit to increase the number of successfully-connected participants. Automating the joining and connection process (e.g. through a web portal) along with a use case feasibility and matchmaking service presents a big opportunity for an AI model to accelerate the 'indirect network effects'* that marketplaces such as a mobility data space rely on to improve the completeness and value of the metadata catalogue. For example, the AI model could help the mobility data space 'operator(s)' target key data providers or data types based on gaps identified in the metadata catalogue from the insights derived through machine learning internally and externally to the data space. On the other hand, the AI tool could provide data sellers interested in connecting with a revenue potential estimate based on the incumbent data space participants and their identified data needs.

Integrating such complementary services will enable the development of a common core service offering for mobility data spaces -which in some ways could overlap with the data broker business model- while remaining decentralised in their operations through a federated data space structure that is connected to the business model under a common governance framework. For example, Cofinity-X is a joint venture to bring marketplace and onboarding services to the automotive data space Catena-X.[22] This approach should be viewed as a positive direction for mobility data spaces in becoming more self-sufficient and incentivising private sector investment. There are evident overlaps and synergies between all four data marketplace archetypes described above, which points to a wider definition of what a data space is or can potentially be.

*Indirect network effects occur when a platform or service depends on two or more user groups, such as producers and consumers, buyers and sellers, or users and developers. As more people from one group join the platform, the other group receives a greater value. [80]

For example, Fintraffic[13] is one of the most advanced mobility data exchange initiatives in Europe which has also integrated the Finnish NAP, yet it is not considered a mobility data space because it is not based on a decentralised architecture.

This reflects that, in many cases, certain existing data sharing ecosystems are expected to evolve into data spaces organically instead of starting from zero, adapting gradually to architectures that provide the core functionality needed to conform to new regulation and standards, such as data availability, transparency, usage control and interoperability (between services).

5.2 Commercialising use cases

A number of use case design methodologies have been developed, such as the Data Sharing Coalition's 'Use Case Playbook',[81] providing a step-by-step methodology of use case generation, scoping, assessment and realisation. Several use cases exist in the lighthouse projects mentioned prior, such as Germany*'s Mobility Data Space.* In fact, the EC-funded PrepDSpace4Mobility project identified at least 400 mobility data sharing initiatives currently active in Europe, with more than half of these in the freight sector.[82] Indeed the formation of use cases in data spaces for mobility will often be leveraging existing initiatives.

Building and operating a data space is an ambitious, multifaceted endeavour. As part of the study, a structured matrix of integrated factors to take into account is presented below.

Key factors to consider in deploying use cases:

The following is a brief framework of factors to keep in mind when forming a data space use case for mobility, alongside the challenges presented in Section 1.3. It overlaps with certain factors to keep in mind for the data space where the use case will be deployed. This overlap is intentional, as use cases themselves can lead to extensible data spaces, fostering new use cases as they scale.

Motivations and incentives

- **What is the business and/or strategic gain for each of the use case participants?**
  - This links to the value proposition (Section 1.2) for the actors of mobility's varied value chains. For example: cost savings, operational efficiency gains, fuelling new innovative services, facilitating joint strategic goals (e.g. more sustainable mobility modes), access to larger data and service markets.

Governance needs:

- **What are the regulatory requirements to be met on a local, regional and European level?**
  As discussed in Section 2.2, this includes both transversal regulation (e.g. Data Governance Act) and more specific to mobility regulation (e.g. ITS Directive).
- **What are the common norms, legal conditions and inter-organisational framework needed that meet the requirements of small and large participants alike?**
  These are non-technical aspects that a data space facilitates for the use case partners participating. Nonetheless, for a use case that is the trigger for creating a data space, these are critical factors.

Ecosystem supply/demand needs and sustainability

- **What data is needed to fulfil local service providers' needs?**
- **Who owns and provides such data (possibly different actors)? Do these data providers, coupled with supporting open data, create a sufficient data offering to generate and support services (data consumers)?**
- **Are data consuming services (and the providers behind them) already identified to exploit such data to create value? Do they exist in the local ecosystem?**

  These services can range from end-user mobility (e.g. ride sharing programme) to data-tech (e.g. AI-driven analytics services for optimising transport operations).
- **For growth and marketplace dynamics, what is the needed balance of demand (service providers) to justify new supply (data providers), and vice-versa?**
- **What additional services are needed to sustain the ecosystem and maintain its infrastructure?**

  It is key to have the transversal technical roles, such as system integrators, SaaS providers and implementation partners to deploy and maintain connectors, (meta)data catalogues, digital certificates, etc. As well for the non-technical roles, such as a neutral authority, association model, etc. to maintain the governance model of the evolving data space, a topic of active discussion in European forums.

Feasibility of use cases

What is the relationship between (a) the use case generation of value for the data providers and data consumers involved, vs. (b) the technical onboarding costs and organisational, legal and financial conditions of joining the data space? Factors involved:

- **Is the use case justified?**

  For example, for mobility studies performed every few years, integration to such a dynamic model is hard to justify. But for services that provide insight or even operational changes on more dynamic data sources, integration to such an ecosystem would be more justified.
- **Is the use case scalable? Is its initial implementation feasible as an "MVP"?**

  For example, could the service of the use case grow with the integration of new data sources to this data space, or be replicated in other data spaces, leveraging the interoperable framework that Europe is developing?
- **Is the value of data clear?**

  Organisations often struggle to understand its value, even if recognising that it indeed needs to be protected commercially. Likewise, services supporting the valorisation of intangibles (data) is an opportunity for data spaces, decreasing their barrier to entry, and increasing its collective offering for new data providers.

  These factors must be contrasted with the initial and recurring costs of participating in a data space. Onboarding costs, for example, will decrease relative to the evolving technology and the market of providers that will implement it, as with any disruptive shift.

Commercial impact framework for use cases

As mentioned above, one of the key factors of successfully deploying a mobility data space use case is to be able to define its potential commercial impact in order to attract investor buy-in from cities and private sector stakeholders. Mobility data space use cases should not be 'one-offs' for short-term financial gain, but rather longer term projects addressing critical mobility challenges while considering the financial sustainability involved in creating, deploying and maintaining the use case. In a commercial context, this study classifies use cases as "revenue-generating" and/or "cost-saving" and presents their respective frameworks as a guide for potential use case investors. These investors can be classified as: data providers (sellers) and data consumers (buyers). Both frameworks are developed based on the expected investment and returns at each stage of the data value chain, which are:

1. **Data creation:** this first step involves the generation and collection of raw data. For example, city cameras for low emission zones (LEZ) with Automatic Number Plate Recognition (ANPR) collecting real-time data on on-road vehicles entering and leaving the city centre.

2. **Data processing:** the raw data (vehicle images and number plate logs) can be processed and refined by a specialist organisation into machine-readable format that satisfies mobility data standards.

3. **Data storage and transfer:** the processed data is packaged into datasets that can be stored in the organisation's cloud or other data storage system. The data stored can also be connected to an API for potential transfers with third parties, and metadata can be generated based on its contents.

These first three steps of the value chain create the 'data product' as defined by the DSSC[75] and tend to be investment-intensive for the data provider (seller), with progressively higher revenue potential as the data is processed, packaged and tailored to the data consumers' needs. Logically, it is more likely that data providers that have/are already investing in one or more of these steps are more willing and able to participate in data space use cases than those who have to enter the market. For example, OEMs who are required by law to collect and maintain high value data on supply chain emissions or vehicle safety could potentially benefit from 'quick wins' by generating external revenues from data spaces. This might explain why the Catena-X data space focuses on tracking data for LCA, or why the German *Mobility Data Space* has a few OEMs offering road condition and safety incident data. Therefore, a preliminary commercial 'check point' of whether a mobility use case is financially sustainable for the data seller is to determine whether:

- The expected revenues from data exchanges facilitated by the data space are enough to generate a positive ROI within a targeted time frame, taking into account the connection cost to the data space and to varying degrees the investment in continuous generation, maintenance and processing of the datasets; and/or:

- The net cost of joining the data space is more favourable than alternative marketplaces.

It is important to highlight that the relative cost of providing data for conventional centralised databases or aggregators is significantly higher than connecting to a mobility data space. Especially when considering the data provider has to relinquish control of this data to an external organisation. It is cheaper and more favourable if it can use a single standard open source or commercially available connector to select and negotiate digitally who gets the data for what purpose and on what conditions.

On the other hand, the barriers to entry for the data consumer are very high at this stage. In other words, it is significantly more challenging for the data consumer to build an investment case to supply its own proprietary data product for a mobility use case. Therefore, the opposite principle applies to a data consumer (buyer) that is potentially interested in joining a mobility data space use case. It has to establish whether:

- The sum of investing in connecting (e.g. CaaS) to the data space and relevant dataset purchase is lower or equal to the cost of vertically integrating and investing in the first three stages of the value chain; and/or:

- The sum of investing in the connection to the data space and relevant dataset purchase is lower or equal to the cost of subscribing to an alternative data marketplace, e.g. a brokering service

However, prospective data space participants who are individually looking to connect to a data space often have asymmetric information, leading to ambiguity in assessing the above points. Data providers (especially in the case of municipalities or SMEs with limited resources) currently face challenges in building an investment case to join a data space because there is no guarantee that the use cases envisioned by the data provider are met by demand from the data space. On the other hand, there can be a mismatch between the data needs of the consumer and the data available through the data space.

Metadata catalogues can potentially mitigate these ambiguities, but more needs to be done in standardising and increasing the quality of data product and service descriptions. In future, these catalogues could also be complemented by an automated use case matchmaking and assessment service that would streamline this decision process for both data sellers and buyers. The data space business model could also integrate a pay-as-you-go (PAYG) to help mitigate this initial hurdle in deploying use cases. This way, the initial connection to the data space would be free until the data provider or consumer are part of a committed use case that generates a financial and/or environmental benefit. This would incentivise stakeholders to identify and mature initial use cases that are more likely to generate a return on investment.

Once these use cases are live and their impact can be advertised, further follow-on use cases may be deployed generating the minimum return on investment that the data consumer or provider need to justify the standard CaaS subscription.

There is an alternative scenario, where the use case stakeholders and MVP are pre-defined (or are already operational) before joining the data space, so there is higher confidence of the successful servitisation of data. In this scenario the data space performs its basic function as a facilitator, offering a potential for other participants to also benefit from the new data available. This approach is likely to suit existing data exchange use cases in peer-to-peer or consortia relationships for example. This is expected to be a more likely scenario for use case commercialisation once the 'freemium' business model of the German *Mobility Data Space* transitions to a paid-only subscription CaaS model.

Once the connection to the data space has been established, the data buyer then has the potential to leverage the purchased dataset to deploy a mobility data space use case which is essentially a mobility service that is facilitated by a data space. This generates revenues and/or leads to operational cost savings. In the case of the "revenue-generation" use cases, the income generated (e.g. from an improved MaaS app) over time should break even over a certain period with the amortised upfront and operational expenditure in developing and maintaining the use case-generated/supported service (e.g. the MaaS app itself).

The whole process from data creation to data use case creation is illustrated in the below diagram:

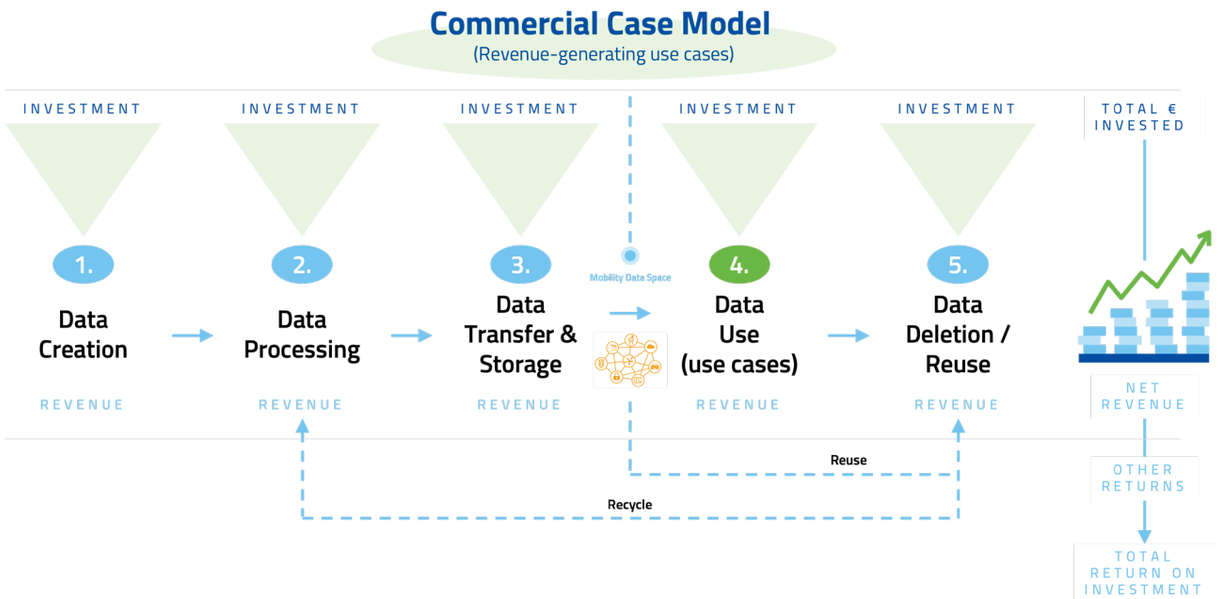


Figure 20: Commercial impact assessment framework for a mobility use case

5.3 Delivering environmental impact

In the face of pressing environmental challenges, it is increasingly evident that investment cases in the transport sector are no longer solely focused on financial gain. The environmental impact has to be factored into the equation, and mobility data spaces offer a promising avenue to address issues such as life cycle emissions, misuse of resources, as well as air quality. One of the critical aspects of leveraging data spaces for environmental sustainability is the integration of LCA methodologies into European mobility data spaces. This approach enables a holistic evaluation of the environmental footprint of mobility solutions, from vehicle manufacturing to end-of-life disposal. By providing comprehensive insights into the environmental impact of various transportation modes, data spaces can empower decision-makers to prioritise sustainable alternatives.

LCA is increasingly used for energy and supply chain emission monitoring, with a clear intent to harmonise regulation and standards both at a European and international level. While the tailpipe emissions reduction potential from petrol to electric vehicles is clear, there is currently a lack of focus on the use-phase of mobility, to an extent due to its complexity, specifically in understanding and accurately measuring the life cycle impact (LCI) of optimising the energy efficiency of the transport system (e.g. from a modal shift) as a result of data-driven innovations. A certain amount of resources are depleted to produce vehicles and the energy that maintains their usage (such as electricity for charging EVs), so it is imperative that mobility users and freight operators optimise vehicle occupancy and modal selection to ensure these (often finite) resources are used in the most efficient way possible. This is where mobility data spaces can potentially have the greatest impact by diagnosing the status quo of transport system efficiency and facilitating use cases that reduce use-phase energy consumption relative to this baseline. A simple example, OptiPark, reduces the time people spend driving around looking for parking spaces by offering a real-time view of parking space occupancy and recommending the best parking options to drivers (such as Park & Ride).[51]

Data space use cases looking at supply chain LCA will likely be industry-led (e.g. Catena-X) due to the stringent EU regulations coming into force requiring detailed digital passports on components such as batteries, for example. However, today the use-phase of mobility faces the challenge of not having the same 'stick'. It is expected that use cases that address the latter will likely be led by public sector stakeholders such as cities, rail operators, other PTOs, etc. The German *Mobility Data Space* is a promising example of a data space with use cases focusing on transforming the use-phase of mobility.

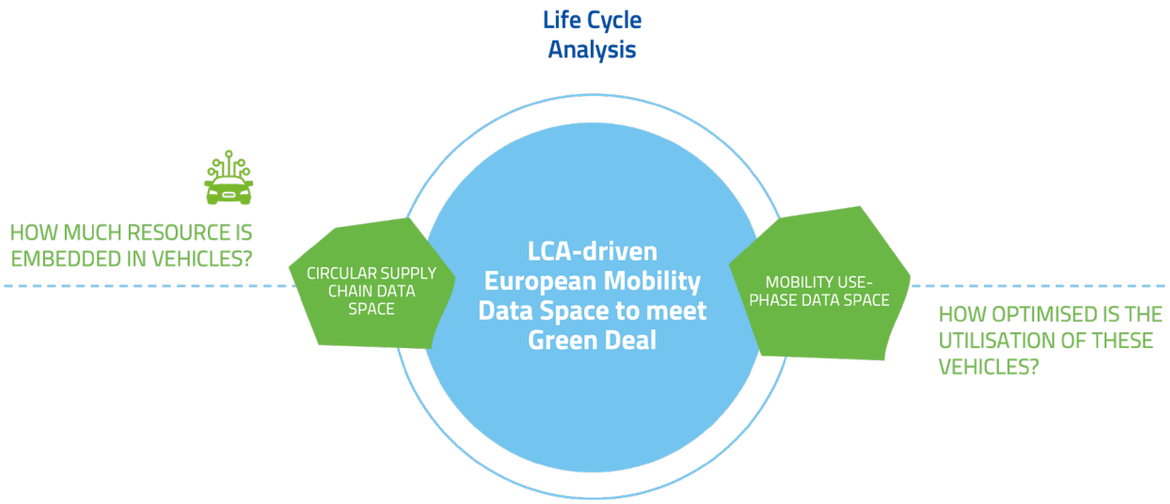


Figure 21: Role of mobility data spaces in realising environmental goals

Mobility use case operators must be able to forecast, measure and quantify the resulting services' environmental impact in order to support an investment case for long-term operation. This is especially relevant for cities from a strategic perspective in meeting SUMI goals, but also for businesses as ESG strategies and regulation increasingly push for net zero emissions. A recent report by the International Transport Forum found that the largest reduction in GHG emissions in Indian passenger transport would be delivered by a modal shift of cars and motorbikes to buses (even if not fully-electric).[83] Another LCA report estimated that the introduction of shared e-scooter services had displaced over 91 tCO2e (34% reduction) from shifting away from personal vehicle usage in a pilot carried out over eight months in Portland.[84]

This study identifies the need for a comprehensive environmental impact framework for mobility and logistics use cases, and recommends the application of the LCA methodology which is highly synergistic with data spaces.

6. Key takeaways

Opportunities for the private sector

As transport systems and mobility services become increasingly data-driven, the private sector stands to benefit significantly from deploying use cases and participating in mobility data spaces. The following conclusions can be drawn from the opportunities identified in this study:

- Beyond its core value proposition of creating trusted environments for secure and sovereign data sharing in business cases, data spaces will facilitate the monetisation of mobility and transport data. This is currently a key challenge for data owners who, although recognise their data as a key intangible asset, still find it very difficult to assess its value in a consistent manner.

- Likewise, data spaces provide attractive markets for mobility service providers where they can find quality data, clear conditions of use and streamlined mechanisms to acquire and consume such data to develop new, innovative services. This ecosystem effect is at the core of many use cases, especially in the MaaS segment.

- Mobility data spaces will accelerate multimodal integration projects by providing the necessary confidence to service providers participating in the MaaS value chain through robust business processes (in terms of security and privacy). This in turn will allow the efficient, traceable and flexible control of access and use of data in the different sub-processes of MaaS (information, planning, booking, ticketing, payment and management of subsidies and incentives).

- Data spaces have great potential to transform the rail sector from the current fragmentation at a national or regional level towards a future European railway system that is highly digitalised and interoperable across borders. This is arguably the market sector with the greatest need and potential in achieving a unified European mobility data space. It is also important to highlight the opportunity to integrate a more demand-responsive railway system in the urban mobility tissue of cities to complement services such as MaaS and last mile operations.

- The decentralised architecture and core functionality of data spaces provides the mechanisms and framework for a more controllable and traceable data-driven service ecosystem between data owners, providers, intermediaries and consumers. This will become more and more critical for the private sector in meeting complex data-related regulations and standards, especially in regulations related to the transparency of supply chains and life cycle emissions that impact the entire freight and logistics value chain. Data spaces will promote and facilitate the harmonisation and standardisation of access to data, and in turn make compliance across multiple supply chain actors much more cost and time effective for all.

- Several mobility and logistics domains are already in a transition to upgrading infrastructure, and incorporating data space approaches in their specifications (e.g. additional connector-based interfaces) will prolong investment lifecycle. For example, freight transport operators will have to upgrade their technological infrastructure to, among other objectives, enable interoperability with third-party systems, such as eFTI and e-CRM. Data spaces have great potential to facilitate this digital transition. The DTLF's freight data space project is well underway and looks to provide clarity on how this sector can leverage its benefits.

- IT solution providers, service providers and system integrators have begun a first generation of offerings, from large IT incumbents to new Connector-as-a-Service (CaaS) models from SMEs. This is echoed in data space standardisation groups and forums, with active participation from the European IT services market as the technology and architecture begins to converge. As data space pilot implementation ramps up, so will the market of solution providers to enable them. Although data space technologies and architectures will continue evolving, there is a clear trend and demand for increasingly more dynamic data and service ecosystems. Data owners and providers will be able to trace and manage their data through their respective value chains, with significantly more control over its usage. Trialling this first generation of data space technology is a key preparatory step for organisations that want to access and exploit these new markets, as well as harness these approaches to develop the required business and data governance processes to adapt to new regulations.

Recommendations for developing mobility data spaces and use cases

There are a handful of lighthouse mobility data space initiatives across Europe that are already piloting mobility use cases (see Section 1). To accelerate the progression of these and future mobility data spaces, this study identifies the following recommendations for future owners and operators:

- **Priority needed for "Minimal Viable Data Space" piloting, with emphasis on the governance approaches.** It is important that any scalable use case is structured into MVP implementation phases that act as short and mid-term demonstrators to start iterating its business scope, technical approach and governance model. This will add clarity to the business case and incentivise the right level of investment from interested public and private sector participants. Although the technical specifications of European standards are still being refined, this should not hold back the deployment of early mobility use case pilots, as the core concepts and functionality will be consistent with new regulation and a market need for more control in the hands of data owners. Therefore, the focus of pilots should not be limited to the business case and technical approach, but also on trialling new governance models and organisational changes.

- **Standardise and improve metadata catalogues.** More needs to be done in standardising and increasing the quality of data and service descriptions to help prospective use case participants build an investment case. This is also an opportunity for such catalogue and onboarding services to be developed and provided for data spaces.

- **Avoid the temptation to re-centralise a data space into a conventional data and service platform.** As the first generation of mobility data space pilots are deployed and the IT market matures in providing supporting components and implementation services, consolidating such offerings into a central platform can be viewed as a more familiar and feasible option. However, although data space ecosystems provide common governance (e.g. rules and regulation) and services (e.g. metadata catalogue, clearing house services, etc.), the key differentiating factor of a data space is its decentralised implementation and operation, which enables the core benefits of data sovereignty.

- **Ensure alignment and connection to the relevant NAP(s) as early as possible in the development stages of the mobility data space.** The mobility data that will be available through NAPs to meet the ITS Directive can be invaluable for a large set of use cases. Furthermore, data spaces can help provide usage visibility and quality control to a NAP's data sources, as well as help integrate it into a wider data sharing ecosystem.

- **Follow a comprehensive commercial impact framework based on ROI so the private sector can better-understand the potential financial gains of mobility use cases and create robust investment cases for long-term use case deployment.** This will also help track and measure the impact of the services developed, piloted or improved through mobility use cases. In turn, this impact data can and should be advertised through the data space to attract further investment in scaling up the use cases or generating new use cases based on the successes. While pilot and live mobility use cases are most likely already generating some form of measurable impact, there is currently very limited (if any) evidence in the public domain of use cases actually delivering this.

- **Develop a roadmap for future service offerings and pricing options that incentivise private sector participation.** For example, offering a PAYG service to new entrants who have asymmetric information on potential use cases. It is important to improve and expand the service offering within the available solutions and architectures beyond the basic CaaS model. This can include services such as data catalogues, app/service marketplaces, independent data quality audits, use case validation and matchmaking services among others that generate value-ad for incumbent and prospective use case participants. Initial examples, such as Cofinity-X, a joint venture to bring marketplace and onboarding services to the automotive data space Catena-X, or the metadata catalogues of the German *Mobility Data Space* and Eona-X are early examples. Best practices in multifaceted marketplaces will apply. The role of AI in streamlining these services should also be explored further.

- **Account for the integration and interoperability of existing mobility data repositories and legacy systems with the new data space architectures.** This has the potential to lower the investment barriers to entry significantly for both businesses and cities that store high quality mobility data in older data management systems and are looking to join a mobility data space. CaaS models and other approaches can facilitate this onboarding.

Further recommendations for cities and regions

In cities, an effective mobility data space will bring structure and transparency in understanding the behaviour and needs of citizens. This data forms the foundation for more efficient mobility models such as Mobility as a Service (MaaS) and smart logistics, which have so far seen their progress inhibited by fragmented data sharing between value chain actors in the mobility sector. In addition to the aforementioned recommendations, to accelerate the deployment of mobility use cases and data spaces, cities can:

- **Integrate mobility data spaces with advanced digital twins of the city to maximise the potential impact of both technologies.** Data spaces are the connection between real-world data sources (input), digital twins, and a market of mobility solutions and services (output). Mobility, logistics and infrastructure data can be channelled and updated through the data space to continually refine the digital twin and predictive models. This circular data flow will drive continuous improvement in the accuracy of digital infrastructures of cities, streamline the planning and execution of urban mobility projects and maximise their positive impact on citizens.

- **Define the roles and responsibilities of the municipality departments, PTAs and PTOs in implementing mobility data spaces and use cases.** Each city will have a unique combination of private and publicly owned transport services, therefore the public sector should take a leading role in mapping the stakeholders involved to create a city mobility data space ecosystem and governance framework. This exercise can help identify the public-private partnerships that are needed to ensure an active role from the private sector, and define which entities are best positioned to act as neutral agents in the governance of mobility data spaces.

- **Learn from the open data community.** On the city and regional level, public administrations responsible for open data have extensive experience in data publishing, metadata management, data quality, dataset discovery and data federation, as well as standards and technologies. They can provide a source of good practices for ensuring quality and veracity of data in a wider data governance.

- **Leverage the LCA methodology to measure potential and real emission displacement from modal shifts as a result of new and improved mobility and logistics services resulting from mobility data space use cases.** Fostering a greater data flow to enable and better monitor more sustainable mobility modes can be a driver for implementing data spaces. A digital LCA methodology can also be connected with the digital twin and mobility data space to visualise use cases and their impact, even as a decision-support tool.

- **Invest in bottom-up regional and city efforts to evolve existing data exchange assets and help local private and public sector stakeholders understand the transformative nature of data spaces** (e.g. data usage control, new governance models and traceability in the value chain) including use case co-design, demonstrator development and more. Another key part of this is to support the integration of complementary mobility and logistics data exchanges that already exist as commercial offerings, re-focusing existing assets into European standards instead of a costly green-field approach.

A pragmatic transition to data spaces is an iterative evolution of these existing centralised exchanges to the more decentralised approach that the benefits of data spaces are derived from. Such activity can complement continued investment by the EC in programmes such as the Digital Europe Programme to advance the European Mobility Data Space.

These actions will enable cities to take the lead in identifying use cases that can have the greatest impact on citizens and look to incentivise private sector participation, as well as help evolve existing data exchange initiatives towards the European Mobility Data Space vision.

Recommendations relevant to National and European approaches

Member states and the European Commission play a central role in defining and implementing the mobility data space vision. The below recommendations provide some actions to support this:

- Although their role is still evolving across Member States, **NAPs should be included in early mobility data space piloting to evaluate scenarios of such extended data and service ecosystems can help facilitate and extend their function in consolidating and providing static and dynamic data.** The emphasis should be to incentivise the provision of high quality dynamic data within the MMTIS and other delegations, as this is critical to mobility services such as MaaS.

- **Data spaces should be promoted as the technical approach and governance framework to facilitate the implementation of mobility data regulations such as those within the ITS Directive at an operational level for the public and private sector alike.** For example, mobility data spaces can facilitate the implementation of the MDMS initiative's proposed revision to the MMTIS regulation (ITS Directive) to enable the opening of transport ticketing to third parties such as MaaS providers. Mobility data spaces can ensure that this revision will improve the confidence mobility service operators have in opening their ticketing resale to third parties, a game-changer for MaaS business models.

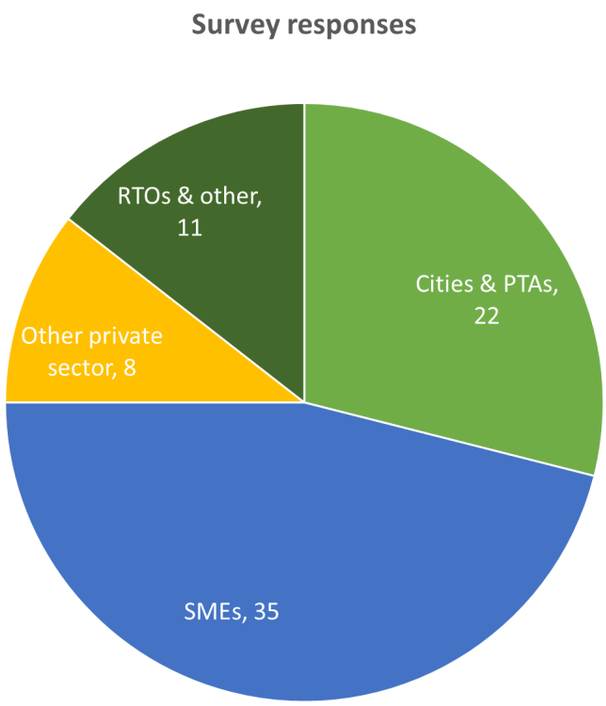
- **Increase coordination efforts between the different member states of the European Union through initiatives such as NAPCORE in terms of implementing the different EC regulations and directives related to NAPs, eFTI and ITS.** This coordination will ensure interoperability between the different national initiatives and facilitate the sharing of best practice and lessons learned to speed up the implementation of the aforementioned European regulations. As transport systems are increasingly interwoven, it is also necessary to increase the interoperability of data coming from different mobility actors and sub-sectors to develop more holistic and innovative services. Different regulations focusing on passenger mobility (ITS Directive) and freight (eFTI) should align on data standards to enable future interoperability in a common mobility data space.

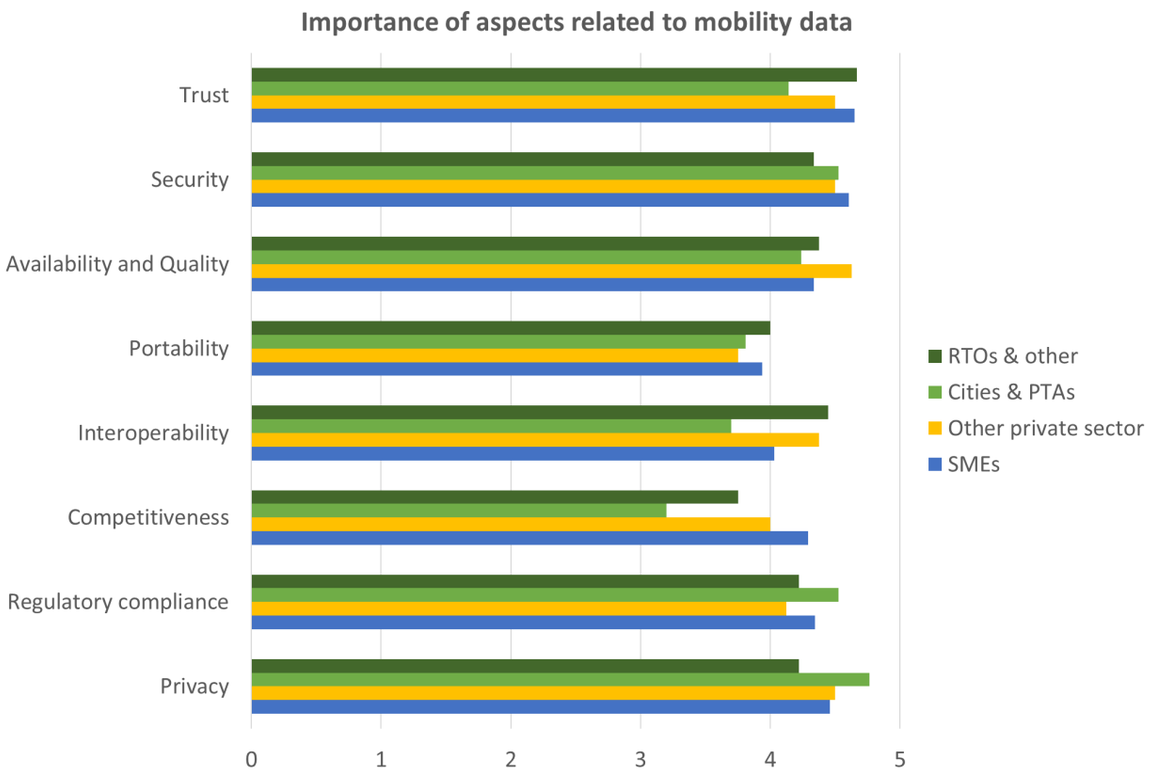
- **Maximise the global impact of mobility data spaces through international collaboration.** While Europe is leading the development of data spaces, it is important to remember that mobility and freight value chains (and supporting data flows) are global. The international expansion of mobility data spaces is the next step in achieving their potential.

Annex: survey results

To support this study, an online survey was shared publicly and within the SIG member network. It received a total of 76 responses from a variety of stakeholder groups such as start-ups, public transport authorities, research organisations and large enterprises.

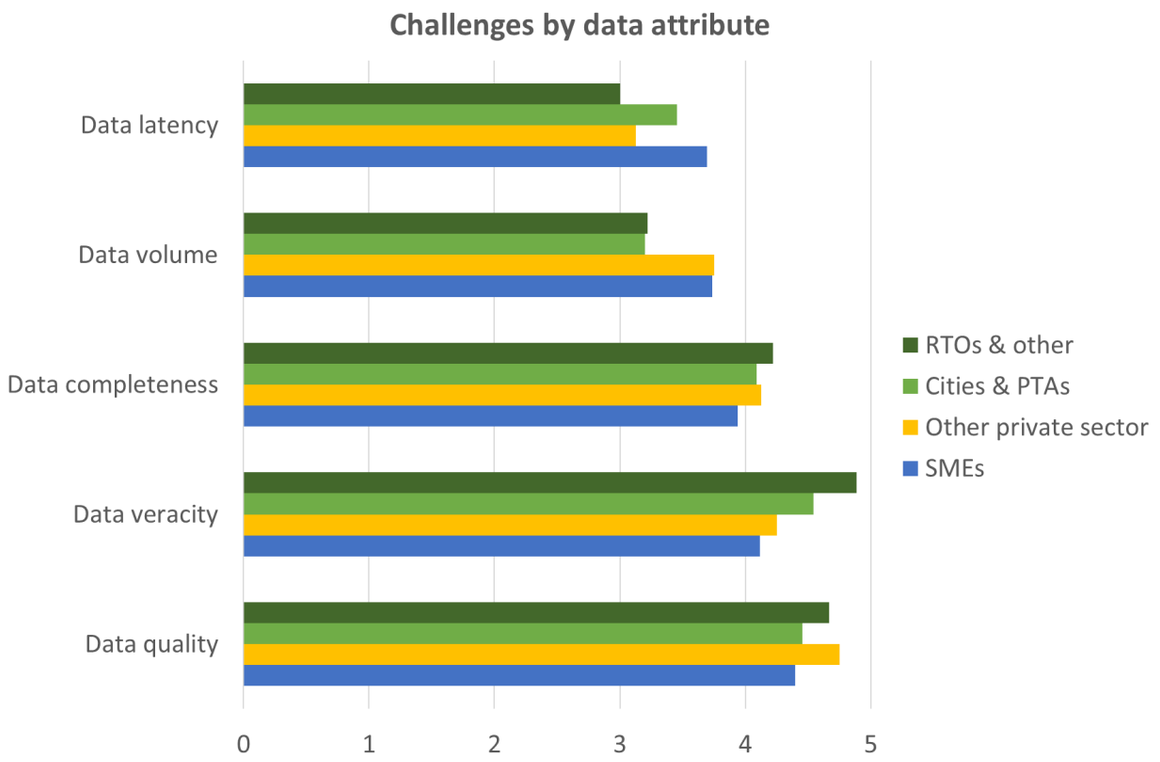
The survey asked participants to rate the importance of different challenges that the data space concept can facilitate, including increased data privacy, security, trust, regulatory compliance, interoperability, portability, availability and quality.





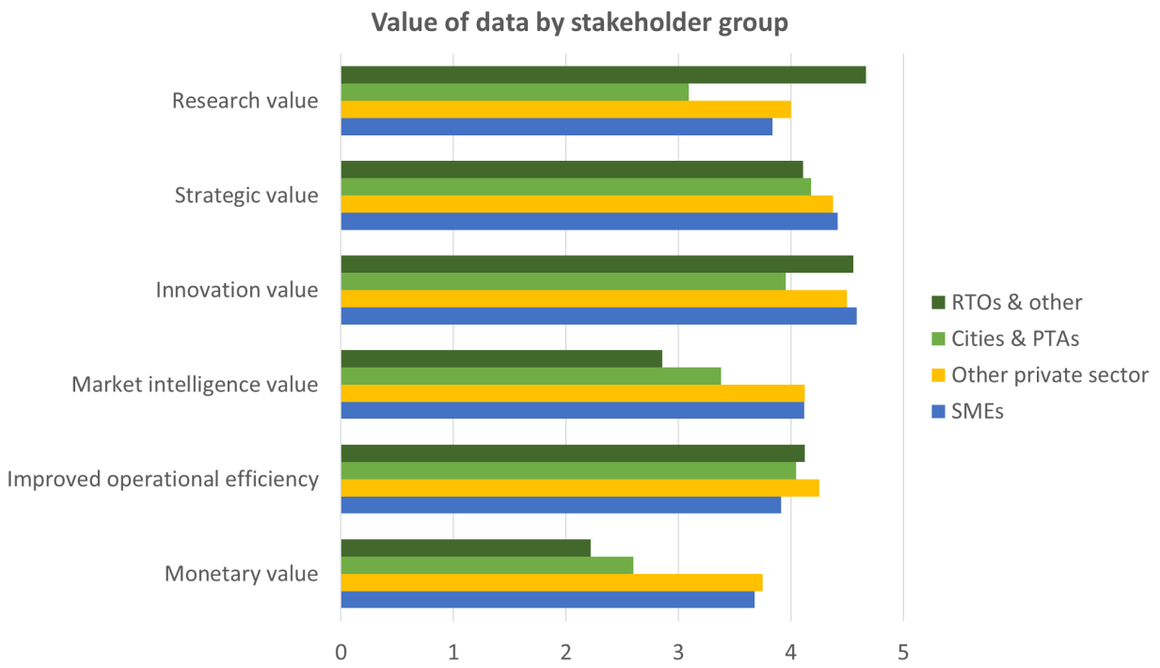
- **Privacy, security and trust** were consistently rated higher than the others ("high" or "very high" by over 85% of respondents across profiles), reflecting a strong recognition of the value of data and the need for clear guarantees for participating in such ecosystems. It is also in line with the priority core functionality of data space technology and standards discussed in Section 4.

- **Interoperability and portability** were rated with a relatively lower priority (although still with over 60% responding "high" to "very high"). Interoperability is relevant for compatibility with legacy systems as well as in the future tense, where investments on a next generation of data infrastructure needs to be one based on accepted standards. This unlocks the "big picture" of the data space vision, such as long-term scalability and integration with other data space ecosystems - undisputed requirements for the long-term European Data Strategy discussed in Section 2. Portability, the ability to migrate data assets from one platform to another, was rated in parity with interoperability.



- **Data quality (e.g. structured) and veracity (e.g. reliability)** were consistently rated higher than other data characterisation factors, including challenges in data volume and latency. This reflects transversal challenges across use cases, whereas latency, for example, can be highly important for some use cases (e.g. connected vehicles), while irrelevant for others (e.g. transport schedules).

The study's survey then focused on the perceived value of potential stakeholders and participants in a data space, ranging from the private sector to cities to research centres. Participants were asked to rate different incentives for participating in data sharing ecosystems:



- As expected, respondents from the private sector rated the **monetary value** or that of **market intelligence** higher than the public sector stakeholder groups.
- However, other priorities were universal, such as harnessing data to increase **operational efficiency,** whether from the perspective of a commercial service provider or a city's PTA.
- **Innovation value** was consistently rated higher than **monetary value** across the stakeholder groups, pointing to the potential of new mobility and digital services derived from the increased access to high-quality data.

In a separate question, participants were asked about the difficulty of acquiring the data they need to provide their services.

- Less than 15% of respondents stated this was currently not difficult, confirming a clear gap in accessibility of quality mobility data*.
- When contrasted with another question about participants' current use of open data, over 50% responded "Yes".

This suggests that open data, although a clear source of value, is not sufficient for the data needs of future mobility. Data spaces are designed to bridge this gap, providing trusted, secure ecosystems to share more sensitive data, in addition to integrating today's evolving collection of open data sources.

*Participants were not asked to provide detail on what type of data they had difficulty acquiring, in an effort to keep the survey accessible, however this is a clear follow-up question for a forthcoming survey.

Abbreviations

AI	Artificial Intelligence
BNDV	Germany's Federal Ministry of Digital Affairs and Transport
CaaS	Connector as a Service (model for data space implementers)
CCAM	Cooperative, connected and automated mobility
CEF	Connecting Europe Facility (EC programme)
CMR / e-CMR	Convention relative au contrat de transport international de Marchandises par Route
DSBA	Data Space Business Alliance
DS4SSCC	Data Space for Smart and Sustainable Cities and Communities (EC project)
DSSC	Data Space Support Centre (EC project)
DUET	Digital Urban European Twins
DRT	Demand-responsive transport
DTLF	Digital Transport and Logistics Forum
EC	European Commission
eFTI	Electronic freight transport information
EU	European Union
IDSA	International Data Space Association
IoT	Internet of Things
ITS	Intelligent Transport Systems (in the context of the ITS Directive regulation)
LCA	Life Cycle Analysis (or Assessment)
LDES	Linked Data Event Streams (in the context of city digital twins)
MaaS	Mobility as a Service
MDMS	Multimodal Digital Mobility Services
MMTIS	Multimodal travel information services (in the context of the ITS Directive)
MVDS	Minimum Viable Data Space
NAP	National Access Point
OEM	Original Equipment Manufacturer (in the context of vehicle manufacturers)
Open DEI	Open Platforms and Large-Scale Pilots in Digitising European Industry
PTA	Public Transport Authority
PTO	Public Transport Operator
ROI	Return on Investment
RTO	Research and Technology Organisation
RTTI	Real-time traffic information services (in the context of the ITS Directive)
SIG	Special Interest Group (in the context of EIT Urban Mobility's Data Space SIG)
SME	Small and Medium Enterprises
SRTI	Safety-related traffic information (in the context of the ITS Directive)
SSTP	Safe and secure parking places for trucks (in the context of the ITS Directive)
SUMI	Sustainable Urban Mobility Indicators
TEN-T	Trans-European Transport Network
V2X	Vehicle-to-"Everything", referring to the low-latency communication between vehicles (V2V) and vehicles and infrastructure (V2I)

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