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STORY ON THE COMMON EUROPEAN MOBILITY DATA SPACE

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Author(s)	CARSA: Marco Graziadio and Pär Weström
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Addressee officer	Katalin IMREI Policy Officer European Commission, DG CONNECT Unit G1 — Data Policy and Innovation MERP 04/B002, L-2920 Luxembourg katalin.imrei@ec.europa.eu
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EXECUTIVE SUMMARY

This document presents an extensive analysis of data sharing in the European mobility sector with a focus on the development and deployment of the Common European Mobility Data Space (EMDS). It leverages inputs from deployEMDS—the first deployment project for the EMDS funded under the Digital Europe Programme and other European initiatives. The study examines market trends, policy frameworks, technological innovations, and real-world use cases to assess how data sharing can drive sustainable and efficient mobility.

Market analysis, trends, challenges and policy context

The mobility sector is a critical pillar of modern society, influencing economic growth, urban planning, and environmental sustainability. The document reviews segmented market data—ranging from passenger cars and electric vehicles to freight and shared mobility—highlighting significant growth rates, revenue forecasts, and an increasing emphasis on sustainable transport.

With transport responsible for a large share of global oil consumption and CO_2 emissions, data-driven innovations are crucial for decarbonizing urban mobility. Increased data sharing, combined with emerging technologies such as the Artificial Intelligence, Digital Twins, and Connected and Autonomous Vehicles (CAVs) are identified as catalysts for transforming the sector. The main barriers and challenges linked to each main trend are mapped, including e.g., lack of standards, limited awareness/acceptance of data sharing and lack of skills.

The report provides an overview of the extensive EU policy framework related to the creation of the mobility data space. Critical regulations include the European Data Strategy, Data Governance Act, Data Act, AI Act, and the ITS Directive, along with initiatives such as the Digital Markets Act, Digital Services Act, and the EU Green Deal. These policies aim to ensure secure and interoperable data sharing across public and private stakeholders, promoting sustainable mobility.

deployEMDS use cases descriptions

The document illustrates potential benefits of a unified mobility data space through analyses and descriptions of three of the sixteen use cases developed within the deployEMDS project:

- Barcelona**:** A multi-operator data governance ecosystem for bus fleets and demand-responsive transport. This use case demonstrates how integrating data from various public and private operators can optimize service planning and improve public transport efficiency.
- Flanders**:** A project focused on optimizing the reuse of traffic measurement data. By harmonizing data collection at a regional level, this initiative improves urban planning and traffic management, paving the way for smarter, data-driven decision-making.
- Stockholm**:** An initiative aimed at implementing and monitoring zero emission zones to reduce car traffic and enforce environmental policies. This use case exemplifies how data sharing supports sustainability by enabling real-time monitoring and adaptive policy interventions.

Additional examples from other projects highlight the broader potential of mobility data sharing, e.g., for traffic optimization, floating bicycle data utilization, and innovative public-private collaborations.

Key insights and conclusions

The document underscores several core insights:

- **Enhanced efficiency and innovation:** A common mobility data space reduces the "overhead" of data collection and management, allowing seamless integration and utilization of data. This benefits urban planners, service providers, and technology developers by enabling new services—from real-time multimodal journey planning to dynamic routing algorithms.
- **Sustainability benefits:** Improved data sharing is linked to reduced congestion, lower greenhouse gas emissions, and better resource allocation. By nudging behavioural changes and optimizing traffic flows, data-driven solutions contribute directly to environmental sustainability.
- **Challenges and future directions:** Despite its promise, the deployment of the EMDS faces challenges such as ensuring interoperability, maintaining data quality across diverse regions, and addressing ethical issues (e.g., privacy, data protection, and digital inequality). Ongoing efforts in standardization, regulatory compliance, and stakeholder education are critical for overcoming these hurdles.
- **Collaborative ecosystems:** The project emphasizes the importance of creating localized data-sharing ecosystems that, while tailored to regional needs, adhere to a harmonized framework. This dual focus supports both local innovation and cross-border interoperability, laying the groundwork for a scalable, pan-European mobility data space.

In conclusion, the creation of a Common European Mobility Data Space represents a pivotal step toward a more efficient, sustainable, and digitally empowered transport system across Europe. The document highlights both the significant opportunities and the practical challenges that lie ahead, urging continued collaboration among policymakers, industry, and research institutions to fully realize the benefits of data-driven mobility.

1 Introduction

As part of the European Digital Strategy and the EU Data Strategy, the European Commission is funding the creation of “Common European Data Spaces” in 14 different industry sectors and domains of public interest, including Agriculture, Health, Finance, Manufacturing, Media, Mobility, etc.[1] They bring together relevant data infrastructures and governance frameworks based on shared policies and rules, to facilitate data pooling and sharing in specific sectors or domains.

DeployEMDS is the first deployment project for a common European Mobility Data Space (EMDS), supported by the Digital Europe Programme, running from November 2023 until October 2026. This study on mobility data sharing leverages inputs from the deployEMDS project and other European initiatives.

Objectives of the story

This report aims to analyse opportunities and challenges of data sharing in the European mobility sector, linked to the development of the European Mobility Data Space. One objective is to provide an update on the status of deployment of the EMDS, with a deeper analysis of three use cases being developed in the deployEMDS project. Additional examples of use cases and initiatives of data sharing and/or data space collaboration are also explored. The use case descriptions are linked to an analysis of the expected benefits and impacts of data sharing in the mobility sector, along with main difficulties and lessons learned.

Methodological approach

The overall research questions addressed in the study are:

- Who are the key actors of data sharing in the EU mobility sector in different constellations (B2B, B2C, B2G, etc.)?
- How does data sharing contribute to sustainable and efficient mobility?
    - What are the opportunities offered by better data-sharing in the EU mobility sector at the moment?
    - What are some successful examples of data sharing in the EU mobility sector?
    - How could data sharing improve the user experience?
    - How can a European mobility data space contribute to sustainability and efficiency?
- What technological solutions enable secure and efficient data sharing in the mobility sector?
    - How does the data space deployment embrace new technologies, such as AI?
- What are the challenges or blocking factors of better data-sharing in the EU mobility sector at the moment?
- What ethical considerations arise in the data sharing practices in the EU mobility sector (access issues, social inequalities, etc.)?
- What legal/policy framework is in place to support data sharing across Member States, within the mobility sector, between the mobility sector and other sectors?
    - What are the EU policy objectives for data sharing in the mobility sector?
    - How can EU-level policies on data support the competitiveness of the European mobility sector?

[1] European Commission website, Digital Strategy | Common European Data Spaces, https://digital-strategy.ec.europa.eu/en/policies/data-spaces

- How can EU policy makers further enhance and support data sharing in the mobility sector?

The data collection approach is based on desk research, with a review of e.g., market statistics, academic- and policy related documents linked the mobility, transport and data sharing. In addition, primary data are gathered through interviews with the deployEMDS project coordinator and with key decision makers for the implementation of the three selected deployEMDS use cases, as well as with representatives of three other initiatives.

In an initial contact with the coordinator of deployEMDS it was agreed to concentrate the analysis on the local implementation projects being developed in three cities/regions, showing relatively good progress.

- Flanders | Use Case: Optimising the (re)-use of traffic measurements.
- Stockholm | Use Case: Implementing and monitoring zero emission zones and reduction of car traffic.
- Barcelona | Use Case: Multi-operator data governance ecosystem for bus fleets and demand-responsive transport.

A list of the interviews and participating persons can be found in the Annex, including representatives from three additional projects/use cases analysed.

Whenever possible, quantitative data sources are presented to add value to the use case descriptions and analyses. However, the deployment of the European mobility data space is still in an early phase, so little quantitative data was found in terms of results or impacts linked to the use cases analysed. Therefore, the story and the main findings have more of a descriptive and qualitative character.

Report structure

Chapter 2 presents the framework settings for the current developments towards increased data sharing in the mobility sector and the creation of a European mobility Data Space. It presents a market analysis of the mobility sector accompanied by an assessment of the main trends, challenges, policies and regulations linked to sustainable mobility and data sharing. [2]

Chapter 3 portrays different use cases and examples of initiatives for mobility data sharing and collaboration. Initially it provides an introduction to the deployEMDS project, its objectives and status of progress. Next, the expected project outcomes and impacts are illustrated through three selected deployEMDS use cases, extended to apply also for a more generic scenario. Finally, additional examples of successful mobility data sharing, from other projects or initiatives, are presented.

Chapter 4 aims to summarise the analysis by providing conclusion linked to the main research questions of the study.

[2] The analysis in Chapter 2 complements the previous report of the European Data Market study: IDC, 2023, Data for mobility study, available at, https://ec.europa.eu/newsroom/dae/redirection/document/100926

2 Market, trends, challenges and related policies in the mobility sector

The first part of chapter 2 presents a market analysis of the mobility sector, with an outlook over the next few years. Both a global and a European perspective of the industry are provided. Subchapter 2.2 explores the impact that data-driven technological innovations will have on the mobility sector, highlighting related trends and challenges. Subchapter 2.3 provides a quick overview of EU policies linked to mobility data and sustainable mobility.[3]

2.1 Market analysis and industry outlook

In this study, the term "*mobility*" refers to the movement of goods, people and information whether by road, rail, sea or air. Therefore, as defined, terms such as transport, logistics and travel should be considered as part of the mobility sector.

The sector as a whole plays a vital role in society and the global economy with a significant impact on employment and economic growth. It is one of the main pillars of modern societies and economies affecting nearly all services within a country. It is challenging to find references regarding the size of the mobility sector, due to its diverse segments. However, as an indication of its importance the transport sector alone contributes with 5% of the European GDP and directly employs around 10 million workers.[4]

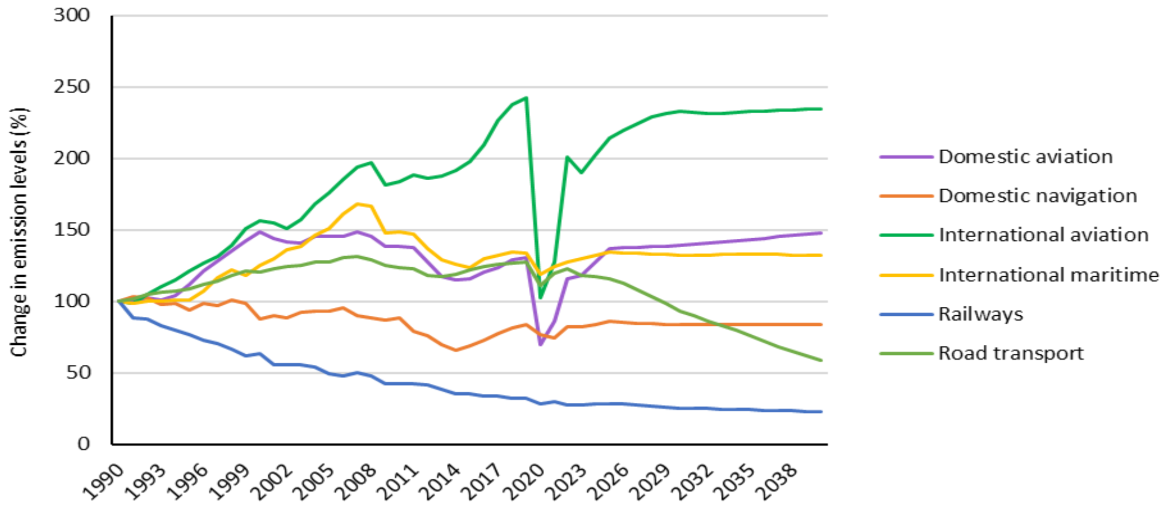
On the other hand, the sector also causes a substantial negative impact on the environment and human health, considering that the sector is a major user of energy and consumes the majority of the world's oil. According to some estimates, transportation accounts for approximately 64% of global oil consumption, 27% of all energy use, and 23% of energy-related CO2 emissions worldwide.[5] In Europe, the mobility sector is responsible for about a quarter of the EU's total greenhouse gas (GHG) emissions.

[3] Subchapters 2.2 and 2.3 are complementing based on a previous report of the European Data Market study: IDC, 2023, Data for mobility study, available at https://ec.europa.eu/newsroom/dae/redirection/document/100926

[4] European Commission, 2020, COMMUNICATION FROM THE COMMISSION TO THE EUROPEAN PARLIAMENT, THE COUNCIL, THE EUROPEAN ECONOMIC AND SOCIAL COMMITTEE AND THE COMMITTEE OF THE REGIONS - Sustainable and Smart Mobility Strategy – putting European transport on track for the future, https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A52020DC0789

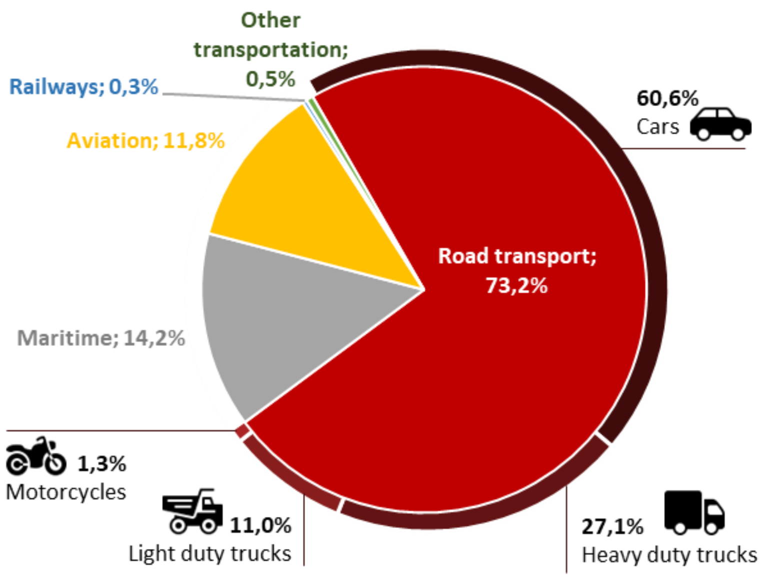
[5] NTU INTERNATIONAL Website, Sector: Transport & Mobility, https://www.ntu.eu/what-we-do/sectors/transport-mobility/

Figure 1. Greenhouse gas emissions from transport in the EU, by transport mode - past and projected



Source: European Environment Agency, 2024[6]

Figure 2.Greenhouse gas emissions breakdown by transport mode (2024)



Source: European Environment Agency, 2024 [6]; Destatis, 2024 [7]; and Statista, 2024 [8]

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[6] European Environment Agency, 2024, Greenhouse gas emissions from transport in the EU, by transport mode and scenario, https://www.eea.europa.eu/en/analysis/indicators/greenhouse-gas-emissions-from-transport/greenhouse-gas-emissions-from?activeTab=8a280073-bf94-4717-b3e2-1374b57ca99d

[7] Destatis, 2024, Road transport: EU-wide carbon dioxide emissions have increased by 21% since 1990, https://www.destatis.de/Europa/EN/Topic/Environment-energy/CarbonDioxideRoadTransport.html#:~:text=Around%20760%20million%20tonnes%20of,trucks%20for%20a%20further%2012%25.

[8] Statista, 2024, Analyze what lies ahead for global mobility over the next 5 years, https://www.statista.com/outlook/mobility-markets#overview

2.1.1 Global overview

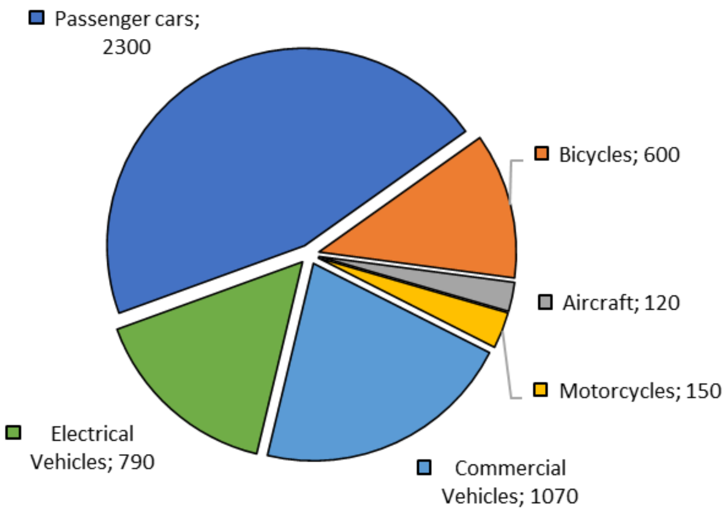
After analysing several studies, it was observed that it is not possible to assess the volume and value of the mobility market in its entirety, but only to evaluate some segments, to the detriment of others. Therefore, the market information provided in this subchapter must be considered as partial and not comprehensive.

For example, Statista provides some current and forecast data on sales, revenues and growth rate, but only for some industry segments such as passenger cars, motorcycles or commercial vehicles, but it neglects the maritime market, which by definition can be considered a segment of the mobility sector.

According to Statista, passenger cars are the market segment among those analysed that is expected to reach the highest turnover in 2024, with a value of approximately 2.300 trillion euro, followed by commercial vehicles and electric vehicles with a turnover of 1.070 and 790 trillion euro, respectively.[9]

Passenger cars is also the market segment among those analysed that is expected to reach the highest annual growth rate in the period 2024-2029, with a rate of 7,99% followed by motorcycles and transportation and logistics with a rate of 3,56% and 2,37% respectively.[10] In terms of sales, the analysis shows that bicycles are the market segment with the most units sold expected to reach approximately 138 million units in 2029 followed by passenger cars and motorcycles respectively with 79 and 63 million.[11]

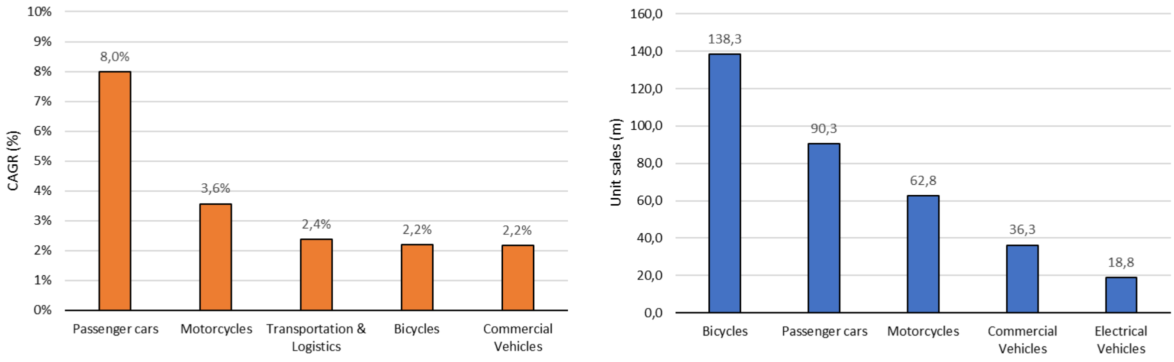
Figure 3. Global revenue forecast (in € trillion) for some segments of the mobility market



Source: Statista, 2024 [12]

[9] Statista, 2024, Analyze what lies ahead for global mobility over the next 5 years, https://www.statista.com/outlook/mobility-markets#overview
[10] Ibid
[11] Ibid
[12] Ibid

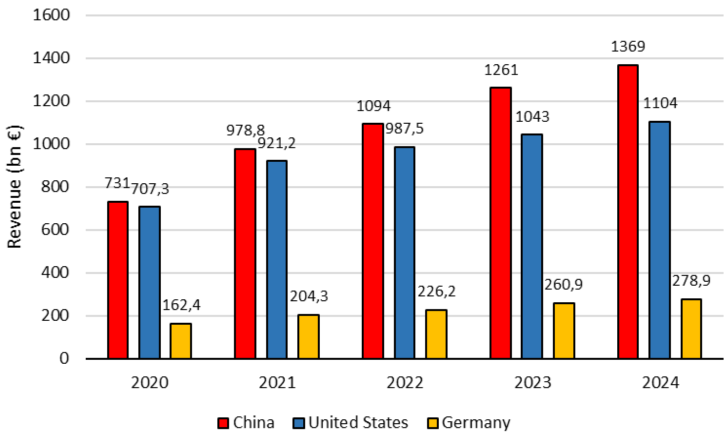
Figure 4. Global annual growth rate (CAGR) forecast for some segment of the mobility market (left) | Global unit sales forecast for some segments of the mobility market (right)



Source: Statista, 2024 [13]

In addition, Statista also provides market insights of the top 3 countries in the world that hold the largest market share. As can be seen in the figure below, over the past 5 years, China, USA and Germany have held the top three positions.[14]

Figure 5. Top 3 countries by revenue in the mobility market in the Period 2020-2024



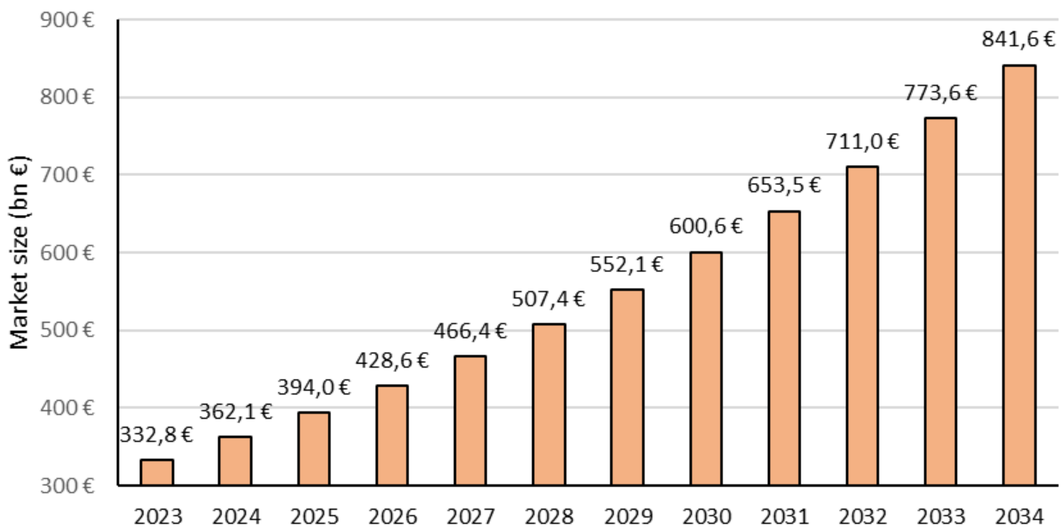
Source: Statista, 2024 [15]

Finally, some market insights are also provided on the state of the shared mobility industry[16], given the importance that this sector is having in many cities across the world, as it promotes the adoption of sustainable and eco-friendly transportation options. In particular, the development of this subsector is strongly connected to the need to facilitate access to different datasets, such as all the datasets showing the location and availability of shared mobility services in real time.

The global shared mobility market was USD 381.17 billion in 2024 and is expected to be worth approximately USD 885.94 billion by 2034, with an annual growth rate of 8.8%.

[13] Ibid
[14] Ibid
[15] Ibid
[16] In this context, the concept of shared mobility refers to any transportation service and resource that is shared between users, either simultaneously or one after the other. This includes public transportation, bike sharing, scooter sharing, car sharing, ride-on-demand, and micro transit, and commute-based or ride-sharing modes such as carpooling and vanpooling.

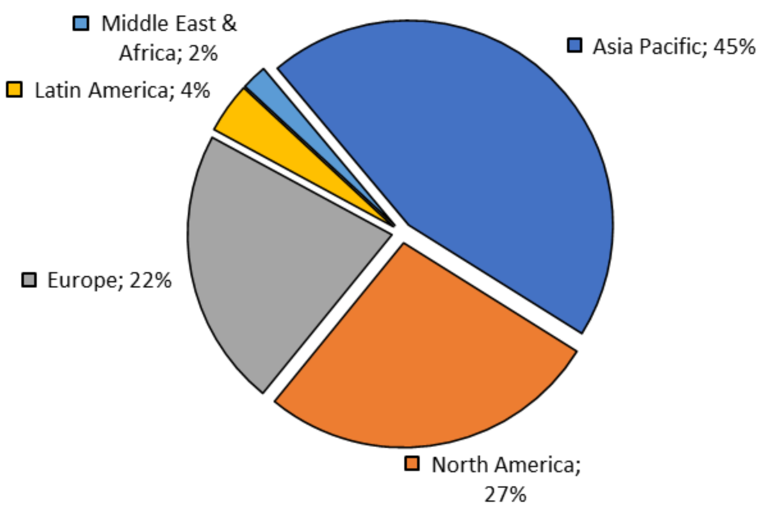
Figure 6. Global shared mobility market size from 2023 to 2034



Source: Precedence RESEARCH, 2024 [17]

Asia Pacific is the region that contributes the largest revenue share, over 45% in 2023. In comparison to other countries, China is expected to generate the most revenue, reaching US$365bn in 2024.[18]

Figure 7. Shared mobility market share, by region, 2023



Source: Precedence RESEARCH, 2024 [19]

2.1.2 European overview

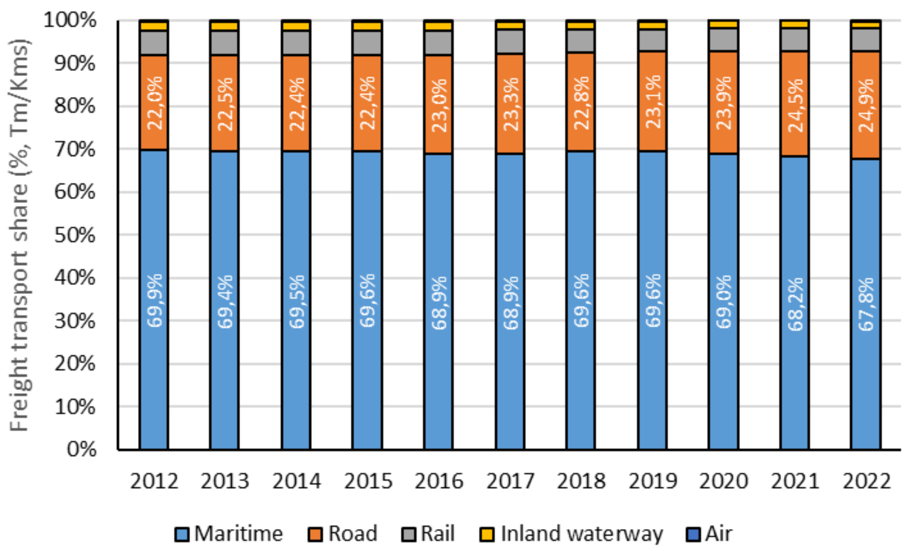
As already seen in the previous chapter, even at European level, it is not possible to quantify in its entirety the value and volume of the mobility market but only to provide estimates of some segments.

[17] Precedence RESEARCH, 2024, Shared Mobility Market Size, Share, and Trends 2024 to 2034, https://www.precedenceresearch.com/shared-mobility-market
[18] Ibid
[19] Ibid

According to Mordor Intelligence, the size of the European freight transport and logistics market is estimated at 1.27 trillion USD in 2024 and is expected to reach 1.55 trillion USD by 2030, growing at a CAGR of 3.37%.[20]

Maritime transport represents the largest share of freight transport performance in the EU, on a quantity of material transported per km performed basis, followed by road and rail transport. [21]

Figure 8. Modal split of freight transport in Europe for the period 2012 – 2022

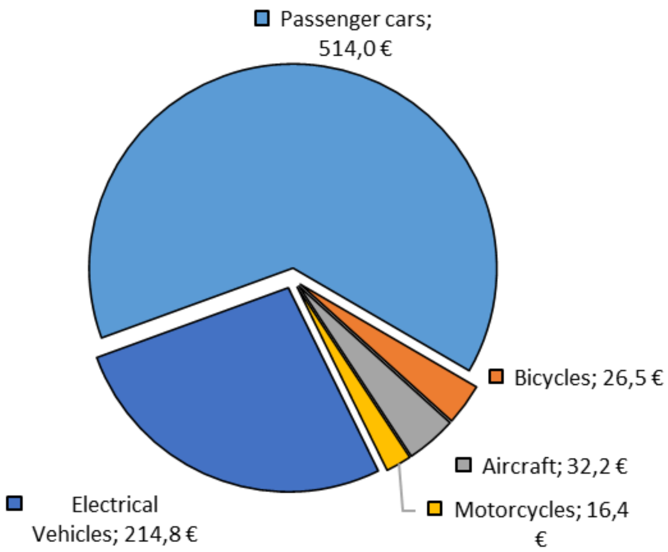


Source: Eurostat, 2024 [22]

Further data regarding the mobility market in Europe is provided by Statista and reported below. In particular, it is noted that the *Passenger Cars with combustion engine* is the market that generates the highest revenues, which is expected to reach €514 billion in 2024, followed by *Electrical Vehicles* and *Aircraft* with 214,8 and 32,2 EUR billion respectively. In the period 2024-2029, *Electric Vehicles*, among the segments analysed, are expected to represent the market share that will grow the most with a CAGR value of11,1%. In contrast, it is observed that the annual growth share of the market will decrease by 9.9% for the "Aircraft" segment. Instead, analysing the units sold expected for 2029, it is estimated that bicycles will reach 22.5 million units followed by passenger cars and electric vehicles with 17.6 and 5.6 million units respectively.[23]

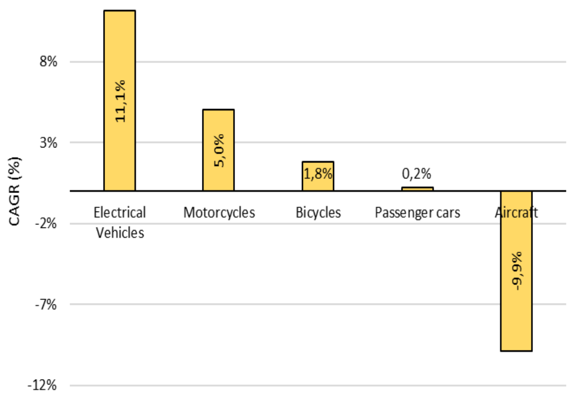
[20] Mordor Intelligence, Europe Freight And Logistics Market Size, 2024, https://www.mordorintelligence.com/industry-reports/european-freight-logistics-market/market-size#:~:text=Europe%20Freight%20And%20Logistics%20Market%20Analysis,period%20(2024%2D2030).
[21] Eurostat, Freight transport statistics - modal Split, 2024, https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Freight_transport_statistics_-_modal_split
[22] Ibid
[23] Statista, 2024, Analyze what lies ahead for global mobility over the next 5 years, https://www.statista.com/outlook/mobility-markets

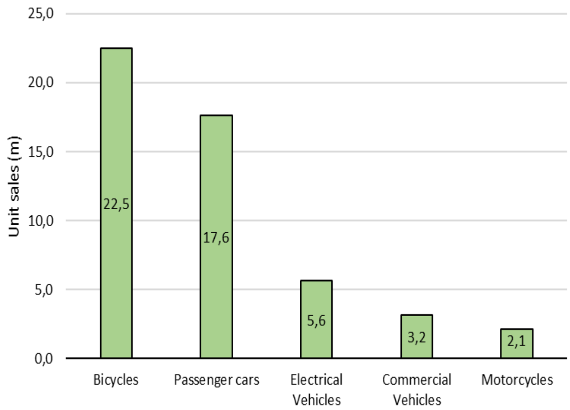
Figure 9. Forecasted revenues in Europe for some segments of the mobility market.



Source: Statista, 2024 [24]

Figure 10. Projected annual growth rate in Europe (CAGR) for some segment of the mobility market (left) | Projected unit sales in Europe for some segments of the mobility market (right)





Source: Statista, 2024 [25]

2.2 Current mobility trends and challenges

Mobility data refers to all information generated by the movement of people, vehicles or goods, obtained through smart sensors, digital platforms and personal devices, which if processed appropriately can help societies and cities to progress in areas such as safer and more efficient transport, decarbonisation, greater accessibility to public transport, reduced traffic congestion, optimised resource allocation, etc.

Therefore, unlocking the full potential of mobility data is essential to support Europe in its transition to a more digital and greener urban environment.

[24] Ibid
[25] Ibid

This chapter explores the impact that data-driven technological innovations such as for example Internet of Things (IoT), Artificial Intelligence (AI), real-time data analytics, digital twin are reshaping how people move and how authorities plan the cities of tomorrow.

2.2.1 Mobility-as-a-Service (MaaS)

The global trend towards digitalization and servitization[26] is driving a complete paradigm shift in the way transportation services are provided, and business models are implemented. The concept of "Mobility-as-a-Service" (MaaS) refers to the trend of integrating various means of transportation and transportation-related services into a single, comprehensive, on-demand mobility service accessible via a single platform or mobile application.

MaaS offers end users the added value of access to a variety of mobility options, from private vehicles to public transport, tailored to customer demands and needs. On the other hand, by accessing customer information, vendors and operators can offer new services and solutions (for example for ticketing, fare management, smart journey planning, payment systems, etc) as well as new travel demand patterns and dynamics. [27]

As defined in this paper, the concept of MaaS can then encompass two other important sub-trends, such as:

- **Demand-driven transportation (DRT)** (also known as demand-responsive transit or on-demand transit): is a flexible transportation service where routes and schedules are determined on a demand, being responsive to passenger needs, rather than following fixed routes and schedules offered by traditional public transportation such as buses and trains. It can refer to all types of vehicles, such as minibuses, shuttles, taxis or rental cars that are deployed based on passenger requests, made via a reservation system.[28]
- **Multimodal mobility**, which is the integration of multiple modes of transportation (public and private) into a single system. Through this system, users can combine a variety of transportation options into a single trip at their convenience.[29]

The concepts of MaaS, demand-driven transportation and multimodal mobility are rooted in the general idea of creating a more flexible, efficient and intuitive transportation system.

[26] Servitization is a paradigm shift that allows manufacturers to create new business models and revenue streams through innovation, adding added value features to their products in the form of services. This helps them to stand out in the market while also delivering a whole range of other benefits [Source: NTT DATA, 2023, Defining Product Servitization and Why It Matters]
[27] Mapbox, The Future of Transportation: Mobility As A Service (MaaS), https://www.mapbox.com/insights/mobility-as-a-service-maas
[28] Interreg Europe, Demand-Responsive Transport, 2024, https://www.interregeurope.eu/find-policy-solutions/policy-briefs/demand-responsive-transport-0
[29] Automative World, Multimodal mobility is a transportation revolution, 2020, https://www.automotiveworld.com/articles/multimodal-mobility-is-a-transportation-revolution/

Table 1. Benefits of Mobility as a Service

Societies	***Users***	***Businesses***
• MaaS solutions promote more use of public transport, shared vehicles and electric vehicles. As a result, cities would achieve a significant reduction in traffic congestion, but also in greenhouse gases generated by combustion vehicles. • Data collected through MaaS applications can be leveraged by urban planners, civil engineers and public authorities to optimize transport networks but also to make better decisions on how to invest resources to build urban infrastructure.	• By accessing different types of transport, both public and private, using a single application, users can plan a trip more easily, saving time and effort. • By comparing offers between different transport operators, users can opt for the travel mode that best suits their needs and requirements.	Data collected within MaaS solutions can be used: • By fleet operators to improve the efficiency of their fleet and optimize the resources used in their management. • By analytics operators to optimize their services or offer new ones, creating new economic advantages. • By public transport operators to optimize trips and schedules and therefore reduce operating costs.

Source: Elaborated by CARSA - Inspired by the articles "Mobility of the future"[30] and "Mobility as a service (MaaS): a digital, efficient and sustainable form of transport"[31]

According to a study from FTA (USA), 15 European countries offer MaaS in some form.[32] These include 13 countries from EU, Austria, Belgium. Denmark, Finland, France, Germany, Italy, Lithuania, Luxembourg, Netherlands, Portugal, Spain and Sweden, and 2 non-EU countries, Switzerland and United Kingdom.

Barriers and challenges

Based on the information gathered from the extensive literature review developed by *Yasanur Kayikci et Ozgur Kabadurmus* the significant barriers and challenges to successful adoption of MaaS can be summarized as follows:[33]

[30] REPSOL, Mobility of the future, 2024, https://www.repsol.com/en/energy-and-the-future/sustainable-mobility/maas/index.cshtml
[31] Iberdrola, Mobility as a service (MaaS): a digital, efficient and sustainable form of transport, https://www.iberdrola.com/innovation/maas-sustainable-mobility
[32] U.S. Department of Transportation, Federal Transit Administration, 2024, Mobility Data – Standards and Specifications for Interoperability, https://www.transit.dot.gov/sites/fta.dot.gov/files/2024-08/FTA-Report-No-267.pdf
[33] Kayikci et al, 2022, Barriers to the adoption of the mobility-as-a-service concept: The case of Istanbul, a large emerging metropolis, https://www.sciencedirect.com/science/article/pii/S0967070X22003006

Table 2. Barriers and challenges to the development of Mobility-as-a-Service

Barrier	Definition
Data standardization	Data collected from different sources may vary in terms of types and formats, but also in terms of accuracy and completeness. Often, this is due to a lack of standards on how to collect and share data or incorrect application of standards by all parties involved in the sharing process. As a result, interoperability between different systems and applications is not achieved and there is a lack of reliability in the data.
Lack of experienced manpower	There is a shortage of qualified personnel with suitable experience in using MaaS applications.
Limited financial resources (insufficient investments and financial subsidies)	Not all the players involved in the mobility ecosystem have at disposal adequate financial resources to set up systems for secure and effective data sharing. In this respect, it is observed often a lack of financial subsides and incentives from public authorities and governments.
Business Model	On one hand, not all the players involved in the mobility ecosystem are aware about the economic benefits data sharing can generate. On the other, there is a lack of business models for MaaS that the different stakeholders can use to operate their business profitably in a specific marketplace.
Laws and regulations	Laws and regulations may vary from country to country and region to region, especially when it comes to data sharing, for example in terms of privacy, intellectual property and liability. The potential of MaaS applications lies in the integration of multiple mobility services into one app. Many of these services do not originate from the same place and are subject to different regulations. These regulatory differences may create legal challenges for cross-border data sharing.
Stakeholder collaboration	There is a general mistrust between the parties involved in data sharing, especially between public authorities and private sector companies/organizations. This is often related to concerns these entities have about losing their competitive advantage or data misuse (e.g. misusing public data for profit).
Customer engagement and acceptance	There is public resistance that hinders the adoption of MaaS. On the one hand, some of the public is concerned about how their personal data might be used. On the other hand, certain groups, such as the elderly, are not able to use new technologies. In general, there is also little willingness to change certain habits, such as using fewer private cars.

2.2.2 Smart Cities

As defined by the European Commission, the term smart city refers to an urban area where traditional networks and services are made more efficient through the use of digital solutions and communication technologies (ICT).[34] In this concept, therefore, mobility data plays a fundamental role in improving the liveability of cities, as this data can be used among other things to improve transport systems, reduce congestion and promote sustainability.[35]

Barriers and challenges

Based on the information gathered from the extensive literature review developed by *Iyawa* the factors that hinder the widespread adoption of Smart Cities can be summarized as follows[36]:

Table 3. Barriers and challenges to the development of Smart Cities

Barrier	Definition
Infrastructure challenges	The adoption of smart city technologies typically involves significant upgrades of current infrastructure and all related elements, such as sensors, ICT communication systems and data collection systems. The high cost and complexity of maintaining this infrastructure can represent a significant obstacle.
Lack of standards	The technologies used in smart city infrastructures often come from multiple providers. As a result, many of these devices have compatibility and interoperability issues. The lack of standardized protocols and frameworks can hinder the integration of these systems and thus the smooth operation of services.
Limited financial resources (insufficient investments and financial subsidies)	Building smart cities requires significant financial resources for activities such as infrastructure deployment, implementation of all related technologies, and long-term maintenance. The accessibility of both public and private financing, along with the willingness of investors to support smart city projects, plays a crucial role in their successful adoption.
Laws and regulations	The lack of well-defined guidelines, policies and regulatory frameworks that address issues such as data privacy and security discourage the creation of an enabling environment for the implementation of innovation.
Stakeholder collaboration	Cooperation between stakeholders is essential for the successful implementation of smart cities. However, reluctance to share data with other organizations or not being aligned on the same goals and interests reduces collaboration and consequently slows down any progress.

[34] European Commission, Smart cities, https://commission.europa.eu/eu-regional-and-urban-development/topics/cities-and-urban-development/city-initiatives/smart-cities_en
[35] Opendatasoft, Driving change with smart city mobility data sharing, 2023, https://www.opendatasoft.com/en/blog/driving-change-with-smart-city-mobility-data-sharing/
[36] Iyawa, 2024, Journal of Engineering Technology and Innovation. Smart city development: factors hindering its widespread adoption, https://www.jetipublications.com/media/media/SMART_CITY_DEVELOPMENT.pdf

Citizen engagement and acceptance	For smart city initiatives to be successful, it is essential that the community accepts the concept and actively participates in all processes, from planning to design, through decision-making, to ensure that the improvements offered are in line with their needs and objectives. A lack of awareness, understanding or resistance on the part of citizens can hinder the adoption process.
Data privacy and security	There are significant concerns among citizens about the privacy and security of their data. Threats such as the loss of personal and sensitive information or the lack of transparency on how this data is managed are factors that reduce public confidence in the acceptance of such technologies. Not directly linked to smart city solutions, but more generally, this concern also stems from an over-reliance on non-European data technologies and services, which increases the risk of losing control over data generated within EU.
Cultural and organizational change	There is a need for a dramatic change in both the culture and organizational structure of an enterprise for widespread adoption, especially in terms of leveraging innovation and adapting to new ways of working.

2.2.3 Sustainable Mobility

In this document, the term sustainable mobility refers to the development and implementation of environmentally friendly, accessible and socially equitable transport solutions.[37]

Advances in artificial intelligence, developments in low-latency and higher bandwidth connectivity and vehicle-to-everything (V2X) connectivity are facilitating the transition towards sustainable mobility solutions, partly due to the need for governments to find alternative solutions to combat climate change and thus reduce carbon emissions.

This definition therefore includes various modes of transport, including electric vehicles (EVs), hydrogen-powered vehicles, shared mobility services such as car-sharing, ride-hailing and micro-mobility solutions, but also all those measures and actions aimed at making the movement and transport of people and goods more socially inclusive and economically viable.[38]

Barriers and challenges

Achieving sustainable mobility is not an easy task, as there are many complexities and obstacles to overcome, as well as the need for transformative change across the board. As illustrated in the table below, the road to sustainable mobility requires a range of measures, from building and modernizing multimodal transport vehicles, implementing new digital solutions and services, promoting vehicle

[37] The United Nations Secretary-General's High-Level Advisory Group on Sustainable Transport, 2016, Mobilizing sustainable transport for development, https://sustainabledevelopment.un.org/content/documents/12453HLAG-ST%20brochure%20web.pdf

[38] Repsol, The solution to the transportation of the future, 2023, https://www.repsol.com/en/energy-and-the-future/sustainable-mobility/what-is-sustainable-mobility/index.cshtml

sharing, financing and building infrastructure for hybrid vehicles as an alternative to petroleum vehicles.[39, 40, 41]

Table 4. Barriers and challenges to the development of sustainability mobility.

Barrier	Definition
Improving the integration of mobility modes	A series of measures and solutions that foster the adoption of multimodal mobility need to be implemented. For example, it is necessary to improve the efficiency of public transport systems to integrate them with mobility services (Mobility-as-a-Service) or encourage innovation in services that promote the concept of vehicle sharing. At the same time, modernize railway and metro stations or integrate a greater number of multimodal terminals to better manage mobility flows.
Infrastructure challenges	Unlike what we have seen in other trends, the infrastructural challenges for sustainable mobility refer more to the need to implement a series of infrastructures, both physical and digital, to embrace cleaner technologies such as hybrid vehicles, whether electric or hydrogen. An example of this can be the integration of large interchange car parks equipped with charging points for zero-emission vehicles.
Community engagement and acceptance	People are accustomed to existing transport systems and are reluctant to change their mobility habits. It is therefore necessary to develop any communication and awareness-raising action to change these habits, promoting sustainable mobility models and consumption

2.2.4 Connected and Autonomous Vehicles (CAVs)

Connected and autonomous vehicles (CAVs) are vehicles designed to support drivers in automatically performing certain driving tasks, such as keeping the cabin in the lane, adjusting speed based on speed limits, etc.[42]

With the continuous evolution of advanced technologies and easier access to mobility data, these systems are becoming more and more reliable: today they allow drivers to perform secondary tasks,

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[39] European Commission, Sustainable urban mobility, https://transport.ec.europa.eu/transport-themes/urban-transport/sustainable-urban-mobility_en
[40] Brighten, The (Still) Challenges of Sustainable Mobility, https://brightenconsulting.com/en/the-still-challenges-of-sustainable-mobility/
[41] Forvis mazars, Sustainable mobility: global challenges and lessons from China, https://www.forvismazars.com/group/en/insights/latest-insights/reinventing-the-wheel-what-s-driving-change/sustainable-mobility-challenges-and-lessons#:~:text=Achieving%20sustainable%20mobility%20requires%20scaling,and%20other%20alternatives%20to%20petroleum.
[42] Brake the road safety charity, Connected and autonomous vehicles, https://www.brake.org.uk/get-involved/take-action/mybrake/knowledge-centre/vehicles/connected-and-autonomous-vehicles#:~:text=Connected%20and%20autonomous%20vehicles%20(or%20CAVs)%20combine%20connectivity%20and%20automated,capabilities%3B%20GPS%20and%20telecommunications%20systems.

but it is expected that in the near future such vehicles will be able to move autonomously in complex urban environments with minimal human intervention.

The impact of these solutions could be enormous. According to some estimates, these vehicles could drastically reduce road accidents, as 90% of road accidents are due to human error, or reduce the cost of public transport by about 50%.[43]

In addition, the widespread adoption of CAVs could also:[44, 45, 46]

- Improve access to mobility for everyone, including those who are unable to drive due to age, disability or other factors, reduce traffic congestion and reduce CO_2 emissions by optimizing driving behaviours.
- Promote the provision of new services such as on-demand mobility and shared mobility.

Barriers and challenges

Autonomous vehicles have the potential to completely reshape the transportation industry. However, there are still many obstacles that prevent their widespread adoption and implementation. Major challenges include safety and liability, technical and technological barriers, as well as ethical and social issues. Below are just a few of the major challenges that autonomous vehicles face.[47,48]

Table 5. Barriers and challenges to the development of Connected and Autonomous Vehicles

	Barrier	Definition
	**Safety and reliability**	Ensuring safety and reliability remains a key element in the development of autonomous vehicles. These guarantees are especially lacking in complex and unpredictable scenarios. Inaccuracies in identifying certain events such as complex traffic situations, adverse weather conditions, deteriorated road conditions, construction zones, or unmapped areas can potentially cause significant accidents, resulting in fatalities for those involved.

[43] Ferrovial, Connected Autonomous Vehicles, https://www.ferrovial.com/en/innovation/technologies/connected-autonomous-vehicles/

[44] WORLD ECONOMIC FORUM, 2024, How autonomous vehicles can be integrated with public transport systems for urban mobility, https://www.weforum.org/stories/2024/10/how-will-autonomous-vehicles-shape-urban-mobility/

[45] Pan et al, 2024, The impacts of connected autonomous vehicles on mixed traffic flow: A comprehensive review, https://www.sciencedirect.com/science/article/abs/pii/S0378437123010099#:~:text=Study%20underscores%20CAVs'%20potential%20to,emissions%2C%20enhancing%20overall%20traffic%20efficiency

[46] IEEE, 2020, Quantifying the impact of connected and autonomous vehicles on traffic efficiency and safety in mixed traffic, https://ieeexplore.ieee.org/document/9294174

[47] Hussain et al, 2024, Advancements, challenges, and implications for navigating the autonomous vehicle revolution, https://www.researchgate.net/publication/384816546_Advancements_challenges_and_implications_for_navigating_the_autonomous_vehicle_revolution#:~:text=These%20difficulties%20include%20security%2C%20safety,design%2C%20performance%2C%20and%20accuracy.

[48] Medium website, 2023, Overcoming Obstacles: Common Challenges in Large-Scale AV Deployments, https://medium.com/@jamesespinosa926/overcoming-obstacles-common-challenges-in-large-scale-av-deployments-8bcd7e17fb28

Technology limitations	As mentioned above, there are several complex and unpredictable scenarios that can cause accidents. To minimize the risks, there is a need to develop robust and reliable technologies. Specifically, there is a need to develop AI algorithms that can quickly process large amounts of data and handle any scenario providing accurate insights and predictions as quickly as possible.
Ethical and social questions	Autonomous vehicles present significant ethical and social challenges, including moral decision-making in situations where harm is unavoidable. Machine learning tools and artificial intelligence (AI) models can be negatively impacted by the training datasets they are fed, as they are often influenced by the subjectivity of the person running them.
Infrastructure challenges	Robust communication networks are needed for autonomous vehicles to operate efficiently and safely. Existing infrastructure may need upgrades to support autonomous capabilities. At the same time, it is critical to integrate a variety of advanced technologies into the urban and transportation network, such as 5G technologies, vehicle-to-vehicle and vehicle-to-infrastructure communication, sensors, etc. Addressing this challenge requires technological advances, regulatory and safety frameworks, but also significant amounts of funding.
Lack of standards	There is a need to initiate collaborative initiatives with the intent of creating standards, protocols and certification of both performance and safety that allow for the evaluation of autonomous functionality and objective conformity under various conditions.
Citizen engagement and acceptance	Public engagement and social acceptance are vital for the successful deployment of autonomous vehicles (AVs). Proactive communication about AV capabilities, safety, and risks helps set realistic expectations and builds trust. Tailored educational outreach and demonstrations can address concerns and promote acceptance. Additionally, the increased costs for making the car autonomous is another barrier. For example, in Europe, Tesla's fully autonomous driving technology can be purchased for around €10.000, but this can vary depending on the country and any local taxes or import fees.

2.2.5 Digital Twin for mobility

Continuous advances in sensors and the ability to collect more and more data on different aspects are leading to an increasing use of digital twin technology also in the mobility sector. Thanks to the ability to virtually replicate a real environment and all the processes and systems that support it, digital twin technologies are becoming a tool that urban planners, public authorities and transport operators are increasingly relying on to optimise the way cities are designed and managed.

By simulating different scenarios, this technology allows testing different solutions before implementing them in real life, facilitating the decision-making process. Therefore, the use of DT in the mobility sector can help optimize urban mobility planning such as public transport, predict when maintenance or repairs of infrastructure are needed, design more efficient and sustainable transport networks, identify vulnerable points in the transport system and implement preventive measures, etc.[49, 50]

Several cities such as Stuttgart[51] and Genoa[52] are already implementing DT technologies as part of their Smart Mobility programs, and more than 500 cities are expected to follow suit by 2025, saving up to $280 billion by 2030.[53]

Barriers and challenges

According to the literature review, Digital Twin technology currently faces several shared challenges alongside AI and IoT technologies. These include barriers related to data standardization and security, increased demand for power and storage, as well as the complexity of its architecture.

The following table showcases only those barriers and challenges that hinder the implementation of Digital Twin in the mobility sector. In this respect it is noted that this analysis also relies on the lessons learned from the City of Aachen, pioneering 'digital twin' technology to enhance urban management and sustainability.[54,55]

Table 6. Barriers and challenges to the development of Digital Twin for mobility

	Barrier	Definition
	**Large-scale industrial applications.**	Scalability is one of the main challenges in implementing digital twin technology. In particular, finding the right trade-off between a simplistic model (which is less expensive, but less accurate) and a very complex model (which is very accurate, but also prohibitively expensive). Therefore, the need to understand well and evaluate on a case-by-case basis.
	**Lack of standards**	There is a need to develop benchmarks and international standards to make the field more mature.

[49] Lehtola et al, 2022, Digital twin of a city: Review of technology serving city needs, https://www.sciencedirect.com/science/article/pii/S1569843222001169
[50] M2050, The digital twin a revolution for the world of mobility, https://m2050.media/en/the-digital-twin-a-revolution-for-the-world-of-mobility/#:~:text=A%20tool%20for%20urban%20mobility&text=This%20is%20where%20digital%20twins,performance%20issues%20and%20generate%20improvements.
[51] HEXAGON press release, 2022, Hexagon, Fujitsu support Stuttgart's urban digital twin project, https://hexagon.com/company/newsroom/press-releases/2022/hexagon-fujitsu-support-stuttgarts-urban-digital-twin-project
[52] M2050, 2022, The world's first fully connected city's transportation network, https://m2050.media/en/hitachi-the-worlds-first-fully-connected-citys-transportation-network-genoa/
[53] SKEDGO, 2023, Leveraging digital twins to improve urban transport, https://skedgo.com/es/leveraging-digital-twins-to-improve-urban-transport/
[54] European Commission, 2024, Digital Twins – Lessons Learned from the City of Aachen, https://urban-mobility-observatory.transport.ec.europa.eu/resources/case-studies/digital-twins-lessons-learned-city-aachen_en#:~:text=In%20the%20field%20of%20mobility,departmental%20collaboration%20within%20city%20administrations.
[55] Nature Computational Science, 2024, The increasing potential and challenges of digital twins, https://www.nature.com/articles/s43588-024-00617-4

Data silos	There is resistance from departments, even within the same authority or administration, to share their data or make it publicly available to other departments. Successful data integration, a key component of DT implementation, required close collaboration between data owners.
Laws and regulations	The implementation of digital twins may encounter legislative obstacles in the mobility sector. For example, in the absence of a clear legal basis for the data processing process, some activities may require greater consideration and therefore more effort to ensure regulatory compliance.
Lack of Open-Source Software	Few software is available under open-source licenses. This raised also important considerations regarding software compatibility and integration with existing systems.

2.2.6 Intelligent Transport System (ITS)

ITS stands for "Intelligent Transport Systems" and refers to any form of transport infrastructure that interact with various elements of the surrounding ecosystem, including other vehicles, pedestrians, traffic signals, road signs, construction sites. Through real-time data exchange, these systems have the potential to make mobility safer. more efficient and more sustainable. ITS can range from a wide array of V2V (vehicle-to-vehicle), V2I (vehicle-to-infrastructure) and V2X (vehicle-to-everything) technologies.[56]

Access to real-time data has the following key benefits:[57]

- Better incident management: When incidents occur, ITS identifies the location of the accident and provides alerts about that area to other drivers. This could reduce the risk of secondary incidents, improve emergency response times, and reduce traffic congestion.
- Better traffic management and control: Data is used to regulate traffic flow, redirecting it when there is traffic congestion.
- Reduced pollution and energy consumption: By reducing the amount of downtime and instances of traffic congestion, ITS ensures that a significant portion of unnecessary carbon emissions are eliminated. At the same time, monitoring the space between vehicles allows for constant speed, thus minimizing fuel consumption.

Barriers and challenges

As with any tech-forward innovation, also ITS has implementation challenges. Below, ITS barriers and challenges are explored.[58, 59]

[56] Paack, 2022, Intelligent Transport Systems (ITS): Definition & Types, https://paack.co/intelligent-transport-systems/
[57] MODESHIFT, 2023, What Is An Intelligent Transport System And How Does It Work?, https://www.modeshift.com/what-is-an-intelligent-transport-system-and-how-does-it-work/
[58] XENATECH, 2024, Challenges and Opportunities of Implementing ITS, https://www.xenatech.com/blog/challenges-and-opportunities-of-implementing-its/
[59] Avci I. et al, 2024, Intelligent Transportation System Technologies, Challenges and Security, https://www.mdpi.com/2076-3417/14/11/4646

Table 7. Barriers and challenges to the development of Intelligent Transport Systems

Barrier	Definition
Lack of experienced manpower	Intelligent transportation systems involve advanced technologies such as machine learning, artificial intelligence, and IoT devices, making them technically complex.
Limited financial resources (insufficient investments and financial subsidies)	The implementation of intelligent transportation systems (ITS) requires a significant initial investment due to the need to purchase and integrate key system components such as sensors, communication devices, cameras and other intelligent infrastructure elements. In addition to these costs, there are those for software development and system integration.
Data privacy and security	ITS systems work best when fed with large amounts of data. However, this can lead to privacy issues. It is essential to implement secure systems and robust security protocols to protect sensitive information from unauthorized access and minimize the risk of data breaches.

2.3 The EU policy setting

The European Union and its Member States are developing a comprehensive set of regulations to ensure the safe and secure use of data and technology, aiming to accelerate sustainable mobility. These regulations focus on the following three main areas:[60]

- **Promoting the growth, governance, and security of the overall data economy.**
    - The European Data Strategy[61], launched in February 2020, seeks to create a unified data market to enhance Europe's global competitiveness. The Strategy aims to improve data access, sharing, and usage, unlocking its potential for economic and societal benefits while safeguarding privacy and data sovereignty. As part of this, the vision of the development of a mobility data space was revealed to position Europe at the forefront of intelligent transport system innovation, including connected cars and other transportation modes. This data space will enable the access, pooling, and sharing of data from both existing and future transport and mobility databases.
    - The European Data Governance Act[62], which seeks to " increase trust in data sharing, strengthen mechanisms to increase data availability and overcome technical obstacles to the reuse of data."

[60] Updated list of policies and regulations, based on a previous report of the European Data Market study: IDC, 2023, Data for mobility study, available at, https://ec.europa.eu/newsroom/dae/redirection/document/100926

[61] European Commission, 2020, A European strategy for data, COM(2020) 66 final, https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A52020DC0066

[62] European Parliament and the Council of the European Union, 2022, Regulation (EU) 2022/868 of the European Parliament and of the Council of 30 May 2022 on European data governance and amending Regulation (EU) 2018/1724 (Data Governance Act), https://eur-lex.europa.eu/eli/reg/2022/868

- The European Data Act[63] provides legal clarity regarding the access to and use of private sector data. It is "designed to enhance the EU's data economy and foster a competitive data market by making data (in particular industrial data) more accessible and usable, encouraging data-driven innovation and increasing data availability."
- The European AI Act[64] lays the foundations for the regulation of artificial intelligence in the EU and intends to "establish obligations for providers and users depending on the level of risk from artificial intelligence."
- The Digital Markets Act (DMA) and Digital Services Act (DSA), regulate large online platforms (including digital mobility platforms) and ensure safer online spaces, fair competition, and more accountability.[65]
- The Open Data Directive [66] "encourages EU Member States to make as much public sector information available for reuse as possible, because of the additional value data-based innovation can create across all economic sectors." Public transport data, including schedules, traffic data, and infrastructure information, is made available under this directive.
- The European Digital Decade programme[67], which defines a "human-centric, sustainable vision for digital society throughout the digital decade to empower citizens and businesses."
- The NIS 2 Directive[68], which deems the organisations operating in the transport sector as "essential entities" and motor vehicle manufacturers as "important entities" in terms of the application of cybersecurity obligations.
- The General Data Protection Regulation (GDPR) [69]

[63] European Parliament and the Council of the European Union, 2023, Regulation (EU) 2023/2854 of the European Parliament and of the Council of 13 December 2023 on harmonised rules on fair access to and use of data and amending Regulation (EU) 2017/2394 and Directive (EU) 2020/1828 (Data Act), https://eur-lex.europa.eu/eli/reg/2023/2854

[64] European Parliament and the Council of the European Union, 2024, Regulation (EU) 2024/1689 of the European Parliament and of the Council of 13 June 2024 laying down harmonised rules on artificial intelligence and amending Regulations (EC) No 300/2008, (EU) No 167/2013, (EU) No 168/2013, (EU) 2018/858, (EU) 2018/1139 and (EU) 2019/2144 and Directives 2014/90/EU, (EU) 2016/797 and (EU) 2020/1828 (Artificial Intelligence Act), https://eur-lex.europa.eu/eli/reg/2024/1689

[65] European Commission website, The Digital Services Act package, https://digital-strategy.ec.europa.eu/en/policies/digital-services-act-package

[66] European Commission website, When open data meets data spaces, https://data.europa.eu/en/publications/datastories/when-open-data-meets-data-spaces

[67] European Commission website, Europe's Digital Decade, https://digital-strategy.ec.europa.eu/en/policies/europes-digital-decade

[68] European Parliament and the Council of the European Union, 2022, Directive (EU) 2022/2555 of the European Parliament and of the Council of 14 December 2022 on measures for a high common level of cybersecurity across the Union, amending Regulation (EU) No 910/2014 and Directive (EU) 2018/1972, and repealing Directive (EU) 2016/1148 (NIS 2 Directive), https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A32022L2555&qid=1741076758796.

[69] European Parliament and the Council of the European Union, 2016, Regulation (EU) 2016/679 of the European Parliament and of the Council, of 27 April 2016, on the protection of natural persons with regard to the processing of personal data and on the free movement of such data, and repealing Directive 95/46/EC (General Data Protection Regulation), https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=celex%3A32016R0679

- **Ensuring the safe and secure use of data and technology for smart and sustainable mobility.**
    - The Commission Delegated Regulation regarding the establishment of the harmonised provision for an interoperable EU-wide eCall.[70]
    - The Commission Delegated Regulation regarding the provision of EU-wide real-time traffic information services.[71]
    - The Commission Delegated Regulation regarding the provision of EU-wide multimodal travel information services. [72]
    - The European Commission Sustainable and Smart Mobility Strategy (SSMS),[73] presents an action plan with 82 initiatives and "lays the foundation for how the EU transport system can achieve its green and digital transformation and become more resilient to future crises."
    - In November 2023, the European Commission adopted a series of proposals designed to improve the experience of passengers and travellers by strengthening their rights, and related to better multimodal travel information services and the creation of a common European mobility data space. [74]
    - The Intelligent Transport Systems Directive[75, 76] provides a framework for the adoption of common standards and specifications in the European Union (EU) for the creation of Intelligent Transport Systems (ITS) in the field of road transport.
- **Supporting the production, operations, and use of green transportation products and services.**
    - The EU Green Deal,[77] aiming to "achieve a 90% cut in emissions by 2050, delivered by a smart, competitive, safe, accessible and affordable transport system."

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[70] European Commission, 2012, Commission Delegated Regulation (EU) No 305/2013 of 26 November 2012 supplementing Directive 2010/40/EU of the European Parliament and of the Council with regard to the harmonised provision for an interoperable EU-wide eCall, https://eur-lex.europa.eu/legal-content/EN/ALL/?uri=CELEX%3A32013R0305

[71] European Commission, 2022, Commission Delegated Regulation (EU) 2022/670 of 2 February 2022 supplementing Directive 2010/40/EU of the European Parliament and of the Council with regard to the provision of EU-wide real-time traffic information services, https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A32022R0670&qid=1741077603250

[72] European Commission, 2017, Commission Delegated Regulation (EU) 2017/1926 of 31 May 2017 supplementing Directive 2010/40/EU of the European Parliament and of the Council with regard to the provision of EU-wide multimodal travel information services, https://eur-lex.europa.eu/eli/reg_del/2017/1926/oj

[73] European Commission, 2020, COM(2020) 789 final, Sustainable and Smart Mobility Strategy – putting European transport on track for the future, https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A52020DC0789

[74] European Commission, November 2023, Press release: Improved rights and better information for travellers, https://ec.europa.eu/commission/presscorner/detail/en/ip_23_6110

[75] European Parliament and the Council of the European Union, 2010, Directive 2010/40/EU of the European Parliament and of the Council of 7 July 2010 on the framework for the deployment of Intelligent Transport Systems in the field of road transport and for interfaces with other modes of transport, http://data.europa.eu/eli/dir/2010/40/oj

[76] Amended by, Directive (EU) 2023/2661, https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=celex%3A32023L2661

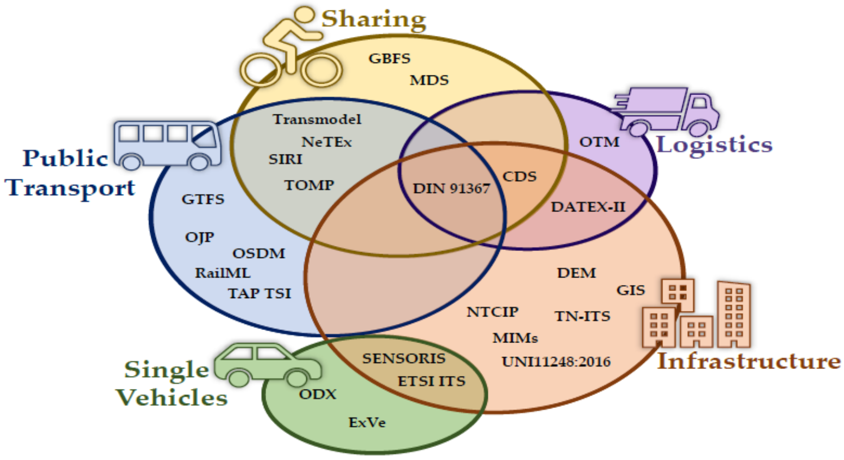
[77] European Commission website, Transport and the Green Deal, https://commission.europa.eu/strategy-and-policy/priorities-2019-2024/european-green-deal/transport-and-green-deal_en

- The EU Directive promoting clean and energy-efficient road transport vehicles.[78, 79]
- The EU Regulation on CO2 emission performance standards for new passenger cars and new light commercial vehicles.[80, 81]

These policies will help to accelerate the transition towards sustainable mobility, by leveraging the strategic role of data and digital technologies to create a market for more seamlessly integrated mobility products and services which better align environmental goals, users' expectations and suppliers' profitability and growth goals.

Besides the above policy and regulation landscape on mobility and data, this transition is also linked to a large number of **standardisation** initiatives. Bellini et al provides a comprehensive overview of mobility and transport data types and standards, summarised in Figure 11, covering the main mobility and transport domains: vehicles, public transport, sharing mobility and logistics: [82]

Figure 11: Overview of data types and data standards for smart mobility domains



Source: Bellini et al [83]

A more detailed mapping of the 28 identified data types and data standards, provided by Bellini, P. et al, shows that most mobility related standards refer to static or real-time data, while historical data are less considered. In terms of mobility domains, most supported standards are found in Public Transport, Infrastructure and Sharing. More than two thirds of the standards mapped use XML or JSON formats (or both), the reason being that they are both human- and machine-readable, making API development easier.[84]

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[78] European Parliament and the Council of the European Union, 2009, Directive 2009/33/EC of the European Parliament and of the Council of 23 April 2009 on the promotion of clean and energy-efficient road transport vehicles, http://data.europa.eu/eli/dir/2009/33/oj
[79] Amended by, Directive (EU) 2019/1161, https://eur-lex.europa.eu/eli/dir/2019/1161/oj
[80] European Parliament and the Council of the European Union, 2019, Regulation (EU) 2019/631 of the European Parliament and of the Council of 17 April 2019 setting CO2 emission performance standards for new passenger cars and for new light commercial vehicles, and repealing Regulations (EC) No 443/2009 and (EU) No 510/2011 (recast), http://data.europa.eu/eli/reg/2019/631/oj
[81] Amended by, Regulation (EU) 2023/851, http://data.europa.eu/eli/reg/2023/851/oj
[82] Bellini, P et al, 2024, Data Sources and Models for Integrated Mobility and Transport Solutions, https://doi.org/10.3390/s24020441
[83] Ibid
[84] Ibid

3 Use cases on data sharing and collaboration – illustrating the importance of developing the European Mobility Data Space

In November 2023, a Communication[85] from the European Commission outlined the way forward for the establishment of a common European mobility data space (EMDS). Aligned to the policies presented under, e.g., the European strategy for data[86] and the Sustainable and Smart Mobility Strategy[87], the communication explains the role of the EMDS in accelerating the digital and sustainable transformation of the European mobility and transport sector.

In this context – and building on the results from the project PrepDSpace4Mobility[88] – the deployEMDS project is the first deployment action under the EMDS initiative. The deployEMDS project[89] aims to facilitate the access, pooling and sharing of transport and mobility data and indicators, thereby aiding policymaking for effective multimodal transportation and traffic management, as well as for tracking the advancement of sustainable urban mobility throughout Europe.

Subchapter 3.1 provides an introduction to the deployEMDS project, its objectives, current status of progress, expected impacts and a list of all project use cases. In subchapter 3.2, the expected outcomes, benefits and potential impacts of the project are further specified and exemplified through three deployEMDS use case descriptions, extended to apply also for a more generic scenario. In subchapter 3.3 additional examples of successful mobility use cases, from other projects or initiatives, are presented – all strongly linked to data sharing and data driven innovation, but not necessarily implemented in a data space context.

3.1 Summary of deployEMDS objectives, activities and current progress[90, 91, 92]

deploy EMDS

The deployEMDS project started in November 2023 and will run until October 2026. The consortium involves 45 European partners with diverse disciplinary and geographical characteristics.

Project objectives

The project objectives are outlined in a summarised manner in the figure below.

[85] European Commission, 2023, Creation of a common European mobility data space, COM(2023) 751 final, https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=COM%3A2023%3A751%3AFIN

[86] European Commission, 2020, A European strategy for data, COM(2020) 66 final, https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A52020DC0066

[87] European Commission, 2020, Sustainable and Smart Mobility Strategy – putting European transport on track for the future, COM(2020) 789 final, https://eur-lex.europa.eu/legal-content/EN/TXT/HTML/?uri=CELEX:52020DC0789

[88] PrepDSpace4Mobility is a Coordination and Support Action, funded under the Digital Europe Programme, laying the foundation for a secured and controlled way of pooling and sharing mobility data across Europe. For more information see: https://mobilitydataspace-csa.eu/

[89] Project website, https://deployemds.eu/

[90] Project website, https://deployemds.eu/

[91] deployEMDS Consortium, 2024, Inception report, Project deliverable D4.1, https://deployemds.eu/wp-content/uploads/2024/04/2024-03-15-D4.1-deployEMDS-Inception-Report-1.pdf

[92] Interview with deployEMDS Coordinator

Figure 12: Summarised objectives of the deployEMDS project

Main objective

- O1: to contribute to the development of a common European mobility data space, compliant with EU mobility and transport legislation.

Specific objectives

- O2: Support the creation and deployment of a technical infrastructure with governance mechanisms for easy access and sharing of key data resources, including cross-border.
  - O2.1: Implement data space building blocks through real-world use cases.
  - O2.2: Support the digitalisation of processes linked to the data space building blocks and their future updates.
- O3: Develop innovative services and applications, and assist in policymaking by making data available, shareable, and reusable for sustainable urban mobility indicators (SUMI) and traffic/travel information.
  - O3.1: Deploy an operational data space for secure and controlled sharing of machine-readable data.
  - O3.2: Support sustainable urban mobility planning and management with accessible data for EU SUMI.
  - O3.3: Provide traffic and travel information in a machine-readable format, in line with the ITS Directive 2010/40/EU and other regulations.

Cross-cutting objectives

- O4: Take into account the work of the EMDS preparatory action (PrepDSpace4Mobility), using as much as possible the common building blocks identified.
- O5: Fully comply with the European Data Spaces Technical Framework. To profit from and use the smart middleware platform and tools that will be developed under topic 2.1.1. of the DIGITAL Work Programme 2021-2022.
- O6: Communicate, disseminate, and exploit the preliminary and final project results.

Source: Elaborated by CARSA, based on information from deployEMDS[93]

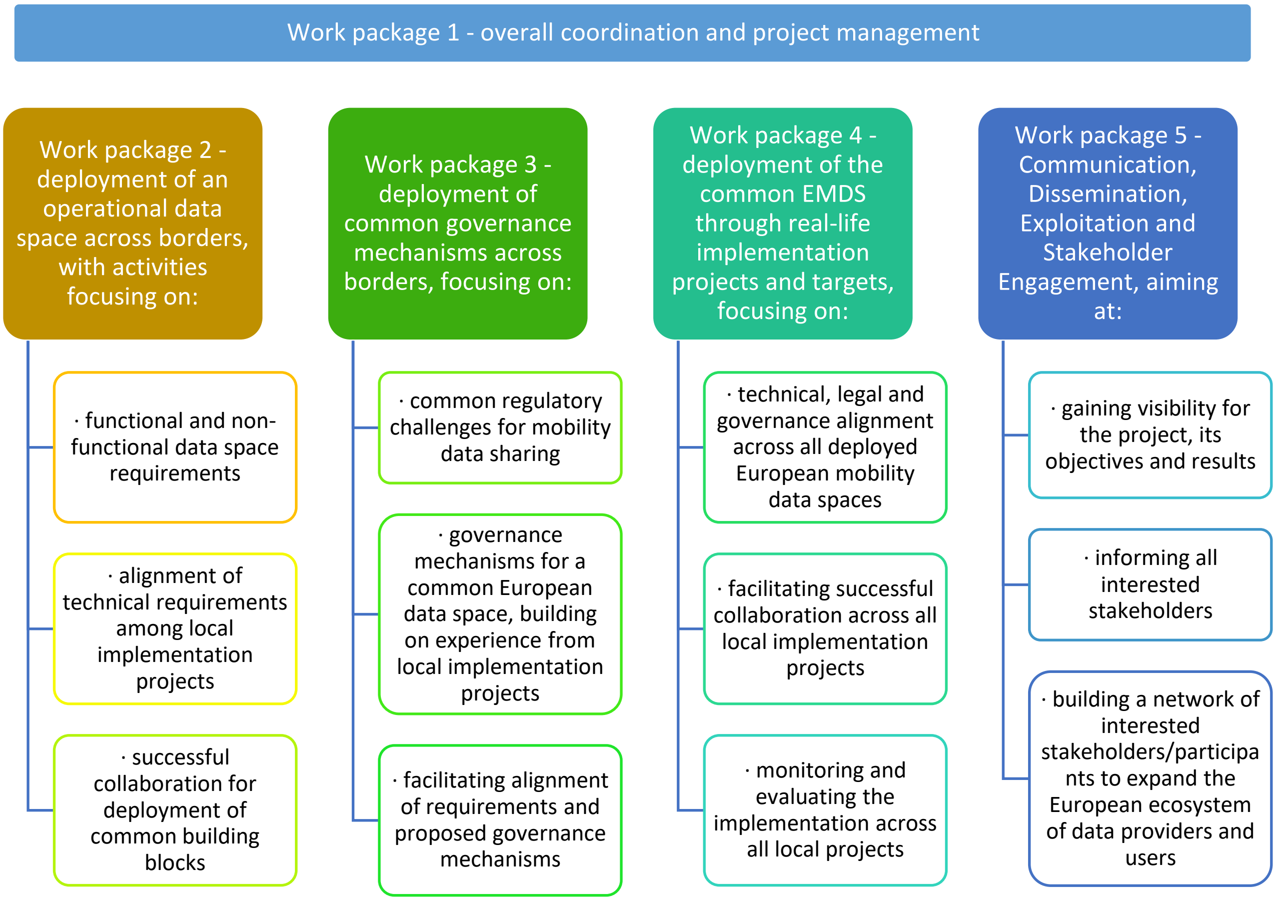
The deployEMDS project showcases its value by highlighting various urban mobility use cases. These examples help stakeholders grasp the practical benefits of data spaces through real-life applications of new or enhanced services and processes. Beyond demonstration, deployEMDS also actively supports the establishment of building blocks for a unified and operational European mobility data space.

Work packages

The project is structured around five work packages (WP), their main activities are briefly outlined in the figure below:

[93] deployEMDS Consortium, 2024, Inception report, Project deliverable D4.1, https://deployemds.eu/wp-content/uploads/2024/04/2024-03-15-D4.1-deployEMDS-Inception-Report-1.pdf

Figure 13: Outline of work packages and activities of the deployEMDS project



Source: Elaborated by CARSA, based on information from deployEMDS

WP4 is of particular interest for this story, as it is directly linked to the "local implementation projects" and their respective use cases, which are the main focus of the analysis.

Progress of the project

The first six months of the project served to elaborate the different use cases and define the data products for the cities and regions and their partners locally. Building on that, the team looked into the technical infrastructure requirements of those use cases, presented in the technical requirements deliverable[94]. Also, a lot of efforts during the first year were put on educating people, to get the whole consortium familiar with the data space concept. Because many cities and regional authorities may have had the ambition already to use some sort of data platform, but they have never heard of the data space concept, nor its possible components, or the maturity of the of the different technical solutions that can be implemented in such a data space.[95]

Currently (January 2025) some progress has been achieved on the mapping and analysis of which kinds of technical solutions are available. The Consortium has prepared a draft version of the technical specifications of the data space but are now waiting for a first release of Simpl smart middleware[96] to

[94] deployEMDS Consortium, 2024, D2.1 Requirements analysis of the technical infrastructure, https://deployemds.eu/wp-content/uploads/2024/05/D2.1-Requirements-analysis-of-the-technical-infrastructure-3.pdf
[95] Interview with deployEMDS Coordinator
[96] See https://simpl-programme.ec.europa.eu/ for more information.

become available and checked against deployEMDS requirements. In parallel, work is being done on mapping and defining the regulatory landscape for data sharing in the mobility sector.[95]

Expected impacts of the EMDS

Linked to the project objectives and to the goals pursued in the different use cases being deployed, the coordinator of deployEMDS highlight the following aspects in terms of the expected overall benefits and impacts of the future European Mobility Data Space.[95]

- The EMDS is addressing one of the main challenges of the data economy, namely the fact that only a small part of collected and potentially useful data actually is made accessible. The EMDS has a very **important role from a data availability and data discoverability perspective**, providing quality data and metadata, enabling data use and reuse for improved mobility services.
- The EMDS, with a decentralized catalogue that anyone can access, will **make it easier to find mobility data and also to acquire data**. Not only open data, **also data with access restrictions**, can be accompanied by e.g., easily accessible ownership information and metadata organized in a way to simplify its use. This means that **entrepreneurs and startups that want to experiment with data and offer new services, have a big advantage vis a vis the current situation**. We could say that the "overhead cost" that is involved with collecting and managing data can be reduced with data space solutions.
- Several data sharing use cases are linked to **mobility services for improved transport efficiency**, spanning from very simple routing services to multi-modal coordination services. What actually make systems for multimodal and demand responsive services very efficient are dispatch algorithms, solving highly complex coordination and optimization challenges. But for a good algorithm, **quality data is a fundamental input**. In the context of creating such new improved services, the EMDS will provide **standardised data formats and agreements on access and use of data**, which will make it easier to integrate the necessary data of different parties.

  Improved efficiency in transports is in turn linked to **reduced environmental impact**. Building on new and innovative mobility services, environmental impact can also be induced, by nudging people to change behaviour and use alternative and more sustainable transport options.
- One of the core goals of the ITS and the real-time traffic information implementing act is to enable **optimized traffic flows**, with benefits such as less congestion, time savings and reduced environmental impact. There is already legislation about the availability of such data, through the national access points for mobility data (NAP). However, data access and quality are currently very heterogeneous in Europe. We are still quite far from compliance with the ITS Directive & Implementing Acts. The deployEMDS Consortium are **exploring possibilities where regional platforms actually act as an intermediary to a national access point, using the data space connector**. This way the NAP can fetch data from those regional or local platforms/data spaces. It would be easier and also closer to the source, instead of one national authority that chases after all the different regional and local authorities to provide data.
- Most of the **deployEMDS use cases are very localized in their value creation and their ambitions**, dealing with particular problems on local or regional level. The project's strategy with each use case is to try to create a meaningful environment, a data ecosystem where

different stakeholders in the region can share data so that the local services actually work better. It is **important to create such collaborative ecosystems locally, where the data use actually takes place and the value added of the data is harvested** or leveraged.

On the other hand, a **harmonised approach** is used across all 16 use cases, **with the same technical implementation, data standards and government models, creating the basis for interoperability** amongst them. Expectantly, this approach will allow the consortium to define a transversal use case on European level. Such definition is an activity on the agenda for this second year of the project.

deployEMDS use cases

As depicted by the table below a total of 16 use cases are being implemented in the project, in nine different cities and regions across Europe, representing different challenges and opportunities in European mobility. It was agreed with the coordinator of deployEMDS to focus the analysis of the study on three use cases, being developed in Barcelona, Flanders and Stockholm, as they show relatively good progress. They are all marked with an asterisk (★) in the table below.

Table 8: Overview of the16 deployEMDS use cases, from 9 cities/regions

City/Region | Use case(s)
Barcelona • Use Case 1★: Multi-operator data governance ecosystem for bus fleets and demand-responsive transport. • Use Case 2: Forecasting system to optimise traffic based on vehicle flow and air quality.
Budapest • Use Case 1: Multimodal connectivity and route planning integration with BudapestGO. • Use Case 2: MaaRLIM – Mobility as a Right for people with mobiLity Impairment.
Flanders • Use Case 1★: Optimising the (re)-use of traffic measurements.
Île-de-France • Use Case 1: MaaS for Companies – MaaS app facilitating the attribution of sustainable mobility credits to employees to tackle the region's commuting challenge. • Use Case 2: Journey planner optimisation – exploitation of journey planner use data for cities and MaaS providers' needs.
Lisbon • Use Case 1: Enhancing seamless route planning. • Use Case 2: Increasing the attractiveness of alternative mobility solutions. • Use Case 3: Increasing schedule reliability and/or commercial speed of buses.
Milan • Use Case 1: Decision support system for local public transport services planning. • Use Case 2: MaaS-based mobility scenarios.
Sofia • Use Case 1: Connected Green & Shared Mobility Journeys (GreenMob) • Use Case 2 (tbc): Connected Parking & Walking Journeys (Park&Walk)
Stockholm • Use Case 1★: Implementing and monitoring zero emission zones and reduction of car traffic.

City/Region | Use case(s)
Tampere • Use Case 1: Collection of data, mandated by ITS directive, and interface to NAP.

Source: Elaborated by CARSA, based on information from deployEMDS

3.2 Extended use case descriptions based on deployEMDS examples

The main findings from the interviews with deployEMDS partners of the three selected use cases are presented in the following subchapters. It should be noticed that in terms of the trials, the project is still in a rather early stage. Although all local implementation projects and the 16 related use cases have been preliminarily defined and planned, their actual progress is still limited. Updated versions of the use case planning documents are currently being created.

In order **to add value to the use case analysis provided in this subchapter, the descriptions of the selected use cases have been extended with additional information**, sometimes going beyond the original scope of the use case defined in deployEMDS. The following table provides some basic information about the three original use cases, used as starting point for the analyses.

Table 9: Basic information about the three original deployEMDS use cases selected for analysis

Barcelona - Multi-operator data governance ecosystem for bus fleets and demand-responsive transport
Mobility themes addressed: Public transport optimisation, fleet management, predictive analytics
Use case scope and objectives: The Barcelona region, through the Metropolitan Transport Authority has developed a platform which constitutes a key asset for the region's mobility strategy, supporting digitalisation of mobility services in the region. The platform is called "SAEi" and it is a Next-Generation Multi-Fleet Management and Passenger Information System, for PTOs and their bus fleets. Evolving the SAEi system from a platform to a data space can open new ecosystem-based opportunities. The main objectives of the use case are to: 1. *Integrate dynamic bus transport modes*: Improve the integration of on-demand and demand-responsive transport with traditional routes to enhance public transportation planning and optimisation. 2. *Develop governance and standardisation*: Enhance quality monitoring, scalability, and harmonization of data and technology across different bus system modes, aligning with the regional PTA's digitalisation goals. 3. *Incorporate third-party service providers*: Enable data usage control for PTOs beyond the SAEi platform, involving third-party platforms, which provide data services and decision-support tools using anonymised mobile data. 4. *Prepare for European integration*: Pilot European data space standards to create an interoperable architecture that connects to national initiatives like the Spanish NAP and the future EMDS, ensuring data availability and cross-border compatibility.
Flanders - Optimising the (re)-use of traffic measurements
Mobility themes addressed: Multimodality, traffic management, environmental impact, transport policy crafting
Use case scope and objectives: The use case pertains to Flanders, Belgium, with the goal of facilitating cross-border data sharing with other deployEMDS sites. Given Flanders' dense interconnections within Belgium and with neighbouring countries, such data sharing is crucial for traffic management and mobility planning. Traffic measurements are utilized for numerous applications both within the mobility sector (e.g., traffic control, policy monitoring) and beyond

(e.g., emissions modelling, noise mapping). Flanders has established the Flanders Smart Data Space (VSDS), that supports data publication and reuse across various use cases. In this context the use case objectives are to: 1. Further develop the VSDS traffic measurements data space in Flanders. 2. Interlink the VSDS traffic measurements data space with other regions via the EMDS. 3. Increase usability for data consumers.
Stockholm - Implementing and monitoring zero emission zones and reduction of car traffic.
Mobility themes addressed: Zero emission zone, car traffic reduction, monitoring of mobility measures, data-driven decision making. **Use case scope and objectives:** To meet Stockholm's environmental and accessibility goals, initiatives include creating zero-emission zones and cutting car traffic by 30% by 2030. Implementing and evaluating these initiatives requires significant digitization and data sharing. Numerous datasets related to the environment, mobility, and public transport are already available on open platforms, and their number is steadily increasing. However, these datasets are not yet provided through a unified data space, and the adoption of governance models and standardization of data formats varies widely. Additional datasets are also needed because some data is either not collected or not available in a suitable format. Ensuring the usability and availability of both existing and newly collected data, while addressing interoperability issues between systems, are some of the anticipated challenges of the project. The goal of the use case is to provide access to high-quality data to evaluate the zero-emission zone. This will be achieved by combining and enhancing many existing datasets, collecting new data, and integrating them into the Stockholm Mobility Data Space, followed by further sharing with the EMDS.

Source: Elaborated by CARSA, based on information from deployEMDS

The extended descriptions corresponding to each of the three selected use cases are presented below.

3.2.1 Multi-operator data governance ecosystem for bus fleets and demand-responsive transport

deploy EMDS *Based on the Barcelona use case.*

The use case relates to several trends identified in subchapter 2.2, particularly ITS and MaaS (demand-responsive transport, on demand transit, and multimodal mobility).

Use case scope and objective

This use case involves various private and public actors linked to the public transport ecosystem. It aims to improve the operational efficiency of public transport buses and increase the quality of the services provided by also integrating demand-based transport models.

Key players involved in data sharing

In general, the main actors involved in the implementation of the use case are:

- Organisation responsible for the technical implementation of the data space (e.g., a Research and Technological Development (RTD) organisation);

- The Public Transport Authority (PTA) of the region, involved in the definition of the local governance model, and responsible for the coordination and onboarding of local operators. The PTA also may provide additional data sources such as ticketing;
- Technology company responsible for providing data-driven analytical services, indicators, data sets and decision support tools for mobility and traffic optimisation;
- Additional digital service providers that connect to the data space and provide platforms, apps and services that enable more demand-based models of bus transport.
- Local/regional network of Public Transport Operators (PTO) that will benefit from the third-party digital services;

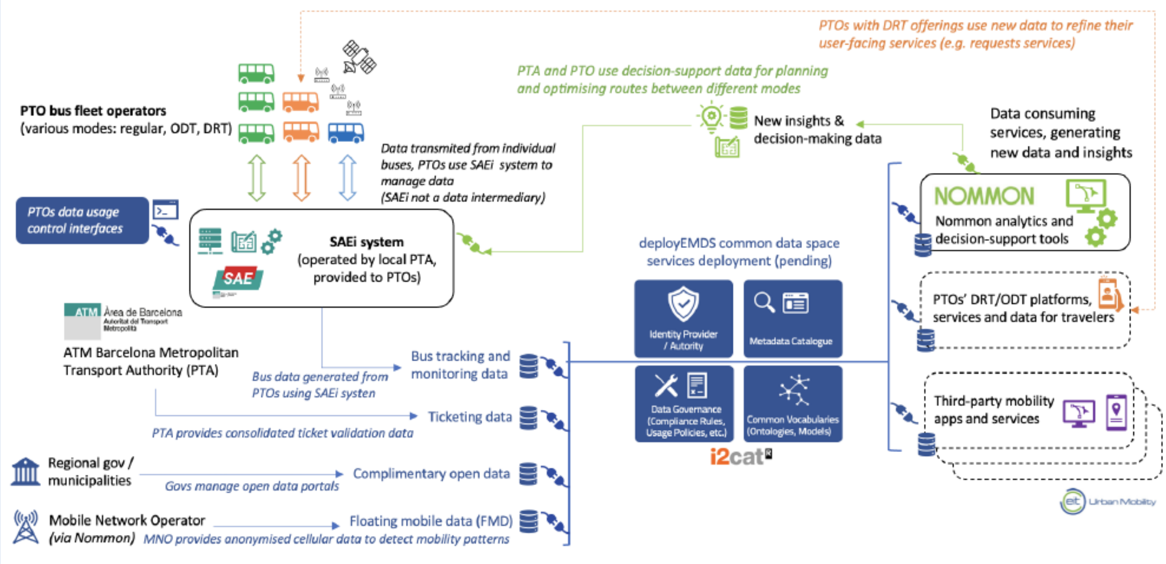
Specific actors involved in the Barcelona use case:

- ***i2CAT Foundation***, a public research and innovation centre responsible for the technical implementation of the data space;
- ***ATM - Barcelona Metropolitan Transport Authority,*** a public consortium responsible for leading the digitalisation of Public Transport Operators (PTO) in the Barcelona area through several ITS projects and for providing an operating platform to the PTO ecosystem;
- ***Nommon***, a for-profit technology company responsible for providing analytics decision support tools for optimising new forms of demand-driven transportation;
- ***Public Transport Operators (PTO),*** responsible for managing bus fleets through the provided platform;
- ***Service Providers*** responsible for providing tools and services enabling bus models for On-Demand Transportation (ODT) and Demand-Responsive Transport (DRT);
- ***Third-party mobility app developers and service providers*** that offer a range of transportation-related services to improve the convenience, efficiency, and accessibility of transportation options;
- ***Telecom companies,*** responsible for giving access to floating mobile data[97].

Figure 14 shows how the actors are connected to each other in the data space use case. The ecosystem is G2B/B2G and B2B. The consumer (traveller) receives benefits from the use case objectives but is not directly involved (not B2C).

[97] Floating mobile data is data collected from the movements of mobile devices connected to cellular networks. The analysis of this data leads to obtaining patterns of mobility, traffic flow and population behavior, used in the context of Intelligent Transportation Systems (ITS) for urban planning and fleet management.

Figure 14. Barcelona data space use case for multi-operator PTO and data service ecosystem



Source: deployEMDS Consortium

Type and format of shared data

To get the most out of ITS in fleet management, various types of multimodal data are needed to enable operators to monitor, analyse and make decisions. In particular, it is essential to gather the following types of data:

- Vehicle data such as vehicle location and GPS data, vehicle condition and diagnostics data, vehicle consumption and efficiency.
- Passenger data such as passenger count on board, passenger location of boarding and disembarking.
- Data from external system such as payment data and ticketing data.
- Floating mobile data such as anonymised mobile network data owned by telecom companies.
- Fleet utilisation data such as vehicle utilisation rate, distance travelled, vehicle availability, fleet size and composition.

What data volumes are we talking about?

Below are some estimates of the data volume associated with operating a fleet of 100 buses serving 60,000 people in total via ITS systems in a generic scenario. In this regard, it is worth noting that:

- The calculated estimates are based on some assumptions and therefore do not necessarily reflect real operating conditions.
- These estimates have not been extracted from the interview linked to the Barcelona use case, but are rather based on additional desk research.

Bus fleet data:

- *GPS location updates:* Every bus equipped with a GPS sensor sends a location signal every 10 to 30 seconds. Therefore, it can be estimated that in a day the GPS positions for 100 buses are updated between 288,000 and 864,000 times.
- *Performance data (speed, fuel level, tire pressure, etc.):* Every bus provides approximately 5-10 performance data points per minute. Therefore, it can be estimated that in a day 100 buses provide performance data approximately 720,000 to 1,400,000 times.

Passenger data:

- *Passenger count:* Every bus report 1-2 data points (total passengers on board and/or new passengers) every 5 minutes. Therefore, it can be estimated that in a day 100 buses report passenger data approximately 28.800 to 57.600 times.

Other data:

- *Ticketing data (e.g., e-ticket transactions):* 60,000 ticketing transactions equal to 60,000 data points per day.

Potential benefits and business opportunities

An Intelligent Transport System (ITS) in public fleet management refers to the use of advanced technologies (including AI), data analytics and communication systems to optimise the management of public vehicles and thus improve the efficiency and quality of service provided by public transport services.

From a general perspective, the following **main service benefits** can be obtained through the use case:

- *Reduction of operational expenses* such as fuel consumption, labour costs and maintenance expenses, thanks to the optimisation of routes and timetables;
- *Increased availability of service and reduction of delays*. As a result, overall passenger satisfaction increases and there is a greater willingness to opt for public transport rather than benefit from private ones.
- *Facilitate planning by predicting frequency and route of buses* based on passenger demand and ensure buses are deployed to meet passenger needs efficiently, whether by traditional route operations or on-demand services.

Looking particularly at the deployEMDS use case of Barcelona, additional technical and ecosystem benefits can be identified:

Technical benefits

- Standardisation and interoperability between traditional and dynamic modes, such as On-demand transport and Demand-responsive transit.
- Future European Mobility Data Space (EMDS) connection interfaces and protocols for PTA and PTO platforms.

Ecosystem benefits

- Facilitate access to an ecosystem of third-party digital service providers while PTOs maintain control over the use of data.
- Promote the development of innovative data-driven services from the market, such as decision-support tools, predictive analytics, e.g., for fleet management or multimodal travel management, etc.
- Provide a scalable public-private governance model of the ecosystem of various profiles in the value chain.
- Enable better integration of PTOs in future evolution of National Access Points (NAP).

Business opportunities

There are two players that will benefit the most from the use of ITS systems in fleet management. In particular:

- Public fleet managers (PTOs) can improve planning between regular, on-demand and demand-responsive transit (DRT), by gaining access to digital services (e.g. predictive analytics and AI-based optimisation algorithms)) and reducing operating expenses. In essence, they provide better mobility services at a lower cost, while also improving the user experience.
- By accessing a large amount of data, analytics providers can promote the development of innovative data-driven services from the market, such a decision-support tools, predictive analytics, etc. for fleet management, multimodal travel management, etc., thereby increasing sales.

There are also strategic gains on a regional level, such as:

- Improved integration between operators and availability of more demand-based services, improving (and thereby promoting) public transport for the traveller.
- Reduced emissions by optimising routes.

Impacts due to data sharing

It is not possible yet to provide qualitative and quantitative evidence of the use of Intelligent Transport System (ITS) in public transport fleet management in the Barcelona area, as it has not yet been estimated. Such an exercise will be carried out after the pilot's first deployment testing in deployEMDS.

However, an overview of the results obtained in other contexts outside the Catalan region is provided below. In this respect, it is worth noting that the following insights have been gathered from other use case studies.

In particular, it is noted that the implementation of ITS in-route optimisation can:

- Improve fleet performance. For example, in Stockholm, a study reported an increase in bus punctuality performance by 5-10%.[98]
- Improve fleet management. In this regard, some studies show that ITS technologies, allowing operators to allocate the right resources according to passenger needs, have improved capacity management by 10-20%.[99]
- Improve the efficiency of public transportation. For example, in Singapore, the LTA group has implemented an electronic road pricing system (ERP) that charges motorists for road use during peak hours, reducing traffic congestion and improving the flow of public transport.[100]

Furthermore, it has been shown through research that effective use of ITS have the potential to reduce travel times by up to 25%, energy consumption and greenhouse gas emissions by approximately 15-20% and the number of accidents occurring in metropolitan areas by up to 20%.[101]

Barriers/blockers that hinder the adoption of the use case concept

There are various obstacles and factors that can hinder the successful implementation and operation of ITS fleet management, from technical, financial, organisational and regulatory point of view. However, it is observed that the **resistance of companies to share their data** is the main obstacle. In particular, companies (e.g., fleet operators) are reluctant to share sensitive data (vehicle data, performance data, fleet utilisation data) also due to security concerns, but mostly because they do not want to lose the value of such data in competitive environments. In general, i.e., not only in this use case, convincing companies to share their data is one of the main challenges. This is where the value proposition offered by data spaces comes in: providing control of data usage, and not just access, to owners of sensitive data. This way, these actors can continue to gain benefits from sharing their data but without losing control over it. Linked to this, the European Data Act, aims to provide clear legal frameworks and fair rules on data access, sharing, sovereignty and ownership. These directions can reassure businesses that they will not lose the value proposition of their data by sharing it, which in turn will help to diminish the reluctance for sharing data.

Another common blocking factor is the **lack of an immediate return on investment** for deploying and operating such a data ecosystem. Such an approach has to be clearly demonstrated to potential participants and stakeholders (e.g. piloting) and the business case analysed. This often involves new business models in marketplace-like contexts.

The technical barriers can be divided into two main classes: **system interoperability** and **semantic interoperability** (for example between public transport standards for planning and for route operations). Data space protocols already provide elements and building blocks to address system interoperability. Whereas on the semantic interoperability side, with or without a data space solution, there is a need to create standards for mobility data management. There are large initiatives such as

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[98] Wahlstedt, J., 2011, Impacts of Bus Priority in Coordinated Traffic Signals, https://www.sciencedirect.com/science/article/pii/S187704281101024X

[99] European Commission, Study on the Deployment of C-ITS in Europe: Final Report , 2014, https://transport.ec.europa.eu/system/files/2016-10/2016-c-its-deployment-study-final-report.pdf

[100] USAPROJECT.ORG, Ensuring Efficiency in Singapore's Public Transportation System, https://usaprojects.org/ensuring-efficiency-in-singapores-public-transportation-system/

[101] Elassy et al, 2024, Intelligent transportation systems for sustainable smart cities, https://www.sciencedirect.com/science/article/pii/S2666691X24000277#bib0005

GTFS (General Transit Feed Specification)[102] and Transmodel[103] working on ITS directives. Meanwhile, semantic models and standards for on-demand and DST are still evolving.

Lastly, another barrier is the costs for developing and maintaining the ecosystem infrastructure.

Replicability of the use case in other contexts

It is not easy to fully replicate the Barcelona use case into other ecosystems since the specific and already existing public transport operating platform used as starting point was built on the unique relationship between PTA and PTOs in the region.

However, the services offered by transport and mobility analytics companies, like Nommon, can be standardised and then provided to other operators and authorities outside the ecosystem using the same type of interface. Likewise, digital service providers from other regions can more easily access the local ecosystem and provide their offering.

3.2.2 Optimising the (re)-use of traffic measurements

deploy EMDS *Based on the Flanders use case.*

This use case can be linked to several of the trends identified in subchapter 2.2, particularly sustainable mobility, digital twin and smart cities.

Use case scope and objective

This use case is relevant for various actors including municipalities, retailers and urban planners. It analyses the sharing of traffic counting data and relates to various fields, such as urban traffic optimization, road maintenance and improvements, transport modelling and simulation, and infrastructure planning.

Particularly in the Flanders use case, a regional traffic measurements data space already exists, which they want to improve and interlink with other regions via the European Mobility Data Space, and thereby also increase the usability for data consumers.

Key players involved in data sharing

The main actors involved in sharing traffic count data fall into 3 main categories:

- Transportation and traffic data providers, that collects and provides detailed traffic count data through various sensors, cameras, GPS data, etc. In addition, there are a number of commercial providers that provide additional data (such as travel speed and congestion levels) through traffic counting devices that are useful for estimating traffic conditions and providing traffic congestion counts.
- Service providers: private organizations, or other entities responsible for analysing traffic data for specific purposes, such as road planning, urban development, and congestion mitigation.
- Government agencies and public authorities, such as the traffic agency, responsible for monitoring and managing transportation networks.

[102] General Transit Feed Specification website, https://gtfs.org/
[103] Transmodel website, https://transmodel-cen.eu/

In the Flanders case, there are currently five different entities responsible for publishing their traffic measurement data within the data space. Specifically, the data monitors the number of pedestrians, bicycles, cars and trucks passing through a specific location.

Type and format of shared data

There are several ways to count traffic data, each of which has its own function in a given context. The following are examples of traffic counting data types and their functions:

- Vehicle count: The number of vehicles passing through a specific point in a given period of time, typically an hour, a day, or a certain rush hour. This data is primarily used to manage traffic flow and congestion, as well as in urban planning.[104]
- Average vehicle speed: The overall average speed of vehicles in a given period of time. This data is primarily used to monitor road conditions and assess road safety.[105]
- Origin-destination (OD) data: The path a vehicle travels within a given area. This data is used, for example, to plan public and private transport as well as to optimise the route of certain means of transport.[106]

In terms of format, CSV and JSON are the most commonly used formats in traffic counting data. However, it is noted that for proper use, such data is often combined with geospatial data such as GeoJSON and Shapefile in order to integrate traffic data with geographic systems.

In Flanders, there are currently over 2500 measurement points from different sources (regional road operator, local cities, private companies, tourism agency, etc.) for a recorded data volume of over 3 Terabytes.

Potential benefits and business opportunities

Promoting the sharing and thus use of traffic counting data can lead to significant economic, social and environmental benefits. Here are some of the benefits that would be obtained from an appropriate use of traffic counting data:

- Traffic data can help public authorities and road operators ***better manage and optimize traffic light schemas.*** In this regard, traffic light scheme optimisation can rely on both static data (i.e. historical data from nearby/intersection counting stations) and dynamic/real-time data (i.e. real-time adjustments of traffic light timing based on current counts). For example, this data can be used to identify strategies to improve road traffic flow or identify quick solutions in the event of traffic congestion due to accidents or road closures, etc. Optimizing traffic flow and reducing traffic congestion results in shorter travel times. The less time spent in traffic, the greater the savings in fuel consumption. In turn, the reduction in fuel consumption results in a reduction in carbon emissions.

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[104] IEEE Access, Bluetooth-Based Vehicle Counting: Bridging the Gap to Ground-Truth With Machine Learning, 2023, https://ieeexplore.ieee.org/stamp/stamp.jsp?arnumber=10156815
[105] Vivacity Blog, Using Speed Monitoring Data to Improve Road Safety, 2021, https://vivacitylabs.com/using-speed-monitoring-data-to-improve-road-safety/
[106] Mohammed et al, 2023, Origin-destination inference in public transportation systems: A comprehensive review, https://www.sciencedirect.com/science/article/pii/S2046043022000223

- Traffic data can help public authorities assess the use of road infrastructure and therefore ***better plan maintenance work***. Therefore, by prioritizing areas that require more attention, resources are allocated more effectively.

- By identifying peak traffic times using traffic count data, public authorities and road operators can ***better optimize the public transport system***. The better the public transport system works, the fewer private cars there are on the roads. As a result, a reduction in carbon emissions is observed, and at the same time often also in operational costs.

- Data analytics services can be offered to municipalities and public authorities, helping them gain insights to better **manage and optimize traffic**. Similarly, they can use this data to build a **digital twin** of the traffic movement in the city and use it, in combination with AI-tools, to **predict scenarios**, such as if a road is cut for maintenance or as part of upcoming new circulation plans/urban vehicle access regulations.

- Fleet managers can use these services to optimize routes, schedules and capacity planning of public/private transport.

- Traffic data can be used by city planners and civil engineers to design road networks or infrastructure, such as highways or bridges, or new public transport infrastructure/connections that help improve traffic flow and reduce congestion.

- In the logistics industry, companies can leverage traffic data to optimize delivery routes and thus reduce transportation costs and emissions.

In addition to the mobility sector, other sectors could also benefit from broader share and access to traffic counting data. Below, two examples of such business opportunities are presented:

- Retailers can request access to traffic counting data to identify high-traffic areas where it makes sense to build a store or create strategies to attract certain customer groups during certain peak hours.

- Traffic data can help tourism boards better understand visitor behaviour and thus optimize services based on demand or improve access to attractions and events.

Impacts due to data sharing

Below a few examples of the impacts observed from the use of traffic counting data in various applications across different industries are reported:

- The Municipality of Singapore saw a 25% reduction in peak-hour traffic after implementing an intelligent traffic management system based on real-time traffic counting data.[107]

- In New York City, city planners used traffic count data to design 5 new lanes on the FDR Drive. This investment reduced traffic congestion by 8% in key corridors and increased transit ridership by 12%.[108]

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[107] Medium, Driving the Future: How AI is Powering Singapore's Smart City Vision for 2030, 2024, https://medium.com/@dirsyamuddin29/driving-the-future-how-ai-is-powering-singapores-smart-city-vision-for-2030-7d371db705fd

[108] Manhattan Community Board Six, The Future of the FDR Drive in Manhattan CB6, 2024, https://cbsix.org/wp-content/uploads/2024/03/240322_FDR-Reimagined_CB6-Report_Ext-1.pdf

➢ In the city of Venice, authorities have implemented smart tourism solutions based on traffic counting data to address significant challenges with overcrowding, especially in popular tourist areas. These solutions have led to a 15% increase in bus and water taxi efficiency during peak tourist seasons and a 12% increase in visitor satisfaction with ease of access to popular sites.[109]

Barriers/blockers that hinder the adoption of the use case concept

It is observed that there are three main barriers that slow down the wider use of traffic counting data by public and private organizations, regardless of the sector they operate in:

- The lack of standardized methodologies and practices on how to manage and use traffic data (how to collect it, in what format and type, how to protect it, etc.) or inconsistent application of such standards by the involved organizations.

  The failure to achieve semantic interoperability (partly due to the above issue) and therefore the difficulty of different systems to understand and interpret such data in a consistent and meaningful way.

  In this respect, the Flemish government has attempted to face this barrier by introducing the OSLO Verkeerstellingen[110,111] data model, which can be seen as a good practice that can be replicated in a different regional area with a similar context.

- The reluctancy of transportation and traffic data providers on sharing traffic counting data, typically linked to the fear of losing monetary opportunities or other competitive advantages.

- Data immaturity in terms of:
  - Inconsistent data collection. Data is collected in an ad hoc manner, using different formats or systems between departments, even when standards exist.
  - Siloed data. Data is stored in siloed systems without a clear data retention policy. Departments cannot easily share or access each other's data or worse, are unaware that other departments have the data they need.

    It would be advisable to provide an incentive for organizations to improve their awareness and their strategies in order to do better.

Replicability of the use case in other contexts

Referring to the use of real-time traffic counting data, by municipalities and public authorities, e.g., to better manage traffic and reduce congestion, the use case is considered highly replicable in other similar contexts, if these actors and the ecosystem in which they operate have the necessary infrastructure and technology to be able to exploit the data appropriately.

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109 The "Good Tourism" Blog, Regaining control: Venice takes ‘smart’ measures to manage mass tourism, 2023, https://www.goodtourismblog.com/2023/05/venice-manage-mass-tourism/

110 Vlaanderen, OSLO Standaardenregister, https://data.vlaanderen.be/standaarden/

111 Vlaanderen, OLSO mapping documentatie, https://informatievlaanderen.github.io/OSLO-mapping/mobility/Geomobility/5_oslo_mapping

In this regard, an added value observed is that every count organized by the government typically has to comply with open data regulations and therefore municipalities and public authorities have no problem accessing it and therefore using it for their benefit.

In Flanders, for example, the collected data is accessible as open data and can be reused by other users. Within the data space, the data is searchable (within a metadata catalogue) and published with the same standard and with the same technical interface. This approach leads to a plug and play experience for data consumers.

Moreover, the Flanders use case foresees a cross-border validation of the EMDS, already within the timeline of the deployEMDS project. Transfer learning will be deployed, which involves training of a machine learning model for e.g., predictions on traffic density. In brief, such AI-model allows rich traffic datasets from Flanders, together with specific context data, for example, weather, parking or garage occupancy, to be used for traffic management in another city/region, such as Barcelona.

When looking at other industries, such as urban planning, logistics, tourism, and more, it is observed that there are several applications that are highly replicable.

For example:

- Traffic data can be used by any municipality or public entity, regardless of the size of the cities or regions they serve, to identify new areas for public buildings/infrastructure, or by businesses for similar purposes but in the private sphere.
- Tourism and hospitality planners can use traffic counting data to make decisions about how to manage crowds or how to manage transportation options, whether it is a large-scale event or a community event, whether it is a popular or less popular tourist destination.

3.2.3 Implementing and monitoring zero emission zones and reduction of car traffic

deploy EMDS *Based on the Stockholm use case.*

The use case relates particularly to the sustainable mobility trend, described in Subchapter 2.2.

Use case scope and objective

In a general perspective this use case involves the deployment of shared mobility data and environmental data to identify and monitor the efficiency of Low Emission Zones (LEZs) or Clean Air Zones (CAZs).

In the particular use case of the city of Stockholm, the objective is to provide access to high-quality data to evaluate the implementation of a zero-emission zone. This is achieved by combining enhanced existing datasets with newly collected data, to be shared through Stockholm Mobility Data Space, and subsequently also through the EMDS.

Key players involved in data sharing

To implement the use case, it is necessary to involve a number of actors, not always directly related to mobility data, but also to environmental data. In particular, the main actors are:

- Municipalities and local authorities. These entities can access and therefore share both air quality data and transport and mobility data.

- Government agencies similar to the cluster above can access and therefore share both air quality data and transport and mobility data.
- Meteorological institutes or similar entities responsible for providing meteorological data that influence pollution dispersion patterns.
- Transport authorities responsible for providing traffic flow data, vehicle counts and congestion models to assess the impact of traffic on air quality.
- Private transport and logistics companies, such as DHL or UBER, responsible for providing data additional data on private vehicle emissions, traffic volumes and travel times.
- Technology providers and data aggregators responsible for providing solutions to aggregate and process different data sources and then provide predictive insights and other information to support decision making.

Specific actors involved in the Stockholm use case:

The choice of actors depends a lot on the ecosystem analysed and the capabilities that these entities/organizations have in providing the essential data. For example, in the Stockholm use case, the information is mainly provided by:

- The City of Stockholm, which besides having a lot of data on mobility and air quality, is also responsible for following and monitoring how the clean air zones affect air quality and traffic.
    - Department of transport responsible for providing traffic and mobility data.
    - Department of Environment and Health responsible for monitoring and modelling air quality as well as modelling environment and health impacts.
- The Swedish Transport Administration, Trafikverket (national government institution) responsible for sharing data on mobility and air quality. They are also responsible for the long-term planning of the transport system for road, rail, maritime and air traffic, and functions as NAP.

Type and format of shared data

To identify areas where air pollution exceeds safe levels, a variety of real-time data needs to be monitored, ranging from air quality to vehicle emissions. Analysing these data sources is key to identifying pollution hotspots and implementing targeted mitigation strategies through the creation of CAZ or LEZ zones.

Below is a list of some data sources needed for monitoring and analysing air quality, especially in the context of LEZs/CAZs. In this regard, it is specified that the list provided is not exhaustive but includes only some data sources. Depending on the capabilities and data availability of the cities and municipalities, other data could be obtained to reinforce the analysis.

- **Traffic flow data** (including volume, traffic speed, vehicle types, fuel type, public transportation usage, etc). This data is needed to assess the contribution of vehicle emissions to local air quality. Therefore, this category collects all data sources that allow understanding how different types of transportation (from private to public vehicles, from combustion to electric vehicles) contribute to pollution levels.

In this regard, it is noted that " the City of Stockholm City uses ANPR (Automatic Number-Plate Recognition) cameras to obtain detailed information about the composition of the vehicle fleet".

This data can be used to gain insights and/or generate models that provide an overview of the types of vehicles passing through a given area at a given time. For example, this data can be used to:

- Understand which types of vehicles contribute the most to pollution.
- Identify areas that typically have high pollution due to traffic congestion hotspots.
- Identify specific patterns, such as the time of the week when traffic congestion is highest.

- **Air quality data** (i.e. the amount of NO_2, CO, CO_2, SO_2, ozone and other pollutants in the air). This data is needed to assess the concentration of harmful pollutants in the air. Integrating this data with mobility data helps to map areas with high levels of pollution and gain additional insights into when air pollution exceeds safe levels (e.g. during rush hour or weekend).

  In this regard, it is noted that the City of Stockholm only measures SO2 and Ozone in urban background levels.

  This information can be used to enforce vehicle restrictions or designate areas under CAZ/LEZ regulations. Typically, this data is collected in real time.

- **Weather data** (including wind speed, wind direction, temperature, humidity, precipitation, atmospheric pressure, etc). This data is crucial to understand how weather affect pollution dispersion and concentration. For example, this data can be used to identify seasonality of air quality, and possibly adjust the regulations accordingly. Or, it can be used to simulate different scenarios and adapt CAZ/LEZ interventions by temporarily banning certain types of vehicles to reduce emissions.

Data types and collection frequency in the Stockholm use case.

The following data types are collected within the Stockholm use case. For each of them, additional information is provided on how frequent these data types are collected.

- Static road data (daily).
- Traffic regulation data (daily).
- Public transport data (daily).
- Goods transport data (daily).
- Micromobility data (monthly).
- Statistics from public authorities (yearly).
- Traffic count data (daily).
- Car sharing data (yearly).
- Air quality and weather data (daily).
- Noise data (twice daily).
- Charging infrastructure data (yearly).

In addition, it is observed that:

- A total of 43 datasets are used.
- The environmental sensor, the noise sensors, and the traffic measurement sensors are all online and will measure in real time.

Potential benefits and business opportunities

The implementation of CAZs and LEZs offers several **benefits**:

- The reduction of transport-related pollutants and fine dust. This is mainly due to the fact that these zones prohibit the use of vehicles that do not meet certain emission standards.
- The reduction of traffic congestion. With reference to what was seen above, these zones lead to the partial or complete elimination of fossil-fuelled vehicles. As a consequence, certain type of vehicles, such as electric vehicles, hybrids and micromobility vehicles such as bicycles and scooters have greater freedom of movement.

Below are some of the **business opportunities** that a wider sharing of mobility data integrated with meteorologic and air quality data will generate.

- Municipalities and public authorities can make more informed decisions in defining areas subject to CAZ or LEZ regulations or adjusting vehicle restrictions during certain weather conditions or at peak traffic times.
- Local governments and policymakers (including environmental and health agencies) can make more informed, data-driven decisions on regulations and interventions needed to better manage urban air quality. They can also assess the effectiveness of CAZ/LEZ policies and adjust them accordingly.
- Urban planners can use data to design smarter and greener cities. For example, they can design CAZ/LEZ to maximize their effectiveness or optimize road networks to reduce traffic congestion in polluted areas or promote the design of eco-friendly buildings and green spaces.
- Academic and research institutions can rely on these data sources to study the cause-effects relationship due to changes in air quality and traffic to spur innovation in cleaner technologies and better urban planning strategies.

Impacts due to data sharing

It is not possible to provide quantitative evidence to assess the impacts that mobility data is having in improving air quality in cities. However, it is noted that there are several cities that already rely on this data to design and optimize Clean Air Zones or Low Emission Zones, for example:

- The city of Berlin has managed to reduce PM10 emissions thanks to a comprehensive set of traffic measures. This data has led to the introduction of a low-emission zone, but also to the design of a series of bike lanes and redesigned sidewalks and intersections to give people more space.[112]
- The city of Cartagena in collaboration with the company Libelium, has responded to several climate-related challenges by implementing a Smart City platform that leverages IoT, AI and FIWARE technologies to identify correlations and patterns that facilitate evidence-based decision-making. Specifically, this platform is fed with real-time air quality data (NO, NO_2, SO_2, CO, PM2.5, PM10), noise and weather data, and traffic data.[113]

[112] Tumi, Low-emission zones: Managing air quality in cities, 2024, https://transformative-mobility.org/low-emission-zones/

[113] Libelium, A more efficient Low Emission Zone in Cartagena with envair360, https://www.libelium.com/libeliumworld/success-stories/low-emission-zone-in-cartagena/

- The city of Barcelona has used data from urban mobility to identify hotspots of pollutant exposure. By analysing this information, Barcelona can pinpoint areas where pollution levels are high and take action to mitigate exposure.[114]

In addition to cities implementing mobility data solutions, there are also several studies that demonstrate the real potential of mobility data to reduce air pollutant levels. For example, in a study conducted by Iran University of Science and Technology, a scenario was examined involving a 9% reduction in vehicle volume and a 4% increase in vehicle speed on the main roads of Area 6 in Qom City. The results revealed that implementing the proposed traffic management scenario can lead to significant reductions in pollutant levels: CO levels could decrease by approximately 20%, NOx by 7%, and PM2.5 by 9%.[115]

Barriers/blockers that hinder the adoption of the use case concept

For the Stockholm use case, the following main barriers have been observed to a large extent deemed to be valid also in a general use case perspective:

- Data standardization and interoperability. Lack of standards across different data sources and platforms can make it difficult to integrate and analyse data from multiple stakeholders and from mobility providers (e.g., traffic flow data, air quality monitoring data, meteorological data, bus mobility data, GPS-positions, number of passengers, etc.)

  Linked to standards interoperability, the actors in the industry of mobility data and services have quite different prerequisites. The suppliers often want to sell a whole new system for data collection, with everything as a package. Then if the municipality is only interested in the data or in the sensors it can quickly complicate the procurement.

- Data is stored in silos. When designing and implementing Clean Air or Low Emission Zones, access to data from multiple domains is needed, and these data must be integrated and analysed together. However, many of the entities share data manually making the process time consuming. In addition, there is a lack of communication and awareness about existing datasets.

- Technical solutions can be blocked by legal and regulatory challenges. Municipalities may have restrictions to implement specific technical solutions due to internal IT policies. For example, in Sweden public administrations are quite restricted in regards to the use of cloud services.

- The lack of information or lack of structured data is prohibiting mobility service providers from establishing themselves in the city. The data space will help to lower the barriers for the service providers.

Replicability of the use case in other contexts

The use case of exploiting mobility data to design, manage and evaluate Clean Air Zones and Low Emissions Zones is highly replicable across cities and regions. However, prerequisites are the access to the necessary data and that relevant governance and stakeholder collaboration frameworks are implemented.

[114] Domene et al, 2017, Modelling Impacts of Mobility on Urban Air Quality and Health: Scenario Analysis for the Barcelona Metropolitan Area (Metropolitan Mobility Plan), https://www.sciencedirect.com/science/article/abs/pii/S2214140517305145

[115] International journal of Modern Achievements in Science, Engineering and Technology, Assessing the Impact of Reduced Vehicle Volume and Increased Speed on Air Quality in Qom City Using AERMOD, 2024, https://ijsetpub.com/index.php/pub/article/view/69

For example, other actors in Sweden could replicate the concept of what the city of Stockholm is doing, learning from their data sharing experiences, as well as the developed evaluation models and tools, and move on faster that way.

3.3 Additional data sharing use case examples

This subchapter presents two additional use cases of data space development or data sharing. These use cases are not developed under the deployEMDS project. However, they were identified as interesting examples during the interviews with deployEMDS representatives.

3.3.1 Traffic optimization through a public-private ecosystem of sensors and digital services

Based on a use case in Terrassa deployed within the Data Space Demonstration Centre of Catalonia.[116]

This use case covers a number of mobility trends described in subchapter 2.2, for example, sharing of real-time traffic data, predictive simulation models, decision support systems and substantiable mobility.

Use case scope and objective

The City Council of Terrassa has engaged in a data space demonstration initiative aiming to optimize urban traffic flow through a scalable ecosystem of devices, sensors and data models, maintaining control and sovereignty of the data within the value chain.

This can be viewed more generally, as a use case for traffic optimisation through the sharing of real-time traffic data in a local/regional ecosystem of public and private organisations.

Key players involved in data sharing

The main actors involved in sharing data for the implementation of the use case are:

- Organisation responsible for the technical implementation of the data space (e.g., a RTD organisation).
  - In Terrasa use case: i2CAT Foundation, a public research and innovation centre.
- Public traffic/transport authority, responsible for the traffic management platform/system of the region and with access to traffic counting sensors and other relevant mobility data sources.
  - In Terrasa use case: Acisa - operator of the traffic management platform used by the Terrassa City Council.
- Technology company responsible for providing traffic optimisation models and tool using real-time traffic data and other mobility data sources.
  - In Terrasa use case: Aimsun - responsible for providing a simulator and AI-based models for the digital twin to evaluate different scenarios through real-time data.

[116] Sources: Interview with Jim Ahtes (i2CAT), use case documentation and additional desk research.

Type and format of shared data

Typically, to optimize traffic flow, ITS systems are fed with various types of data such as GPS data, incident and event data, road condition, etc.

However, in the Terrassa use case, traffic was optimized simply based on traffic counters, i.e. data on the number of vehicles passing through a specific point, be it a road, an intersection or a highway.

Indicative estimation of data volumes

Apart from road sensors such as in the Terrassa case, another approach in European urban mobility is to use CCTV[117] systems and cameras. To provide an indication of the data volume needed to optimize traffic management using only "vehicle counting", it is assumed that a camera with an average resolution of 1080p is used. In general, these cameras typically record between 2 and 3 MB per minute. Therefore, assuming a city with 500 cameras, the data volume would range approximately 1.5 TB per day, or 45 TB per month.

Potential benefits and business opportunities

An Intelligent Transport System in urban traffic management refers to the use of advanced technologies, data analytics, communication systems and real-time monitoring to optimize the transportation system in urban areas.

In general, the following **benefits** can be observed through the integration of ITS:

- **Optimize traffic flow:** by monitoring real-time data from traffic sensors, municipalities can adjust signal timings dynamically or traffic management strategies.
- **Reduce congestion:** by monitoring real-time data from traffic sensors, municipalities can detect congestion points due traffic or accidents and rerouting the traffic.
- **Improve road safety:** by monitoring pedestrian and bicycle movements in certain traffic scenarios, municipalities can adjust traffic signals to prioritize their safety.
- **Minimize environmental impacts:** by monitoring air quality and emissions in certain point, municipalities can adjust traffic management systems, rerouting it or restricting vehicle access to certain areas.

In addition, by accessing real-time data streams, municipalities can:

- Monitor traffic conditions (congestion, weather, traffic light plans, etc.) and set different priority levels for certain categories of vehicles in circulation. For example, the system would allow optimizing the level of circulation of public vehicles such as buses or emergency vehicles, limiting the intensity and occupancy of private vehicles in certain areas.
- Manage resources more efficiently, for example by redirecting traffic police to areas with a higher probability of traffic congestion or by deducing in advance the areas that need road maintenance.

[117] Closed-circuit television - a video surveillance technology.

- Predict possible traffic congestion situations in advance and then redirect traffic, consequently improving the efficiency of public transport and promoting greener and safer mobility.

Specific benefits in the Terrassa use case

The Terrassa use case is part of a data space demonstration initiative. In this respect the project showed that data spaces allow for high-quality automated data exchange to enhance traffic monitoring and optimization, while ensuring secure and decentralized governance. It also emphasized the importance of using technology to manage data sovereignty across the value chain.

On the other hand, platform, digital twin and traffic model providers, such as Acisa and Aimsun in the Terrassa case, see this ecosystem as an opportunity to offer innovative solutions that leverage high-quality data sources.

Impacts due to data sharing

Qualitative and quantitative evidence of this use case in traffic optimization in the municipality of Terrassa cannot be provided, as it has not yet been estimated for the first technical demonstration. Therefore, a few examples of the results obtained in other locations and contexts are provided below.

- In Los Angeles (USA), the use of real-time detectors to track traffic between intersections led to 10% reduction in travel times across major roads and to 10% reduction in congestions across over 4.000 intersections.[118]
- In the city of Stockholm, Sweden, ITS use reduced traffic congestion by an average of 22% during rush hour. As a result, people reported a 13% reduction in fuel consumption.[119]
- In Seoul (South Korea), the integration of ITS systems reduced carbon emissions by 14% and improved fuel efficiency by 10%.[120]

Barriers/blockers that hinder the adoption of the use case concept

One of the major obstacles slowing down the integration of ITS systems for traffic optimization is the lack of robust infrastructures and tools that enable to transmit and process real-time data. The successful implementation of ITS in-traffic management requires a significant amount of data exchanged from different sources (cameras, sensors, vehicles, etc) that must be processed and transmitted in real time.

The data space deployment requires modernization of APIs as well as operation and upkeep of the decentralised architecture deployed among the public administration, traffic operator and third-party service providers. A feasibility analysis is needed to see at which point scaling that ecosystem would offset the operating expenses.

Replicability of the use case in other contexts

This use case is highly replicable in any urban area. Every City Council has a traffic authority. Even if their legacy systems are different, the modus operandi is basically the same: standardizing your

[118] ITS DEPLOYMENT EVALUATION, Los Angeles' Automated Traffic Surveillance and Control System Reduced Travel Time by Ten Percent Using 40,000 Loop Detectors Across 4,500 Connected Intersections with Automated Signal Control, 2023, https://www.itskrs.its.dot.gov/2023-b01770
[119] Centre for Transport Studies STOCKHOLM, The Stockholm congestion charges: an overview, 2014, https://www.transportportal.se/swopec/cts2014-7.pdf
[120] University of Seoul, Seoul’s Intelligent Traffic System (ITS), 20227, https://www.seoulsolution.kr/en/content/6536

interfaces to connect easier to service providers of e.g., predictive traffic analytics and decision-making tools for traffic optimization.

3.3.2 The potential and value of floating bicycle data (FBD) in the mobility sector and beyond

MegaBITS Mobilizing Europe's Green Ambition through Bicycles and Intelligent Transport Systems

Based on a pilot under the MEGABITS' flagship project in Copenhagen - Smart Traffic Management for Cyclists.[121]

This use case covers a couple of mobility trends described in subchapter 2.2, such as smart cities and sustainable mobility.

Use case scope and objective

The analysed MEGABITS pilot aims to develop and obtain floating bike data for Copenhagen and thereby establish the base for a new administrative traffic management plan in the city. In a general use case perspective such data, once they are available, can be used to:

- Promote the use of bicycles in urban mobility, contributing to environmental objectives.
- Facilitate bicycle traffic management.
- Enhance the overall experience for bike users.
- Increase cyclist safety.

Key players involved in data sharing

The main actors involved in sharing floating bicycle data (FBD) fall into 4 main categories:

- **App providers and bike sharing providers**, such as Strava, Komoot and Lime whose responsibility is not only to collect trip data, but also to process that data to provide advanced insights to bike-sharing operators, bike users, or other stakeholders such as urban planners, public authorities, etc.
- **Navigation providers** such as Apple Maps and Google Maps that collect data on motorized traffic as well as bicycles. They could provide, aggregate and analyse FBD data to optimize traffic flow and improve mobility for cyclists, but this is not yet done. Potentially they could also share that data to help public authorities plan better cycling infrastructure and mobility solutions.
- **Bike users** who are responsible for generating data through their interactions with bikes. This category includes both users who use their own bikes and customers who rent and ride bikes. The former facilitate data collection through data storage platforms or apps, such as Strava and Apple. As for the latter, data is often obtained through systems embedded in the rented bikes, such as sensors that capture information such as GPS location, speed, battery status, etc.

[121] Sources: Interview with Ronald Jorna (MOVECO) and Wim Dijkstra (Province of Overijssel), project website (https://www.interregnorthsea.eu/megabits/pilots/city-of-copenhagen) and additional desk research.

- **Public authorities and municipalities** responsible for using floating bicycle data for infrastructure planning, traffic management and bike policy in general.

Type and format of shared data

The term "floating bike data " encompasses various types of data, mainly related to the status and location of bicycles, as well as the user's use of them. The type of data that can be recorded depends on the type of bicycle - whether a bicycle is equipped with sensors or not, and the specific use case - whether it is a private bicycle or a shared bicycle.[122]

Therefore, the following data can be included in the category of "floating data":

- Bike status: Availability (in use, reserved), battery status, tire pressure, brake condition.
- User activity: Duration, distance, speed.
- Location: GPS coordinates.

While common formats for this data are JSON as a common format for transmitting data and CSV for tracking in real-time.

What data volumes are we talking about?

It was not possible to collect any information to estimate the volume of data shared by a fleet of "docked bike" within the analysed use case. Therefore, the data provided below refers to some estimates and calculations by CARSA, taking as reference the city of Bilbao.

In particular, the analysis is based on the following facts and assumptions:

- In the city of Bilbao there is a fleet of 750 docked bikes;[123]
- Bilbao is in first place as the city with the highest number of daily bicycle trips, equal to 7;[124]
- In the city of Bilbao, docked bikes are available from 5 am to 12 pm (19 hours in total);[125]

The average duration of bicycle trips tends to vary between 15-30 minutes per trip. Therefore:

- Location data: Each bike sends updates on its current location (both in use and not) every minute. Therefore, the fleet of docked bike in Bilbao generates 750 updates per minute, 45.000 updates per hour, and 855.000 updates per day. If each update is 100 bytes the total volume of data for location per day is 81,55 MB/day.
- Battery status: Each bike sends updates on its current battery status every 5 minutes. Therefore, the fleet of docked bike in Bilbao generates 9.000 updates per hour, and 171.000 updates per day. If each update is 100 bytes the total volume of data for battery status per day is 16,33 MB/day.

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[122] MegaBITS project, Recommendations on a specification for Floating Bicycle Data, 2024 https://www.interregnorthsea.eu/sites/default/files/2024-06/D23_recommendations_specification_FBD_20240530%20%281%29.pdf
[123] Cycling Industries Europe, SUPPLEMENT - SHARED AMBITION: BENCHMARKING BIKE SHARING IN 148 CITIES, 2024, https://cyclingindustries.com/fileadmin/CIE_Bike_Sharing_2024_-_Supplement.pdf
[124] Cycling Industries Europe, SHARED AMBITION, 2024, https://cyclingindustries.com/fileadmin/CIE_Bike_Sharing_Shared_Ambition_2024_.pdf
[125] Bilbaobizi webpage, https://www.bilbaobizi.bilbao.eus/es/bilbao/

- User activity: Each bike sends user activity updates (including duration, distance, speed, and other metrics) per minute. Therefore, the fleet of docked bike in Bilbao generates between 78.750 and 157.500 updates per day. If each update is 1000 bytes the total volume of data for user activity per day is between 9,4 MB and 150,73 MB/day.

In conclusion, based on these assumptions, the total volume generated by the fleet of docked bikes in Bilbao varies between 107,28 and 248,61 MB/day, equivalent to 3.218,4 and 7.458,3 MB/month.

Potential benefits and business opportunities

Promoting the sharing and thus the use of floating bike data can lead to significant **economic, social and environmental benefits**.

In the city of Copenhagen, integrating this data into traffic management tools would facilitate the measurement of several variables, including the average travel time of bicycle trips, the number of stops in specific corridors, the average speed of cyclists or the identification of congested areas. The correct use of these variables leads to several benefits such as reducing travel time and number of stops, while exploring the priority of cyclists over other road users during peak hours.

Furthermore, appropriate sharing of floating bike data can also lead to the following benefits:

- Public authorities such as municipalities and road operators can use the data to **optimize transportation networks or improve the multimodal transportation system**. For example, by analysing such data, public authorities can identify potential bottlenecks or areas in need of cycling infrastructure and thus make better decisions about infrastructure investments such as bike paths or parking.

In parallel, by ensuring greater availability of bicycles at public transport hubs, they improve the overall efficiency of multimodal transportation.

- Urban planners can use the data to **improve urban planning and infrastructure development**.
- **Improve the cycling experience**. For example, Strava and similar apps can provide users with detailed metrics that make cycling more engaging for fitness-minded users. Similarly, the data can be used by authorities to provide cyclists with recommendations for the best routes to take based on traffic conditions or changes in the route. For example, in The Netherlands, issues in traffic congestion of cycling routes are quite common. Such data could be used to better manage traffic light or advice elderly people to get a different route.

By processing data from floating bicycles, public authorities and the government can obtain insights that highlights the environmental, social and health benefits of cycling and thus promote targeted campaigns for greater use of this means of transport.

The use of floating bike data opens up numerous **business opportunities** in the mobility sector such as for example:

- Fleet management companies can offer services to bike-sharing operators to optimize fleet operations, rebalancing, and maintenance.
- Data aggregation and analytics platforms can use the collected data to provide insights into user behaviour, traffic patterns, and urban mobility trends. This information can then be sold to different stakeholders for different purposes.

- Urban planners and civil engineers can rely on mobile bike data to optimize infrastructure, improve road safety, design road networks and/or bike parking facilities. This information can be proposed to public authorities to obtain funding for public works.
- MaaS platforms can integrate mobile bike data with other transportation modes (e.g. public transportation, car sharing) to offer users seamless multimodal transportation solutions.

Impacts due to data sharing

It is not possible to provide qualitative and quantitative evidence on the impacts that floating bike data has had on the Copenhagen ecosystem, as the use case study is still in its early stages. Therefore, below are some examples of results obtained in other locations and contexts.

- Lime, an electric scooter and bike sharing provider, leveraged FBD to improve bike availability. The company reported a 40% increase in user satisfaction due to improved bike availability in high-demand areas.[126,127]
- In a study conducted in Dublin city, it was decided to use FBD and GPS data to assess how pollution affects cycling populations, e.g. by investigating possible links to causes of premature deaths. The benefits that could be generated by these insights are varied: for example, urban planners and public authorities could use these insights to identify new strategies and actions to improve the circulation of people and goods within a specific area, while they also could support governments to continue to promote actions that push commuters towards more sustainable modes of transport.[128]
- In the Netherlands 10.000 participants in a travel data panel collect travel data, including FBD, through a smartphone app, to get a good picture of the travel behaviour in the Netherlands. Previously this was done manually by asking inhabitants to keep track of their travel behaviour through a logbook. It provides valuable information on bike use, route choice, modal split, destinations, etc.

Barriers/blockers that hinder the adoption of the use case concept

It is observed that the main obstacle slowing down the widespread and appropriate use of FBD is the lack of awareness or interest from stakeholders in recognizing the potential value of such data. This lack, which is partly also due to the absence of clear policies or regulations regarding the collection, sharing, or use of floating bike data, leads to insufficient attention towards the collection and analysis of such data. As a result, there is less opportunity to exploit the benefits listed above.

Furthermore, it is observed that:

- There is a lack of standardized methodologies and practices on how to manage and use FBD (how to collect it, in what format and type, how to protect it, etc.) or inconsistent application of such standards by all organizations.
- Data aggregation and analytics platforms are primarily responsible for collecting mobile bike data. However, these services do not collect data that represents the behaviour of the entire population but only those referring specific target groups such as for example male that ride

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[126] MIT Technology Review, The secret data collected by dockless bikes is helping cities map your movement, 2018, https://www.technologyreview.com/2018/09/28/139983/the-secret-data-collected-by-dockless-bikes-is-helping-cities-map-your-movement/
[127] Lime, Changing Spaces: How to solve London's shared e-bike parking challenge, 2024, https://uk.steergroup.com/sites/default/files/2024-05/E-bike_parking_bay_gap_analysis_report.pdf
[128] Smith et al, 2021, Using floating bike data to determine cyclist exposure to poor air quality, https://www.sciencedirect.com/science/article/pii/S2214140521000025

sports bike. This makes it difficult for stakeholders to acquire consistent and meaningful representative data on usage trends and patterns. These data gaps compromise analysis and forecasting activities and as a consequence the decision-making and the ability to extract valuable insights.

Replicability of the use case in other contexts

The use case is considered highly replicable in other similar contexts, if these actors and the ecosystem in which they operate have the necessary infrastructure and technology to be able to exploit the data appropriately.

3.4 Oher mobility data sharing examples identified as interesting

This subchapter provides other brief examples of promising initiatives that developed and implemented solutions based on mobility data. In this respect, it is noted that these cases have been analysed through desk research, although some of them were identified through the interviews.

MOBIDATALAB

MobiDataLab is an initiative funded by the European Commission that aims, among other things, to prototype new solutions and services based on sharing mobility data to help cities solve concrete challenges.[129]

Among the various innovations implemented, the following stand out:

The “*Hubs and Shared Mobility*” tool implemented in the city of Leuven (Belgium), to identify and plan optimal locations and services for multimodal mobility in real time. Through this tool, the city of Leuven wants to encourage residents and visitors to opt for other modes of transport than private vehicles, while ensuring more comfortable and efficient travel.[130]

The "*Active Mobility Planning*" tool to support the City of Paris in developing an effective pedestrian strategy. By feeding the tool with a variety of data, including sidewalk extensions, sidewalk discontinuities, crosswalks, traffic signals, etc, the tool provides insights to create a more pedestrian-friendly and vibrant urban landscape.[131]

The “*Event Accessibility Planning*” tool to support the city of Milan in developing effective traffic mitigation plans during major events, such as concerts, fashion week, football matches. The solution, in addition to ensuring that attendees reach event locations efficiently and conveniently, also aims to develop plans that help reduce emissions and improve air quality.[132]

REFOCUS project

REFOCUS is an EU funded project under the Interreg Europe programme. The main objective is to provide local and regional communities with a range of different Decision Support Tools (DST) to facilitate decision making in planning sustainable zero-carbon mobility.[133]

[129] MOBIDATALAB website, https://mobidatalab.eu/
[130] Virtual Lab, Leuven Codagon Challenge. https://labs.mobidatalab.eu/challenge-details/?id=122
[131] Virtual Lab, Paris Codagon Challenge, https://labs.mobidatalab.eu/challenge-details/?id=121
[132] Virtual Lab, Milan Codagon Challenge, https://labs.mobidatalab.eu/challenge-details/?id=120
[133] REFOCUS project, https://www.interregeurope.eu/refocus

Several good practices have been presented in the REFOCUS project and have proven to be effective, efficient, sustainable and transferable. Some of them are presented below.

Data Fusion and Dynamic Traffic Management in Thessaloniki

The Region of Central Macedonia (RCM) has implemented a data-driven system for traffic management (and emergency operations) along specific urban corridors in its territory. Since its deployment, the City of Thessaloniki has observed measurable improvements in travel times (7% improvement) and reduction in CO2 emissions during the morning rush hour (5% reduction).[134]

CERTH/HIT 4-phase model for strategic decision-making

Also in the Thessaloniki area, a multimodal macroscopic traffic simulation model has been developed to support public authorities and public transport operators in making the best decisions in transport network design. To date, more than 79 public transport lines have been redesigned.[135]

CERTH/HIT 4-phase model for strategic decision-making

In the Emilia-Romagna Region, there is a plan to integrate a MaaS platform into an existing app*, App Roger*, which allows users to purchase travel tickets and parking services. The integration of such a system will enhance the benefits of the app by providing users with a valuable tool to plan an intermodal trip based on the exchange of harmonized data from transport operators. It is not yet possible to provide concrete proof of success, as the experiment is still in its infancy, but more than 1,500 candidates have been observed for the trial phase of the service via the Roger app. [136]

NordicWay

NordicWay is a major initiative co-funded by the European Union's Connecting Europe Facility, whose mission is to demonstrate the use and feasibility of Cooperative Intelligent Transport Systems (C-ITS) services in Northern Europe.[137]

In particular, C-ITS services are defined in terms of use cases. Among these, the following stand out:

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[134] Interreg Europe, Data Fusion and Dynamic Traffic Management in Thessaloniki, https://www.interregeurope.eu/good-practices/data-fusion-dynamic-traffic-management-in-thessaloniki

[135] Interreg Europe, CERTH/HIT's 4-step model for strategic decision making, https://www.interregeurope.eu/good-practices/certhhits-4-step-model-for-strategic-decision-making

[136] Interreg Europe, Emilia-Romagna digital public transport data harmonisation based on MaaS paradigm, https://www.interregeurope.eu/good-practices/emilia-romagna-digital-public-transport-data-harmonisation-based-on-maas-paradigm

[137] NordicWAY website, https://www.nordicway.net/

Dynamically Controlled Zones

The service is intended to enable road authorities to adapt traffic policies, protocols and traffic rules in real time and distribute this information through data to road users. As a result, users can adapt the characteristics of their vehicles in defined zones.

In this regard, it is noted that many European cities implement regulated zones in urban areas (e.g. environmental zones, restricted zones) that need to be adapted in real time in case of events, such as traffic congestion or weather conditions, that affect the desired characteristics of the vehicle in defined zones.

In-vehicle signage

The service is intended to inform drivers via in-vehicle systems about everything they need to know about road signs, whether real, static or dynamic. In addition to increasing awareness, by providing drivers with information about road signs, it simplifies their task of observation and interpretation.

In this regard, it is noted that depending on the conditions of the road environment (reduced visibility due to fog or darkness, obstacles of various kinds, etc.) the attention and response of drivers decreases.

Hazardous Location Notifications

The service is intended to inform road users about potentially hazardous situations on the road, providing them with a series of information (type of danger, distance to the danger, its expected duration) to increase their attention and allow them to adapt their driving behavior accordingly.

Road Works Warning

The service is intended to inform road users in advance of all roadworks in the vicinity, whether mobile, static, short-term or long-term, allowing them to adapt their driving behavior.

Emergency Vehicle Approaching

The service is intended to inform all road users about emergency vehicles approaching an accident zone.

Signalized Intersections

The service is intended to inform road users about possible traffic light intersections to support safe, smooth and efficient crossing.

Entur

Entur is an important Norwegian initiative, whose mission is to promote and facilitate people's access to public transport.[138]

To do this:

- Data on routes and trips were collected to create digital services for public transport in the form of tools;
- These tools were then made available to all types of business for using them, completely free of charge.

So far, three tools have been developed. Below a description of them is provided together with some examples of how businesses can benefit from them.

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[138] ENTUR website, https://entur.no/

Travel Link	Tavla	Entur app
A tool that creates a departure board, showing all the available travel options via public transport. In particular, the tool provides real-time schedules and information about departures from the stops closest to the desired destination. Stakeholders such as hotel owners and retailers can rely on this tool to provide their customers with the easiest way to reach them.	A tool that helps people to easily plan their journey to specific destination using public transportation. Hotel owners, event organisers, tourism boards and other similar stakeholders, can provide to people detailed travel itinerary that includes all available transport options.	A tool that suggests itineraries based on the user's criteria. Through the app, in addition to being able to organize different trips taking into account all the transport options in Norway, customers can also access different features including purchasing tickets online.

Mobidata-bw

MobiData BW® is a cross-modal integration platform, developed in the German state of Baden-Württemberg, which aims to facilitate access to diverse mobility data (via open licenses) to promote climate-friendly mobility. Currently, the platform provides more than 113 datasets made available by a consortium of 13 organizations.[139]

These datasets can be grouped in 8 categories, such as:

Public Transport	Parking Space	Traffic Counting Data	Accessibility
Sharing Offers	Pedestrian/Bycicle Traffic Data	Public Transport	Miscellaneous

REGIO-MOB

REGIO-MOB is an EU-funded project under the Interreg Europe programme, whose overall objective is to ensure sustainable growth in Europe by promoting sustainable mobility. The project, which lasted 4 years and ended in March 2020, presented several good practices, including several focused on promoting demand-based transport.[140]

Among them, the following stand out:

Tele-Bus on-demand transport

To make public transport routes more efficient and convenient for users, especially commuters, students and seniors, the municipality of Niepołomice in Poland implemented a bus service on demand, without regular routes or timetables. According to reports, more than 3,500 people per

[139] MobiData BW® Project, https://mobidata-bw.de/
[140] REGIO-MOB project, https://projects2014-2020.interregeurope.eu/regio-mob/

month currently use this service, thanks to continuous efforts to improve the service to meet people's needs.[141]

Demand-responsive transport service for persons with disabilities

In the city of Ljubljana, small electric vehicles have been made available for people with reduced mobility. By calling, it is possible to book one of these vehicles. In addition, each user has been given a card indicating the type of mobility limitation, which can be passed to the driver so that he knows what he is dealing with and thus makes the service intuitive and therefore more accessible.[142]

ACUMEN

ACUMEN is project that received funding from the European Union's Horizon Europe, whose mission is improve the management and increase the efficiency of multimodal transport services.[143]

Within the project, 4 pilots have been launched with the idea of test a small-scale version of the project before full implementation. These are:

Pilot project in Athens: aims to develop and evaluate an innovative mobility platform that collects multimodal data from different sources. By integrating the platform with Digital Twin, it is intended to develop an innovative tool for traffic analysis and forecasting.[144]

Pilot project in Helsinki: aims to integrate AI-based multimodal traffic management and analytics tools with the ACUMEN Digital Twin Architecture to explore sustainable traveller routes and modes.[145]

Pilot project in Amsterdam: aims to demonstrate how effective multimodal management can be an effective response to infrastructure disruptions, such as tunnel closures or traffic diversions due to roadworks, etc..[146]

Pilot project in Luxembourg: aims to demonstrate on-demand mobility of automated vehicles (AVs) as a solution to improve freight fleet capacity.[147]

SAFE-UP

SAFE-UP is project that received funding from the European Union's Horizon Europe, whose mission is to test the readiness of connected automated vehicles (CAVs) in safety-critical scenarios. In particular, these scenarios are built by integrating traffic accident data and traffic courting data.[148]

The project aims to demonstrate how CAVs address various challenges through four demonstrations, such as:

[141] Interreg Europe, 2018, Policy brief: Demand responsive transport, https://www.interregeurope.eu/sites/default/files/inline/2018-06-27_Policy_Brief_Demand_Responsive_Transport.pdf
[142] Ibid
[143] ACUME project, https://acumen-project.eu/
[144] ACUMEN, Athen pilot project, https://acumen-project.eu/pilots/athens/
[145] ACUMEN, Helsinki pilot project, https://acumen-project.eu/pilots/helsinki/
[146] ACUMEN, Amsterdam pilot project, https://acumen-project.eu/pilots/amsterdam/
[147] ACUMEN, Luxembourg pilot project, https://acumen-project.eu/pilots/luxembourg/
[148] SAFE-UP project, https://www.safe-up.eu/about

DEMO 1 Improving the occupant protection system for automated vehicles in critical road safety scenarios	**DEMO 2** Improving vehicle-Vulnerable Road Users interaction in adverse weather conditions.
DEMO 3 Integrating advanced intervention functions to avoid critical events	**DEMO 4** V2X-based safety solution to enable early warning provisions.

OMICRON

OMICRON is project that received funding from the European Union 's Horizon 2020, whose mission is building safer, faster and more efficient road infrastructure with the help of cutting-edge technologies such as robots, drones and other innovative technologies.[149]

Within the project, a broad portfolio of solutions has been created to:

- Increase road safety in road intervention actions.
- Improve management of road interventions and reduce traffic congestion.
- Reduce overall maintenance costs.
- Increase the capacity of the road network.

In particular, these solutions have been tested within five demonstrations, such as:

Dem. #1	**Title**	Virtual demonstration: Smart construction of bridge overpasses, in Oporto
Output		Validated methodology and detailed BIM model of the new solution.
Key technologies		Smart construction.
Dem. #2	**Title**	Technical demonstrator: A-2 Guadalajara, Spain
Output		Integration of inspection and related digital technologies for final demonstrator.
Key technologies		Dedicated Terrestrial Inspection Vehicles, V2X communication, VR and AR technologies.
Dem. #3	**Title**	Technical demonstrator: A-92 Seville, Spain
Output		Improved intervention times and execution quality for the final demonstrator
Key technologies		Smart Pavement, Smart construction.
Dem. #4	**Title**	Technical demonstrator: A-7 Valencia, Spain
Output		Improved intervention times and execution quality for the final demonstrator.
Key technologies		Modular Robotic Platform
Dem. #5	**Title**	Final demonstrator: A1 Florence-Bologna, Italy
Output		Final results from OMICRON's Intelligent Platform to be evaluated and compared to the expected impact of the project.
Key technologies		Modular Robotic Platform, VR and AR technologies, V2X communication, Unmanned Aerial Vehicles – drones, Dedicated Terrestrial Inspection Vehicles, Decision Support Tool, Road Digital Twin.

Source: OMICRON project.

[149] OMICRON project, https://omicronproject.eu/project/

4 Final considerations and conclusions

The analyses presented in this report provide insights on how the deployment of a common European data space in the mobility sector is evolving, linking experiences from selected use cases and initiatives to the identified trends and challenges in the mobility and transport sector. This chapter intends to summarise the analysis by responding to the principal research questions of the study (subchapter 4.1) and by providing some general conclusions (subchapter 4.2).

4.1 Answering the research questions

- **Who are the key actors of data sharing in the EU mobility sector in different constellations (B2B, B2C, B2G, etc.)?**

Data sharing occurs across various configurations, including Business-to-Business (B2B), Business-to-Government (B2G), and Business-to-Consumer (B2C).

The use cases analysed from the deployEMDS project are all (in line with the strategy of the project) linked to a data ecosystem on municipal or regional level, primarily focused on **B2G** data sharing. Typically, businesses share data with regional government bodies to improve public services, e.g., data used to assist in urban planning, traffic management and environmental protection. Key players involved are: public transport- and traffic authorities; public transport operators; private transport and logistics companies; technology companies, providing services and products related to e.g., data analytics, mobility indicators/data sets, or modelling and decision support tools; RTD organisation/company supporting the technical data space implementation; third-party mobility companies providing data-driven mobility platforms, applications, tools and services; etc.

Interviewed deployEMDS partners affirm that the data space concept and infrastructure will allow for increased data sharing in general, including also in Government-to-Government (**G2G**) constellations. The establishment of standardised data formats and harmonised governance rules will facilitate and encourage collaboration between public authorities on local, regional and/or national level. Improved findability and accessibility of data will also support such collaborations and help to break down data silos.

None of the analysed use cases focus directly on **B2B** data sharing. On the other hand, looking at the trend of connected and autonomous vehicles, presented in subchapter 2.2, data exchange between businesses is a core concept. In this context, B2B collaborations between car manufacturers and technology companies enable the exchange of data to enhance connected vehicle services and develop advanced driver-assistance systems.

Finally, all the analysed use cases are somehow linked to improvements for the mobility consumer (or end-user), but regarding **B2C** data sharing, the use case considered most representative is the one on floating bike data (see subchapter 3.3.2). Here bike users ("consumers"), either by using their own bikes or by renting bikes, are responsible for generating data that is shared with e.g.: app providers and bike sharing providers (such as Strava, Komoot and Lime); navigation providers (such as Apple Maps and Google Maps); and public authorities and municipalities.

Another example of B2C data sharing is linked to the trend on multimodal mobility and ride-sharing services, where companies such as Uber and Bolt collect and share data with consumers to optimize routes, provide real-time updates, and improve user experiences.

- **How does data sharing contribute to sustainable and efficient mobility?**
    - What are the opportunities offered by better data-sharing in the EU mobility sector at the moment?
    - What are some successful examples of data sharing in the EU mobility sector?
    - How could data sharing improve the user experience?
    - How can a European mobility data space contribute to sustainability and efficiency?

This story presents several trends and use case examples demonstrating the **opportunities and benefits linked to data sharing and data space collaboration** in the sector. In summary, the main opportunities and user experience benefits are:

- **Enhanced operational efficiency and resource optimization**

  Data sharing enables multimodal coordination, integrating different transport modes (buses, trains, bicycles, etc.) through common platforms. For example, the Barcelona use case describes a multi-operator governance ecosystem that allows bus fleets and demand-responsive services to coordinate effectively, allowing to improve the user experience and reduce the time for travelling and/or commuting.

  From a sustainability perspective, enhanced data interoperability will foster services that adjust supply to the actual demand and thereby allow to reduce the wasted capacity and the environmental impact.

  By pooling mobility data, including both static and real-time traffic counting data (as in the Flanders use case), authorities can better manage traffic flows, monitor congestion and plan infrastructure maintenance, which translates into reduced delays and optimized resource allocation, e.g., lower fuel consumption and emissions.

- **Reduced data management costs enabling innovative mobility services and new business models**

  A standardized and accessible data environment (as envisioned in the European Mobility Data Space) reduces the “overhead cost” associated with collecting, managing, and reusing data. This benefit is especially valuable for startups and SMEs looking to experiment with innovative and data-driven mobility services and new business models.

  With richer, standardised datasets available, new digital services can be developed—from dynamic route optimization to integrated ticketing systems—thereby fostering innovation across the mobility value chain.

- **Evidence based policy and decision making**

  Shared mobility data facilitates a deeper understanding of local and regional travel patterns, supporting urban authorities to make informed decisions about e.g., traffic management and infrastructure investments, and related policy changes.

  In the use case of Stockholm data sharing, through the deployment of a data space, will support both the monitoring and enforcement of environmental policies related to zero-emission zones.

Several good practice examples are presented under the REFOCUS project (subchapter 3.4) illustrating practical implementations where shared mobility data and decision support models and tools allow regional authorities to streamline operations and improve overall service quality.

- **Potential user experiences improvements**

  Having real-time data available from various mobility operators, will enable new services for integrated journey planning, where users can plan seamless multimodal trips (e.g., combining bike-sharing with public transit) in a single app. Up-to-date traffic and schedule information help users to avoid delays and optimize their travel routes. In addition, in case of traffic incidents or similar, the service providers are able to tailor recommendations based on real-time conditions and historical travel patterns, enhancing comfort and convenience.

  Furthermore, it will facilitate the implementation of interoperable payment and ticketing systems, reducing friction for the user when switching between different modes of transport.

  Operators will be able to improve the service quality, as they can more rapidly detect and address service disruptions, ensuring that users have access to reliable transport services. Finally, user data and feedback, when anonymized and shared, can help providers to achieve continuous services improvements over time, progressively increasing the user experience.

➢ **What technological solutions enable secure and efficient data sharing in the mobility sector?**
   - How does the data space deployment embrace new technologies, such as AI?

The analysis of the use cases involving interviews have shown that the technical development is normally not among the main challenges when setting up a data space. Instead, aspects like, awareness of data space concept, the reluctance of stakeholders to share (sensitive) data and governance mechanisms are identified as important barriers. For this reason, less focus has been put on technical analysis of the use cases. The two most important technologies that have surfaced in the analysis are: AI/Machine learning to support modelling and decision support tools and Digital Twin technology, to support e.g., scenario building and predictive infrastructure maintenance.

For the interested reader, below some additional technologies facilitating secure and efficient data sharing in the mobility sector are listed, accompanied by references:

- **Blockchain technology** provides a decentralized ledger that ensures data integrity, transparency, and security, making it suitable for applications like vehicle-to-vehicle (V2V) data sharing and ride-sharing services.[150,151]

- **Digital Twin Technology** to enable the creation of virtual representations of physical entities, facilitating real-time data sharing and analysis in vehicular networks.[152]

[150] J. Cui et al, 2021, Secure and Efficient Data Sharing Among Vehicles Based on Consortium Blockchain, https://ieeexplore.ieee.org/document/9457110
[151] Naik, M. et al, 2024, Decentralizing ride-sharing: a blockchain-based application with smart contract automation and performance analysis, https://doi.org/10.1007/s11042-024-20317-5
[152] Chenhao Wang et al, 2024, Secure and Flexible Data Sharing With Dual Privacy Protection in Vehicular Digital Twin Networks, https://ieeexplore.ieee.org/document/10462010?utm_source=chatgpt.com

- **Artificial Intelligence and Machine Learning** enable the analysis of large amounts of mobility data quickly and securely. These technologies can be used for predictive maintenance, route optimization, and anomaly detection, providing insights that can be shared between stakeholders in a secure manner.[153]

- **Cloud Computing and Edge Computing** enable real-time data sharing and analysis. Cloud computing allows for centralized data storage and processing, while edge computing processes data closer to where it is generated.[154]

- **5G Networks** provide faster, low-latency communications between vehicles, infrastructure and data centers, enabling real-time data sharing and improving the efficiency of connected and autonomous vehicle ecosystems. This technology is a crucial enabler both for innovative solutions such as automated vehicles but also for the promotion of digitalized modes of transport.[155]

➢ **What are the challenges or blocking factors of better data-sharing in the EU mobility sector at the moment?**

As analysed in Chapter 2.2, the barriers and blockers that hinder better data sharing in the mobility sector are often similar across the various trends examined. In particular, most of these, albeit with small variations, can be grouped into macro categories, such as:

- **Inconsistent data types and formats:** The mobility industry is highly fragmented, with multiple stakeholders as municipalities, urban planners, and service providers, often using data in different formats and types. This inconsistency can make data exchange, integration, and analysis challenging, leading to issues such as communication breakdowns between systems, inconsistent data representation, or errors in data processing. This blocking factor often arise from the lack of standardized practices for collecting and sharing data or from improper application of existing standards.

- **Conflicting laws and regulations**: Regions and jurisdictions may have different laws and regulations regarding data sharing, particularly in terms of data privacy, data ownership, and data governance. These regulatory differences can slow down the smooth exchange of data by inhibiting collaboration, whether between private and public entities, across countries, or even within different sectors within the same country.

- **Aging infrastructure:** The integration of new technologies and services is often hampered by the limitations of existing infrastructures, as they were often built before the advent of modern technologies. The challenges within this category vary from the high costs of upgrading, adapting or replacing systems to the complexity of integrating new technologies into older, more established frameworks.

[153] FACTUAL website, 2024, The impact of AI in mobility, https://factual-consulting.com/impact-ai-mobility
[154] European Commission, Key technologies for the digitalisation of transport, https://digital-strategy.ec.europa.eu/en/policies/technologies-digitalisation-transport
[155] Ibid

- **Lack of collaboration:** There is a general mistrust among the parties involved in data sharing, even when the collaboration occurs between private companies and public authorities. On the one hand, companies are concerned about the misuse of data, for fear of losing competitive advantages. On the other hand, public entities are wary of private companies for fear that the data will be exploited for profit.
- **Public resistance**: There is community resistance to accepting data-driven mobility interventions and actions. This resistance stems from several factors, often related to a lack of awareness of how personal data is used or shared and concerns about privacy. However, in the mobility sector, resistance is also observed due to the inability of the community to change habitual attitudes and behaviours, such as the strong attachment to the use of private cars and conventional forms of transportation.

In addition to these barriers, there are a number of blocking factors that are less representative, as they only find their applicability for certain trends. For example, barriers such as scalability, data silos, and lack of open-source licensed software only apply to the implementation of Digital Twins.

Finally, the main barriers and obstacles that emerged from the interviews are presented. After the analysis in Chapters 3.2 and 3.3, the following is observed:

- **The reluctance of stakeholders (both private and public) to share data** is one of the most significant challenges in data sharing initiatives, regardless of the use case analysed. In a fragmented sector such as mobility, collaborations between different entities are crucial to foster the development of smart mobility solutions and services, as successful large-scale implementation relies heavily on the combination of data from different sources.
- **Replicability of use cases may be more limited in smaller municipalities.** These municipalities lack the budget, skilled personnel, and technological infrastructure to build a robust data ecosystem. As a result, there is a greater possibility that these municipalities will miss the opportunity to leverage data to improve transportation services, smart city solutions, and sustainability initiatives.
- The development of large-scale use cases is driven by the collection of vast amounts of data from multiple sources. However, the accuracy and completeness of this data varies significantly from stakeholder to stakeholder. **Inconsistent data quality can undermine the credibility of analyses and models based on it**. As a result, there is a large risk of making poor decisions as well as ineffectively allocating resources. As mentioned, establishing standards that ensure data quality is met before it is shared is essential.
- Issues such (1) **inconsistent data collection** and (2) **siloed data systems are more prevalent than expected**, in organizations or authorities that are intended to operate cohesively and efficiently.
- In the first case, while there may be some standards for data collection, these protocols are often not applied consistently. The absence of a clear and standardized approach to data collection can result in incomplete, inaccurate, or incompatible data sets. For example, it might have different departments that collect similar and therefore non-complementary data, or collect different data but in different formats. These inconsistencies make it difficult to combine or analyse data holistically.

  In the second case, storing data in separate systems that are not interconnected leads to the inability of departments to easily access each other's data. If data is isolated, it cannot be used effectively, and thus the ability to analyse a problem or opportunity in a comprehensive manner is lost.

- **What ethical considerations arise in the data sharing practices in the EU mobility sector (access issues, social inequalities, etc.)?**

The development of data sharing ecosystems and data spaces comes with some cross sectoral ethical considerations, such as privacy, transparency, inclusiveness and fairness.

Clearly, the most reoccurring concern in relation to the use cases covered in the study refers to data privacy. The lack of trust is one of the most common barriers for data sharing, not only in the mobility sector, but in general. This is exemplified by the Barcelona use case where several companies (e.g., fleet operators) demonstrated to be hesitant to share data that is considered sensitive, such as vehicle data, performance data and fleet utilisation data. In the Flanders use case providers of traffic counting data showed similar reluctancy to share their data. In both cases this is mainly due the risk of losing the value of such data to competitors. This is where the data space value proposition comes in, building on decentralized data sharing and data sovereignty, providing owners of sensitive data the control of both access to and usage of their data.

As demonstrated by the analysed use cases, digitalisation and data sharing in the mobility sector typically aim to provide the public with positive benefits, such as flexible, efficient and sustainable transportation options. Even though it is considered to be out of scope for this study it is worth mentioning that some research studies also discuss the risk for increased inequalities following this trend, e.g., due to digital skills gap in different groups of people, or differences in mobility opportunities between rural and urban areas.[156]

- **What legal/policy framework is in place to support data sharing across Member States, within the mobility sector, between the mobility sector and other sectors?**
  - What are the EU policy objectives for data sharing in the mobility sector?
  - How can EU-level policies on data support the competitiveness of the European mobility sector?
  - How can EU policy makers further enhance and support data sharing in the mobility sector?

The framework of EU policies and regulations and initiatives described in subchapter 2.3 were designed to promote the transition towards more sustainable mobility, leveraging the opportunities of the data economy, encouraging data sharing while ensuring privacy and security. The European Commission's strategy for data emphasizes the creation of common data spaces, including a European Mobility Data Space, to facilitate such collaborations and create a more efficient, sustainable, and user-centric mobility sector in the EU.

[156] See for example: Interreg Europe website, Shared mobility for low-carbon and inclusive transport, https://www.interregeurope.eu/find-policy-solutions/stories/shared-mobility-for-low-carbon-and-inclusive-transport; Guan X. et al, 2024, Shared micro-mobility and transport equity: A case study of three European countries, https://www.sciencedirect.com/science/article/pii/S0264275124005122#s0075

The interaction with deployEMDS representatives has highlighted the Data Act as having direct provisions on data sharing and data space interoperability, and in a similar manner the Interoperability Europe initiative should also strengthen the context for cross-border data sharing. However, as depicted in subchapter 2.2, the framework of policies and regulations is ample, and there are several other relevant initiatives, such as, the cybersecurity act, anti-trust legislation and the GDPR. Adding to the complexity, several pieces of legislation interact with each other, and it is not always fully clear how they apply in practice. In this sense, one of the lessons learned from the project so far, is that local and regional authorities need support on how they should interpret these legislations. The EMDS deployment certainly has a role in this sense, contributing to a greater awareness and understanding of the existing policy framework.

In upcoming policy initiatives for continued data space development in the mobility sector it is recommended to focus primarily on local level transportation and the support to cities and regions, because the daily travel of people is the most relevant focus concerning the potential impact. It is considered important to start with creating local data sharing ecosystems, close to where the data is used and the value added is harvested. Certainly, a harmonised approach concerning data standards and government models, etc., is needed to support interoperability and the longer-term objective of creating an EMDS also covering transversal use cases on European level.

4.2 General conclusions

In conclusion, the establishment of a common European mobility data space is one of the crucial steps towards creating a more efficient, sustainable and digitally advanced mobility system across Europe. As the sector continues to evolve, particularly with the growth of electric vehicles, autonomous systems, and smart cities, the need for seamless data exchange becomes increasingly vital to harness these technologies effectively across Europe.

As highlighted in the analysis, facilitating seamless data sharing between various stakeholders, be they public or private stakeholders, can lead to significant opportunities for improving mobility services, operational efficiency and innovation. Through collaborative data sharing, cities can create more responsive and adaptable transport systems, enabling real-time traffic management, predictive maintenance for infrastructure, and optimized public transit routes. Furthermore, the exchange can promote and improve the effectiveness of different B2B, B2C and B2G business models. For instance, by collaborating, a technology company and a public authority can merge their mobility data to optimize products and services, while improving the efficiency and availability of public services. Similarly, two private entities such as a fleet manager and a city planner, by collaborating, can optimize fleet operations and reduce downtimes, while improving the evidence base for decision-making on infrastructure investments and transport policies.

The analysis underlines that data spaces have the potential to help overcome technical, legal, and organizational challenges related to data sharing, making collaborative initiatives such as deployEMDS pivotal. Interviews confirm that data spaces could enable increased data sharing, even in Government-to-Government (G2G) contexts.

However, challenges such as data quality, lack or limited adoption of data standards, or incomplete legal and regulatory compliance persist. For instance, data quality issues often stem from the lack of uniformity in data formats across different sources, as well as incomplete or outdated data, which can hinder efforts to create reliable insights. Similarly, fragmented legal frameworks across Europe present significant hurdles in terms of ensuring privacy, security, and compliance.

While none of these issues are easy to solve— many of these obstacles are endemic to strategic sectors — they remain critical blocking factors that hinder the successful implementation, sharing, or use of data within data spaces. Without meaningful measures and coordinated efforts to tackle these challenges, the true value of the data space will never be fully unlocked. As a result, there is the risk that data spaces may fail to progress beyond the conceptual stage or the risk they will become tools that cater only to niche market segments or specific use cases, limiting their broader potential.

Therefore, to unlock the full potential of data spaces, it is considered essential to continue promote collaboration between key stakeholders—including public authorities, industry leaders, research institutions and policymakers— to address these challenges, whether through standardization efforts, regulatory harmonization, or the development of robust data governance frameworks.

The analysis ultimately reveals that there are numerous promising mobility data-sharing use cases across Europe. However, it is difficult to find tangible and measurable evidences of the benefits and impacts. Identifying and documenting successful use cases on local and regional level can be a game changer to scale up these data sharing efforts. In this context, a sense of urgency and commitment is considered essential to step up the pace to prevent these opportunities are not lost.

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ANNEX

List of interviews (online meetings)

Project / Use case	Name	Company – Position
deployEMDS / Barcelona Data Space Demonstration Centre of Catalonia / Terrassa	Jim Ahtes	i2cat – Head of Data Space Innovation and Strategy
deployEMDS / Flanders	Casper van Gheluwe	Imec – Solution architect Urban mobility & logistics I Mobility data expert
	Steven Logghe*	Movias – Managing Director
deployEMDS / Stockholm	Kristine Bull Sletholt	City of Stockholm Transport Department – Innovation manager
	Tobias Johansson	City of Stockholm Transport Department – Project Manager Traffic Analysis
	Max Elmgren*	City of Stockholm Environmental Administration – Environmental investigator
deployEMDS Project Coordinator	Lucie Kirstein	acatech – Team Lead European Projects
MegaBITS / Floating bike data	Ronald Jorna	MOVECO advise – Senior consultant in traffic and transport
	Wim Dijkstra	Province of Overijssel (NL) – Strategic advisor sustainable mobility
MOBIDATALAB / Various use case examples	Thierry Chevallier	Akkodis – Software Project Leader, Research and Innovation

** Written contributions (not interviewed online)*