DELPHI

FeDerated nEtwork of pLatforms for Passenger and freigHt Intermodality

Grant Agreement Number: 101104263

D.2.2: Multimodal transport trends in urban and peri urban areas, towards a common passenger/ freight mobility ecosystem

Document Identification			
Status	Final	**Due Date**	Monday, 30 September 2024
Version	1.0	**Submission Date**	01/10/2024
Related WP	WP2	**Document Reference**	D2.2
Related Deliverable(s)	D2.1, D2.3	**Dissemination Level**	PU
Lead Participant	ICCS	**Document Type:**	R
Contributors	EBOS, ATD, STASY, AUM, SEAB	**Lead Author**	Margarita Kostovasili (ICCS)
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Funded by the European Union

DELPHI project has received funding under grant agreement No 101104263. It is funded by the European Union. Views and opinions expressed are however those of the author(s) only and do not necessarily reflect those of the European Union or the European Climate, Infrastructure and Environment Executive Agency (CINEA). Neither the European Union nor the granting authority can be held responsible for them.

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Document History			
Version	**Date**	**Modified by**	**Modification reason**
0.1	18/04/2024	Margarita Kostovasili (ICCS)	ToC circulation
0.2	06/06/2024	Margarita Kostovasili (ICCS)	First draft and literature review
0.3	10/07/2024	Margarita Kostovasili (ICCS)	Analysis of survey results and extraction of practices and enablers
0.4	02/08/2024	Margarita Kostovasili (ICCS)	Inclusion of validation activities results and socio-economic analysis
0.5	25/09/2024	Sofia Kokonezi (ICCS)	Incorporated changes from peer review
1.0	30/09/2024	Sofia Kokonezi (ICCS)	Final version to be submitted

Quality Control		
Role	**Who (Partner short name)**	**Approval Date**
Deliverable leader	ICCS	30/08/2024
Quality manager	eBOS	13/09/2024
Project Coordinator	ICCS	27/09/2024

Executive Summary

This deliverable report is the result of the research and SotA analysis performed in the context of DELFI WP2, task T2.1 "Multi-modal trends in urban and peri-urban areas, towards a common passenger/freight mobility ecosystem". It provides a thorough overview of the current key trends along with relevant practices, strategies, enablers, barriers and opportunities for improvement. The employed methodology is a combination of desk research and literature review, followed by the validation as well as enrichment of the emerging findings through dedicated surveys (questionnaires) targeted to both internal audience (consortium) and external audience (AB, MTMC members etc.). This process resulted in the identification of relevant R&D initiatives and real implementation cases from the industry, focusing on both multimodal transportation in urban & peri-urban areas as well as on multimodal trends towards common passenger and freight mobility. The report also addresses the socio-economic factors impacting this ecosystem and highlights global best practices in all modes of transport, to support the creation of an integrated approach in the optimisation of the multi-modal passenger and freight transport. This report complements D2.1, which focuses on governance and stakeholder interactions, and both will contribute to D2.3 "Multi-level Governance and cross sectorial regulatory aspects report" towards the development of an integrated, neutral framework. These deliverables collectively serve as the basis for developing DELFI's business cases, user stories, and technological strategies and solutions, which will be implemented in the pilot demonstrations.

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Abbreviations & Acronyms

Abbreviation / acronym	Description
AB	Advisory Board
AI	Artificial Intelligence
D1.1	Deliverable number 1 belonging to WP 1
DRT	Demand-responsive transport
EC	European Commission
IoT	Internet of things
MaaS	Mobility as a Service
MFT	Multimodal freight transportation
MTMC	Multimodal Traffic Management Cluster
OoH	Out-of-Home
PI	Physical Internet
PO	Project Officer
R&D	Research & Development
SotA	State of the art
SULP	Sustainable urban logistics plan
SUMP	Sustainable urban mobility plan
UAM	Urban air mobility
UAV	Unmanned Aerial Vehicle
WP	Work Package

1. Introduction

1.1 Purpose of the document

This document describes the key outcomes from the state-of-the-art (SotA) analysis on multimodal passenger/freight transportation in urban and peri-urban areas. It is part of WP2 activities that focus on the analysis of urban and peri-urban transport ecosystem, aiming to set the foundation for the innovations that will be implemented in the 4 pilot demonstrations of DELPHI project. More specifically, D2.2 depicts the comprehensive analysis of the current freight and passengers' intermodal transport models that has been conducted in terms of operational frameworks, collaborative schemes and relevant integrated solutions and ecosystems, identifying general and specific barriers and improvement opportunities for advancing towards an integrated approach in the optimisation of the multi-modal passenger and freight transport.

Additionally, the respective SotA analysis is exploited to understand the operational interactions between passenger and freight urban mobility freight, as well as to study the socio-economic aspects of multimodal transportation and integrated passenger and freight transport schemes. To achieve this, the deliverable maps out best practices applied on a global level, while all modes of transport have also been examined. The ultimate goal of this report is to outline the key multimodal trends and relevant best practices in urban and peri-urban areas, examining all transport modes and presenting enablers, barriers and socio-economic aspects towards a common passenger/freight mobility ecosystem.

It shall be noted that this report is highly interconnected with D2.1 "State-of-the-art report in governance, relative technologies and stakeholder ecosystems in passenger and freight transport", focusing on the interactions among all involved actors and stakeholders in the transportation industry and the respective governance schemes that are implemented. These two reports thar are publicly available provide a SotA analysis of passenger and freight transport, covering complementary aspects and perspectives of urban mobility that will be further detailed and analysed in D2.3 "Multi-level Governance and cross sectorial regulatory aspects report" towards the development of an integrated, neutral framework. Since this framework will be highly dependent on the DELPHI case studies and the respective pilot demonstrations, it will contain sensitive information about the interactions, roles and responsibilities of involved stakeholders and for this reason this document will be confidential. However, it is important to note that all three deliverables (D2.1, D2.2 & D2.3) compose a comprehensive analysis of transportation ecosystem, based on which the DELPHI business cases, user stories and technological approaches and solutions will be developed and further implemented in the pilot demonstrations.

1.2 Intended readership

This deliverable is public and is addressed to any interested reader. It is primarily written for the European Commission (EC), Project Officer (PO) and the consortium members of DELPHI project, as a useful guidance for multimodal transportation. It is use case-driven and provides a state-of-the-art analysis of multimodal transportation both for passenger and freight mobility ecosystem. Furthermore, it provides valuable input for the conceptualization of DELPHI solutions through the extraction of multimodal trends and relevant enablers that can be exploited for the integration of passenger and freight transport systems.

1.3 Document Structure

The structure of the document is as follows:

- Section 1 presents the Introduction.
- Section 2 presents the methodology followed for the identification of relevant research projects and implementation cases to be analysed and the findings' validation activities to be performed.
- Section 3 presents the results and findings from the analysis of relevant R&D initiatives and the real implementation cases, dealing with multimodal transportation in urban and peri-urban areas worldwide.
- Section 4 presents the multimodal trends extracted by the SotA analysis towards common passenger and freight mobility, as well as respective practices, strategies, enablers and barriers, considering also socio-economic aspects.
- Section 5 presents the Conclusions.

2. Methodology

As already mentioned, the main objective of this report is to provide a holistic overview of multimodality and how it has been designed and implemented in various cases in urban and peri-urban areas, towards the identification of relevant best practices and enablers that could facilitate the integration of passenger and freight transportation into a common system. To achieve this, a comprehensive analysis of current practices, cases and studies worldwide needs to be conducted, mapping potential strategies or challenges and covering not only the operational perspective, but also the associated social and economic effects. This section outlines the methodological approach for developing and implementing the SotA analysis on multimodality in passenger and freight transport systems. The process for identifying relevant projects and implementation cases to be included in the SotA analysis is also presented, along with the key characteristics and features to be studied. This analysis serves as the basis for extracting valuable information about current workflows, challenges and opportunities related to the conceptualization and implementation of multimodality in passenger and freight transport systems.

2.1 Project mapping and identification of implementation cases

In general, a two-fold methodological approach has been developed and followed to study and analyse the respective topic, focusing on two main pillars:

- Research & Development (R&D) initiatives: This category includes research and innovation projects, studies and initiatives that have been developed and realized dealing with transport multimodality for passenger and/or freight mobility. These projects are analysed according to their overall goal and objectives, as well as to the respective case studies that have been defined based on actual user needs or existing market challenges. In most projects, these cases have been broken down into realistic business scenarios, while a relevant pilot demonstration has been defined and performed at small scale and for a short period to facilitate the testing of the developed strategies, solutions and services and their implementation and validation in realistic conditions.
- Real case studies from the industry: This category includes case studies of multimodality for passenger and/or freight transportation that have been designed for and implemented in real operational conditions, typically at a regional level for a longer period of time, or fully tested, validated and adopted by the respective stakeholder communities and ecosystems. These cases are usually applied at a city or wider area and may be part of an overall strategy and a well-defined sustainable urban mobility plan (SUMP) or a sustainable urban logistics plan (SULP). In other cases, some of them may refer to case studies and projects that have been developed and implemented at smaller scale, aiming to test and validate a strategy or policy and facilitate urban planners and other involved stakeholders (authorities,

regulators, operators etc.) to evaluate their performance and decide whether they will be implemented and adopted at a larger scale or not.

Based on these two categories, a wide and thorough pool of cases can be created that can be used for the analysis of multimodality and the extraction of relevant results and findings, connecting both the academia and the industry and leading to valuable insights and conclusions.

2.2 Selection criteria

More specifically, the first step for performing this analysis is to elaborate an extensive list of R&I projects, innovative solutions and real implementation cases across Europe and worldwide dealing with multimodal transportation in urban freight and passenger mobility. Given that there are numerous research projects and case studies dealing with these domains, the implementation of high-level criteria for selecting the most critical and relevant cases to be analysed is considered necessary to narrow down the topic and perform efficient research. For the research projects, these criteria were related to the proximity of the case study in time and the focus points in the transportation universe, while for the implementation cases the involvement of associated areas in green transport and smart cities initiatives was considered. More specifically, the following criteria were implemented:

- R&D initiatives:
    - European research projects funded by EU: This criterion has been defined due to the nature of DELPHI project itself that is an EU-funded research project, to provide a common ground and exploit the similarities of research across EU countries and the directions of EU for future mobility in general.
    - Past and ongoing projects starting from 2018 and onwards (H2020 and HEU): This criterion has been defined to exclude projects and initiatives that have been developed many years ago and may not be aligned with updated strategies and directions or their results and provisions might have become obsolete.
    - Projects focusing on multimodality: This criterion has been defined to eliminate projects and initiatives that may partially deal with transportation using various transport means and keep only the ones that have as focal point the analysis and implementation of multimodality as a holistic concept and strategy.
- Real case studies from the industry:

- Multimodal cases worldwide: This criterion has been defined to ensure that best practices and challenges related to multimodal transportation for passenger and/or freight transportation from all around the world have been included in the analysis, aiming to gain knowledge and insights from different areas and ecosystems.

- Implementation cases from 2018 and onwards: As above, this criterion has been defined to exclude cases that have been implemented many years ago without continuation or updates, since this means that they have been tested, evaluated and abolished for long-term adoption.

- Mission Cities[1]: Given that the primary objective of multimodality is to increase the efficiency of transportation and reduce the environmental footprint, this criterion has been established to ensure that the cities selected by EU to serve as climate-neutral lighthouses will be included in the analysis.

Based on the criteria described above, the selection of relevant projects and implementation cases have been identified and included in the analysis, based on which associated results and findings have been extracted.

2.3 SotA validation process

After the mapping of relevant research projects and implementation cases dealing with multimodality and their analysis, some valuable findings and conclusions can be extracted. However, since the analysis has been narrowed down, some significant cases might have been excluded or some novel concepts not yet studied or implemented have not been captured. To overcome this potential risk, a focused SotA validation process has been defined and performed aiming to validate the results and findings extracted by the SotA analysis, but also to collect additional input on multimodal transportation and other key topics of DELPHI project. More specifically, this survey has been developed as part of WP2 in total, addressing all relevant key topics and has been applied through the distribution of a questionnaire to focus groups. The main target group that has been selected to participate in this survey is the DELPHI consortium, since it consists of a wide range of transport stakeholders and especially several transport operators that can share their experience, deep knowledge of the market and overall perspective.

Additionally, a briefer and more simplified version of the questionnaire has been created and addressed to external audience, aiming to enrich the findings and enhance the validity of the analysis, through the inclusion of top experts and professionals from

[1] https://netzerocities.eu/

the industry. To achieve this, the updated version of the questionnaire has been distributed to the members of the DELPHI Advisory Board (AB) and the members of the Multimodal Traffic Management Cluster (MTMC), where DELPHI participates along with its sister projects, ACUMEN and SYNCHROMODE. Both versions of the questionnaire can be found in Annex 1. The audience has been asked to provide feedback and insights with regards to existing and future business models, interactions with stakeholders, governance schemes, multimodal trends, information flows and data sharing in both passenger and freight transportation. The main objective of this survey is to address the key topics of all WP2 tasks and to provide valuable input for the identification of existing challenges and issues encountered, the adoption of current good practices and lessons learned, as well as the development of novel solutions and frameworks for sustainable and multimodal transport of people and goods.

It shall be noted that the overall methodological approach and the respective selection criteria for both research projects' mapping and identification of relevant business cases from the industry has been commonly developed as part of WP2 activities and has been also adopted by other WP2 tasks and reports, such as D2.1 and D2.3. This has been done to shape a common ground and conduct complementary and parallel analysis on different perspectives of the same topic, using the same baseline for the analysis. However, since the examined aspects of the analysis vary from document to document, the same applies to the identified projects and implementation cases to be studied based on the selection criteria. This leads to a partially similar, but not identical list of projects and cases used for the analysis of passenger/freight transportation. The following sections present the mapping of relevant research projects and implementation cases based on the selection criteria, as well as their main features that have been studied as part of the analysis.

3. Multimodal transportation in urban & peri-urban areas

3.1 Literature review

Transportation is considered as one of the main pillars of societies towards ensuring smooth and seamless mobility of people and goods. Various transportation options, means and services are provided, aiming to fulfil transport requirements. Each mode has its own coverage area, type of service and governance scheme varying from public transport and fixed route services such as buses, vans and light rail to private demand-responsive services, such as taxis, ride sharing and DRT buses. Additionally, various micromobility modes have been introduced during the last years, including bike-sharing systems, cargo bikes, e-scooters etc., aiming to facilitate first- and last-mile transportation of people and goods and complement existing services without affecting negatively already congested and environmentally burdened urban environments.

Even though each transport mode supports an efficient mobility option, the provided services have their own operational limitations, while urban transport networks are quite complex and require combined solutions to ensure seamless flow of people and goods. For this purpose, the concept of multimodality has been studied during the last decades, aiming to exploit the features and benefits of each transport mode and service in an interoperable way. Initially, multimodality was introduced and explored within the freight transportation industry, since the sector is strongly affected by high fragmentation and operation silos. In parallel, it has started to be adopted for people's mobility as well and specifically in large cities and dense urban environments where mobility flows are often subject to congestion and disruptions, while various services and transport modes are available.

According to the United Nations Economic Commission for Europe (UNECE), multimodal freight transportation is defined as the transportation of goods by a sequence of at least two different modes of transportation, with transportation units varying from boxes or containers to road/rail vehicle or even a vessel. Initially, multimodality was introduced as concept for freight transportation, since the utilization of various transport modes - maritime, road, rail and air- was needed to support different types of cargo movements, such as long-haul or short-haul, considering the limitations corresponding networks and services. However, during the last years, many cities have adopted multimodality for urban logistics and even passengers' mobility to exploit as much as possible the possibilities of each mode, enable complementarities and increase the overall efficiency of transportation.

The discussion about the importance of multimodality has started several years ago and, in some cases, even decades ago. Back in 2015, almost a decade ago, multimodal mobility was already considered as essential for city centre accessibility, with its attractiveness depending on the quality of mobility services offered [1]. The overall goal of multimodality was not to reduce mobility, since this would negatively affect social participation, progress and growth, but to adopt an optimised and smarter orchestration of transport systems that could handle the multi-dimensional complexity of transportation and facilitate a socio-technical transition towards a sustainable urban mobility system. Based on the same study, information flows could play a significant role on data exchange and interoperability of systems, with the availability and accessibility of open big data for urban mobility and logistics considered as the most prominent enabler. The development and implementation of strategic plans for sustainable urban mobility and logistics were also perceived as significant contributors for holistic management and orchestration of transport modes, services and stakeholders towards the promotion of multimodality and the optimization of transport systems.

More recently and according to Natera Orozco et al. [2], the integration of different transport modes has become crucial to guarantee the fast and sustainable flow of people in large metropolitan areas, where multimodal transport systems can be described as multilayer networks following a network science approach, with the networks associated to different transport modes not considered in isolation, but as a set of interconnected layers. Again, the importance of high-quality mobility data availability is highlighted, leading to the necessity for implementation of multi-level governance and adoption of regulatory frameworks facilitating collaboration among transport stakeholders. In parallel, multimodal frameworks that integrate shared services with traditional public and private transport infrastructures are becoming necessary to ensure real-time and user-centred solutions for planning, forecasting and managing services, while increasing safety, reducing congestion and emissions.

Overall, multimodality is not only implemented at operational level – combining provided services or infrastructure – but also at economic or even institutional level. In freight transportation, a holistic implementation of multimodality shall cover the implication of two or more modes of transport under one contract in the process of transportation, freight transportation under one document (through bill of lading), use of through tariff rate, as well as presence of one of responsible parties, such as multimodal transport operator, that is responsible for freight from the moment of taking it under control up to the moment of its transfer to the consignee [3]. To facilitate this holistic approach, various practices shall take place covering all aspects of freight transportation, such as transport policies and regulations, multimodal transport planning and relevant systems and corridors, infrastructural balancing and creation of multimodal logistics hubs, containerization of freight transportation etc.

According to an extensive analysis of potential barriers that could obstruct the implementation of multimodal freight transportation (MFT) conducted by Karam et al.[4], such barriers could be related to MFT terminals and MFT networks, as well as management, regulations, delivery and interoperability perspectives. Such barriers could be associated with poor service flexibility and reliability, lack of terminals and long transit times, limited freight data, lack of incentive policies, transport outsourcing, different information formats etc. On the other hand, various technologies and concepts could mitigate the impact of such barriers and facilitate multimodal freight transportation. One of these could be the adoption of Physical Internet (PI) concept that especially in urban logistics can significantly transform the fragmented freight transportation, logistics and distribution industries into an industry based on hyperconnected logistics [5].

Micromobility is also identified as a valuable alternative to conventional transport means, with its integration to public transport contributing to the provision of more efficient and complementary transport options. Micromobility is mainly used for people transportation and interconnection among various transport modes (e.g. from home to bus stop, from train station to work etc.), while during the last years it has also been quite utilised for urban logistics through cargo bikes/scooters etc. A relevant study by ITDP [6] has shown that multimodal integration aims to bring together physical infrastructure, payment, information, and/or institutional management across multiple transport modes to improve the multimodal trip experience for users, while integrating micromobility with public transportation can improve trip efficiency and provide more diverse travel options for people.

Another technology that is becoming an increasingly important aspect is Unmanned Aerial Vehicles (UAVs) or more commonly known as drones. Cities can achieve quicker delivery times and build a more adaptable and durable transportation infrastructure by incorporating drones into the current transportation infrastructure. At the same time, by swiftly and effectively delivering tiny packages (mainly in last-mile delivery tasks) they can greatly reduce traffic on conventional road networks and thus reduce the related emissions. However, due to a number of challenges, drone development is relateively slow compared to other modes. Regulatory obstacles provide a major barrier as airspace laws are strict and often not yet adapted to allow for the broad use of drone operations. Safety and privacy concerns also need to be addressed, as the potential for accidents and the intrusive nature of drones can lead to public apprehension[12]. Further impeding quick adoption are technological limitations such as battery life, payload capacity, and the need for advanced navigation systems to avoid obstacles in dense urban environments. Technology providers, regulatory organisations, and urban planners must work together to overcome these problems in order to guarantee that drones can be easily and safely incorporated into the urban transportation ecosystem.

3.2 R&D results and findings

This section presents the main research projects that have been included in the SotA analysis of multimodal transportation. Based on the selection criteria described above, a list of relevant projects has been created covering different aspects of multimodal transportation, either for passenger or freight mobility in urban and peri-urban environments. Each project has undergone a detailed analysis to extract its key characteristics and focus points, its relevance to multimodality, the transport modes involved, the type of environment studied, as well as the associated case studies and business scenarios implemented. The list below provides a high-level description of these projects and their approach on multimodality, while the full list with the detailed classification of projects is presented in Annex 2.

- TANGENT[2] – Enhanced Data Processing Techniques for Dynamic Management of Multimodal Traffic: TANGENT focuses on the development of new complementary tools for optimising traffic operations in a coordinated and dynamic way from a multimodal perspective and considering automated / non-automated vehicles, passengers, and freight transport. Among others, one of the project's case studies is deployed in Rennes Métropole and focuses on fostering intermodal cooperation of passenger and freight transport in urban areas. Following the city's 2030 mobility strategic plan to reduce single occupant cars and enhance public transport and active mobility, TANGENT's case study aims at gathering and processing data from different stakeholders (public and private) and providing various schemes for data sharing to guarantee interoperability and improve multimodality.

- DIT4TRAM[3] – Distributed Intelligence and Technology for Traffic and Mobility Management: DIT4TRAM offers an alternative decentralised approach, swarm intelligence, that helps local and bottom-up regulation, aiming to improve traffic operations, mobility management, demand-supply synchronisation, and shared mobility. Within Amsterdam's case study, resilient mobility management through cooperation between travelers and stakeholders is explored, where human decisions are combined with a dynamic simulation to determine the consequences of decisions for multimodal transport networks. The pilot revolves around the cooperation between travelers themselves about auctioning mobility permits and between providers for harmonization of private and public objectives.

- FRONTIER[4] – Next generation traffic management for empowering CAVs integration, cross-stakeholders collaboration and proactive multi-modal network optimization: FRONTIER aims to empower a seamless transition to a new era in transport

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[2] https://tangent-h2020.eu/
[3] https://dit4tram.eu/
[4] https://www.frontier-project.eu/

management. Different cutting-edge systems and solutions are being leveraged to create the ultimate integrated network and traffic management systems, that will favour among others seamless transfer among different modes of transport and better collaboration among different stakeholders. Two of FRONTIER's case studies deal with multimodality, namely the Athens and the Antwerp ones, where dedicated collaborative platforms have been realized allowing stakeholders to share data and collectively implement, test and deliver multimodal traffic management strategies and solutions that encourage modal shifts towards public transport and improved sustainable mobility.

- ORCHESTRA[5] – Coordinating and synchronising multimodal transport improving road, rail, water and air transport through increased automation and user involvement: ORCHESTRA aims to establish a common understanding of multimodal traffic management concepts and solutions, with and across modes, for various stakeholders and multiple contexts. It focuses on the definition of a Multimodal Traffic Management Ecosystem (MTME) where traffic managements in different modes and areas (rural and urban) are coordinated to contribute to a more balanced and resilient transport system, bridging current barriers and silos. The two associated Living Labs, namely Malpensa Airport & Herøya Industry Park, focus on traffic orchestration for the mobility of people and for freight respectively, collectively covering both road, rail, water, and air transport.

- IN2CCAM[6] – Enhancing Integration and Interoperability of CCAM eco-system: IN2CCAM aims to accelerate the implementation of innovative CCAM technologies and systems for passengers and goods, while it intends to develop, implement and demonstrate innovative services for connected and automated vehicles, infrastructures and users. More specifically, the Tampere Living Lab focuses on the integration of traffic and CCAM fleet for last-mile mobility of people, implementing a New Mobility Hub for public transport, connected fleet of CCAVs, micro-mobility devices, bicyclists and pedestrians. In parallel, the follower Living Lab of Bari includes the development and simulation of a route planner for people and goods involving automated vehicles among other transport means, while it also facilitates innovative urban freight logistics.

- CONDUCTOR[7] – Advanced High-Level Traffic and Fleet management: CONDUCTOR's main goal is to design, integrate and demonstrate advanced, high-level traffic and fleet management that will allow efficient and globally optimal transport of passengers and goods, while ensuring seamless multimodality and interoperability.

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[5] https://orchestra2020.eu/
[6] https://in2ccam.eu/
[7] https://conductor-project.eu/

Among other objectives, the multi-modal system (combining different transportation modes such as pedestrians, connected/autonomous cars, motorcycles, taxis, delivery cargo vehicles, buses, etc.) is optimised based on the user needs to ensure transport resilience and business continuity. The Use Case 1 – Athens' solution optimises the synchronisation of buses and on-demand services with the metro and tram by adapting their schedules to reduce door-to-door travel times for passengers, while the Use Case 3 – Madrid investigates and proposes last-mile delivery solutions based on the integration of urban distribution of goods with existing on-demand passenger transport services.

- STARS[8] – Shared Mobility Opportunities and Challenges for European Cities: STARS aims to explore the diffusion of car sharing in Europe, its connections with technological and social innovations, as well as its impact on other transport modes, such as private car, bike, walk, taxi, public transport etc. Studying the implications and impacts of car sharing, rather than focusing exclusively on the implementation of the system itself, a co-modality approach is defined, setting the optimal combination between car-sharing use and other modes of transportation. An overall study and assessment of how other travel modes can be affected by the growth of car sharing has been implemented, with the aim of integrating the project's results into the Sustainable Urban Mobility Plans (SUMPs)[13].

- ENTRANCE[9] – European matchmaking platform for innovative transport and mobility tools and services: ENTRANCE provides a European matchmaking platform and complementary offline services with the aim of mobilising financial resources to accelerate market access and scale up breakthrough solutions for sustainable transport. The overall concept focus of the ENTRANCE project lies in the "supply-demand-finance" triangle that is envisaged for all transport and mobility modes and all relevant stakeholders. The transport modes (air, water, rail and road) are considered not only independently but also as combined and cross-modal transport concepts such as multi-, synchro, inter- and co-modality.

- FEDERATED[10] – European Federated Network of Information exchange in Logistics: FEDERATED project developed the foundations for a secure, open and neutral data sharing infrastructure provision, facilitating decentralized data collaboration in logistics. The overall goal was to develop the European federated architecture for data sharing in the form of digital corridor information systems serving the European logistics community, providing the appropriate digital framework to perform collaborative planning, efficient and sustainable operations and execution

[8] https://stars-h2020.eu/
[9] https://www.entrance-platform.eu/
[10] https://www.federatedplatforms.eu/

monitoring in various corridor scenarios and contexts. Three out of 15 Living Labs were focused on multimodality, addressing: (i) Collaborative Decision Making (CDM) – deleting the concept of siloed data, i.e. introducing new ways to share and retrieve important logistics data from supply chains; (ii) Enhancement of supply chain visibility enabling effective planning of intermodal - trucks and ferry –through cross border data sharing between different nodes/hubs/and place of interest; and (iii) cooperation of companies representing different modalities (road, maritime, railway, and air) with cargo owners and authorities in a transparent network.

- ULAADS[11] – Urban Logistics as an on-Demand Service: ULLADS' vision is to foster sustainable and livable cities through the deployment of innovative, share, zero-emission logistics, while dealing with the impact of the on-demand economy. Among other solutions, ULAADS developed and implemented the Dual MobiHub solution, providing a smart point in the transport network that seamlessly integrates different modes of transport through multimodal supportive infrastructure (including carsharing parking slots, bike-sharing docks, public or collective transport stations, EV-chargers and public cargo bike-sharing platforms). In parallel, the Cargohitching solution assessed the integration of on-demand high-speed delivery of small goods with shared passenger transport, using the spare capacity of transport vehicles.

- URBANE[12] – Upscaling Innovative Green Urban Logistics Solutions Through Multi-Actor Collaboration and PI-inspired Last Mile Deliveries: URBANE aims to provide novel, sustainable, safe, resilient and effective last-mile delivery solutions, combining green automated vehicles and shared space utilisation models. The project also leverages digital twinning tools, a data-driven impact assessment radar and blockchain-based smart contracts to deliver results, enabling it to verify the "physical internet" (the transport network) for urban deliveries. The Bologna demo case explores the requirements for introducing ADVs/drones for the movement of goods and the Valladolid one aims to promote the use of electric vehicles in the urban freight delivery service, while the Karlsruhe case looks into the combined use of trams, robots, and cargo bikes for last-mile delivery.

- FOR-FREIGHT[13] – Flexible, multi-modal & robust freight transport: FOR-FREIGHT aims to maximise the utilisation of multimodal freight transport capacity, achieve competitive sustainability with higher levels of efficiency, and reduce the average cost of freight transport through the development of novel solutions and their integration with legacy logistics systems. The solutions to be developed solutions

[11] https://ulaads.eu/
[12] https://www.urbane-horizoneurope.eu/
[13] https://www.for-freight.eu/

target the end-to-end optimization of multimodal/multi-stakeholder logistics processes and improved access to transshipment services through real-time door-to-door tracking, decision-support systems, increased resilience and security, as well as carbon footprint assessment and transport networks. The Spanish use case focuses on end-to-end transport planning from ship to port, to central warehouse, to last-mile, exploiting the existing Metro network for last-mile delivery, while the Greek one enables end-to-end multimodal logistics process by providing logistics operators and end-users the overall real-time and end-to-end picture of the logistics process. In parallel, the Romanian use case will enhance supply chain visibility and functionalities, combining information from all individual management systems to allow access to fluent and accessible information on transport flow[14].

- MULTIRELOAD[14] – Port solutions for efficient, effective and sustainable multimodality: MULTIRELOAD aims to enable European ports and freight hubs to actively drive the transition to greenhouse gas emission-neutral shipping and wider multimodal mobility by 2025, reducing freight transport on road by shifting it to inland waterway and rail, and enhancing cooperation between different freight hubs. The innovation area of Smart Multimodal Logistics will develop innovative inter-/multimodal transport solutions linking all relevant modes, using transshipment technology with different intermodal transport units (ITU's) (incl. transport of bulk cargo using multimodal containers), and concepts for an optimized, standardized global goods transport system based on the concept of the Physical Internet, while the innovation area of Digital and Automated Multimodal Nodes and Corridors will transform intermodal freight nodes into interconnected data platforms to connect actors, physical and digital infrastructure, assets, resources and services on three levels: terminal, node and corridor, creating a truly integrated transport and logistics network.

- SPROUT[15] – Sustainable Policy Response to Urban mobility Transition: SPROUT provides a new city-led innovative and data-driven policy response to address the impacts of emerging mobility patterns, digitally-enabled operating & business models, and transport users' needs. The aim is to build cities' data-driven capacity to identify, track and deploy innovative urban mobility solutions. In particular, the Valencia use case designed an advanced concept of intermodal urban transport nodes integrating bikes (and other green transport options), public transport means (train, tramway, metro, bus) and last mile freight distribution through the co-location of new advanced complementary services. Moreover, the Budapest use

[14] https://multireload.eu/
[15] https://sprout-civitas.eu/

case implemented and assessed the impact of shared passenger mobility (free-floating car- and dockless bike-sharing) in the city.

- SUMP-PLUS[16] - Sustainable Urban Mobility Planning: Pathways and Links to Urban Systems: SUMP-PLUS helped cities of all shapes and sizes and at various development stages to enhance their SUMP implementation processes and address diverse mobility challenges. Working within six co-creation laboratories, it equipped cities to develop the next generation of SUMPs and put mobility at the heart of sustainable urban transformation. The Antwerp city lab was focused on the provision of seamless intermodality and non-transport solutions, through new mobility partnerships, innovative solutions and intermodal hub design, as well as on the promotion of collaborative urban logistics through the enhancement of multimodal hubs, shared mobility "dropzones" and "ringzone" train stations.

- HARMONY[17] – Holistic Approach for Providing Spatial & Transport Planning Tools and Evidence to Metropolitan and Regional Authorities to Lead a Sustainable Transition to a New Mobility Era: Harmony's vision was to enable metropolitan area authorities to lead a sustainable transition to a low-carbon new mobility era and update the Sustainable Urban Mobility Plans of the future through harmonised spatial and multimodal transport planning tools modelling the changing transport sector and spatial organisation. One of the main project's objectives is the integration of automated vehicles and drones with traditional transport modes, while the HARMONY Model Suite operates on three integrated levels of modelling, namely strategic, tactical and operational, with the latter serving as a multimodal network assignment model system. The Oxfordshire case study dealt with the integration and demonstration of electric AVs for passenger and freight and heavy-lift drones for transportation of essential medical supplies and delivery of parcels within Milton park.

- MOVE21[18] – Multimodal and interconnected hubs for freight and passenger transport contributing to a zero emission 21st century: MOVE21 aims at transforming European cities and their surroundings into smart zero emissions nodes for mobility and logistics, through connecting urban systems in an integrated approach and address both goods and passenger transport. The aim is to improve efficiency, capacity utilization of existing vehicles and transport related infrastructure, accessibility and innovation capacity in urban transport. The Oslo case study focuses on integration of micro mobility with public transport, as well as on mobility hub network including public transportation, shared cars, cargo bikes,

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[16] https://sump-plus.eu/
[17] https://harmony-h2020.eu/
[18] https://move21.eu/

private bikes and micro mobility, while the Hamburg one focuses on last mile deliveries or first mile pick-ups via cargo bikes.

- TRANSIT[19] – Travel Information Management for Seamless Intermodal Transport: TRANSIT's vision is that of a multimodal European transport system where the different modes are seamlessly integrated, so that passengers travel from door to door in an efficient, sustainable and resilient manner. Realising this vision requires coordinated planning and collaborative decision-making across transport modes, as well as multimodal information systems that allow passengers to plan and reconfigure their journeys in real time. The respective case studies were focused on integrated ticketing & schedule coordination, as well as on disruptions, where several intermodal solutions were implemented, such as ticket integration, identification of origin-destination demand, resilient regional transport network, timetable synchronization, airport reassignment, passenger rebooking to other transport modes, estimation of the travel time from door to airport, frequencies and schedules updating etc.

- RE-ROUTE[20] – Integrated intelligent multi-modal transport infrastructure: distributed localised decision-making at the network edge: RE-ROUTE aims to improve the multi-modal Mobility-as-a- Service transport integration through localised Edge-based real-time data sharing, decentralised decision making, and localised network that places the processing at the proximity of data, contribute to evidence-based policy and physical infrastructure development and developing a unique skill set for the participating partners and improving their career prospects in the emerging ITS job market. The project aims to enable mobility services accessible 'on demand', including shared and multi-modal services using modes such as carsharing, bikes, ride-hailing, e-scooters, by an integrated Multimodal Intelligent Transport System (M-ITS), incorporating both motorised and non-motorised transport, as well as private and public systems through the concept of Mobility as a Service (MaaS).

3.3 Implementation cases

This section presents the main implementation cases that have been included in the SotA analysis of multimodal transportation. Based on the selection criteria described above, a list of real case studies of multimodality for passenger and/or freight transportation has been created, covering cases that have been designed, implemented, tested, validates and/or adopted in real conditions and ecosystems.

[19] https://www.transit-h2020.eu/
[20] https://reroute-project.eu/

- The transport system of Barcelona offers 12 metro (underground) lines, 14 trains and 108 bus lines covering the whole municipality, while in parallel it presents a variety of micromobility options that offer a wide set of choices to travellers, ranging from public bike-sharing systems to moped-sharing services. Based on relevant studies, most micromobility users rely on a single type of transport mode on a weekly basis, in contrary to e-scooter, shared bicycle, and moped-style scooter users that develop different weekly mobility combination strategies. While personal micromobility options (private e-scooter) are associated with monomodal tendencies, sharing services (bicycle sharing and moped-style scooter sharing) encourage multimodal behaviours [7].

- Brussels - "Good Move Plan"[21]: Good Move is the Regional Mobility Plan for the Brussels-Capital Region that defines the main policy guidelines in the field of mobility. The plan resolutely opts for a pleasant and safe city, comprised of peaceful neighbourhoods, connected by intermodal structural corridors and focused on efficient public transport and improved traffic flow. The plan's measures are designed to provide each user with adapted, facilitated and integrated mobility solutions, enabling them to choose the most appropriate mode of travel for each of their trips, depending on their destination and needs at a given time. Among other focus areas, Good Move aims to offer users a range of integrated services, which replace the need to own a personal car, and which promote the combination of modes of travel and public transport networks. To do this, the Region has chosen three main areas of development: (i) to bring the transport options together, both digitally and physically, in terms of information, reservation and price, to facilitate mobility and multimodality; (ii) to increase the quality, readability and accessibility of public transport networks and services; and (iii) to strengthen the interconnection of different services and intermodality through the development of hubs.

- Helsinki: Helsinki is among the most advanced cities in Europe in terms of integrated transport network and provision of various alternatives and services to improve mobility[15]. The capital of Finland was the first large city to introduce the smartphone-based "Mobility as a Service" multimodal journey planning app as a way to reduce the use of cars within the city[22]. This mobility ecosystem includes a wide variety of alternative transport modes available, including taxis, public transport, scooter and car sharing, car rental and bicycles and the associated application integrates all these transport modes and related services into a single interface, combining information on transportation infrastructure, services, payments, and other data. Based on this model, Helsinki aims to bring together the

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[21] https://mobilite-mobiliteit.brussels/en/good-move
[22] https://www.theagilityeffect.com/en/case/helsinki-pioneers-maas/

capabilities of public and private entities and through collaboration and integration of all services, to achieve a seamless and demand-driven user experience. In addition, Helsinki has introduced the Bicycle Action Plan[23] that focuses on the integration and promotion of biking, facilitating in parallel the delivery of goods using micromobility services. For this purpose, dedicated loading zones have been marked, bicycle parking conditions in buildings have been improved and the cycling route maps are regularly updated to ensure the smooth implementation of the plan.

- Budapest: An integrated transport application named BudapestGo has been developed and released by the BKK public transport company in Budapest, allowing allows riders to plan their journey, purchase tickets and passes, as well as provide real-time information on the actual transport situations and traffic-related changes during journey planning. This application covers all available transport modes, including Budapest transit, regional buses, and local public transport lines of every major urban settlement in Hungary, along with on-demand bus service[24]. Micromobility is also promoted in Budapest with infrastructural and spatial integration of relevant modes, management and control of providers, and digital integration of associated services through a common platform (MaaS).
- Leuven: Leuven has developed its own Sustainable Urban Mobility Plan (SUMP) and climate neutrality strategy. Among other practices, several mobility hubs have been created and introduced during the last years, aiming to foster multimodality and improve mobility and social impact. The hubs typically integrate different transport modes in one place, such as a bus stop, electric vehicle charging stations and various shared vehicles, including electric cars, bicycles and scooters, while they also offer additional services and facilities related to parcel deliveries, such as parcel lockers. It shall be noted that Leuven has decided against free-floating shared mobility to ensure proper use of public space and accessibility, providing though sufficient relevant services at the mobility hubs[25].
- Gothenburg: Gothenburg is one of the pioneering cities in the provision of MaaS services, with the associated application UbiGo[26] being one of the first and most innovative ones implemented. UbiGo was a web-based smartphone application combining all available transport modes and services of the city, such as public transport, car sharing, rental car service, taxi, parking and bike-sharing services. Through this application, users could select a mobility subscription scheme and search and book their journeys, being charged through a single bill for all modes and

[23] https://www.hel.fi/en/urban-environment-and-traffic/cycling/promotion-of-cycling
[24] https://mobility-innovators.com/budapest-launched-budapestgo-app-to-move-towards-maas/
[25] https://www.polisnetwork.eu/news/polis-publishes-new-report-on-shared-micromobility/
[26] https://www.fluidtime.com/en/ubigo/

providers. Real-time information and data were also provided to the users related to service availability and traffic conditions.

- Amsterdam Hubs – The sharing of vehicles such as bicycles, mopeds and cars in Amsterdam has been identified as significant contributor for better use and reduced needs for vehicles, leading to less traffic. In parallel, sharing is often cheaper and faster, and it is also sustainable and good for air quality. To enhance sharing, the City of Amsterdam has introduced the concept of Hubs that serve as junctions where different types of shared transport come together, ranging from bicycles and cargo bikes to mopeds and cars[27]. At these points, travellers can transfer, and goods can be transhipped to other forms of transport. In order to cover all transport needs, Hubs vary from neighbourhood and district hubs with (electric) shared transport to logistics hubs and city and regional hubs with connections to major public transport hubs. Hubs also support "Park & Ride" services, allowing people to park their cars at a P&R location on the outskirts of the city and travel to the city centre of Amsterdam by public transport.

- Xiong'an New Area, China [8]: The city of Xiong'an has adopted various initiatives facilitating multimodality, such as "car-free zone" implementation, controlled parking provisions, and vehicle purchase and use policies, while greater use of public transport and reduction of parking dependency and parking-space supply are also promoted. To enhance the scale of multimodality implementation, several regional connectivity-enhancement initiatives have been introduced, such as planning and operational strategies for multimodal interchange hubs, integrated corridor management (ICM), and seamless airport access.

3.4 Validation activities

Based on the validation process that was performed to the initial findings of the SotA analysis, a dedicated survey took place targeted to both internal audience (consortium) and external audience (Advisory Board members, MTMC members etc.). Through the analysis of the feedback collected, the majority of preliminary findings was validated and confirmed by the respondents, especially from the ones representing transport operators and service providers, while some additional input and considerations related to projects, initiatives and implementation cases were collected and presented below.

Among other contributing approaches and practices, on-demand mobility was highly proposed as a significant contributor to transportation optimization and provision of efficient multimodal services, since it can fill the gaps of other transport modes and

[27] https://www.amsterdam.nl/en/traffic-transport/shared-mobility/

services and provide flexible alternative options to the users, such as taxi services, carpooling, ride-hailing and demand-responsive transport (DRT) services. This type of mobility can be easily integrated with other transport modes and improve the typically challenging first-/last-mile leg of a journey, improving also flexibility and scheduling, as well as accessibility and inclusivity. Combined also with electromobility, it can significantly contribute to the reduction of associated emissions and the enhancement of sustainable mobility.

Leveraging active mobility services for last-mile parcel delivery, such as walking and cargo bike are also promising applications of micromobility in logistics. Through walking and cargo bikes, operators can navigate urban environments more efficiently, reduce emissions, and alleviate congestion, particularly in city centres where traditional delivery vehicles face challenges. Such services not only provide additional transport options and modes to consumers, but also contribute to the protection of the environment, the promotion of responsible consumption practices and the overall enhancement of environmental sustainability. In this way, urban logistics supported by eco-friendly delivery options, creating in parallel positive social and environmental impact at every step of the delivery process. In the same direction, some of them provide e-commerce delivery services that prioritize informing consumers about available transport options, the associated environmental impact, and mitigation measures, aiming to engage them in the process and allow them to make informed decisions, considering the environmental impact of transportation. Furthermore, the emergence and growth of Out-of-Home (OoH) services, including lockers and pickup/drop-off points, represent a significant multimodal trend in the transportation and logistics industry. These services offer convenient alternatives for parcel delivery and retrieval, catering to the evolving needs and preferences of consumers.

Another rising practice is the utilization of drones or other light unmanned aerial vehicles that have been extensively studied and explored during the last years. Currently, drones and especially swarms of drones are already used to collect data of multimodal vehicle trajectories (including pedestrians and soft modes)[11]. This new transportation mode is also used at small scale for last-mile delivery in urban environments to facilitate fast, efficient and environmental-friendly transportation of small parcels or packages to the consumers, avoiding congested road networks. In parallel, the exploitation of drones for passenger transportation is also explored and tested, aiming to be further developed and validated and provide a safe, secure and sustainable alternative for people' mobility. In this way, the third dimension of transport networks will be also widely used and exploited, releasing already congested modes and services, enhancing systems' performance and improving the overall mobility efficiency. Towards the promotion of multimodality, it seems that the integration of UAM services for certain mobility routes will rise in the coming years, both for cargo and passengers' transportation.

As already mentioned, data availability, integrity and accessibility are crucial for transport operations and can be one of the most important factors affecting the implementation of multimodality for both passenger and freight mobility. The collection and availability of data and information through smartphones, sensors incorporated in vehicles and sensors installed all over cities can certainly facilitate data analysis and exploitation for improvement of transportation services and enhancement of multimodality. Moreover, the development and utilization of common interfaces and APIs, as well as unified systems and platforms among transport operators are widely applied to enable the integration of various components and solutions and facilitate information flows and data exchange.

In order to achieve real integration of transport modes and services and ensure real-time data exchange among tools, systems and platforms, efficient network connectivity and capacity is critical and 5G technology can serve as a game changer towards this direction. Thanks to 5G capabilities and features allowing for network slicing, low-latency communication, large number of connected devices and large capacity for mobile broadband services, it can significantly contribute to the integration of systems, modes and services and enable efficient data exchange among all involved stakeholders, from service providers to final users. Additionally, another important technique and direction is to enhance data processing at the edge, since it can improve operations and reduce energy consumption, so data processing at all levels can significantly contribute to data exchange in the most efficient and environmental-friendly way. During the last years, 5G technology has been widely tested and evaluated in various sectors and domains and it has also started to be adopted by pan-European Transport & Logistics (T&L) industry as a prominent solution for systems' integration and interoperability.

In parallel, as the work towards automatization and digitalization of mobility and supply chain is highly promoted and enhanced, various practices exploiting innovative solutions and technologies are explored and may be further studied and implemented in the following years. The adoption of digital platforms and smart technologies, such as Artificial Intelligence (AI), Internet of Things (IoT), and blockchain, would enhance the coordination and efficiency of multimodal transport by providing real-time data, predictive analytics, and secure data sharing. Given that data exchange is crucial for multimodality, one of the most promising techniques is the exploitation of blockchain technology that can facilitate integration and sharing of data in a transparent and secure way, ensuring also trust among involved parties. In these cases, contract management procedures shall also be defined and implemented to enable data flow and collaboration. AI can also be used and contribute to multimodality, with the integration of autonomous or AI-based participants in the transport ecosystem, such as robot taxis. However, the use of AI requires thorough study and attention to ensure secure data exchange and proper system operation, since it may add new dimensions of vulnerability in the transport ecosystem, such as adversarial attacks or usage of AI-Agents to construct attacks. Moreover, systems for transactions and communication between autonomous participants can also be used to facilitate integration of infrastructure, modes and services, e.g. automated loading of an autonomous electrical car at an autonomous charger station.

With regards to multimodal transportation addressing both people and cargo, several practices and policies have been introduced and applied trying to facilitate and optimize both transport pillars in a combined way. One of the most important practices is the integrated transport planning, since the development of comprehensive transport plans that consider all modes of transport can optimize passenger and cargo flows, reduce congestion, and improve efficiency. Collaboration between public and private sectors can also be promoted through the implementation of public-private partnerships (PPP), facilitating the sharing of resources, expertise, and investments. Additionally, the development of regulatory frameworks and the implementation of standardized regulations and guidelines at regional and national levels can contribute to the harmonization of operations across different transport modes. Another good attempt to align the different strategies of people and goods' transportation is the directive related to rail capacity, even though better collaboration and infrastructure upgrade are essential to allow cargo being moved to rail at scale. However, multimodality for urban logistics is still under study and exploration and requires extensive planning and testing before being implemented at large scale, in order to lead to the expected results in terms of performance, efficiency and overall sustainability.

Through the validation process, some additional examples of relevant practices and initiatives were also extracted, providing valuable insights from real implementation cases where multimodal transportation has been applied and performed in large scale and real conditions. Given that the majority of respondents were from the EU, these examples are focused on European cases and practices. Also, more detailed information was provided for the cities involved in DELPHI use cases by the relevant stakeholders (public transport operators, municipalities etc.).

- In Community of Madrid, the public transport system comprises underground, light rail and suburban railway networks, and the city and suburban bus networks. This system includes operators, infrastructure and modes of transport, being part of the Consorcio Regional de Transportes Públicos Regulares de Madrid (CRTM), which establishes a collaboration framework of the public transport system of the Community of Madrid and is responsible for planning and managing the transport services. The functions of the CRTM include planning of public-transport infrastructure; planning of services and coordination of operating programs for all forms of public transport; definition of a comprehensive fare system for the transport as a whole; establishment of a stable funding framework; control and monitoring of the financial management of operators; creation of a general overview of the system, bringing external relations and users together. In parallel, the existence of transport operators covering the last-mile delivery for e-commerce has been expanded, with most of them providing micromobility services and integrated multimodal solutions. Some of the key strategies used to optimize efficiency and enhance service delivery include:

  - Common Microhubs: Shared microhubs are operated where merchandise is commonly handled for multiple transport operators. This consolidation of operations allows to achieve critical mass, streamline processes, and improve overall operational efficiency.
  - Dynamic Data Exchange: Real-time information sharing is also supported to enhance visibility and coordination throughout the supply chain. This allows for agile decision-making and proactive management of shipments.
  - Operating with Customer's Systems: Some of the transport operators follow the operations' procedures of their customers, in cases where the latter prefer to use their own systems. While this approach may offer flexibility, it can sometimes result in reduced synergies and critical mass, leading to less efficient operations.
  - Micromobility services, such as last-mile parcel delivery walking or using cargo bikes are also extensively used. In Madrid, last-mile delivery providers like KOIKI company collaborate with the local council to manage a microhub that facilitates the integration of various transport and delivery services. In this Madrid Microhub, parcel services for Amazon and Geopost/DPD are handled, utilizing their respective IT systems for efficient management.

- In Cluj-Napoca, several practices related to multimodal transportation have been implemented facilitating passenger mobility around the city, such as:
  - Micromobility – Electric scooter rental services are available through three operators: Flow, Bolt, and Lime. All operators provide users with a mobile application through which they can rent scooters and make payments using a bank card. In the case of Lime, it collaborates with the ride-hailing operator Uber, allowing users to access Lime scooters through the Uber app without the need for an additional application. The city of Cluj-Napoca is the first in Romania that has developed regulations for the use of electric scooters rented within the city, which were approved by Decision no. 790/2020. The regulation outlines the

rules for parking and placing scooters on the municipality's public domain and the obligations and sanctions imposed on operators.

- Bike-sharing services – The project ClujBike, currently nearing completion, involves the construction of 50 bike rental stations (of which 43 are in Cluj-Napoca, 4 in Florești, and 3 in Apahida) equipped with 540 bicycles, as well as the creation of 18.8 km of additional bike lanes to the existing 6.8 km. Additionally, another 41 km are being arranged as "routes suitable for cyclists", involving merely the installation of traffic restriction and warning signs.

- Electromobility – In Cluj-Napoca, there are 40 electric vehicle charging stations within the municipality's territory and in neighboring areas such as Apahida and Florești. These stations are in city parking lots, as well as within some gas stations or hotel facilities. The stations serve both the downtown area and some of the neighborhoods of the municipality (e.g., Mănăștur, Mărăști). Also, it is important to mention that over 50% of the total public transport is electric (electric buses, trolleybuses and trams) and the Municipality is continually replacing the older fleet with electric options. In parallel, tests and preparations are conducted by the municipality in partnership with the Technical University of Cluj-Napoca to achieve the target of having 25 hydrogen-powered buses by 2030.

- Parking – Four different types of parking have been established: (1) Parking areas located in the city's neighbourhoods, available through an annual subscription, built with municipal funds, and appropriately marked, numbered, and signalled; (2) Parking spaces and garages located in the city's neighbourhoods, available through annual land lease contracts, built by citizens based on a construction permit; (3) Closed parking with barriers - parking spaces available on a pay-by-the-hour basis, with a non-stop schedule and controlled access; (4) Parking areas located in the city's neighbourhoods with parking spots available through annual subscriptions intended for local residents. Closed parking with pay-by-the-hour options are the most relevant types of parking for those looking to plan a multimodal journey through the city. These facilities enable the public to integrate their personal vehicles with other forms of public transportation. By parking in these located facilities, individuals can easily switch from driving to using public transit systems, biking, or walking, thus facilitating efficient and flexible urban mobility.

- Drop boxes – E-commerce services are also available in Cluj-Napoca, with the majority of relevant deliveries being facilitated through drop boxes available in key areas of the city. However, these services are mainly provided by private companies, without any collaboration among them or direct partnership with the municipality.

- Common mobility hubs – Several hubs have been implemented around the city, integrating various modes of transportation such as bus stops, tram stations, bike-sharing stations, and areas for micromobility devices like scooters and ride-sharing services. These hubs are essential for facilitating seamless transfers and improving overall mobility within the city, since they serve as focal points where passengers can easily switch between different modes of transportation, enhancing accessibility and convenience for commuters. Additionally, they contribute to the promotion of sustainable and efficient urban mobility by encouraging the use of alternative transportation options and reducing dependence on private cars.

- Multimodal transport application – The application (provided by Tranzy company and available for iOS and Android) ensures the planning of routes with public transport in Cluj Napoca. In addition to route planning, users have access to real-time information on the location and arrival of public transport means at the station. The application does not yet allow payment for the trip, but this service is already provided through the e-ticketing system. Planning with the local bike-sharing system is not currently functional in the application. The public transport company CTP provides access to information on timetables, routes and ticketing to the users through their main portal, while an embedded map provided through Tranzy partnership program provides information regarding real-time location and routes of public transportation buses.

- In Berlin, a common app for all transport means (including micromobility) was developed, supporting search, execution and charging for all modes. This application named Jelbi[28] has been developed by Berlin's public transport authority BVG according to their smart mobility strategy and aims to connect every shared mobility offer in the German capital into a single marketplace for its residents to provide an attractive alternative to private cars. In parallel, the deployment of the Small Electric Vehicle Regulation (eKFV) at country-level, introducing fines to persons using electric balance vehicles without type approval on the road was also a significant

[28] https://www.trafi.com/jelbi-app-berlin

contributor to the control of vehicles moving around the city and their operation and interactions with pedestrians and other transport means.

- In Greater Manchester, the bike-sharing service has also been integrated into the existing bus service application, allowing for combined journeys and promoting multimodal transportation of people. In parallel, e-cargo bike share schemes are emerging with operations launched in Manchester, aiming to increase the number of deliveries, reduce the associated emissions and improve mobility flows.

- In Belgium and the Netherlands, another practice that has improved the transportation flow and efficiency is the control of access to city centres through the implementation of low emission zones. In these zones, access is allowed under specific criteria related to vehicle size, cargo type, emission standards etc., leading to access limitations and even restrictions for large transport vehicles and delivery vehicles. To overcome these limitations, last-mile delivery services are becoming more popular as a viable solution to facilitate urban logistics in dense city centres, without imposing negative impact to the environment and the society. Among other last-mile services, the exploitation of cargo bike services and relevant bookings by logistics service providers is the most common approach for last mile delivery.

- In Dublin, the utilization of unmanned aerial transport means and specifically drones has risen during the last years, with services related to delivery of packages by drones being available in selected neighbourhoods of the city. The service is provided by the company Manna[29] that enables the transportation of small packages related to food, coffee, medical supplies etc. through very fast and efficient drones. The service is supported by the associated web-based smartphone application that has been released and allows users to order goods from various suppliers, exploiting a fast, safe, green, quiet and private alternative to conventional transport options. The service is currently available to specific areas of Dublin and is planned to be extended to larger scale, while relevant trials are also under testing in Dallas, Texas, aiming to make progress in the US market.

[29] https://www.manna.aero/

4. Multimodal trends towards common passenger/ freight mobility

Either transporting people or goods, the ultimate goal is common and is about achieving movement from origin to destination in a quick, easy, safe and reliable way, with the lowest possible cost and environmental footprint. This common approach has already been applied in aviation and rail transportation, where infrastructure is used to move people and goods simultaneously (e.g. airplanes with specially designed spaces for passengers or goods, specially designed wagons for each use, etc.) [9]. However, in road transportation, these two mobility types are still treated as independent systems with different modes of operation and separate infrastructures, resulting in isolated solutions that do not take into consideration possible interactions and potential opportunities for synergy. A promising solution to this issue could be the definition of a common framework that would enable the integration of passenger and freight transport systems, through the implementation of integrated models satisfying the needs and requirements of both transport types.

One of the main objectives of DELPHI project is to integrate passenger and freight transport into a single federated system, working towards integrating sectors, harmonizing data, and leveraging advanced methodologies, to transform transportation systems, for a sustainable future. The DELPHI's concept is based on the delivery of technical and governance/ regulatory enablers towards a federated network of platforms for multi-modal passenger and freight transport, capable of sharing in a seamless and secure manner, cross-sectoral, multi-modal passenger and freight transport data, as well as traffic management systems information. To achieve this, it aims to develop and implement among others secure data federation, novel governance and regulatory schemes, along with multi-/inter-modal optimization, exploiting diverse modes for integrated/hybrid passenger and freight transport in different ecosystem types.

In general, an integrated transportation model is based on the concept that people and goods can use common infrastructure, means of transport and services for simultaneous or parallel movement, without one system hindering the other. This integrated approach focuses on the efficiency and reliability of a mixed traffic model, leading to more sustainable operations than the existing model, where passengers and freight are referred to as independent systems. Although the goal is common, there are several functional differences impeding the implementation of a mixed movement model, related to decision-making process and parameters, transport flows' patterns etc. At the same time, the two systems are not only treated as independent at an operational level, but also in an institutional and legal framework, since they are governed by different authorities and subject to different rules and guidelines, different contractual and employment structures. An integrated traffic model should be accompanied by consistent policies and coherent planning [10], as the regulatory and regulatory aspects are crucial to the success of such an initiative and are currently the biggest barrier to its spread.

Multimodality can significantly contribute to the conceptualization and design of such an integrated system, since it can provide transportation solutions and alternatives combining various transport means – even further to the conventional ones – and ensure efficient, optimised and redundant transportation options for both passengers and goods. The sections below present the most prominent practices and strategies that could enhance the implementation of common passenger/freight mobility, along with the relevant enablers and barriers that need to be taken into consideration. Additionally, associated socio-economic aspects are presented, to provide a holistic overview of such multimodal trends and their overall impact on transportation industry and the society in total.

4.1 Practices and strategies

Analysing the aforementioned projects, initiatives and cases addressing multimodal transportation for passengers and/or goods, some common approaches and directions that are followed for the exploitation of multimodality can be extracted, while some of them can serve as contributors to the unification of passenger and freight transportation systems. Relevant practices and strategies that have been designed, implemented, tested and adopted by some areas, regions, cities etc. and can facilitate the integration of currently fragmented transport systems for passenger and freight mobility can be summarized as follows:

- Collaborative schemes based on dynamic data exchange: In most cases, the collaboration is mainly focused on the identification and consolidation of all available transport means and services and the extraction of more efficient alternatives based on multimodal transportation. Such collaborative schemes are usually implemented through independent platforms that support dynamic data exchange, linking demand and supply and facilitating the communication and collaboration between users and service providers.

- Micromobility/Light Mobility: The promotion of micromobility has been highly suggested as viable alternative to conventional transport means and especially for dense and congested urban environments, facilitating the last-mile transportation or delivery. To achieve this, the least intervening approaches are followed such as enabling dynamic data exchange and federated solutions among involved modules and systems.

- Hubs/Terminals: Another widely adopted practice is the establishment of common hubs and intermodal terminals where goods can be transferred between different transportation modes efficiently in both regional or urban environment (e.g. a shipment might arrive at a port by sea, be transferred to a rail terminal, and then moved to a trucking facility for final delivery, vs. a parcel might move from a warehouse to a local distribution centre by truck, be transferred to delivery box by cargo bike and then be collected by the consumer that arrive on foot). A similar concept can also be applied to passenger mobility, where hubs can serve as the connection points among various transport means (e.g. a location where a metro station coincides with a bus station and/or a bike-sharing terminal).

- Mobility as a Service – MaaS: The concept of MaaS has been highly studied and implemented in various environments and ecosystems, being considered as one of the most prominent strategies and concepts for efficient, safe, green and sustainable transportation. MaaS allows users to plan, book and pay for a trip that combines multiple transport modes and services using one user interface (platform, website or application) and performing one payment. MaaS systems may include private and public transport means, such as metro, bus, tram, car-sharing, bike-sharing, e-scooter etc. and aims to enhance mobility experience for users, reduce car ownership and increase transport efficiency and performance. Typically, this concept is applied by public administration or transport authorities at regional level (e.g. town, city, or metropolis), incorporating all available transport modes and services.
- Shared Mobility: Several transportation schemes and systems where travellers share a vehicle either simultaneously as a group (e.g. ride-sharing) or over time (e.g. carsharing or bike sharing) as personal rental have been widely introduced during the last years, creating a hybrid option between private vehicle use and mass or public transport. It is a transportation strategy that allows users to access transportation services on an as-needed basis and encompasses a variety of transportation modes including car sharing, bike-sharing systems, ride-sharing companies, carpools, and microtransit. Shared mobility may have positive impact on travel behaviour, the environment, and the development of cities and urban areas, allowing for enhanced transportation accessibility, reduced driving, decreased personal vehicle ownership, better use of public space, reduced congestion and environmental emissions etc.
- Urban Air Mobility – UAM: The use of small, highly automated aircrafts/drones to carry passengers or cargo at lower altitudes in urban and suburban areas has been explored during the last years and seems to be one of the most prominent transport modes of the future. UAM is designed to carry passengers or cargo in urban and suburban areas, facilitated by cutting-edge technologies and incorporated into multimodal transport networks. The electric aircrafts that are used can be operated remotely or by an onboard pilot. The potential of UAM services lies in their ability to link remote areas where ground transport is inefficient or unfeasible from economic or environmental point of view, both economically and environmentally. UAM

services can drastically cut travel time, addressing emergency transport needs and improving overall safety. Their economic contributions can also provide significant advantages to urban and regional areas.

- Same day delivery: Several companies worldwide have introduced the concept of same-day delivery, where the purchases are received on the very day the order is placed, in order to address the rapid growth of e-commerce, increase their value chains, customers and profit, as well as to improve their competitive advantage. Typically, such services are provided at a localized scale and are supported by multiple fulfilment centres, while delivery management procedures such as real-time tracking, route optimisation, and advanced analytics to improve overall delivery performance are in place to ensure the viability and efficiency of this concept.

- Requests and offers balance: One transport trend that has been extensively explored during the last years is related to the balance of demand and supply to ensure higher exploitation of services and better management of requests. This topic always was one of the priorities of logistics service providers aiming to increase their efficiency and profitability, however it was limited to each company's operation, since no such data was exchanged due to competitiveness. During the last years, several initiatives aim to gather such information and relevant data from various providers and make them accessible by the purchasers, increasing the overall ecosystem transparency and visibility and optimizing the overall operation and efficiency of supply chain.

- Delivery hubs/boxes: Another interesting trend is the installation of delivery hubs at key points of an area, providing multiple locker-type facilities, such as boxes that can store small- or medium-size parcels for a small period of time (2-3 days) allowing the final customers/purchasers to pick it up whenever fits better to their schedule. This concept is one of the most effective last-mile delivery strategies and has been highly accepted both by businesses and the consumers.

- Crowdsourced delivery: This practice is related to the involvement of couriers or non-professional people in undertaking the delivery of packages and goods, instead of conventional delivery companies and personnel. This "Uber-ization" of last-mile delivery can significantly contribute to faster and more efficient logistics operations. Leveraging technology and requiring minimal resources, crowdsourced delivery has a significant advantage to conventional logistics operations, since it exploits the vehicle fleet of the couriers without any need for additional fleet ownership and maintenance, while in parallel it provides a demand-responsive solution to the market.

4.2 Enablers and barriers

In order to facilitate and promote the aforementioned practices and strategies, there are several solutions, concepts and technologies that can serve as enablers for the implementation of multimodality and the adoption of novel transport schemes, such as common passenger and freight mobility. These enablers might be technological, strategic or operational and can address the main weaknesses of current transport systems and initiatives. The most significant ones are:

- Marketplaces: In order to address the dynamic challenges of freight transportation, several logistics marketplaces have been developed and released, aiming to bring logistics stakeholders together, enhance their collaboration and improve the efficiency of supply chain. Such marketplaces enable not only the holistic mapping of transport networks and services, but they also provide real-time response to disruptions, minimizing the associated impacts. Moreover, due to their transparency and neutrality, they can be easily trusted by logistics stakeholders, allowing in parallel the orchestration of individual logistics operations in an optimised and holistic way.

- Big data & Data spaces: The mobility sector is associated with huge datasets that are usually under-utilized, mainly due to their size and complexity. However, their processing and exploitation could lead to positive impact in transportation and improved mobility services. In parallel, the development of common and interoperable data spaces in transport industry and subsystems can significantly contribute to the collection, sharing and re-use of mobility data. Following the direction of EU Data Strategy and the Digital Europe Programme, the implementation of the mobility data space is currently ongoing to map existing initiatives and identify common building blocks, aiming to enhance data availability, especially for urban mobility. Among other initiatives, the Mobility Data Space[30], supported by the German government, is an open decentralised ecosystem allowing mobility data providers to share data, to keep control, and to link existing mobility data platforms.

- Blockchain: Blockchain can significantly contribute to multimodality, especially in freight transportation, since it can provide a transparent and immutable ledger for recording the movement of goods across different modes of transport. This allows all parties involved to track shipments in real time, ensuring proper and efficient data management and exchange and increasing the overall visibility and traceability of the entire supply chain.

[30] https://mobility-dataspace.eu/

- Smart contracts: The concept of smart contracts is one of the applications of blockchain technology that allows to automate and enforce contractual agreements. In multimodal transport, they can be used to automatically trigger payments, update shipment status, or release goods when predefined conditions are met, reducing the need for intermediaries and manual processes. In parallel, they support anonymous, secure and trusted transactions among stakeholders, without requiring a central coordinating mechanism. Serving as a distributed solution, it ensures that the transactions executed are efficient, accurate and immutable.

- Physical Internet (PI): Physical Internet has gained momentum as a network of networks ensuring interoperability amongst logistics actors and providers in a common environment for optimized operational structures and shared resource and capacity planning and can significantly contribute to the promotion and implementation of multimodality, especially in freight transportation. It allows to connect logistics networks into an integrated network, supporting multiple transportation modes and options, along with real-time information. Moreover, PI enables better use of resources and transport capacities, including the challenge of empty vehicles and back-haul traffic, while in parallel, it enables real-time tracking and tracing and seamless flow of goods.

On the other hand, there are several issues that may hinder the implementation of a combined transport system and can be considered as barriers that need to be overcome. In most cases, there are several solutions, tools and services focusing on urban mobility and urban logistics. Although most of them serve their purpose and assist citizens in their daily travels and the logistics service providers in distribution of goods within cities, the lack of integration leads to a loss of potential synergy in changing transportation behaviour. The various datasets existing and generated by these systems are not integrated into a single database within cities, hindering the development of urban environment and the optimization of passenger and freight mobility. To overcome this and enable common passenger and freight mobility, there are several challenges that need to be addressed and mitigated, covering a variety of perspectives, such as technical, operational, infrastructure, financial, regulatory etc. These challenges are presented below:

- Technical Challenges: Implementing new modes of transportation often requires advanced technological solutions for vehicle management, user interfaces, and data integration. Ensuring compatibility and interoperability between various systems and technologies used by different transport modes can be technically challenging and impede seamless integration and data sharing. A significant part of such technical challenges is related to data availability, integrity, ownership, sovereignty, accessibility, formatting, integration, interoperability and exchange in general. Moreover, data integration and interoperability require complete reporting of transport data that currently may not be reported, digitalization of data and information flows that might not be fully digitalized, alignment of data formats and protocols, common language and semantics, as well as a secure and trustworthy framework for data exchange that will ensure data ownership, integrity and sovereignty. Additionally, different levels of digitalization and automation of services may exist between modes, affecting significantly their participation in an integrated and interoperable scheme.

- Operational Challenges: Coordinating the operations of different transportation modes, including schedules, routes, and services, as well as the integration with micromobility solutions, can be quite complex. In order to efficiently manage the transfer of passengers and goods between different modes of transport requires well-planned logistics and infrastructure. Typically, transport operators or service providers have their own business plans and objectives that might be contradictory to others, affecting their planning schedules and feasibility strategies. Competition is another perspective of this barrier since the implementation of multimodality and the combination of passenger and freight transport might limit the coverage area or customer base of an operator.

- Infrastructure Development: The development of the necessary infrastructure to support new transportation modes and schemes, such as dedicated lanes, hubs, park & ride facilities, charging stations etc. might be a significant challenge, affecting the implementation of multimodality. In addition, designing and constructing new infrastructure in urban environments is quite challenging, since most of them are very dense with limited free space available to host additional infrastructure. Moreover, new infrastructure or renovation of existing one is associated with financial challenges (described below), while in parallel it needs to be integrated in an overall development plan that incorporates all transport modes and services to ensure adequate service provision and continuity during the transition period.

- Financial Challenges: High initial investment costs for infrastructure development and technology implementation can be a significant barrier for many transport organizations, along with funding the implementation and maintenance of new transportation modes and infrastructure. Securing sufficient financial resources, whether through public investment, private partnerships or other funding mechanisms is crucial to make sure that the project can be implemented at a high level. More specifically, cost challenges can indeed be a significant hurdle when integrating new modes of transportation or other multimodal trends into your services, since they may imply additional costs related to infrastructure renovation or adaptation in order to host the new transport modes or schemes.in parallel, implementing new modes of transportation, such as micromobility options like walking deliveries, cargo bikes or scooters, can entail substantial operational costs. These may include vehicle acquisition or leasing, maintenance, insurance, and personnel training. Integrating these new modes into existing logistics operations requires careful budgeting and resource allocation to ensure financial viability. Also, it often necessitates investments in technology and infrastructure. Integrating these technologies into existing IT systems and operational workflows can incur development and integration costs. In parallel, multimodal services may have an economic disadvantage in logistics, since the additional moves of cargo between the different modalities may make the business case weak for each individual logistics service provider.

- Regulatory Challenges: The regulatory aspect is one of the most crucial pillars for the implementation of new transport modes, schemes and frameworks, since they may establish or block them. Diverse and fragmented regulations across regions and transport modes can create compliance complexities and hinder smooth integration. Compliance with regulations and legal requirements governing the operation of new transportation modes, such as licensing, safety standards can also pose regulatory challenges. Navigating these regulatory frameworks and obtaining necessary permits or approvals may require time and resources. The adaptation of existing regulations and the definition of new regulatory frameworks related to the accommodation of new transportation modes is the only way to facilitate such modes and schemes and ensure safety and accessibility. In parallel, there is a significant lack of regulations related to automation and scalability, limiting the functionalities that can be implemented and affecting the wider adoption of solutions that have already been tested at limited scale. With regards to UAM, airspace and local authorities may not develop or adopt new legislation to match the rate of technological development, leading to different levels of readiness and thus to inability to align and adopt innovative mobility frameworks in a uniform way.

Overall, the integration of new modes of transport or revision of conventional mobility services (e.g. exploitation of excess or unused capacity of passenger transport means for transportation of goods and facilitation of urban logistics services) require significant redefinitions of operational and technical processes, as well as important infrastructure investments. Also, an open dialogue and engagement of all involved stakeholders, including transport operators, service providers, users, authorities, regulators, urban planners, public administrations, local communities etc. would be crucial for establishing an optimum operational framework and ensuring the success of such a concept.

4.3 Socio-economic aspects

Apart from the analysis of multimodality in terms of extracting trends and practices that could facilitate the implementation of common passenger and freight mobility, another important aspect is the socio-economic perspective of such strategies and enablers. This mainly relies upon the significant impact that these aspects may have on the decision to adopt it by the regulators/authorities, operators etc., as well as on the social acceptance of new transport schemes and frameworks by the users.

One major social parameter of such a combined transport scheme is related to the reduction of required infrastructure to the absolutely necessary, minimizing the need for vehicles, trips, stations, etc. and thus optimizing the use of public space and the free areas for people. More specifically, an integrated passenger and freight transport system can promote the exploitation and federation of existing solutions and models towards a collaborative mobility system, focusing on the optimal management of space and underused or scarce resources, while in parallel it can facilitate the establishment of cooperative schemes for public and private stakeholders that can "Free the City" and deliver liveable spaces in cities. However, special attention shall be given to the alternatives proposed, especially the ones related to last-mile delivery, since the expansion of delivery hubs and boxes aiming to improve distribution of goods might also negatively affect the use of public space.

Another important parameter associated with the social point of view of mobility is road safety. The implementation of an integrated transport system can ensure that all transport modes operate collaboratively, minimizing congestion, disruptions or potential conflicts and providing smoother flow of people and goods and enhanced safety for all involved stakeholders (passengers, operators, vulnerable users, etc.), disruptions and the enhancement of safety on roads, since all transport modes operate collaboratively.

Moreover, the social acceptance of multimodal transportation is a critical factor affecting the development of relevant solutions and novel transport services, their integration with conventional transport means and the overall adoption by the communities. Usually, people tend to be reluctant to use novel solutions they are unfamiliar with, requiring a significant period to learn about them, feel comfortable, test and evaluate provided services and finally get engaged and adopt them. The same also applies to service providers that might be reluctant to introduce new services, due to concerns related to social acceptance and economic feasibility and sustainability of these services. To overcome these barriers, extensive testing and analysis of provided services need to be performed prior to the introduction of services to the market by the providers, while trial period and relevant incentives need to be provided to the users in order to attract and engage them.

In parallel, the provision of smoother and more efficient mobility can improve people's lives, since the required routes might become: shorter (e.g. reduced distance to approach a delivery hub and pick up a package or smaller delivery/journey times); simpler (easy transfer or transshipment from mode to mode); cheaper (unified and normalized payment for all involved route legs); and more relaxed (smoother transportation with real-time adaptability in case of disruption can lead to minimization of stress related to daily commutes). In this way, network bottlenecks can be encountered, substantially increasing safety, security, resilience and overall performance of the entire transport network, while seamless door-to-door mobility for passengers and freight can be achieved, cutting congestion, journey times and traffic jams across transport modes, and thereby significantly reducing emissions.

At the same time, this reduction in traffic discrepancies has the potential to significantly affect environmental aspects too. By optimizing routes and consolidating trips, this integrated approach can minimize the number of vehicles on the road, thereby decreasing traffic congestion and reducing idle times, leading to more efficient energy consumption and lower greenhouse gas emissions. Additionally, the adoption of eco-friendly vehicles or soft modes within this network further amplifies the environmental benefits. This holistic strategy not only enhances mobility and logistics efficiency but also contributes to cleaner, more sustainable urban and peri-urban environments.

With regards to the economic perspective, a common passenger and freight transport framework could strengthen the flow of people and goods within urban environments and thus increase the overall transport capacity and the associated economic costs. The implementation of multimodality can provide enhanced access to economic opportunities for people, leading in parallel to less costs related to vehicle ownership, maintenance, and rising fuel prices. Additionally, urban logistics can be further developed and enhanced with the least impact on people's lives, increasing the coverage of business operation and the overall market uptake.

Overall, multimodality is a cost-effective mobility strategy, allowing for optimised routes and improved service efficiency, either for people or freight transportation. Combining these two systems and exploiting resources in a common way wherever this is feasible (e.g. transportation of goods exploiting the excessive capacity of passenger transport means) can further improve the cost-effectiveness of mobility, since it will reduce the need for additional vehicles and trips and the associated costs, as well as it will reduce the journey times and increase the competitiveness and profitability for transport operators. Moreover, since operators' costs will be reduced, they can subsequently reduce the cost of transport services for users, that can purchase trips and services in a uniform way for multiple transport means.

5. Conclusions

As urban and peri-urban areas face growing transportation demands and challenges, integrating multimodal transportation paves the way to more efficient, sustainable, and resilient mobility solutions. In recent years, micromobility modes like bike-sharing, cargo bikes, and e-scooters have emerged to support first- and last-mile transport, complementing existing systems while aiming to reduce congestion and environmental impact in urban areas. Furthermore, developing a unified passenger and freight mobility ecosystem is crucial for enhancing sustainability, efficiency, cost-effectiveness, and improved user experience, making it vital for the future of urban and peri-urban transport.

However, passenger and freight mobility in road transportation are still perceived as separate systems with distinct operations and infrastructures, leading to isolated solutions that overlook potential synergies. A promising solution is to establish a common framework that integrates both systems, allowing for unified models that address the needs of both transport types.

This report presents a comprehensive overview of the most prominent practices and strategies and SotA that could support the implementation of common passenger and freight multimodal mobility, along with the relevant enablers and barriers that need to be taken into consideration. It also examines the associated socio-economic aspects at play, offering a holistic overview of multimodal trends towards common passenger and freight mobility and their broader impact on the transportation industry and society as a whole.

In conclusion, achieving the vision of an integrated multimodal transport system for both passengers and freight will require overcoming several challenges, including governance issues, stakeholder collaboration, technological integration, policy harmonization, and social acceptance. By embracing innovation, adopting global best practices, and addressing these barriers, urban and peri-urban mobility can evolve into a cohesive system that efficiently serves both passengers and freight, contributing to more sustainable urban development.

Disclaimer of Warranties

This document is part of the deliverables from the project DELPHI, which has received funding from the European Union's Horizon Europe research and innovation program under Grant Agreement No 101104263.

The information and views set out in this deliverable are those of the authors and do not necessarily reflect the official opinion of the European Union. Neither the European Union institutions and bodies nor any person acting on their behalf may be held responsible for the use which may be made of the aforementioned information.

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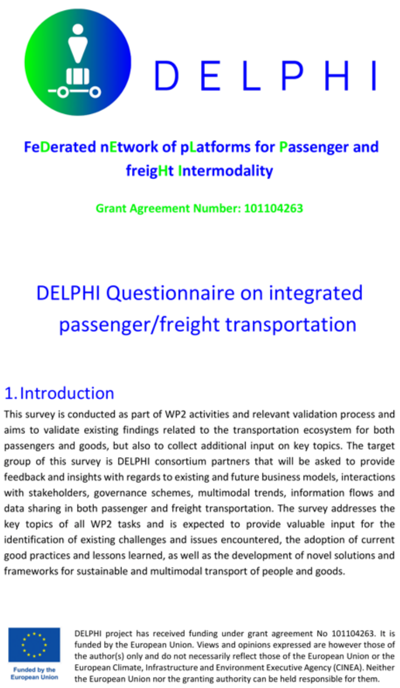
Annex 1: SotA validation questionnaire

As part of the SotA validation survey, three similar questionnaires have been developed, each one of them addressing a different audience. More specifically, the questionnaires addressed to the consortium members, the DELPHI Advisory Board members and the Multimodal Traffic Management Cluster (MTMC) members are presented below.

SotA validation questionnaire addressed to DELPHI consortium members



FeDerated nEtwork of pLatforms for Passenger and freigHt Intermodality

Grant Agreement Number: 101104263

DELPHI Questionnaire on integrated passenger/freight transportation

1. Introduction

This survey is conducted as part of WP2 activities and relevant validation process and aims to validate existing findings related to the transportation ecosystem for both passengers and goods, but also to collect additional input on key topics. The target group of this survey is DELPHI consortium partners that will be asked to provide feedback and insights with regards to existing and future business models, interactions with stakeholders, governance schemes, multimodal trends, information flows and data sharing in both passenger and freight transportation. The survey addresses the key topics of all WP2 tasks and is expected to provide valuable input for the identification of existing challenges and issues encountered, the adoption of current good practices and lessons learned, as well as the development of novel solutions and frameworks for sustainable and multimodal transport of people and goods.

Funded by the European Union

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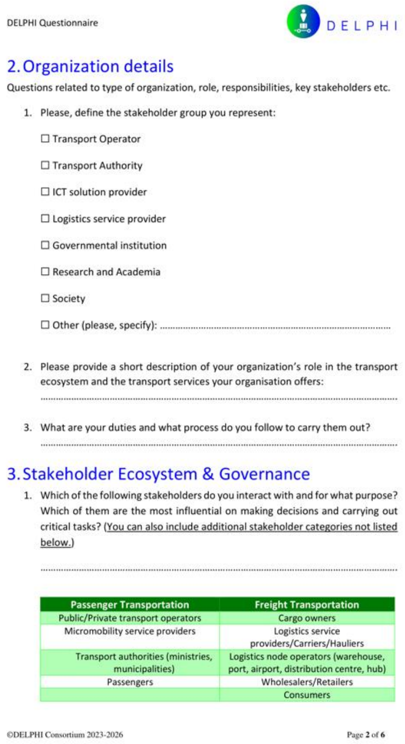

DELPHI Questionnaire

2. Organization details

Questions related to type of organization, role, responsibilities, key stakeholders etc.

1. Please, define the stakeholder group you represent:

☐ Transport Operator

☐ Transport Authority

☐ ICT solution provider

☐ Logistics service provider

☐ Governmental institution

☐ Research and Academia

☐ Society

☐ Other (please, specify): ……………………………………………………

2. Please provide a short description of your organization's role in the transport ecosystem and the transport services your organisation offers:

……………………………………………………………………………

3. What are your duties and what process do you follow to carry them out?

……………………………………………………………………………

3. Stakeholder Ecosystem & Governance

1. Which of the following stakeholders do you interact with and for what purpose? Which of them are the most influential on making decisions and carrying out critical tasks? (You can also include additional stakeholder categories not listed below.)

……………………………………………………………………………

Passenger Transportation	Freight Transportation
Public/Private transport operators	Cargo owners
Micromobility service providers	Logistics service providers/Carriers/Hauliers
Transport authorities (ministries, municipalities)	Logistics node operators (warehouse, port, airport, distribution centre, hub)
Passengers	Wholesalers/Retailers
	Consumers

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ICT solutions providers
Urban planners
Regulators
R&D and Academia
Society

2. What is the critical information (e.g. data, decisions, inputs) your organisation requires from other stakeholders to deliver its services efficiently and effectively and how do you collaborate with them for aligning activities and decisions?

   ……………………………………………………………………………………………………

3. Do you make any decisions in collaboration with other organisations? If so, how do you arbitrate on the different interests and priorities among the involved stakeholders?

   ……………………………………………………………………………………………………

4. Is there any other type of stakeholder you feel you would need to interact with and for what purpose (lack of proper collaboration yet)? What are the current gaps/issues/limitations preventing your organisation from having a more fluid collaboration and governance framework?

   ……………………………………………………………………………………………………

5. Are there any regulations or EU guidance your organization follows on how to coordinate with other stakeholders and how to arbitrate if necessary?

   ……………………………………………………………………………………………………

6. What are the most significant challenges your organization faces when coordinating with different stakeholders in the transportation ecosystem?

   ……………………………………………………………………………………………………

4. Multimodality

1. Does your organization collaborate with other transport operators and means to support/offer multimodal services and how (e.g. common hubs, dynamic data exchange, common interfaces, unified services etc.)?

   ……………………………………………………………………………………………………

2. Does your organization offer any service incorporating shared micromobility (e.g. shared bikes or scooters), electromobility (e.g. electric fleet, EV charging

stations) or urban air mobility (e.g. drones) and how does it operate?

   ……………………………………………………………………………………………………

3. Is your organization aware about multimodal transport systems incorporating micromobility services (e.g. integration of public transport with shared bike/scooter service, last-mile parcel delivery using cargo bikes etc.)? If so, please provide some details about these systems and how the integration is implemented in each case (e.g. bike station at the same location as metro station, unified interface for booking among bikes and buses, booking of cargo bike services by logistics service providers etc.)

   ……………………………………………………………………………………………………

4. Is your organization aware about e-commerce delivery services that inform the consumers about the available transport means, the associated environmental impact of the transportation process and/or the mitigation measures (e.g. option to select among transport combinations or to postpone the delivery to reduce emissions, alternatives for last-mile delivery etc.)?

   ……………………………………………………………………………………………………

5. Are you aware of any additional multimodal trend or practice that has risen during the last years or will rise in the following ones?

   ……………………………………………………………………………………………………

6. What challenges (operational, technical, financial, logistical, regulatory etc.) hinder the integration of new modes of transportation (e.g. micromobility, urban air mobility etc.) or other multimodal trends into your services?

   ……………………………………………………………………………………………………

5. Information flows and data sharing

1. Which are the existing information flows (collection, processing, utilization) within your organization related to traffic management, transportation and logistics (e.g. traffic sensors, GPS from logistics vehicles or public transportation etc.)?

   ……………………………………………………………………………………………………

2. Is there a standard protocol or system you follow for data management and\or sharing (eg. DATEX II, NeTEx, GTFS, Transmod), or is it handled on a case-by-case basis?

   ……………………………………………………………………………………………………

3. How do you address privacy and security concerns when sharing data across systems, tools and platforms related to mobility services (e.g. encryption, security audits, compliance with regulations like GDPR)?

   ……………………………………………………………………………………………………

4. Are there existing digital tools or services you use for managing multimodal traffic/demand in context of passenger's transportation and\or logistics operations (integration of data from different transportation modes to support planning, real-time adjustments, predictive modelling)?

   ……………………………………………………………………………………………………

5. What infrastructure do you currently have in place for managing and sharing data (e.g. cloud storage solutions, data processing pipelines, analytics platforms etc.)?

   ……………………………………………………………………………………………………

6. What challenges does your organization face in the collection, processing, and utilization of traffic and transportation data?

   ……………………………………………………………………………………………………

6. DELPHI approach

Recognizing the complexity of stakeholder landscapes, fragmented transportation systems, and the need for secure data sharing, DELPHI is focused on the strategic dimension of integrating passenger and freight transport into a single federated system, working towards integrating sectors, harmonizing data, and leveraging advanced methodologies, to transform transportation systems, for a sustainable future.

A federated system refers to a collection of interconnected but autonomous systems or components that work together to achieve a common goal. These systems maintain their independence while sharing data and resources as needed. More specifically, federated architecture is an organizational blueprint for IT systems that allows coordinated management and interoperability of data, resources, and processes across different systems, locations and organizational boundaries. It serves as a decentralized model for architecture, breaking away from traditional monolithic systems to create an interconnected network where each participant (e.g. system, application or database) maintains a level of autonomy. This architecture allows organizations to collaborate and share resources without giving up local control. This architecture is designed to easily interact with various systems, even those built on entirely different technologies, protocols, or standards. Even though each unit is autonomous, there are usually agreed-upon standards for interaction to ensure seamless communication and data sharing between systems. In transport and logistics, such a federated system could be

formed by different stakeholders in the relevant value chain that need to cooperate, for goods or passengers to reach their final destination, in an automated end-to-end fashion.

1. Would your organization be willing to optimize or upgrade its operations and services by participating in a multimodal system? If so, could you please provide some examples of potential collaboration that would be interesting for your organization (e.g. exploitation of available infrastructure/vehicles/transport services, interconnection of distribution centres with passenger rail, micromobility hub or drone system etc.)?

   ……………………………………………………………………………………………………

2. Would your organization be willing to participate in a federation of systems/platforms with multiple transport services available? If so, which benefits do you recognize and what challenges?

   ……………………………………………………………………………………………………

3. What data would you be willing to share with other stakeholders and under what conditions in order to benefit from multimodal transportation and logistics as well as collaboration across industry stakeholders in general? What governance measures would you require for such data sharing? What benefits would you be expecting?

   ……………………………………………………………………………………………………

4. What are the top features or improvements you would like to see in a future system that could significantly enhance your daily operations or existing systems in traffic management, transportation and logistics?

   ……………………………………………………………………………………………………

5. In case your organization is aware of similar initiatives, what are the main pain points or lessons learned related to the adoption of multimodality for passenger and freight transportation?

   ……………………………………………………………………………………………………

6. Please provide any additional thoughts or comments related to multimodal transportation for passengers and freight, integrated and/or federated transport schemes, as well as multi-level governance and data sharing in the transportation industry.

   ……………………………………………………………………………………………………

Thank you for your participation!!

SotA validation questionnaire addressed to DELPHI Advisory Board and MTMC members

DELPHI

FeDerated nEtwork of pLatforms for Passenger and freigHt Intermodality

Grant Agreement Number: 101104263

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☐ Transport Authority
☐ ICT solution provider
☐ Logistics service provider
☐ Governmental institution
☐ Research and Academia
☐ Society
☐ Other (please, specify): ………………………………………………………………

2. Please provide a short description of your organization's role, fields of expertise and interactions with the transportation industry and ecosystem:

………………………………………………………………………………………………

3. What are your main responsibilities related to transportation and what process do you follow to carry them out?

………………………………………………………………………………………………

3. Stakeholder Ecosystem & Governance

1. The following table below presents the main stakeholder groups involved in the transport industry for passenger transportation and urban logistics. The collaboration (either existing or envisioned) among which of them do you consider as the most critical and for what purpose? (<u>You can also include additional stakeholder categories not listed below.</u>)

………………………………………………………………………………………………

Passenger Transportation	Urban logistics
Public/Private transport operators	Cargo owners
Micromobility service providers	Logistics service providers/ Carriers/ Hauliers
Transport authorities (ministries, municipalities)	Logistics node operators (warehouse, port, airport, distribution centre, hub)
Passengers	Wholesalers/Retailers
	Consumers
ICT solutions providers	
Urban planners	
Regulators	
R&D and Academia	
Society	

2. Which do you consider the best approach for effective governance arbitration among passenger/freight mobility service providers for integrated multimodal mobility solutions (e.g. mobility management coordinator, alternative setup)?

………………………………………………………………………………………………

3. Are you aware of any relevant regulations or EU guidance on stakeholders' coordination and arbitration?

………………………………………………………………………………………………

4. In your opinion, what are the current gaps/issues/limitations preventing transport organisations (passenger/freight) from having a more fluid collaboration and governance framework?

………………………………………………………………………………………………

4. Multimodality

1. Which do you consider the most important trends of multimodal transport that could serve as enablers for integrated passenger and freight transport?

………………………………………………………………………………………………

2. Are you aware of any best practices or policies of multimodal transportation addressing people and/or cargo flows?

………………………………………………………………………………………………

3. What challenges (operational, technical, financial, logistical, regulatory etc.) hinder the integration of multimodal practices/trends in transport industry?

………………………………………………………………………………………………

5. Information flows and data sharing

1. In your opinion, which are the most important information flows related to T&L traffic management facilitating the integration of passenger/freight transport?

………………………………………………………………………………………………

2. Are you aware of any existing digital tools or services for managing multimodal traffic/demand (integration of data from different transportation modes to support planning, real-time adjustments, predictive modelling)?

………………………………………………………………………………………………

3. Which do you consider the best approach/framework for managing and sharing transport data?

………………………………………………………………………………………………

4. What are the main challenges faced in data exchange among various data sources, transport means and transport operators/providers and what could be the main approaches towards overcoming them?

………………………………………………………………………………………………

6. DELPHI approach

Recognizing the complexity of stakeholder landscapes, fragmented transportation systems and the need for secure data sharing, DELPHI is focused on the strategic dimension of <u>integrating passenger and freight transport into a single federated system</u>, working towards integrating sectors, harmonizing data and leveraging advanced methodologies, to transform transportation systems for a sustainable future.

A federated system refers to collection of interconnected but autonomous systems/components that work together to achieve a common goal. These systems maintain their independence while sharing data and resources as needed. More specifically, federated architecture is an organizational blueprint for IT systems, allowing coordinated management and interoperability of data/resources/processes across different systems, locations and organizational boundaries. It serves as a decentralized model for architecture, breaking away from traditional monolithic systems to create an interconnected network, where each participant (system, application or database) maintains an autonomy level. This architecture allows organizations to collaborate and share resources without giving up local control and is designed to easily interact with various systems, even those built on entirely different technologies, protocols or standards. Even though each unit is autonomous, there are agreed-upon standards for interaction to ensure seamless communication and data sharing between systems. In T&L, such a federated system could be formed by different stakeholders in the relevant value chain that need to cooperate, for goods or passengers to reach their destination, in an automated end-to-end fashion.

1. Which do you consider the top features or improvements that an integrated and federated passenger/freight transport system could bring in traffic management, logistics and the overall transport ecosystem?

………………………………………………………………………………………………

2. In case you are aware of similar initiatives, what are the main pain points or lessons learned related to the adoption of multimodality (passenger/freight)?

………………………………………………………………………………………………

3. Please provide any additional thoughts/comments related to passenger/freight multimodal transportation, integrated and/or federated transport schemes, as well as multi-level governance and data sharing in the transportation industry.

………………………………………………………………………………………………

<u>Thank you for your participation!!</u>

Annex 2: Research project mapping

ID	Acronym	Full Title	Programme	Start date	End date	Budget	Coordinator	Website	Category	Relevance to multimodality	Transport modes	Environment
1	TANGENT	Enhanced data processing techniques for dynamic management of multimodal traffic	H2020	01-09-2021	31-08-2024	€ 4.849.348,75	Universidad de Deusto	https://tangent-h2020.eu/	Passenger, Freight	Intermodal cooperation of passenger and freight transport	Metro, bikes, buses	Urban
2	DIT4TRAM	Distributed Intelligence & Technology for Traffic & Mobility Management	H2020	01-09-2021	31-08-2024	€ 4.997.171,36	TUDelft	https://dit4tram.eu/	Passenger	Multimodal network, cooperation between travelers and between providers	Car, car sharing, PT, active mobility	Urban, peri-urban
3	FRONTIER	Next generation traffic management for empowering CAVs integration, cross-stakeholders collaboration and proactive multi-modal network optimization	H2020	01-05-2021	30-04-2024	€ 4.998.963,75	EURECAT	https://frontier-project.eu/	Passenger	Integrated network, seamless transfer among different modes of transport and better collaboration among different stakeholders	Car, bus, metro	Urban, peri-urban
4	ORCHESTRA	Orchestrating multimodal transport for more efficient and resilient transport services	H2020	01-01-2021	30-04-2024	€ 5.167.361,88	ITS Norway	https://orchestra2020.eu/	Passenger, Freight	Optimal utilisation of transport networks and efficient multimodal transport services	road, rail, water, air	Peri-urban
5	IN2CCAM	Enhancing Integration and Interoperability of CCAM eco-system	HEU	01-11-2022	31-10-2025	€ 5.576.481,25	Politecnico di Bari	https://in2ccam.eu/	Passenger, Freight	Interoperability and intermodality between automated vehicles and public transport	Car, CAV, PT	Urban
6	CONDUCTOR	Fleet and traffic management systems for conducting future cooperative mobility	HEU	01-11-2022	31-10-2025	€ 6.065.150,00	Netcompany-Intrasoft	https://conductor-project.e	Passenger, Freight	Synchronisation of buses and on-demand services with the metro and tram, integration of urban distribution of goods with existing on-demand passenger transport services	Bus, DRT, metro, tram	Urban
7	STARS	Shared mobility opporTunities And challenges foR European citieS	H2020	01-10-2017	31-03-2020	€ 1.805.665,00	Torino Police	https://stars-h2020.eu/	Passenger	Co-modality assessment involving car sharing and other travel modes (private car, bike, walk, taxi, public transport…)	Car, car sharing, PT, active mobility	Urban
8	ENTRANCE	European matchmaking platform for innovative transport and mobility tools and services	H2020	01-01-2021	31-12-2023	€ 1.567.125,00	Ciaotech	https://www.entrance-plat	Passenger, Freight	Implementation of cross-modal transport concepts such as multi-, synchro, inter- and co-modality	air, water, rail and road	All

9	FEDERATED	European Federated Network of Information exchange in Logistics	CEF Transpo	01-04-2019	31-03-2022	€ 60.613.464,00	ERTICO	https://www.federatedplat	Freight	Enhancement of supply chain visibility and bundling capacity, enablig synchronised operation planning for a responsive, resilient and multimodal transport ecosystem	road, maritime, rail, air	All
10	ULAADS	Urban Logistics as an on-Demand Service	H2020	01-09-2020	29-02-2024	€ 3.150.390,00	FREIE HANSESTADT BREMEN	https://ulaads.eu/	Freight	Integration of different modes of transport through multimodal supportive infrastructure, integration of on-demand high-speed delivery of small goods with shared passenger transport, using the spare capacity of transport vehicles	car-sharing, bike-sharing, PT	Urban
11	URBANE	Upscaling Innovative Green Urban Logistics Solutions Through Multi-Actor Collaboration and PI-inspired Last Mile Deliveries	HEU	01-09-2022	28-02-2026	€ 10.000.945,20	Inlecom	https://www.urbane-horiz	Freight	Use of intermodal (passenger) nodes reducing the impacts of freight deliveries, use of electric vehicles in the urban freight delivery service, combined use of trams, robots, and cargo bikes for last-mile delivery	road, rail, bike	Urban
12	FOR-FREIGHT	Flexible, multi-modal & robust freight transport	HEU	01-09-2022	31-12-2025	€ 8.935.495,00	CERTH	https://www.for-freight.eu	Freight	seaport-to-city (last mile) with the use of the subway network, seaport-to-airport with the use of trucks, and inland (river) port-to-mainland via rail transport	road, maritime, rail	Urban, peri-urban, rural
13	MULTIRELOAI	Port solutions for efficient, effective and sustainable multimodality	HEU	01-09-2022	31-08-2025	€ 8.913.653,75	Duisburg Port Company	https://multireload.eu/	Freight	innovative inter-/multimodal transport solutions linking all relevant modes, using transshipment technology with different intermodal transport units, transformation of intermodal freight nodes into interconnected data platforms	road, rail, maritime, inland waterway	Peri-urban

14	SPROUT	Sustainable Policy Response to Urban mobility Transition	H2020	01-09-2019	28-02-2023	€ 4.412.553,75	FUNDACION ZARAGOZA LOGISTICS CENTER	https://sprout-civitas.eu/	Passenger, Freight	intermodal hubs within the city boundaries bringing together passenger and freight traffic, both public and private; self-driving pods for 'cargo-hitching', giving passenger transport an additional freight-carrying capacity; shared mobility, through dockless bike-sharing and car-sharing systems	car, bike, rail, train, tram, metro, bus	Urban
15	SUMP-PLUS	Sustainable Urban Mobility Planning: Pathways and Links to Urban Systems	H2020	01-09-2019	28-02-2023	€ 3.987.862,50	STAD ANTWERPEN	https://sump-plus.eu/	Passenger, Freight	enhancement of multimodal hubs, shared mobility "dropzones" and "ringzone" train stations; collaborative urban logistics	car, bike, rail, PT	Urban, peri-urban
16	HARMONY	Holistic Approach for Providing Spatial & Transport Planning Tools and Evidence to Metropolitan and Regional Authorities to Lead a Sustainable Transition to a New Mobility Era	H2020	01-06-2019	28-02-2023	€ 7.649.645,25	UCL	https://harmony-h2020.eu	Passenger, Freight	Integration of automated vehicles and drones with traditional transport modes	drones, AVs	urban, regional
17	MOVE21	Multimodal and interconnected hubs for freight and passenger transport contributing to a zero emission 21st century	H2020	01-05-2021	30-04-2025	€ 9.479.717,50	OSLO KOMMUNE	https://move21.eu/	Passenger, Freight	Integration of micro mobility	car, bike, micromobility	urban
18	TRANSIT	Travel Information Management for Seamless Intermodal Transport	H2020	01-05-2020	31-10-2022	€ 1.226.490,00	NOMMON SOLUTIONS AND TECHNOLOGIES SL	https://www.transit-h2020	Passenger	Ticket integration, timetable synchronization, rebooking to other modes, schedule updates	car, bus, rail	regional
19	RE-ROUTE	Integrated intelligent multi-modal transport infrastructure: distributed localised decision-making at the network edge	HEU	01-01-2023	31-12-2026	€ 671.600,00	UNIVERSITY COLLEGE DUBLIN	https://reroute-project.eu/	Passenger	Integrated Multimodal Intelligent Transport System (M-ITS), MaaS	carsharing, bikes, ride-hailing, e-scooters	urban