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Multimodal Traffic Management: Roadmap for 2030 and beyond

TANGENT

Orchestra

DIT4TraM

FRONTIER FUTURE MOBILITY

SYNCHROMODE

DELPHI

Acumen

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Multimodal Traffic Management Cluster

Summary

This Multimodal Traffic Management (MTM) Roadmap sets forth a comprehensive strategic vision to transform Europe's transport networks into multimodal, sustainable, and resilient systems, aligning with EU climate neutrality and resilience goals and preparing the transport sector for future challenges and opportunities.

Multimodal Traffic Management refers to the coordinated control and optimisation of multiple transportation modes, integrating various transportation modes to enhance the efficiency, resilience, safety, and sustainability of the transportation system for both passengers and freight.

The MTM Roadmap aims to provide a strategic vision and framework for the development and implementation of integrated MTM systems across Europe. It addresses the complexities and challenges of managing multimodal transport networks, focusing on three main inter-related areas: a) Technologies and Services, b) Data, and c) Policies, each of which is critical for achieving a seamless, efficient, and resilient multimodal transport system by 2030 and beyond.

Technologies and Services are a critical focus area, with the goal of leveraging advanced technologies, such as Artificial Intelligence (AI), advanced Decision Support Systems (DDS) and Cooperative Connected and Automated Mobility (CCAM) to create an adaptive and resilient multimodal transport system. Challenges include integrating diverse technological systems, ensuring cybersecurity, managing high computational requirements, while ensuring that the use of new technologies is publicly accepted. Ongoing pilot projects in various EU cities are focusing on improving MTM, enhancing public transport, and integrating novel vehicle technologies.

In the realm of Data, the roadmap envisions developing a comprehensive data ecosystem to support real-time decision-making and predictive analytics. Challenges in this area include ensuring data quality, interoperability, sovereignty, and real-time availability across different transport modes and jurisdictions. The creation of the common European mobility data space (EMDS), supported by PrepDSpace4Mobility and deployEMDS projects, as well as projects such as NAPCORE, are advancing data sharing harmonisation frameworks, use of standards and protocols. However, there remains a need for the adoption of standardised regulations and enhanced data governance to fully realise this vision.

Finally, policy plays a crucial role in supporting MTM. The vision is to create a robust policy framework that fosters collaboration between public and private stakeholders. However, challenges include navigating diverse regulatory environments, ensuring cross-border cooperation and aligning local, national and EU policies. Current initiatives under the Paris Agreement and the EU's Smart and Sustainable Mobility Strategy (SSMS) aim to reduce emissions and promote sustainable transport modes, providing a solid foundation for future efforts.

By 2030, the roadmap aims to achieve resilience in MTM through proactive measures that anticipate and mitigate the impacts of disruptions. Effective governance models will be developed to facilitate collaboration among public authorities, infrastructure managers, traveller information service providers and transport service providers, including freight transport companies. Seamless integration of physical and digital infrastructures across all transport modes will enhance and exploit the capabilities offered by increased connectivity and automation. High-quality, standardised data will be used by modelling and simulation tools to support informed decision-making and optimise transport operations.

Strategic actions to be achieved also by 2030 include: harmonising regulations, promoting Sustainable Urban Mobility Plans (SUMPs), and ensuring compliance with EU climate neutrality targets. Establishing federated data spaces, enhancing data interoperability, and ensuring secure data sharing practices are also key priorities. Additionally, investing in AI, CCAM, and predictive analytics, and promoting the controlled deployment of these technologies before wider implementation, will be crucial for achieving the roadmap's goals.

Table of Contents

The Multimodal Traffic Management Cluster

The Multimodal Traffic Management Cluster (MTMC) is a collaborative initiative involving seven EU-funded Horizon Europe research projects under the topic of Multimodal Traffic Management (MTM): DiT4TRAM[1], FRONTIER[2], ORCHESTRA[3], TANGENT[4], SYNCHROMODE[5], DELPHI[6] and ACUMEN[7]. MTMC aims to harvest the collective experience and expertise of the participating research projects, to tackle the emerging challenges and harness opportunities in MTM through a collaborative approach. The MTMC focuses on creating an integrated framework for future-proof MTM, supporting the seamless operation and management of various transport modes, promoting sustainable, efficient, reliable and resilient mobility systems and solutions across Europe.

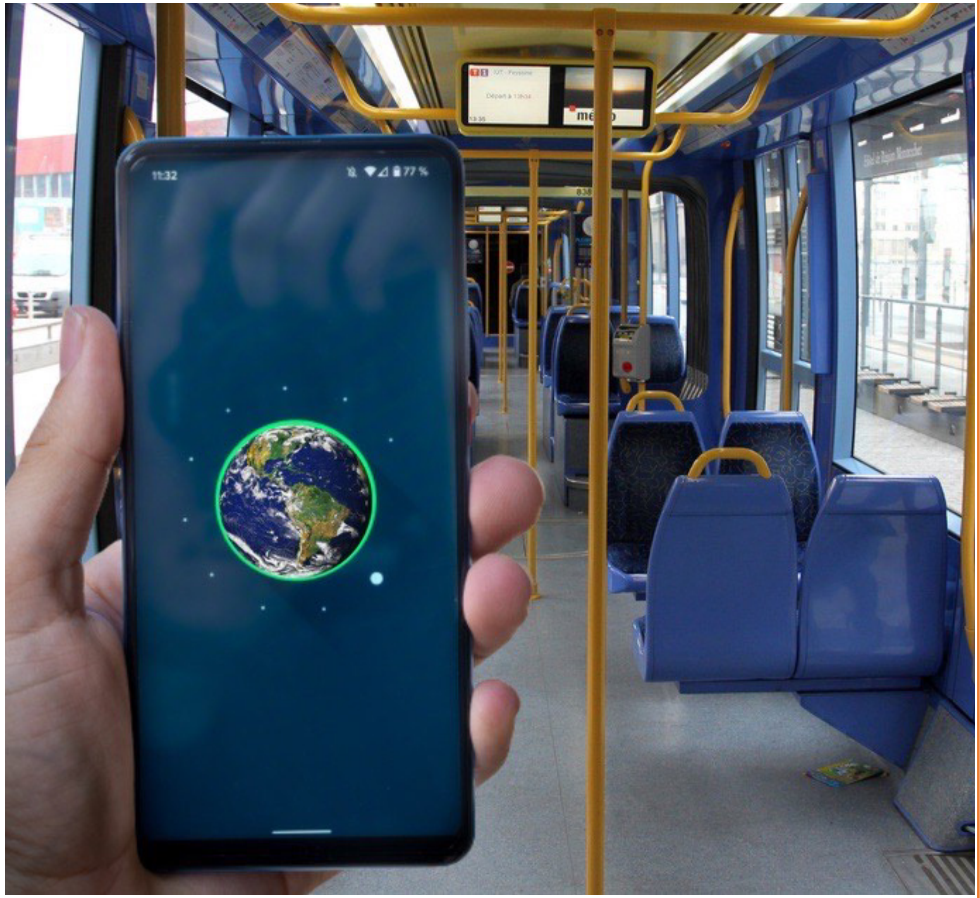
The primary objective of the MTMC is to drive a transformative shift towards advanced MTM. This entails the integration of innovative MTM solutions, designed to optimise the use of various modes for passenger and freight transport, thereby enhancing the overall system efficiency, sustainability, reliability, and robustness. Achieving this objective requires fostering robust cooperation among a diverse array of stakeholders in the passenger and freight transport domain, including public authorities, transport network operators, logistics operators, private sector participants, and the end-users (drivers and travellers of all modes).

This roadmap is primarily focused on land transport and encompasses aspects and modes covered by the aforementioned R&D projects, such as public transport, shared mobility and autonomous vehicles. Consequently, maritime transport, air transport, and customs-related aspects are excluded from this roadmap.

The members of the MTMC have elaborated the present report titled "Multimodal Traffic Management: Roadmap for 2030 and beyond", which aims to:

- **provide an improved understanding on Multimodal Traffic Management,**
- **assess the current status around three main influencing factors (technologies/services, data and policies), and**
- **provide a roadmap for achieving an improved multimodal traffic management, accounting for the already identified challenges, the maturity of already achieved results and future research needs.**

What is Multimodal Traffic Management?



Multimodal Traffic Management (MTM) refers to the coordinated control and optimisation of multiple transportation modes within a given network or area. MTM integrates various transportation modes, such as cars, buses, bicycles, pedestrians, and rail systems, to enhance the efficiency, resilience, safety, and sustainability of the transportation system for both passengers and freight. Key aspects of MTM include:

Integration of Modes: Coordinating different and new transportation modes to ensure seamless transitions and efficient use of the network.

Dynamic Traffic Management: Using historical and real-time data and advanced technologies to manage both traffic flow and traffic demand, reduce congestion, and improve travel times across all modes.

Sustainability: Promoting low-emissions transportation options and reducing the overall environmental impact of the transportation system.

Safety: Enhancing the safety of all users, including Vulnerable Road Users, by implementing appropriate safety measures.

Accessibility: Ensuring that all users, including VRUs and those with limited mobility, have access to reliable and convenient transportation options.

Smart Infrastructures: Utilising smart infrastructure, such as intelligent traffic signals, real-time information systems, and connected vehicles technologies, to improve the efficiency and responsiveness of MTM systems.

Exploitation of multi-source data: Effective use (collection, sharing, analysis) of high-quality real-time data from multiple sources (e.g. vehicle data, roadside sensors data, crowd-sourced data) for evidence-based and data-driven decision-making and optimisation of multimodal transportation networks and systems.

Collaboration of stakeholders: Structured cooperation processes and governance models with the cooperation and coordinated decision-making of various stakeholders, each having different interests, priorities and operational requirements are needed for the successful implementation of advanced MTM solutions.

Overall, MTM aims to create a balanced and efficient transportation system that meets the diverse needs of urban and suburban populations and businesses across Europe.

The need for Multimodal Traffic Management

Traffic management has historically focused on optimising conditions for road traffic, considering mainly private vehicles, which led to a disproportionate space allocation to road vehicles. Multimodality needs to be enabled, in order to provide the society with low emission, safe, seamless, efficient and resilient transportation systems, accounting for different travel and commuting needs. MTM is an enabler for this, proactively fostering multimodality at urban and sub-urban areas through efficient traffic orchestration, spanning across networks, modes, and different stakeholders. Future traffic management needs to support reliable and safe public transport, efficient logistics operations, Mobility-as-a-Service (MaaS) offerings with micro-mobility, connected and automated vehicles and on-demand transport options. Besides these, MTM systems require policy frameworks to support their implementation at local, national and European level.

Baseline: Factors affecting Multimodal Traffic Management

Multimodal Traffic Management is significantly influenced by three main factors: the adoption of new technologies, the availability and use of data, and policies. The adoption of innovative technologies and MTM services, which enable accurate sensing and monitoring of traffic conditions, facilitate data exchange, and support decision-making processes, is crucial for the effective implementation of MTM. Additionally, the use of multi-source, dynamic datasets is essential for real-time decision-making, as these datasets provide the necessary information for effective traffic management. Lastly, policies play an overarching role, establishing the framework and setting the targets that must be followed by the relevant organisations to ensure the success of MTM

1: Technologies and MTM Services

Major advances have been achieved in the last years, also within the framework of the MTMC projects, related to MTM technologies and services. This section covers topics related to the integration of advanced technologies into MTM, including monitoring, detection, modelling, and prediction systems. By combining AI with traffic simulation and utilizing the Physical Digital Infrastructure (PDI), these technologies enhance traffic flow, safety, and congestion management. Technologies including dynamic dashboards, simulation tools, and data-driven solutions are able to optimize decision-making and to enable effective and resilient MTM.

Monitoring, Detection, Modelling and Predictions

The integration of monitoring and modelling within MTM constitutes a critical interface for transforming data into actionable decision-making insights. Embracing advanced modelling approaches, such as the combination of AI with traffic simulation, MTM becomes more robust and proactive.

The infrastructure perception is the first layer of a smart transport system, which is comprised of several different types of sensors of mature TRL technologies that allow monitoring and capturing different aspects such as flow (of vehicles, fleets and passengers) and safety (detecting incidents, monitoring the weather, etc.). These make up what is referred to as the Physical Digital Infrastructure (PDI), the array of sensors and communication systems that enable real-time data collection and analysis.

Technological advances in data-driven solutions detect congestion and predict its evolution based on data that have been observed in the past. Novel technologies are developed to tackle the challenge of urban traffic congestion for detecting and managing traffic bottlenecks in city networks. To quantify the impact of congestion, a novel metric is introduced[8] , representing the economic cost of traffic jams. Such a measure allows for the prioritisation of interventions based on the severity of congestion.

Under non-recurrent situations, such solutions will be inaccurate and unable to reflect the real conditions. To overcome this issue, methodological synergies between data analytics and transport simulation tools are explored. More specifically, transport simulation tools enable:

Modelling of the cause of specific events and predict their evolution in space and time, whereas data can only observe the effect at the locations where real data is available.

Representation and replication of non-recurrent situations (such as accidents, road closures, etc.) within a digital environment, in real-time as well as offline for the assessment of future scenarios and design of intervention strategies.

A core input to simulation models is the travel demand, which is usually obtained from travel planning models and adjusted using real traffic measurements that represent average (regular) traffic conditions. Significant research has been conducted 12,13 on the development of efficient methods for estimating the demand offline and a few efforts are made towards developing demand prediction methods based on innovative AI-based solutions. Nevertheless, given the inherent challenges of the demand estimation and prediction problems, further research is needed.

Tools assisting MTM

The development of operational and strategic dashboards has been crucial in MTM in monitoring and managing complex transport systems. Effective dashboard design involves careful selection and arrangement of information from multiple sources, utilising maps, color-coded indicators, and interactive features, such as incident management and simulation, to enhance the decision-making process by providing situational awareness of the transport network. Furthermore, interactive dashboards provide feedback loops that incorporate human intelligence into the system. This interaction is pivotal, as it ensures models are updated with evolving traffic patterns and that the system retains a level of human oversight, enhancing the reliability and trustworthiness of automated detection of occurred situations

1: Technologies and MTM Services

MTM measures

Driven by changing policy objectives with a reduced focus on improving car mobility, traffic management is moving into an era where the multimodal aspect is becoming more and more important. This requires rethinking traditional approaches to control traffic flows, from the perspective of control objectives, algorithms, but also sensing and actuation. Currently, the state-of-the-art provides limited insights on how to make the step towards generic approaches to network-wide MTM. Research trends focus on developing deployable, distributed approaches such as:

- Distributed network wide MTM: an integrated control approach, focusing on the solution of critical bottlenecks in the network;
- Connected intersections with prioritisation of bicycles and HOVs: integrating conventional intersection-level traffic light control with C-ITS infrastructure to enable MTM;
- Market-inspired management strategies for intersection control: novel auction-based approaches for signalised intersection control under a connected vehicle setting, ensuring fair treatment of movements served by fewer lanes;
- Bus prioritisation at intersections and dynamic bus lanes: guarantee exclusive space for buses aiming to maximise passenger throughput, ensuring reliability and smooth operation of public transport. Strategies for dynamic sharing of space to reduce the impact for cars of the unused reserved road space while maintaining bus priority;
- Dynamic reservable lanes: aiming to optimise the utilisation of road space by reallocating lanes between opposite directions, operated in a connected environment.

Demand and transport service management measures

With increasing understanding that managing traffic will not be sufficient to solve all issues, focus on (integrating) demand and transport service management (e.g., pricing, reduced access of specific types of traffic, shared vehicle relocation, etc.) has been increasing.

Advanced vehicle balancing for shared mobility services

Fleet rebalancing plays a crucial role in fleet management, ensuring an ongoing alignment between supply (vehicle position) and demand (ride request locations). Extensive exploration of decentralised rebalancing strategies has been performed, through simulation-based analyses. These encompass various approaches such as providing information to drivers to influence relocation behaviours, implementing auctioning processes for allocating relocation options, and deploying hierarchical rebalancing frameworks and dedicated pricing designs.

Demand management schemes with tradable credits and permits

Tradable Credit Scheme is a demand management policy aiming at encouraging travellers to change their travel habits towards more sustainable behaviours, as a more equitable alternative to congestion pricing. The main difference with congestion pricing schemes is that is a quantity-based policy, whereas pricing is a price-based policy. It means the regulator sets the quantity of travel, not the price.

2: Data Sharing

Data is crucial for future MTM both services and technologies, leveraging multiple sources, new sensors as well as technologies like AI for optimal and resilient MTM. This necessitates stakeholders providing high-quality and standardised data. This data must include comprehensive metadata for proper discoverability and governance.

Data availability and sharing are fundamental to driving innovation and collaboration in optimising MTM and traffic operations. The ability to discover, access and exchange data among various stakeholders within the transport ecosystem is crucial for developing and testing innovative solutions. However, data sources are currently managed by different data providers and made available in a plethora of heterogeneous public and private data portals. This fragmentation poses significant challenges to effective data sharing and collaboration.

The EU Data Strategy[9] envisions a common European mobility data space (EMDS)[10]for secure, cross-Europe mobility data sharing. Several initiatives are contributing to this vision. The PrepDSpace4Mobility project[11] lays the groundwork of the EMDS by proposing building blocks for different types of data sharing, including event-driven smart contracting, persistent data, streamed data, and local data processing. Building on this foundation, the deployEMDS project[12], focuses on the implementation of use cases to support policy making and the development of innovation services by enabling data sharing and reuse, notably for efficient MTM, with a focus on urban and regional areas across Europe. To ensure harmonisation and interoperability, efforts are underway to develop architectures and standardised building blocks for data spaces. A new action is expected to support the establishment of a lasting collaboration structure between stakeholders and to the deployment of further cross-border use cases[13].

The NAPCORE project[14] aims to coordinate, harmonise, align and improve the interoperability of more than 30 EU National Access Points (NAPs)[15] that already operate and provide mobility date exchange within EU countries. NAPCORE is working on the development of a harmonised architecture of EU NAPs and of a potential NAP federation. Additionally, particular focus is placed upon the adoption as well as the extension of widely used standards, such as Datex II, TN-ITS, NeTex and SIRI[16].

The Gaia-X Framework[17] connects data ecosystems through compliance, federations, and data exchange frameworks.

The FEDeRATED Project[18] proposes a reference architecture for data sharing in logistics, emphasising event-driven smart contracting.

NordicWay[19] implements a Cloud2Cloud solution for location-based traffic data exchange.

Data and metadata quality is another important parameter that has significant impacts on the quality, performance and effectiveness of MTM systems. Indicators and methodologies able to assess data quality as well as impute missing and correct erroneous date are being developed[20].

MTM systems require diverse data types in relation to specific traffic management actions, often managed by other stakeholders. In general, for dealing with both the demand and the supply side, data should reflect the dynamics of the four basic choices users are conducting in a system (time of departure, route choice, mode choice and cost/pricing), as well as the geometry, traffic and control conditions on the network. Externalities induced by weather, economic growth, ICT, energy etc should be also captured through specific parameters that may affect transport operations. Other essential data for MTM includes but are not limited, planned routes, planned events, transport service types, current operation status, load factors, cargo types, and vehicle characteristics. Traffic managers can share data on traffic regulations, management measures, and conditions with service providers and navigation service providers to support and influence transport operations.

ITS Directive, RTTI & MTIS Delegated Regulations: The revised Intelligent Transport Systems (ITS) Directive 2023/2661[21] sets the policy framework for the deployment of ITS services in the field of road transport and for interfaces with other modes of transport, while the updated Real-Time Traffic Information (RTTI) Delegated Regulation 2022/670[22] provides specific requirements and specifications for the provision and exchange of various types of static and dynamic traffic-related data, in a standardised and machine-readable format, to support the creation of seamless and effective real-time traffic information services. These data sources encompass transport infrastructure, electronic traffic regulations and restrictions (incl. traffic circulation plans), prevailing traffic conditions, and road network status (incl. road infrastructure closures). The RTTI Delegated Regulation extends its original geographic coverage from the TEN-T road network and national motorways to the entire road network that is publicly accessible to motorised traffic (incl. TEN-T road segments, national motorways, and other primary roads that are not private). Furthermore, it includes new types of data and introduces the notion of crucial data sets, thus emphasising their vitality for the provision of traffic related ITS services to EU road users and their availability by Member States and their digital data exchange infrastructures. The revised RTTI Delegated Regulation contains new provisions for the benefit of public authorities. Firstly, public authorities can access under FRAND (Fair, Reasonable, and Non-Discriminatory) conditions certain in-vehicle data sets for the tasks of traffic and asset management and road safety. Secondly, ITS service providers are required to consider any existing traffic circulation plans and electronic traffic regulations in their services, e.g., routing advice, provided that the respective data sets are made accessible via the national or common access point in a digital machine-readable format. The Delegated Regulation 2017/1926[23] related to the provision of EU-wide multimodal travel information services (MTIS) establishes specifications for multimodal travel information services, aiming to enhance data interoperability across various transport modes. It supports the use of standardised protocols and national access points for sharing static and dynamic data on transport services.

Traffic management systems operating under the realm of the ITS Directive and its supplementing Delegated Regulations face the dual mandate of promoting interoperability and ITS services. This regulatory framework encourages the adoption of standardised data formats and protocols to ensure the seamless exchange of information. However, translating these principles into uniform practices across diverse regions and systems can be a demanding task. Differences in interpretations and implementations of these standards pose significant challenges to the sharing of real-time traffic data, as e.g. each stakeholder may utilise its own data collection and processing system and conceive in a different manner each dataset type and category.

Smart and Sustainable Mobility Strategy:

In 2021, the Council adopted conclusions on EC's Smart and Sustainable Mobility Strategy (SSMS) outlining EU goals towards making mobility smart, green and resilient[24]. The European climate law makes EU's climate goal of reducing emissions in EU by 55% in 2030 a legal obligation. This is included in the Fit for 55 package[25], which involves key initiatives to decarbonise road, air and maritime transport.

Recent EU policy initiatives focusing on different transport networks include:

Reduction in CO2 emissions:

In 2023, the Council revised the 2019 EU regulation, to reduce CO2 emissions by 55% for new cars and by 50% for vans from 2030 to 2034 (in comparison to 2021 targets). Similarly for heavy-duty vehicles (including smaller trucks, urban buses, coaches and trailers), CO2 emission reduction target in road transport is set for -45% (2030), -65% (2035) and -90% (2040). New urban buses have to be zero-emission vehicles by 2035[26]. Special focus is placed by the EU on climate neutral and smart cities, through the selection of 112 cities that participate in the EU Cities Mission, aiming to achieve climate neutrality by 2030[27].

3: Policy

Impact of modal split in lowering pollution and congestion:

As conveyed in the Sustainable and Smart Mobility Strategy (SSMS), set out in 2030 climate target plan, increasing the modal split of collective transport, active modes (i.e. walking and cycling), connected and multimodal mobility will significantly lower pollution and transport congestion. The Commission will engage with Member states and cities ensuring large and medium sized cities (that are urban nodes in TEN-T network) have their own SUMPs by 2030. These plans will include goals such as having zero fatalities on roads.

Active mobility and safe infrastructures:

Considering the growth in cities towards active transport modes, especially cycling, SSMS aims towards having 5000km in safe cycling lanes by next decade. Within the Flagship 10 of SSMS focusing on enhancing transport safety and security, protection of pedestrians, cyclists and other road users (often categorised within the umbrella term 'vulnerable road users') is a priority. Associated measures to tackle this includes giving more space to various forms of active mobility to prevent serious injuries/fatalities for vulnerable road users.

GDPR:

Being compliant with the General Data Protection Regulation (GDPR)[29] is essential for guaranteeing trust within a data sharing ecosystem. Real-time traffic data, vehicle data and public transport data could qualify as personal data necessitating the application of the rules and principles set out by the GDPR. Mobility data more generally share some characteristics that make their sharing a potential privacy risk because they are highly unique and regular. Unicity refers to the data of different individuals being easily differentiable, meaning that each entity possesses distinct and identifiable characteristics, particularly linked to some specific locations. The starting and ending locations of users' trajectories are often their home and work locations which are highly unique and can lead to reidentification. Studies show that users' full trajectories can be uniquely recovered with the knowledge of only two locations.

However, understanding the legal implications of collecting and processing mobility data is not always evident. For example, defining data controllership (i.e. the actor mainly accountable and responsible for complying with the GDPR) can be challenging. Given the multitude of actors potentially active in a data sharing ecosystem, the correct characterisation of each actor's role under the GDPR and identifying those carrying the main responsibility can be quite challenging. Other challenges include using the appropriate legal basis, particularly managing consent, and exploring which privacy-preserving techniques could be applied without sacrificing the value of the mobility data shared.

Based on the above identified factors that affect MTM, the next section addresses the current challenges for MTM, including integration of modes, policy integration, stakeholders' collaboration, innovative solutions implementation, infrastructure enhancement, data reliability, management, use and sharing, resilience and adaptability and public engagement and acceptance. The vision and recommendations for overcoming barriers (associated to each challenge) to create a resilient, efficient, and sustainable transportation system in the coming years is presented.

Current challenges, vision and pathway for MTM by 2030 and beyond

Current challenges, vision and pathway for MTM by 2030 and beyond

The MTMC emphasises the critical need for a coordinated and collaborative approach to MTM across different transport interfaces, both urban, inter-urban and cross-border. The following table summarises the currently identified challenges, the related vision as well as the pathway (recommendations), categorised in eight priority areas of the MTMC for Multimodal Traffic Management by (a) 2030 and (b) beyond 2030:

PRIORITY AREAS

- Integration of modes
- Policy integration
- Stakeholders' collaboration
- Innovative solutions implementation
- Infrastructure enhancement
- Data reliability, management, use and sharing
- Resilience and adaptability
- Public engagement and acceptance

Integration of modes

Challenges

- Lack of coordination: Existing transport modes operate in silos, leading to inefficiencies and longer transition times for passengers and freight.
- Reduced accessibility: Many transport systems are not fully accessible to people with limited mobility or those living in underserved areas.
- Mobility costs: The overall cost of mobility remains high for both users and providers, also as a result of inefficient integration of transport modes.
- Environmental impacts: Current transport systems contribute significantly to pollution and other environmental externalities, including significant impacts on climate.

Vision

Coordinating different transport modes for both passenger and freight transport, to ensure seamless transitions at multimodal hubs, safe and efficient use of the network, ensuring accessibility for all. Also, the reduction of mobility external costs, including impacts on climate, and the overall cost of mobility for all stakeholders should be considered and handled through sustainable urban mobility planning.

PATHWAY - RECOMMENDATIONS

BY 2030 – NEAR IMPLEMENTATION

- Identification and synthesis of requirements from all involved stakeholders is needed, in order to achieve integrated planning of multimodal networks for passenger and freight transport.
- Inclusion of all areas (including less connected, such as rural areas) in the planning should be undertaken where the approach of integrating freight transport in passenger transport will reduce costs and minimise impacts on the environment.
- Reduction of external costs should combine optimised MTM with sustainable urban mobility planning taking into consideration also climate impacts, social acceptance, land use and overall quality of life.

BEYOND 2030 – FURTHER RESEARCH NEEDED (RESEACH QUESTIONS RQs)

- RQ1: How can the integration of different modes of transport, including waterways along with rail and road networks, be optimised for both passenger and freight transport to create a truly multimodal framework that minimises environmental impact, particularly GHG emissions?
- What are the specific environmental benefits and challenges associated with integrating waterways into existing road and rail networks?
- What technological, infrastructural, and policy changes are needed to achieve this integration?
- RQ2: What are the most effective policy frameworks for transitioning from a "user-pays" to a "polluter-pays" principle to internalise the external costs of transportation, including environmental impact and air pollution?
- How do various strategies like low emission zones, parking management, and dynamic congestion pricing compare in terms of effectiveness and public acceptance?
- What additional regulatory or market-based mechanisms could be implemented to further reduce mobility-related external costs?
- RQ3: What benefits can be identified for both users/customers and transport operators that would facilitate the development of cost-efficient, resilient, and sustainable transport services?
- How can demand management strategies be optimised to create a well-orchestrated transport ecosystem that reduces unnecessary trips and mobility services?
- What role does real-time data sharing play in enabling a holistic approach to transport management, and what are the technological and privacy challenges associated with it?

Policy integration

Challenges

- Regulatory fragmentation: Different regions and levels of government have different regulations, leading to a lack of cohesive policy frameworks.
- Low adoption of standards: There is a low level of adoption of uniform standards related to transportation, traffic management and Intelligent Transport Systems.

Vision

Developing and adopting harmonised regulatory frameworks that support seamless, safe, secure and equitable MTM operations. This includes aligning local, national and EU policies to reduce regulatory fragmentation and promote the use of uniform standards across regions.

PATHWAY - RECOMMENDATIONS

Policy integration

BY 2030 – NEAR IMPLEMENTATION

- **Development of EU-wide policies and standardised regulations, aiming at enhancing safety and efficiency of MTM operations, including standards for signalisation.**
- **Extend the current SUMPs guidelines, so that cities (especially urban nodes along the TEN-T) efficiently utilise the capabilities offered by MTM.**

BEYOND 2030 – FURTHER RESEARCH NEEDED (RESEACH QUESTIONS RQs)

- **RQ4: Which are the most effective Key Performance Indicators (KPIs) that can be commonly agreed upon and used at EU level to measure the effectiveness of MTM and assist in performance-based policy making?**
  - *Which KPIs are currently used across different EU member states, and how do they compare in terms of measuring efficiency, sustainability, and user satisfaction?*
  - *What challenges exist in standardising these KPIs across diverse transport systems, and how can they be addressed to create a unified framework?*
- **RQ5: How can a commonly agreed Level of Service (LOS) method be developed for MTM operations across the EU?**
  - *Which criteria should be included in a standardised LOS method to ensure it reflects the diverse operational realities of different modes of transport?*
  - *How can this system be designed to be adaptable to the varying regional contexts within the EU while maintaining consistency in service quality assessments?*

RQ6: Which are the necessary common skills and competency requirements for multimodal TMC operators at EU level to ensure effective and standardised operations?

- *How do current skill requirements for TMC operators vary across EU member states, and what are the gaps in knowledge and training that need to be addressed?*
- *Which training programs and certification processes could be established to ensure that multimodal TMC operators possess a standardised skill set that meets the demands of a harmonised EU-wide multimodal transport system?*

Stakeholders’ collaboration

Challenges

- Conflicting interests: Public authorities, private companies and citizens often have conflicting priorities and interests, making collaboration difficult.
- Ineffective communication: There are insufficient platforms and mechanisms for effective communication and collaboration among stakeholders.
- Limited participation: Not all relevant stakeholders are adequately involved in decision-making processes, leading to gaps in perspectives and representation.

Vision

Encouraging active participation and collaboration among all relevant stakeholders, utilising platforms for dialogue and cooperation between public authorities, transport network operators, private companies, and citizens to ensure that all perspectives are considered in the decision-making process.

PATHWAY - RECOMMENDATIONS

Stakeholders' collaboration

BY 2030 – NEAR IMPLEMENTATION

- Multi-actor cooperation plays a crucial role with the development planning and regulatory frameworks in MTM. This includes close cooperation between public and private actors, where the actors need to align objectives although they have varying needs and requirements. Some cooperation models have been already identified for private-public partnerships: memorandum of understanding (MoU), formal contract, and informal information sharing. The European Digital Infrastructure Consortium (EDIC) for Mobility and Logistics Data, in preparation by Member States, could be leveraged.
- The public-private collaborations helping local authorities encounter challenges that have been tackled in many ways in the past and can serve as a lesson for future implementations. Some of these challenges include lack of resources (in terms of finance, scale and time) and skills on the local/ regional level, limited legal regulations and frameworks to work with innovative technologies (difficult to go beyond piloting into long-term implementation), and vast difference of capacities, culture, resources, infrastructure readiness across the EU making it difficult for the cross-country collaboration between the administration as well as with private organisations.
- Different aspects of MTM involve a wide range of actors and its implementation requires close collaboration among them. In this context, the spectrum of parties and interactions involved in the process is particularly complex. This requires solutions involving arbitration, which supports decision-making aiming at identifying the collective, consensus-based opinion of stakeholders on the relative importance of conflicting transport network objectives. Besides, the need to cover the functional urban area, often going beyond administrative boundaries, and to enable cooperative action involving neighbouring municipalities and the region, highlights the importance of a wide-ranging planning framework including all relevant actors and authorities, within and beyond the administrative boundaries.

BEYOND 2030 – FURTHER RESEARCH NEEDED (RESEACH QUESTIONS RQs)

- RQ7: Which are the new business models needed for MTM, that incorporate diverse needs and interests of multiple involved stakeholders?
- RQ8: How to create ecosystems where win-win cooperation is ensured between all the stakeholders, without leaving anyone behind, and making it possible to integrate new stakeholders in the future? How the different impacts of MTM choices on each stakeholder can be assessed and shared in close-to-real time? What cost- and gain-sharing mechanisms, and compensation, incentivisation and arbitration schemes could be implemented, and how should they be orchestrated?
- RQ9: Which would be the most efficient governance model of the MTM? How should the roles of each stakeholder be defined? Should there be a central body acting as a neutral orchestrator for all the transport networks, or a governance cooperation among key stakeholders? What would be the role, liabilities, scope and limitations of an orchestrator?

Innovative solutions implementation

Challenges

- **Slow adoption:** Adoption of advanced technologies like ITS, C-ITS, MaaS, and connected vehicles is slow, due to high costs and resistance to change.
- **Funding gaps:** Challenges are faced in securing adequate funding for the development and deployment of innovative solutions.
- **Technological integration:** Integrating new technologies into existing transport systems without causing disruptions is a complex task.
- **Scalability issues:** Ensuring that new technologies and solutions can be scaled effectively across different regions and transport networks is difficult. Pilot projects often face challenges when transitioning to full-scale deployment.
- **Modelling and Digital Twins:** Developing accurate multi-level models for real-time and off-line data analytics and predictive modelling is a complex task. These tools require high-quality, standardised data and sophisticated models and methodologies to provide reliable insights and support decision-making.
- **Environmental sustainability:** Many current transport modes are not climate-friendly, and there is resistance to adopting sustainable alternatives.

Vision

Facilitating the adoption and integration of cutting-edge MTM solutions, encompassing dynamic multimodal infrastructure and demand management systems, ITS and C-ITS, innovative mobility services such as Mobility-as-a-Service (MaaS), connected and automated vehicles, real-time data analytics exploiting advanced techniques for accurate multi-level transport modelling and digital twins, and the promotion of the use of climate friendly and sustainable transport modes.

PATHWAY - RECOMMENDATIONS

Innovative solutions implementation

BY 2030 – NEAR IMPLEMENTATION

- Development of appropriate behaviour models capturing interactions between AV users and other modal users
- Modelling is the interface between data and decision making. Monitoring and modelling should be treated as a joint process, where the steps required to move from monitoring, to data, to modelling are well visited yet not benchmarked. Generic frameworks can be attained, but there is a need to further adapt to specific conditions, since modelling is a very problem-specific endeavour.
- Models should be resilient, transferable and generalisable. It is very important that usability, actionability and acceptability of models are considered, thus it is important to ensure the accuracy, robustness, fairness, transparency and trustworthiness of the models, so that the stakeholders understand the importance of modelling to an efficient decision-making process.
- Predictive modelling is needed to account for the increasing needs of pro-active decision making.
- Elaborate on the responsible use of AI and other ICT advancements in MTM, ensuring they are used in a human centred and ethical manner.
- Define commonly agreed conditions for testing of innovative MTM technologies and solutions in Living Labs.
- Development of data-driven optimised models for MTM and urban traffic control to improve safety, energy efficiency, and reduce emissions.

BEYOND 2030 – FURTHER RESEARCH NEEDED (RESEACH QUESTIONS RQs)

RQ7: Which are the new business models needed for MTM, that incorporate diverse needs and interests of multiple involved stakeholders?

RQ8: How to create ecosystems where win-win cooperation is ensured between all the stakeholders, without leaving anyone behind, and making it possible to integrate new stakeholders in the future? How the different impacts of MTM choices on each stakeholder can be assessed and shared in close-to-real time? What cost- and gain-sharing mechanisms, and compensation, incentivisation and arbitration schemes could be implemented, and how should they be orchestrated?

RQ9: Which would be the most efficient governance model of the MTM? How should the roles of each stakeholder be defined? Should there be a central body acting as a neutral orchestrator for all the transport networks, or a governance cooperation among key stakeholders? What would be the role, liabilities, scope and limitations of an orchestrator?

RQ10: Which design features and technological upgrades are most effective for creating multimodal hubs that provide seamless transitions between different modes of transport, such as integrating Mobility as a Service (MaaS), unified ticketing systems, and real-time information displays? Which are the key user needs and operational requirements that should guide the design of these hubs?

RQ11: Which are the lessons learnt from implementing CCAM technologies in controlled environments or testbeds, and how can these results be used to expand the implementation of these technologies to more complex real-world environments, like urban and peri-urban settings?

RQ12: Which communication protocols should be defined among EU Member States to ensure seamless operation and enhance the use of CCAM across different modes of transport? How can these protocols be standardised to support interoperability and data sharing while considering the varied technological infrastructures and regulatory environments of different Member States? What are the potential challenges in harmonising these communication protocols, and what strategies can be employed to address them?

RQ13: How can the development and use of digital twins help facilitate the monitoring of real-time data flows, predict potential bottlenecks and congestion, and forecast future network conditions to optimise performance and reliability of the traffic network?

RQ14: How can AI technologies be responsibly integrated into MTM systems to ensure safety, transparency, and fairness in real-time decision-making processes? Which are the key regulatory, ethical, and operational challenges in deploying AI-driven solutions such as predictive modelling, real-time traffic optimization, and automated decision-making? How can these challenges be addressed to ensure compliance with the EU AI Act and to build public trust in AI technologies used in MTM?

Infrastructure enhancement

Challenges

- Aging infrastructure: Existing transport infrastructure is outdated and not designed to support modern multimodal connectivity.
- Limited PDI coverage: Co-existence and connectivity between physical and digital infrastructures in the multimodal networks are limited.
- Fragmentation of transport systems: Different transport modes and regions often have separate and incompatible systems, which hinder seamless transitions and efficient multimodal connectivity.
- Technical compatibility: There is a lack of standardisation in technology and equipment used across different transport systems and modes, making it difficult to achieve interoperability and efficiency in operations.
- Digital divide: There is uneven implementation of digital infrastructures, such as smart sensors, IoT devices, and data analytics platforms, across regions. This digital divide limits the efficiency and effectiveness of transport systems.
- Cybersecurity: As digital infrastructure is enhanced, the risk of cyber threats increases, necessitating robust cybersecurity measures to protect sensitive data and ensure system integrity.
- Integration of new technologies: Upgrading infrastructure to incorporate advanced technologies such as smart sensors, IoT devices, and AI for traffic management and real-time data analytics is essential but complex. This integration requires significant investment and technical expertise.
- Compatibility with existing systems: Ensuring that new technologies and new modes of transport (e.g. urban air mobility) are compatible with existing infrastructure and do not cause disruptions during implementation is a major challenge.

Vision

Upgrading and modernising physical and digital infrastructure to support multimodal transport. This includes enhancing connectivity between different transport modes, improving the interoperability of transport systems, following EU-wide harmonised standards and investing in infrastructure that supports the deployment of novel vehicle technologies.

PATHWAY - RECOMMENDATIONS

BY 2030 – NEAR IMPLEMENTATION

- The physical infrastructure is multi-layered and ageing rapidly in different parts of Europe. There is a need to identify links between these layers and their dependencies. Costs, benefits and acceptable risks should be assessed for users (including passenger vehicles, public transport, shared-mobility, micromobility, and active modes of transport).

BEYOND 2030 – FURTHER RESEARCH NEEDED (RESEACH QUESTIONS RQs)

- RQ15: How can road infrastructure be designed to prioritise safety, accessibility, and multimodal integration while ensuring effective multimodal interfaces (e.g. airports, bus stops, train stations) that contribute to the cross-sector resilience of transportation networks?
- RQ16: What are the potential vulnerabilities in PDI systems related to multimodal transport management, and how can they be mitigated? How can PDI services adhere to cybersecurity requirements?

Data reliability, management, use and sharing

Challenges

- Lack of clear and commonly used data sharing frameworks (incl. use of standards): There is a lack of unified data sharing frameworks across different regions and transport modes. Existing frameworks are often fragmented, leading to inefficiencies and compatibility issues. The absence of commonly agreed-upon standards for data formats, protocols, and interfaces makes data sharing and re-use difficult. Without standardised practices, integrating data from diverse sources becomes complex and error prone. Varying legal and regulatory requirements across jurisdictions hinder the development and implementation of common data sharing frameworks.
- Limited data coverage: Many transport systems have incomplete data coverage, meaning that crucial data points (such as real-time traffic conditions, vehicle locations, and passenger flows) are not consistently captured. Also, there are significant gaps in the collection of data across different transport modes and geographic areas, resulting in an incomplete picture of the overall transport network.
- Data quality: Data collected from various sources often varies in quality, with issues such as inaccuracies, missing values, and outdated information. There are no universally accepted methods for assessing and ensuring data quality, leading to uncertainty about the reliability of the data used for decision-making.
- Underexploited use of multi-source multimodal data: Data from different transport modes and sources are often siloed, limiting the potential for comprehensive analysis and optimisation. Integrating data from various sources into a cohesive system that allows for holistic analysis and insights is complex and often underutilised. The potential of advanced data analytics, such as machine learning and predictive modelling, to leverage multi-source multimodal data is not fully exploited. This limits the ability to make data-driven decisions and to enhance transport management.
- Dynamic data needs: MTM requires dynamic and real-time data to respond to changing conditions and optimise transport flows. Existing data spaces may not support the required level of responsiveness and adaptability.

Vision

Establishing robust data governance frameworks that enable secure and efficient sharing of high-quality multi-source data among stakeholders. This includes the development of federated data spaces, ensuring that high-quality, standardised data for all modes is available for real-time decision-making and predictive analytics.

PATHWAY - RECOMMENDATIONS

BY 2030 – NEAR IMPLEMENTATION

- Enhance data governance frameworks by establishing federated data spaces, or leveraging existing ones, for secure, multi-source data sharing to ensure high-quality, standardised data for real-time decision-making and predictive analytics. Establish the EMDS as top layer data space to increase availability, discoverability and accessibility of mobility and transport data across the EU.
- Ensure coordination and seek alignment with actions supporting the EMDS and the Mobility and Logistics Data EDIC in preparation.
- Adopt harmonised methods and processes at EU level that ensure the high quality of data used for operational MTM.

BEYOND 2030 – FURTHER RESEARCH NEEDED (RESEACH QUESTIONS RQs)

- RQ17: How can current data quality assessment frameworks be extended in order to cover the specific needs of the MTM domain?
- RQ18: Which are the necessary new developments needed in MTM data analytics, to extract knowledge that assists MTM operations?
- RQ19: Which novel technologies can be used to extend the coverage of real-time data collection needed for MTM, particularly in areas with limited sensor equipment installed?
- RQ20: How can maintenance/operational costs and quality aspects of data from sensors be reduced and improved through the use of novel, cost-efficient data sources?

Resilience and adaptability

Challenges

- **Ineffective management of planned or unplanned disruptions:** Responsible entities manage planned or unplanned events with significant impacts on multimodal transport systems without the use of elaborated response plans.

- **Uncoordinated communication between responsible entities:** Responsible entities lack processes and tools that allow coordinated planning, communication and collaboration in cases of disruptive events.

- **Integration of resilience principles into operational traffic management:** Operational traffic management systems and procedures do not currently account for the ability to cope with disruptive events, ensuring a minimum accepted level of service and restoring quickly to normal operations.

Vision

Ensuring that multimodal transport systems are resilient and adaptable to disruptions.

PATHWAY - RECOMMENDATIONS

BY 2030 – NEAR IMPLEMENTATION

- **Implement measures to mitigate the impact of unexpected events on multimodal transport networks.**
- **Integrate road-works management platforms with operational MTM systems.**
- **Develop and operationalise contingency plans that enhance the capacity for real-time monitoring and response.**

BEYOND 2030 – FURTHER RESEARCH NEEDED (RESEACH QUESTIONS RQs)

- **RQ21: How can resilient MTM be extended in order to cover new needs associated with emerging modes, including electrified vehicles and CCAM systems?**
- **RQ22: How can MTM utilize predictive and real-time management strategies for effectively managing the impacts of large-scale disasters, such as extreme weather events, in urban, rural and highway environments?**

Public engagement and acceptance

Challenges

- **Limited incentives to participate:** The public is not provided with sufficient incentives to actively participate and engage in testing and evaluation of innovative solutions.
- **Lack of awareness:** The public is often unaware of the benefits of new multimodal transport solutions and technologies.
- **Limited dissemination of significant R&D outcomes:** The public is often unaware of developments taking place at the technology side.
- **Translation of technical results to easily interpretable messages for the public:** Often technical results are only presented with technical terms, which cannot be understood by the general public.

Vision

Promoting public understanding and acceptance of new technologies and multimodal transport solutions. This involves conducting awareness campaigns, public consultations, and pilot projects to demonstrate the benefits of MTM and address any concerns from the public.

PATHWAY - RECOMMENDATIONS

Public engagement and acceptance

BY 2030 – NEAR IMPLEMENTATION

- The public lacks experience with automated vehicles involving Cooperative, Connected and Automated Mobility (CCAM) capabilities, which creates a challenge to introduce technological innovations in the field with public acceptance. This creates a need to increase public engagements with different stakeholders involved for the implementation of real-world CCAM use cases.
- Include public consultations, awareness campaigns, and pilot projects to demonstrate the benefits of CCAM and address public concerns.
- Considering the new technologies surrounding CCAM, a human-centric approach should be the guiding pathway. Initiating small pilot tests and experiments, involving urban planners, utilities and constructors, policy makers, educational institutions (e.g., schools, universities) and service providers to test, educate and validate the new/updated infrastructure in controlled environments (living labs/testbed) is crucial.
- Exchange of knowledge and lessons learnt between different cities, regions or agglomerations should be encouraged.
- Assess the impacts of the use private service navigation services (e.g. mobile apps used by travellers) to system-wide traffic conditions for all modes of transport. Include aspects related to route efficiency, safety, security and environmental impact.
- Assess the willingness of travellers to follow system-optimum routes, recommendations and modes that may negatively affect individuals but have a positive impact collectively.
- Assess the degree to which travellers follow such recommendations and guidance if these come from private service providers or the responsible (public) authorities.
- How can citizens become more actively engaged in co-creating more efficient, just, sustainable and inclusive MTM systems?

BEYOND 2030 – FURTHER RESEARCH NEEDED (RESEACH QUESTIONS RQs)

- RQ23: How can MTM operations become fully automated? Which are the challenges and solutions for operationalizing such systems that are accepted both by responsible authorities as well as the public?

Roadmap for the implementation of MTM technologies and services by 2030 and beyond

Roadmap for the implementation of MTM technologies and services by 2030 and beyond

MTM TECHNOLOGIES AND SERVICES	NEED FOR IMPLEMENTATION	PATHWAY – RECOMMENDATIONS	
		By 2030 - NEAR IMPLEMENTATION	BEYOND 2030 - FURTHER RESEARCH NEEDED
Monitoring, Detection, Modelling and Predictions	The integration of monitoring and modelling technologies, including AI and traffic simulations, is essential to transform real-time data into actionable insights for proactive decision-making in MTM. These technologies help manage congestion, predict bottlenecks, and ensure smoother traffic management across modes.	Develop advanced systems for real-time monitoring and AI-driven traffic simulations to manage and predict traffic congestion.	Further develop predictive modelling using digital twins for real-time traffic and transport network optimisation.
Tools assisting MTM	Operational and strategic dashboards are crucial for enhancing situational awareness of transport networks by aggregating and ensuring high quality of data from various sources, improving decision-making processes. Dashboards must be interactive, with incident management and simulation tools included..	Deploy interactive dashboards that integrate real-time, multimodal, multi-source data and human feedback for accurate decision-making involving both traffic management operators and all stakeholders. Ensure that data quality assessment and improvement methods and protocols are applied.	Leverage AI and machine learning for continuous improvement of tools and integrate them into seamless decision-support systems.
MTM measures	There is an increasing need to focus on multimodal traffic management that prioritises sustainable mobility and sustainable transport modes. This includes bus prioritisation, dynamic lane management, and distributed network-wide MTM strategies.	Implement distributed control strategies for multimodal and dynamic traffic management (incl. dynamic lanes management and adaptive management of smart intersections).	Research and develop market-based management strategies, like auction-based signalised intersection control.
Demand and transport service management measures	Demand management through strategies like dynamic pricing is essential for balancing transport demand and promoting sustainable mobility practices.	Implement real-time traffic demand balancing, by promoting the use of shared mobility modes and by implementing advanced demand management schemes, such as tradable credits.	Integrate AI-driven demand management strategies and explore new methods for dynamic traffic balancing, accounting also for the capabilities offered by CCAM.
Advanced vehicle balancing for shared mobility services	Efficient rebalancing of shared mobility services is necessary to align vehicle supply with user demand, thus reducing inefficiencies and waiting times.	Introduce decentralised rebalancing strategies using auction-based systems for shared mobility services.	Explore further AI-driven predictive models to enhance multimodal balancing and optimise shared mobility service delivery, accounting also for the capabilities offered by CCAM.
Demand management schemes with tradable credits and permits	Tradable credits can encourage travellers to adopt more sustainable modes of transport, offering an equitable alternative to congestion pricing schemes.	Deploy early versions of tradable credit schemes to reduce congestion and promote sustainable and climate friendly travel options.	Continue refining the framework for tradable credits, including integrating more advanced systems for monitoring travel behaviour and mobility patterns.

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Project Descriptions

SYNCHROMODE

EU funding:
4.849.348,75 €

Duration:
01/05/2023 to 30/04/2026

Project Acronym:
SYNCHROMODE

Project title: **Advanced traffic management solutions for synchronized and resilient multimodal transport services**

Project Number: 101104171

Website: https://www.synchromode.eu

Project objectives:

Develop advanced multi-actor cooperation models for multimodal mobility service operation, network and traffic management.

Develop a set of new interoperable solutions for data gathering, harmonisation, fusion and analysis.

Perform simulations for assessing the impacts of the provision of the most efficient and effective multimodal traffic management strategies utilising connected vehicles technologies and services and increased connectivity and data exchange from different sources and systems, capable of reacting to various events disrupting the transport network.

Develop new artificial intelligence methods and tools, for network-wide multimodal transport, able to optimise the coordination of passengers and freight transport, network load balancing with the use of new traffic management capabilities (e.g., CCAM), the synchronisation of shared/on-demand and public transport, and optimised response plans for bottlenecks and events management.

Integrate models, algorithms and tools in the SYNCHROMODE toolbox, for an efficient multimodal traffic management framework applied to various environments and addressing mobility users & stakeholders' needs.

Test and validate the SYNCHROMODE toolbox and evaluate the impact of multimodal traffic management strategies to passenger and freight mobility patterns and to provide insights to system-related benefits.

Develop a framework guiding through replication capabilities for innovative multimodal traffic management in Europe, relying on interoperability and scalability capabilities of the developed services and the SYNCHROMODE toolbox.

Pilots:

- Multimodal traffic management for urban and peri-urban transport networks (Thessaloniki, Greece)
- Traffic management for large duration events management (Netherlands)
- Enhancing collaboration between mobility and logistics operators (Madrid, Spain)

Expected outcomes:

- Development and application of new AI and transport simulation models for MTM
- Use of multi-source data by different stakeholders
- Management of disruptions and bottlenecks through advanced data analytics and simulation
- Improved traffic prediction models
- Reduction of important traffic related KPIs through advanced MTM (e.g. travel times, emissions, delays)
- Formulation and acceptance of new multi-stakeholder governance models
- Adoption of the SYNCHROMODE Toolbox by relevant authorities and stakeholders
- Re-use and extension of the achieved results by the scientific and technology communities

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Project Descriptions

TANGENT

EU funding:
4.849.348,75 €

Duration:
01/09/2021 to 30/11/2024

Project Acronym:
TANGENT

Project title: **Enhanced Data Processing Techniques for Dynamic Management of Multimodal Traffic**

Project Number: 955273

Website: https://tangent-h2020.eu/

Project objectives:

- to orchestrate the multiple agents in the overall transport network (Traffic Managers, Transport operators, infrastructure managers, Transport Users), both public & private, for the different transport modes, aiming to collectively identify their roles, responsibilities and needs; identify new ways of cooperation among the agents, including the design of new arbitration models that balance individual versus collective needs; and to define the specifications for the TANGENT tool architecture and functionalities.
- to identify, collect and harmonise & fuse the relevant data to feed the system, considering different data sources, e.g., multimodal travel and traffic data from transport operators, traveller data and open data.
- to understand and model the transport users' behaviour and motivations in a multimodal and automated landscape: their individual needs, preferences and sentiments, as well as their effect on the transport system.
- to develop a state-of-the-art framework to monitor and forecast the traffic flow& traffic conditions, as well as transport demand& supply under various circumstances (e.g. large/sport events, roadworks, accidents, ...).
- to optimise traffic management according to different performance targets both off-line and on-line by means of Artificial Intelligence techniques and to calibrate the designed arbitration models for regular and disruptive traffic situations.
- to integrate the overall solution and set up the necessary infrastructure for building up the decision-making support tool for traffic operations. To empower transport managers and decision makers with clean graphical user interfaces with automatic functionalities.
- to test, validate and assess the impact of the delivered decision-making tool and services in the multimodal network through simulation in four scenarios: Rennes (Fr), Lisbon (PT), Greater Manchester (UK) and a virtual case in Athens (HE) building-up Case Studies addressing multimodal transport, CAVs, events, changing traffic flows, safety aspects, etc.
- to disseminate results, training for transport operators and policy makers to pave the way of future mobility in Europe.
- to study new business models based on transport agents' cooperation.

Pilots:

- Fostering intermodal cooperation of passenger and freight transport in urban areas (City of Rennes)Integrated urban and interurban transport management with C.-ITS (Coty of Lisbon)
- Optimisation of transport flows both in urban and in rural/ semi-rural region (Greater Manchester)
- Future transport management with CAVS (virtual case study: city of Athens)

Expected outcomes:

- TANGENT solution for data harmonisation and fusion
- Travel choice modelling (set of models, code)
- Framework for real-time traffic monitoring and forecasting
- Data-driven demand estimation and prediction methods
- Traffic state predictions supply
- Module for anomaly detection in the transport network
- Transport Network Optimisation Module
- Development of TANGENT integrated solutions (Dashboard and API Engine), containing:

(1) Enhanced information service for multimodal transport management – Dashboard & API: The framework will integrate information from all modes (cycling, walking, bikes, micro-mobility, PT, train, DRT, car-sharing, car-polling, CAVs, ferry/inland-waterways, etc.), both from public and private stakeholders. This information is provided in a single dashboard for traffic managers, and through APIs to transport operators, service providers and transport users.
(2) Real-time Traffic Management Services: delivers response plans at operational/ tactical level to transport agents, including the transport recovery and optimisation in the light of events. This service aims to optimise the overall transport network operations on a day to day basis.
(3) Transport network optimisation for Transport Authorities: This service aims to support decision-makers at the strategic and tactical level for producing policies or response plans that contribute to optimise the performance of the network, including dynamic transport network management and transport supply optimisation.

- **New transport governance models**
- **Transport policy recommendation**

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ORCHESTRA

EU funding: **4,998,798.75 €**

Duration: **01/05/2021 to 30/04/2024**

Project Acronym: **ORCHESTRA**

Project title: **Coordinating and synchronising multimodal transport improving road, rail, water and air transport through increased automation and user involvement**

Project Number: 953618

Website: https://orchestra2020.eu/

Project objectives:

The long-term vision of ORCHESTRA is a future where it is easy to coordinate and synchronise the traffic management of all modes to cope with diverse demands and situations. The overall objective of ORCHESTRA was to provide European policy makers, public authorities, transport providers and citizens with new knowledge and technical and organisational solutions to enhance collaboration and synchronising of operations within and across transport modes.

The project has:

- Established a common understanding of multimodal traffic management (MTM) concepts and solutions, within and across different modes, for various stakeholders and multiple contexts.
- Defined 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
- Supported MTME realisation and deployments, through the provision of tools, models, and guidelines – including the integration of connected and automated vehicles and vessels (CAVs).
- Validated and adjusted MTME for organisational issues, functionality, capability and usability.
- Maximised outreach and uptake of project results through strong stakeholder involvement.

Pilots:

The project validated and evaluated the MTM concept and related tools in its two Living Labs (LLs). The LLs was both used for testing selected tools and strategies in real-world use cases, and as case studies and sources of real-life data for simulations:

- **Herøya Industry Park, Norway:** This LL focused on the optimisation of freight transport. Three main scenarios were analysed, covering both gods coming by sea and road, and demonstrating the utilisation of connected and automated vehicles (CAVs) to facilitate efficient transport within the industry park.
- **Malpensa Airport, Italy:** This LL focused on the mobility of people and showed how the integration of transport data originating from outside the airport (e.g. trains and cars) can support the optimisation of passenger movements within the airport, in particular in the event of delays, reducing number of passengers missing their flights. In addition, Malpensa demonstrated the allocation of on-demand transport services for late arriving passengers.

Outcomes:

- Knowledge on evolving needs, requirements, and feasibility – including a target vision for 2030 and 2050.
- Policy and strategy white paper and roadmap – presenting what is needed from a legal and regulatory perspective to implement MTM, also taking into account the deployment of MTM in the context of increased automation.
- Polycentric multimodal architecture (PMA) – a reference architecture for MTM that aims to support the understanding of the MTM concept and to specify the related functionality and how diverse systems in the MTM ecosystem should interact.
- Lessons learned from MTME pilots, simulations and trials – based on the finding from the LL activities and evaluation activities.
- Enabling toolkit supporting the realisation of MTME – this includes decision support and other prototypes for operative traffic orchestration, training modules and training guidelines, and assessment tools to support evaluations and analyses.
- Deployment toolkit supporting the roll-out of MTM – comprising organisational, business and market models for MTM, in addition to contractual and administrative issues.

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DIT4TRAM

EU funding:
4,997,122 €

Duration:
01/09/2021 to 01/09/2024

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Project Acronym:
DIT4TRAM

Project title: **Distributed Intelligence & Technology for Traffic & Mobility Management**

Project Number: 953783

Website: https://dit4tram.eu/

Project objectives:

- Develop innovative multi-actor cooperation models for decentralised, multimodal traffic management, enabling the seamless coordination of various transport services and stakeholders across urban and interurban environments.
- Design interoperable solutions for data collection, integration, and analysis to support decentralised traffic management, enabling the efficient fusion and harmonisation of data from diverse sources, including shared mobility and smart infrastructure.
- Conduct simulations to assess the impact of decentralised traffic management strategies, utilising advanced vehicle technologies and enhanced data exchange systems to respond to real-time events and disruptions in the transport network.
- Create advanced artificial intelligence methods and tools to optimise network-wide traffic management, focusing on synchronising passenger and freight transport, load balancing, and improving coordination between shared, on-demand, and public transport services.
- Integrate models, algorithms, and tools into a comprehensive Distributed Network and Traffic Management (DNTM) framework, tailored for various traffic environments and addressing the needs of mobility users and stakeholders.
- Test and validate the DNTM framework in real-world settings, evaluating its impact on multimodal traffic patterns, and providing insights into system efficiency, resilience, and scalability.
- Develop a replication framework to guide the application of innovative decentralised traffic management solutions across Europe, ensuring scalability and interoperability of the DNTM framework and associated services.

Pilots:

- **Bordeaux (FR).** This pilot focused on enhancing the existing GERTRUDE traffic management system, particularly for prioritising cyclists and high-occupancy vehicles (HOVs). The system integrated C-ITS (Cooperative Intelligent Transport Systems) and dynamic prioritisation strategies at two major intersections. The aim was to improve traffic flow, reduce travel times, and support the city's sustainable mobility objectives.
- **The Utrecht (NL)** pilot concentrated on two key objectives: (1) testing a queue estimation method using Floating Car Data (FCD) to potentially replace radar-based systems, and (2) optimising bike priority at intersections to reduce cyclist waiting times. The pilot showed that while FCD has potential for queue estimation, it still faced limitations in real-time accuracy.
- **Amsterdam (NL).** This pilot explored the implementation of Tradable Mobility Credits (TMCs) to manage urban traffic demand, balancing road space usage and promoting sustainable transport modes. TMCs, inspired by cap-and-trade models, were used to reduce emissions and manage congestion by allowing users to buy and sell mobility credits. The pilot demonstrated the effectiveness of TMCs in controlling vehicle access, promoting public transport use, and aligning mobility behaviour with environmental and social policies.
- **Glyfada (EL)** This pilot aimed to optimise traffic flow in a suburban setting by implementing a decentralised traffic management system. The pilot tested the system's ability to manage traffic across different vehicle types and prioritise public transport.
- **Athens (EL).** This pilot applied AI-driven, decentralised traffic control strategies to manage peak-hour traffic in a dense urban environment. The focus was on integrating multi-agent reinforcement learning to dynamically adjust traffic signals based on real-time conditions.
- **Mediterranean Highway (AP-7) (ES).** This interurban pilot focused on applying Tradable Mobility Credits (TMCs) to reduce congestion on the AP-7 highway and improve traffic distribution between the main highway and secondary roads.

Expected Outcomes:

- Simulation-based frameworks and tools: These enable the assessment of traffic management strategies in various urban contexts, ensuring scalability and adaptability.
- Insights from real-world pilots: Lessons learned from the Bordeaux, Utrecht, Amsterdam, Glyfada, Athens, and Mediterranean Highway pilots provided valuable feedback on the practical implementation of decentralised systems.
- Comprehensive toolkits: These include decision support tools, training modules, and evaluation frameworks to assist in the roll-out of distributed traffic management solutions.
- Established a robust DNTM system that serves as the backbone for managing decentralised traffic across multiple modes and regions. This system enhances the coordination of traffic flows, balances network load, and improves resilience to disruptions, ensuring a seamless and efficient transport experience for passengers and freight.

Project Descriptions

FRONTIER

EU funding:
4.998.963,50 €

Duration:
01/05/2021 to 30/04/2024

Project Acronym:
FRONTIER

Project title: **Next generation traffic management for empowering CAVs integration, cross-stakeholders collaboration and proactive multi-modal network optimization**

Project Number: 955317

Website: https://www.frontier-project.eu/

Project objectives:

- provide the network and integrated traffic management strategies of the future, taking into account new types and modes of transport and automated vehicles, the minimisation of pollution and capacity bottlenecks, the reduction of accidents, and the need to reduce the cost of mobility for all users.
- facilitate the transition towards resilient multimodal autonomous mobility by establishing the processes of collaboration and arbitration among stakeholders while developing the business models that will address the commercial viability of the identified solutions.
- develop, apply and test autonomous management systems, secured by design, that will constantly evolve using data generated from real-time monitoring of the transportation system, knowledge generated by operators and decision makers, and simulation models providing system optimal solutions accounting for new mobility services and technologies. These systems will support and enact proactive decisions, realising our vision to empower a **seamless transition to an autonomous and integrated transport management for future mobility services.**

FRONTIER follows a cognitive approach based on the **Observe, Orient, Decide, Act (OODA)** loop of situational awareness recognised as one of the main models for quick, effective and proactive decision making - the key for continuous situational awareness.

Pilots:

- Oxfordshire, UK: smart Infrastructures and CAVs integration, enhancing collaboration between traffic management teams and public transport
- Athens, Greece: multimodal mobility for passengers and cross-stakeholder collaboration
- Antwerp, Belgium: shift from traditional road-based transport to more environmentally friendly waterway options for transporting freight.

Achieved outcomes:

- Autonomous Network and Traffic Management Engine and Act services (ANTME)
- Which includes the Response plan generator, taking as input the anomalies and critical situations detected in the traffic network to generate many response plans aiming to optimise the transport network by using a developed simulation framework
- The FRONTIER simulation framework
- The FRONTIER information services, including:
- Network and traffic visualisation dashboard enabling multistakeholder common situational awareness and collaboration thought incident detection, response plan selection and monitoring functionalities
- Citynaut mobile app offering a range of services including a journey planner and updates from the network's response plan generator to enhance urban navigation and act as a demand management tool incorporating travellers in the response plans.
- The Network and Traffic Management Dataspace
- Smart Road Infrastructure Classification Index

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DELPHI

EU funding: 4,999,561.50 €

Duration: 01/07/2023 to 30/06/2026

Project Acronym: **DELPHI**

Project title: **Federated Network of Platforms for Passenger and Freight Intermobility**

Project Number: **101104263**

Website: : https://delphi-project.eu/

Project objectives:

- Delivery of novel governance and regulatory schemes, as well as models and stakeholder analysis with detailed and specific roles assignment for the entire logistics, as well as passenger transport ecosystems, towards a harmonised digitalisation of the end-to-end information flows of international supply chains, and multimodal passenger transportation systems.
- Design and development of a Platform Federation Reference architecture towards a "Multimodal Passenger and Freight Transport Network of Platforms (NoP)" framework, seamlessly integrating heterogeneous MPFT platforms.
- Design and development of an AI/ML-powered transport network and traffic management (TNTM) optimisation framework, digesting information from diverse systems and offering intelligent, responsive, predictive, and secure functionalities, for reducing passenger/freight transport-related emissions, delivery time, as well as cost.
- Validation of the developed federated network of platforms, along with the AI/ML-powered optimisation framework, in a two-fold methodology (via 4 pilots & via simulation-based analysis).
- Ensuring compatibility with existing and forthcoming EU standards in the freight and passenger mobility domains, as well as it will promote and contribute to the standardisation of multimodal and multi-stakeholder freight and passenger management solutions and information systems.

Pilots:

- USE CASE #1: Multimodal transport for a Sustainable Last Mile Delivery (LMD) supported by blockchain for sharing economy in the e-commerce Channel (Madrid, Spain)
- USE CASE #2: Integrated freight and passengers' models and data sharing framework in the Attica region (Greece)
- USE CASE #3: Integrated freight and passengers' models and data sharing framework at the island of Mykonos (Greece)
- USE CASE #4: Integrated passengers' models and data sharing governance framework in the Cluj-Napoca Metropolitan Area (Romania)

Expected outcomes:

- A neutral governance structure, as well as regulatory framework recommendations and guidelines
- A central, cloud-based platform-of-platforms
- A reference architecture for multi-modal passenger and freight transport platforms' federation
- Multimodal, common optimisation models for passengers and freight transport processes
- KPI-driven evaluation of the DELPHI performance, analysing both pilot-driven and simulation-driven results
- Delivery of four complementary operational trial sites combining technology, infrastructure, and components from different MPFT stakeholders
- Contributions towards relevant SDOs and transport and logistics initiatives/communities pushing for the adoption of cross-stakeholder solutions in both the logistic chain, as well as the passenger mobility ecosystems

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ACUMEN

EU funding:
4 999 476.25 €

Duration:
1/6/2023 to 31/5/2026

Project Acronym:
ACUMEN

Project title: **Ai-aided deCision tool for seamless mUltiModal nEtwork and traffic management**

Project Number: 101103808

Website: https://acumen-project.eu/

Project objectives:

- designing a safe, secure, privacy-preserving, decentralised data framework allowing all mobility providers and operators to share information in real-time;
- resorting to advanced concepts from explainable AI and hybrid intelligence to develop new monitoring and forecasting tools with unprecedented accuracy;
- developing and testing new decision-making and management solutions, acting on all urban scales (section, intersection, network, fleets management) and fostering cooperation between mobility providers

Pilot:

- Pilot 1 – Athens: design, implement, and test an innovative holistic mobility platform for decision-making in the Athens Metropolitan area.
- Pilot 2 – Helsinki: dynamically affect travellers' route and mode choice behaviour to achieve KPIs focussed on sustainability and citizens well-being.
- Pilot 3 – Amsterdam: demonstrate the potential of joint multimodal management in devising resilient response to major infrastructure disruptions.
- Pilot 4 – Luxembourg: demonstrate the use of Automated Vehicles (AVs) to provide seamless and integrated on-demand mobility.

Expected outcomes:

- new framework for assessing traffic management performances
- AI-based solutions including Hybrid Intelligence for ensuring efficient coordination between different traffic management strategies
- technological integration of traffic management solutions through the Digital Twin framework
- standardised data framework that leverages AI-based decentralised methods for the monitoring of mobility
- enhancing network level demand and traffic forecasting, reducing the implementation costs of advanced simulation tools
- integration of advanced ML/AI methods to reach an unprecedented level of accuracy for travel demand and multimodal travel times prediction
- predictive mobility management orchestrator to enable the selection of proper short-and longer-term strategies adapting to changing urban mobility conditions
- high-end solutions to better synchronise transport modes through efficient data exchange between service providers, predictive modelling, and decision making
- co-creation of the management solutions with relevant stakeholders and end-users, relaying knowledge and providing capacity building

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