Orchestra

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ORCHESTRA Project Deliverable: D2.2

Pre-studies on environment analysis and drivers

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About ORCHESTRA

The long-term vision of the 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. Also, to facilitate optimal utilisation of transport networks and efficient multimodal transport services, both in rural and urban areas.

The project will:

- Establish a common understanding of multimodal traffic management concepts and solutions, within and across different modes, for various stakeholders and multiple contexts
- Define 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
- Support MTME realisation and deployments, through the provision of tools, models, and guidelines – including support for connected and automated vehicles and vessels (CAVs)
- Validate and adjust MTME for organisational issues, functionality, capability, and usability
- Maximise outreach and uptake of project results through strong stakeholder involvement

The project will provide a Polycentric Multimodal Architecture (PMA) that specify how diverse system components collaborate and interact, taking into account smart infrastructures, technical and organisational aspects and polycentric governance. The PMA will be supported by: 1) Enabling toolkit, 2) Deployment toolkit, 3) Documented lessons learned.

The project will validate the PMA and related tools and toolkits in two Living labs (in Norway and Italy), collectively covering both road, rail, water, and air transport. The Italian Living lab is focusing on traffic orchestration for the mobility of people, while the Norwegian Living lab is focusing on traffic orchestration for freight. The Living labs will be supported by simulations to enhance evaluations.

Legal disclaimer

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Executive Summary

The pre-studies on environment analysis and drivers provide an overview of the context in which the multimodal traffic management will operate.

Therefore, the report provides general definitions, such as transport networks, and multimodal traffic management. Moreover, it offers an understanding of the drivers, which are legal, technical, economic, and human considerations that influence – either in facilitating or preventing – the realisation of the MTME target vision. The methodology includes a description of the literature review, as well as the primary data collection via more than twenty expert interviews, working in academia, business, or public authorities in the traffic and transport sector.

The results sections provide the drivers and barriers for MTME in regard to the status quo from four different perspectives: Legal and regulatory perspective, economic and market perspective, safety and security perspective, as well as psycho-sociological and acceptance perspective. Organisational and technical aspects are taken into account by all four perspectives.

The **legal and regulatory perspective** outlines European Union policies and regulations, which affect the implementation of MTMEs, such as the European Green Deal, the Sustainable and Smart Mobility Strategy (SSMS), as well as the European Data Strategy and the Data Mobility Space Initiative. The concept of shared data is key for implementing an MTME and the lack of willingness and incentives for companies to share data (B2B, B2A) is one of the biggest barriers. Therefore, the legal framework for different steps of sharing data is at focus.

The **economic and market perspective** analyses the economic and business relevance of MTMEs, as well as the techno-economic challenges. Current barriers for traffic management are, for instance,the lack of (real-time) information for various actors, as well as insufficient forecast capacities. Challenges for the MTME vision derive out of the lack of necessary infrastructure, as well as the need for data standardisation and compatibility if shared with a variety of different stakeholders. However, emerging possibilities of efficiency improvement deriving out of technology leading to more sustainable traffic flows are the main drivers. The introduction of external costs for emissions fosters this process.

The **safety and security perspective** provides an overview of relevant safety aspects for different traffic sectors, such as road, air, maritime and rail. The topic of cybersecurity is a barrier for the implementation of the target vision. Challenges arrive also out of the limitation of expertise in companies, as well as the connection of different traffic systems risking the entire system in case of attack, potentially putting human lives in danger. Important aspects of cybersecurity are confidentiality andintegrity. State of the art cybersecurity measures, such as technical features securing systems and technologies are offered by the Transport Cybersecurity toolkit.

The **psycho-sociological and acceptance perspective** analyses the acceptance of MTME. The main barrier for actors other than end-users, is the variety of stakeholders that need interaction and exchange of information for the orchestration of the traffic. In addition, the low compatibility and difficult quantification of benefits, as well as implementation and maintenance costs are barriers. The findings of the literature review on acceptability and acceptance of autonomous shuttles focus on the end-user, showing that the beneficial impact on road safety is found in research outcomes. The interviews mentioned governance and better flow management as drivers for MTME implementation.

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List of Abbreviations

Table 1: List of abbreviations

Abbreviation	Explanation
A2A	Administration to administration
A2B	Administration to business
AI	Artificial Intelligence
AIS	Automated Identity System
B2A	Business to administration
B2B	Business to business
B2G	Business to government
B2G	Business to Government
CAV	Connected Automated Vehicle
CCAM	Connected, cooperative, and automated mobility
CoP	Community of Practitioners
CRITIS	critical infrastructure
CT	Combined Transport
ERA	European Union Agency for Railways
EU	European Union
GNSS	Global Navigation Satellite Systems
GSM	Global System for Mobile Communications
ICAO	International Civil Aviation Organisation
ICT	Intelligent Combined Transport
IMO	International Maritime Organisation
IoT	Internet of Things
IPR	Intellectual Property Rights
ISM	International Safety Management
ITS	Intelligent Transport Systems
MaaS	Mobility as a Service
MS	Member State
MTM(E)	Multimodal Traffic Management (Ecosystems)

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Abbreviation	Explanation
NAP	National Access Points
NGO	Non-governmental organisations
PESTEL	Political, Economical, Social, Technical, Environmental, Legal
PI	Physical Internet
R & D	Research & Development
RAT	Regulatory Authority of Transport
SDG	Sustainable Development Goals
SSMS	Sustainable and Smart Mobility Strategy
TEN(-T)	Trans European (Transport) Network
TSI	Technical specification for interoperability
UN	United Nations
UTAUT	Unified Theory of Acceptance and Use of Technology

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List of Definitions

Table 2: List of definitions

Definition	Explanation
Transport Networks	The defining elements of a transport network are “the network geometry and the level of connectivity” which together determine the extent to which the three characteristics of ideal, spatially continuous transport networks – ubiquity, fractionalization, and instantaneity – are achieved (European Parliament. 1996. Decision No 1692/96/EC)
Multimodal traffic management	Combination of road, rail, sea, and air traffic networks in an integrated management approach
Environment analysis	An environment analysis aims to evaluate all internal and external forces or components that affect a system.
Drivers	Drivers are legal, technical, economic, and human considerations that can facilitate the realisation of the target vision.
Barriers	Barriers are legal, technical, economic, and human considerations that can prevent the realisation of the target vision.
Intelligent Transport Systems	Systems in which information and communication technologies are applied in the field of road transport, including infrastructure, vehicles and users, and in traffic management and mobility management, as well as for interfaces with other modes of transport (Art. 5 ITS Directive).
Integrated transport system	The organizational process, in which the elements of transport system (network and infrastructure, fares and ticketing, information and marketing, etc.) served by different operators, who use different transport modes, interact more efficiently and closely (Stopka, O, Bartuška and Kampf, 2015).

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1 About this Deliverable

Today still, the mobility sector struggles to fulfil its CO_2-reduction goals. However, the EU aims to be carbon neutral in 2050. Thus, the mobility sector will face a fast and significant transformation within the next years. For this transformation, it is necessary to combine all means of transportation in a holistic and integrated system. This implies that the future of traffic management needs to be integrated and multimodal. Today, several obstacles prevent the communication between the different means of transport. Legal barriers do prevent efficient data exchange, the non-existence of business models hinders companies and institutions to do intermodal traffic management. Nevertheless, the future of traffic management must consider (data) security and safety aspects as well as social aspects and acceptance. Finally, all of this must lead to an efficient market regulation, allowing to open the field for an efficient multimodal traffic management.

As a first step to this future, this document summarises the status quo of **Multimodal Traffic Management (Environments) (MTM(E))** within the EU based on an interdisciplinary environmental analysis of transport networks and (multimodal) traffic management. To do so, four in-depth analyses are performed and summarised within this document. These Pre-Studies are focusing on the following aspects (with main contributing institute in brackets): (1) legal and regulatory aspects [IKEM], (2) economic and market related aspects [IKEM], (3) security and safety aspects [HESSO] and (4) psycho-sociological and acceptance aspects [CEREMA]. As stated above, the goal must be to create an efficient market regulation for the (future) MTM(E). More research on general societal aspects of MTME implementation will be addressed in D2.3 and D4.2. A more functional approach towards acceptance of the MTME will be developed in WP6.

1.1 Why would I want to read this deliverable?

The document gives an overview of the current state of multimodal traffic management from various perspectives and serves as an introductory document. It gives first ideas about definitions, as well as about the general status quo. With this, it allows for an easy access to the topic as well as for a quick overview for researchers and interested stakeholders. Furthermore, it gives hints for more detailed information.

1.2 Intended readership/users

The document provides an easy access into the topic as well as summarizing the current status quo from a practical perspective. Thus, it allows the reader to understand the current situation as well as current problems for future research. The document shall be interesting for a broad variety of readers – from interested stakeholders to get a first idea of the topic to researchers who want to know about the current situation for MTM(E). The document can be considered a good starting point for a deep dive into the research conducted within ORCHESTRA.

1.3 Structure

The document is structured as follows. First, general (working) definitions and theoretical background are given, Furthermore, the methodology applied for the in-depth Pre-Studies is presented, followed by the individual results. Lastly, a conclusion of the research is given.

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2 Theoretical Background

Traffic and cities have been intricately linked with human settlements.[1] Until the year 2050 the population of cities is likely to increase by 2.5 billion (compared to 2018),[2] leading to an even higher mobility demand than today and an increasing traffic infrastructure. However, wherever there is traffic infrastructure, there will be traffic. This is especially known for the road infrastructure (induced traffic). Thus, traffic management needs to consider the current situation, while planning development. It's too late to react, when the traffic is already there.[3] Further, the number of vehicles tends to "[increase] faster than the available traffic infrastructure".[4] Consequently, traffic congestion and management naturally become a pressing matter. This creates several negative concerns for the environment and society such as increasing the number of traffic accidents, economic impacts, and high levels of greenhouse gas emissions. In this context, modern societies can rely on traffic management and transportation efficiency systems to minimize traffic congestion and its negative effects.[5] Further, an efficient multimodal traffic management can help to decouple the increase of vehicles and growth of population. Therefore, all means of transportation must be interlinked. However, "improving transportation efficiency is still an active, challenging research area"[6], that needs to be tackled from various perspectives. The concept of multimodal traffic management (MTM) and respectively a multimodal traffic management ecosystem (MTME) is a promising approach to making intermodal transport, and thus transport flows per se, more efficient, environmentally friendly, and generally more sustainable. For a general understanding of the concept, this chapter gives a general introduction into MTME as well as the working definitions that are used in the paper.

2.1 General Definitions

Considering the need for sustainable, CO_2-neutral mobility, ORCHESTRA aims to address the demands of stakeholders in traffic management and to bridge the gap of solutions between transport modes by establishing and orchestrating an efficient, environmentally friendly, safe, secure, adaptable, cost-effective, and resilient MTME. The MTME supports new multimodal transport services that will help achieve transportation policy goals through more effective utilization of transportation networks while balancing the needs of transportation of people and goods.

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[1] Organization for Economic Co-operation and Development (OECD) & European Conference of Ministers of Transport (ECMT). (2004, January). *MANAGING URBAN TRAFFIC CONGESTION*.

[2] United Nations. o. J. „Cities and Pollution". United Nations. United Nations. accessed: 26. Oktober 2021. https://www.un.org/en/climatechange/climate-solutions/cities-pollution.

[3] Rickard, K. (2014). p.7 The Ultimate Traffic Management System: Making Traffic Work. *RESEARCH GATE*. Published. https://doi.org/10.13140/RG.2.1.1841.7123.

[4] Allan De Souza et al., 'Traffic Management Systems: A Classification, Review, Challenges, and Future Perspectives', *International Journal of Distributed Sensor Networks* 13, no. 4 (1 April 2017): 14, https://doi.org/10.1177/1550147716683612.

[5] Allan De Souza et al., 'Traffic Management Systems: A Classification, Review, Challenges, and Future Perspectives', *International Journal of Distributed Sensor Networks* 13, no. 4 (1 April 2017): 14, https://doi.org/10.1177/1550147716683612.

[6] Allan De Souza et al., 'Traffic Management Systems: A Classification, Review, Challenges, and Future Perspectives', *International Journal of Distributed Sensor Networks* 13, no. 4 (1 April 2017): 14, https://doi.org/10.1177/1550147716683612.

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For a better understanding, the following general definitions are applied within this study. They must be understood as working definitions which will evolve and become more specific over time. Generally, multimodality is a cross-cutting topic, covering different dimensions of the (European) transportation network, including infrastructures, modes of transport, information, and data collection. Thus, transportation networks are described briefly, first. Secondly, the dimensions of these networks are shown. Further, a working definition of MTME is given. Lastly, this chapter gives a short overview to environmental analysis in general.

2.1.1 Transport Networks

The concept of a MTME is applied based on the existing traffic infrastructure. This infrastructure especially includes the transportation networks, allowing for the flow of traffic to get from the starting point to its destination. Scientifically, networks (or graphs) can be understood as "structures that convey energy, matter or information from one point to another"[7]. The idea of transport networks is an analogy that **represents the structure and flow of transport systems** more generally. Transport networks are part of the superclass of spatial networks, because their "design and evolution are physically constrained", unlike "non-spatial networks such as social interactions"[8]. The defining elements of a transport network are "the network geometry and the level of connectivity" which together determine the extent to which the three characteristics of ideal, spatially continuous transport networks – ubiquity, fractionalization, and instantaneity – are achieved.[9]

More specifically, traffic networks can be seen from different perspectives and are spread over all means of transportation. Thus, transport networks encompass "**road, rail, air and water transport networks and related infrastructure"[10] as well as their interconnection points**. Further, the scope of the network also includes traffic management systems[11] and with this is directly interlinked to (intermodal) traffic management.

Furthermore, regarding transportation networks, one can differentiate between the **hardware** of the network, thus the infrastructure itself, as well as the **services** provided by the network. While the first offers the ability for traffic to flow, especially the last opens possibilities for business models and efficiency increases and includes the data provided and digitalization of the network.

[7] Barthélemy, Marc. „Spatial Networks". Physics Reports 499, Nr. 1–3 (Februar 2011): 1–101. https://doi.org/10.1016/j.physrep.2010.11.002.
[8] Rodrigue, J-P et al. (2020) The Geography of Transport Systems, Hofstra University, Department of Global Studies & Geography, https://transportgeography.org.
[9] European Parliament. 1996. Decision No 1692/96/EC of the European Parliament and of the Council of 23 July 1996 on Community Guidelines for the Development of the Trans-European Transport Network. Bd. No 1692/96/EC. OPOCE. https://eur-lex.europa.eu/legal-content/EN/TXT/HTML/?uri=CELEX:31996D1692&from=EN.
[10] European Commission-Joint Research Centre. o. J. „Transport Networks", accessed 22. November 2021. https://inspire.ec.europa.eu, inspire.ec.europa.eu/theme/tn.
[11] European Parliament. 1996. Decision No 1692/96/EC of the European Parliament and of the Council of 23 July 1996 on Community Guidelines for the Development of the Trans-European Transport Network. Bd. No 1692/96/EC. OPOCE. https://eur-lex.europa.eu/legal-content/EN/TXT/HTML/?uri=CELEX:31996D1692&from=EN.

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In conclusion, transport networks are **spatial networks with a geometry and level of connectivity, which can be viewed, theoretically, as a network of overlapping pathways[12] of the modes of transportation.**

2.1.2 Multimodal traffic management

Traffic management is defined as the "**organization, arrangement, guidance, and control of stationary and moving traffic**, including pedestrians, bicycles, and all types of vehicles. It aims to provide for the safe, orderly, and efficient movement of persons and goods, and to protect and, where possible, enhance the quality of the local environment on and adjacent to traffic facilities"[13]. In order to manage an efficient and successful flow of traffic between different modes of transport (road, rail, sea, air), a unified platform that interlinks and coordinates these different transport networks in real-time and in the future is required. Therefore, within the context of traffic management, 'multimodal' refers to the **combination of road, rail, sea, and air traffic networks in an integrated management approach**. However, as of today, a lack of data exchange and communication between the individual networks still exists.

The typical process for an efficient traffic management plan begins by monitoring existing systems, as well as forecasting future economic and demographic developments, to identify future transport needs or challenges, before one then evaluates and prioritizes strategies or projects to meet these, and ultimately designs financial and logistical plans to carry them out[14]. In recent years, road traffic in urban areas has expanded from mainly comprising of motorized vehicles, mostly being cars, to a wide variety of vehicles in different types and sizes, hence creating a more complex ecosystem to manage[15]. Moreover, interactions between different road vehicles, and other modes of transport, such as rail, have been on the rise due to digitalisation. As for air and sea transport, the control and planning of traffic occurs in a similar manner for both, entailing systems that offer guidance and protocol for departure, travel routes including time, and destination arrival procedures.[16] The goal is to be able to provide the most suitable traffic routes in real-time, depending on the set criteria, for different types of transport applications (passenger (private and public), freight, logistics, etc.) by interlinking these transport networks to each other.

Due to the ongoing rapid technological progression and innovation, the future ambition to effectively manage and link multimodal traffic routes, schedules, and networks to each other has become both more vital and achievable.

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[12] Ng, Adolf K.Y., Changmin Jiang, Paul Larson, Barry Prentice, und David Duval. 2018. „Transport Networks and Impacts on Transport Nodes". In Transport Nodal System, 9–28. Elsevier. https://doi.org/10.1016/B978-0-12-811067-6.00002-X.

[13] Robin T Underwood, *Traffic Management: An Introduction* (Melbourne: Hargreen Pub., 1990).

[14] Ghandeharioun, Zahra, Anastasios Kouvelas, Federico Bigi, und Francesco Corman. 2020. *Integrated Multimodal Network Management: An Agent Based Approach.* In , 16. Monte Verità / Ascona. http://www.strc.ch/2020/Ghandeharioun_EtAl.pdf.

[15] Sandjai Bhulai, Dimitris Kardaras, and I Semanjski, *Proceedings of the 7th International Conference on Data Analytics 2018* (IARIA, 2018).

[16] Sandjai Bhulai, Dimitris Kardaras, and I Semanjski, *Proceedings of the 7th International Conference on Data Analytics 2018* (IARIA, 2018).

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2.1.3 Understanding of drivers

Drivers are understood as the elements and forces behind a development that influence this development especially in the long term. On a global scale, drivers can also be seen as mega trends, influencing the development of society as a whole. For example, the UN identifies five megatrends, namely: (1) climate change; (2) demographic shifts, particularly population ageing; (3) urbanization; (4) the emergence of digital technologies and (5) inequalities.[17]

Within this study, drives are understood as legal, technical, economic, and human considerations that can influence (facilitate and prevent) the realisation of the target vision.[18] Hence, these considerations exist in the status quo but have strong interaction with the future developments of MTME.

2.2 Overview stakeholders

Stakeholders or stakeholder groups are groups, directly and indirectly affected by developments and therefore should be integrated in any development process.[19] Within the multimodal traffic management ecosystem, several different stakeholders exist. This makes the development of a multimodal traffic management ecosystem very complex as some stakeholders in the mobility sector can be seen as very niche oriented,[20] while multimodal mobility asks for the combination of different niches.[21]

Generally, stakeholders related to this analysis, can be separated regarding the type of traffic (freight or passenger) and the mode of transportation they are most familiar with (road, rail, water, air). Further, their professional or affiliation, hence how they are affected by MTME, allows for a distinction between them. This includes especially state authorities, private and public companies, NGOs or research organisation. Generally, a combination of any of these aspects is possible. Last, their personal expertise with respect to a specialty is a relevant distinguishing criterion specifically for this analysis. Thus, they can be differentiated within this analysis into more legal, economic and business, safety and security or social focused, corresponding to the focus areas of this analysis.

A detailed description of stakeholders participated by interviews to this study is given in chapter 3.

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[17] United Nations. 2020. 'Shaping the Trends of Our Time'. Report of the UN Economist Network for the UN 75th Anniversary. https://www.un.org/development/desa/publications/wp-content/uploads/sites/10/2020/10/20-124-UNEN-75Report-ExecSumm-EN-REVISED.pdf.

[18] ORCHESTRA Grant Agreement.

[19] Wöhe, Günter, and Ulrich Döring. 2008. Einführung in die allgemeine Betriebswirtschaftslehre. 23., vollst. neu bearb. Aufl. Vahlens Handbücher der Wirtschafts- und Sozialwissenschaften. München: Vahlen.

[20] Schippl, Jens, and Annika Arnold. 2020. 'Stakeholders' Views on Multimodal Urban Mobility Futures: A Matter of Policy Interventions or Just the Logical Result of Digitalization?' Energies 13 (7): 1788. https://doi.org/10.3390/en13071788.

[21] See in regard to MaaS and multimodal mobility: Arnold, Annika, Jens Schippl, and Sandra Wassermann. 2018. Von der Nische in den Mainstream? Über Akteure, Angebote und das Diffusionspotiential von mobility as a service. Stuttgarter Beiträge zur Risiko- und Nachhaltigkeitsforschung Arbeitsbericht, Nr. 37 (September 2018). Stuttgart: ZIRIUS, Zentrum für Interdisziplinäre Risiko- und Innovationsforschung.

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3 Methodology

In this chapter the general approach of the analysis is described. Therefore, first, the general, interdisciplinary approach is described. Afterwards the data collection is outlined more in-depth. The study is based on an interdisciplinary environmental analysis. As stated above, special focus is given to (1) legal and regulatory aspects, (2) actor and market analysis (3) security and safety issues and lastly (4) psycho-sociological, ethical aspects, and acceptance. Furthermore, technical, and organizational considerations are understood as cross-cutting issues and thus elements to all focus analysis. With this approach, the study follows the idea of the PESTLE analysis. From a more interdisciplinary perspective, the PESTLE analysis is very useful. The acronym summarises the external forces of various disciplines: political (e.g., political stability, trade, fiscal, or tax policy), economic (e.g., interest rates, foreign exchange rates, inflation, etc.), socio-demographic (e.g., population growth, demography, cultural trends), technological (e.g., access to new technologies, alternative production chains), legal (e.g., safety laws, certification), and environmental (climate change, carbon footprint).[22] The advantage of the PESTLE analysis with its broad and interdisciplinary approach can also be seen as its downside, thus, being "too generic"[23]. However, by modifying the PESTLE and highlighting elements of critical importance, this criticism could be overcome.

Furthermore, special emphasis is given to the legal and regulatory aspects, as only an efficient regulation will allow for the (future) MTM(E). To implement the MTME in the European market, special attention must be paid to European regulation, which sets the framework for further development in all other areas. For all focuses, two main methods of data collection were applied. On the one hand, primary data could be collected from various interviews. On the other hand, secondary information was gathered from literature The distribution of interviews varies among the focuses, but primary data could be collected for all.

[22] Moser, Christian. 2012. User Experience Design. X.Media.Press. Berlin, Heidelberg: Springer Berlin Heidelberg. https://doi.org/10.1007/978-3-642-13363-3.

[23] Burt, George, George Wright, Ron Bradfield, George Cairns, and Kees van der Heijden. 2006. 'The Role of Scenario Planning in Exploring the Environment in View of the Limitations of PEST and Its Derivatives'. International Studies of Management & Organization 36 (3): 50–76. https://doi.org/10.2753/IMO0020-8825360303.

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The following graph gives an overview of the principal research process for the interdisciplinary environment analysis.

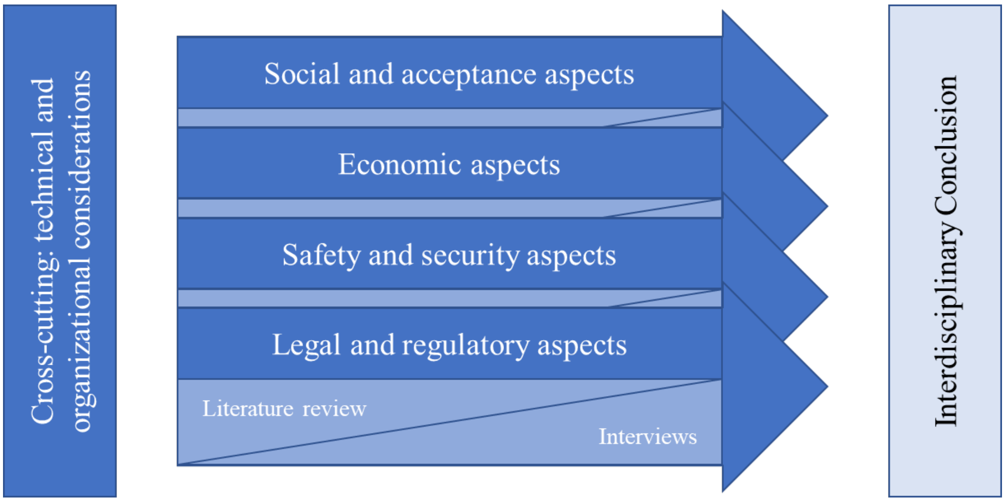

Figure 1: Principal research process

3.1 Literature Review

For each focus analysis, a literature review is performed. Thereby, every discipline follows its individual approach. For the economic analysis, different overview studies were evaluated, and a keyword search was performed. However, the focus is based on primary data evaluation by interview in contrast to the legal analysis. To present the legal framework, the relevant legal norms are identified and examined, using jurisprudential methods. For safety and security aspects, a special focus was given to relevant technical and legal norms and standards, while for the social and acceptance perspective the relevant literature was analysed originating from the most recent publications and including relevant primary resources. For a better understanding of the specific approaches, each result section includes an overview on the performed approach.

3.2 Primary data collection via expert interviews

Semi-structured expert interviews with CoP members and other stakeholders of the MTME concept were undertaken by researchers of HES-SO, IOTA, IKEM and CEREMA. The method of qualitative interviews was chosen because it offers the possibility to collect the expert's opinions on the specific questions, while also providing flexibility and room for the expert's own interpretation.[24] The concept of MTMEs is complex, due to its level of abstraction. Thus, semi-structured interviews provide the benefit of possible clarification, if further queries arise. Since the MTMEs concept of ORCHESTRA is newly contextualised and not yet implemented, qualitative research methods are highly suitable.

3.2.1 Choice of interviewees

The aim of the interviews was to identify the status quo of MTM(E) from the point of view of experts in different fields. To select interviewees, online research regarding relevant stakeholders from the relevant groups was performed and stakeholders were contacted via mail. Furthermore, personal contacts were used to get in touch with stakeholders from authorities, research institutions as well as

[24] See for the benefits of semi-structured qualitative interviews: Blackstone, A. (2012). *Principles of Sociological Inquiry – Qualitative and Quantitative Methods*. Saylor Foundation, p. 108 cont.

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(private and public) companies. The focus was laid on legal, economic, security and social aspects of MTME, as well as on technical and organizational aspects being a cross-cutting factors. Interviewees were selected according to these areas and are specified in the following.

Economic Interview Partners (IKEM)

- ERTICO-ITS Europe (European Road Transport Telematics Implementation Coordination). They are an Intelligent Transportation System (ITS) organisation in Europe that promotes research and defines ITS industry standards. It connects public authorities, industry, infrastructure operators, users, national ITS associations, and other organisations (**Private Sector)**
- Berliner Verkehrsbetriebe (BVG) (**Public transport operator)**. Besides expertise in public transport, they also run the platform “Jelbi” for shared mobility services in the context of MaaS and can therefore give practical insights in traffic management on city level.
- Mobility Inside (**technical service provider)** responsible for digitizing the public transportation sector and developing standards based on the Association of German Transport Companies (Verband Deutscher Verkehrsunternehmen, VDV) and hence an expert in multimodal transportation digitization was interviewed.
- VMZ (**service provider)** who designs, develops, and operates complete control centres, as well as software for analysis and control, data flow management and integration of external data sources.
- Researcher at the Federal Ministry of Transport and Digital Infrastructure (BMVI)
- Researcher at the Technical University of Berlin (TU Berlin)
- Researcher at Bocconi University in Milan

Legal Interview Partners (IKEM)

The choice of interview participants for the legal section, involved several academic partners, as they are intensively involved with (legal) research related to multimodal transport and digitization law. From academia the following interview partners have been chosen:

- a law professor from Universidad Nacional de Educación a Distancia (UNED)
- a law professor from University of Jena (UJ)
- a law professor from University of Roma Tre (UR)

From the category of public authorities:

- The European Union Agency for Railways was interviewed.

Technological Interview Partners (IOTA, HES-SO)

Interview partners from the technological background included:

- a Project Manager from Det Forenede Dampskibs-Selskab (DFDS) whose expertise lies in freight forwarder, passengers and goods, sustainable, and autonomous transportation.
- a Senior Expert, Technical and Policy Advisor from ERTICO-ITS Europe who has expertise in Connected Automated Mobility, ITS, IoT, Digital Infrastructure, DLT.
- a Project Leader at Trondheim Kommune, under the Lighthouse project CityXchange.
- a Professor for computer science at HES-SO Valais
- a Project Manager for innovation in public transport from Transport publics fribourgeoise (TPF)
- a Project Manager at Verkehrsbetrieb Zürich (VBZ)

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- an Employee at Institut für Verkehrsrecht und Verkehrsverhalten (IfVV)
- a Business Developer at YUnex AG
- a Project Coordinator at Swiss Transit Lab, a Future Mobility Network especially piloting and automated driving

Interview partners (CEREMA)

Five semi-directive interviews were conducted, each lasting about 45 minutes, with

- A university professor working on governance issues in the field of passenger transport, mainly but also freight transport
- the Director of Strategy and Development of the Port of Calais
- a Project Manager in the field of air safety
- a Project Manager in the field of urban freight transport
- an international director of a large French food company

3.2.2 Structure of the interviews

Two research questions were posed in the interviews in order to collect insights into a hypothetical MTME:

- **Research question A:** What is the current structure of multimodal transport management from the perspective of logistics and freight transport companies, public authorities, infrastructure managers and IT companies?
- **Research question B:** What are the challenges and starting points for setting up a data exchange system in an integrated multimodal traffic management digital platform?

As an established method of qualitative empirical social research, guideline-based **semi-structured interviews** offer the possibility of targeted data collection. The possibility to ask follow-up questions during the interview to deepen specific topics also gives the format a special flexibility.[25] While creating the interview guide, a brief outline of the topic with detailed questions was used. This proposed outlined guide was divided into four main sections. In Section 0 of the interviews, the interviewees were personified and introduced. The first part of the interviews comprised general questions for all interview participants. This was followed by specific questions that were adapted to the field of expertise and the profession of each interviewee. Discussion questions were asked at the end for an overall impression on the topic.

The questions used in the interview guide structure were primarily derived from discussion group sessions of involved researchers on what questions could be useful for the current state of inter- and multimodal transportation and scholarly literature. Informed consent was signed by interviewees prior to the start of the interview. Interviewers were transparent about their research goals, the interview procedure, the recording of the interview, and the dissemination of potential research results. Interviewees who wish to continue participating in the project, are able to do so as members of the Community of Practitioners (CoP).

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[25] Blackstone, A. (2012). *Principles of Sociological Inquiry – Qualitative and Quantitative Methods*. Saylor Foundation, p. 163-171.

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The questionnaire was designed based on following key aspects:

- Traffic planning in daily operations and bottlenecks
- Digital solutions for traffic management
- Sharing of different data types (B2B and B2A)
- Existing integrated traffic management platform/system and communication platform between interview partners and logistics/freight companies
- Navigation systems used for traffic forecasting
- Real time monitoring of vehicle fleet in daily operations
- Management of multimodal transport
- Usage of autonomous vehicles in transport operations
- Role of sustainability aspects

The questionnaire along with responses are attached in the appendix (Annex A – Interview Protocols) for further analysis.

3.2.3 Evaluation of interviews

In order to evaluate the interview outcomes, the interviews were recorded and transcribed. The informed consent provided by the interviewees covered the permission to record the interview session.

Interview protocols were drafted, using the questionnaire catalogue, that was included in the interview guide. The interview protocols were used as a basis for the further assessment of the results.

Further analysis of the answer's provided by the experts included the identification of key topics, both barriers and drivers, for the future implementation of MTMEs. Those key topics were used to undertake more literature research, as well as research on the regulatory framework in order to create detailed overviews of the legal, economic, security and acceptance perspective.

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4 Results: Legal and regulatory perspective

Policies and regulations are major enablers for the development of a MTME. The status quo of the legal framework will be summarised in this chapter. Based on the thereby determined legal situation, the scope of application of policies and regulations is evaluated and delimited by means of legal interpretation. In the next step, the standards of the scope of application are systematically processed and the respective regulatory contents are presented. Based on the legal framework determined in this way and drawing on the relevant literature, regulatory barriers to MTME are identified and analysed.

4.1 European Union policies

The European Union, in recent years, has established itself as a central figure in the development of a framework for multimodal transport and liberalisation of mobility data.

"Accelerating the shift to sustainable and smart mobility" is one of the objectives of its 2019 ***European Green Deal***.[26] Automated and interconnected multimodal mobility together with intelligent traffic management systems are a focus of the Deal and shall be realised with attention to smart systems for traffic management.

Based on the Green Deal, the European Commission, in December 2020, has published its **"*Sustainable and Smart Mobility Strategy – putting European transport on track for the future*"**.[27] Herein, multimodality is seen as an opportunity to make sustainable and smart alternatives in transport widely available since it "takes advantage of the strengths of the different modes, such as convenience, speed, cost, reliability, predictability, and in combination, can offer more efficient transport solutions for people and goods [and] is also crucial to improving the resilience of our transport system and how ready the public is to embrace sustainable alternative modes of travel".[28]

In its Strategy, the Commission shows great awareness of a number of issues for multimodality that have shown to be crucial in our research for the development of a MTME, too. The Commission intends to resolve barriers to multimodal mobility through various policy actions, including:

- the deployment of ITS, and connected, cooperative, and automated mobility (CCAM), and multimodality through partnerships and harmonisation of relevant traffic rules;
- addressing liability questions for automated vehicles;
- the installation of a specific **agency or body** to support safe, smart, and sustainable road transport operations and the deployment and management of ITS and CAVs in Europe;
- **Technical rules** harmonising the use of CAVs and recharging infrastructures, road safety requirements and data collection;
- adapting the legal framework to close the gap in the **availability and accessibility of data** for multimodal information, ticketing and interoperability of payment services; electronic certificates and freight transport information as well as real time tracking, and tracing of goods shall be explored.

[26] Communication from the Commission, "The European Green Deal", COM(2019) 640 final ("EU Green Deal").

[27] Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions, "Sustainable and Smart Mobility Strategy – putting European transport on track for the future", COM(2020) 789 final ("SSMS").

[28] SSMS, para. 28.

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- updating the technical foundations, notably **technical specifications for interoperability (TSIs)**, to include 5G and satellite data, which will be useful in the development of rail automation and traffic management (para. 62).

To accomplish the mobility objectives, the Commission declares to support the development of new technologies and services and enabling legislative tools. It also highlights the need for an uninterrupted 5G coverage across Europe[29] and AI. The Commission equally proposes to build a European **Common Mobility Data Space** (cf. European Data Strategy). Data availability, access and exchange are recognised as core issues for the digital information of transport and mobility. "Currently, they are often hampered due to unclear regulatory conditions, a lack of an EU market for data provision, the absence of an obligation to collect and share data, incompatible tools and systems for data collection and sharing, different standards, or data sovereignty concerns. The availability of data and statistics is also essential, in particular real time data […]."[30] Cybersecurity, data sharing options within and across sectors, privacy and competition are also key concerns for the Commission.

Moreover, in February 2020, the Commission has announced the ***European Data Strategy***[31] which shall create a single market for data in the EU. The single market for data will allow data to flow within the EU and across sectors, will assure privacy and data protection whilst making data access and data use conditions fair, practical and clear as well as protecting competition. The Commission identifies multiple problems in the data economy. Multiple of these problems are relevant for data in the mobility sector, too:

- Insufficient data sharing between businesses (B2B): A lack of economic incentives and of trust between economic operators leads to data not being shared and reducing its efficient use.
- Lack of private sector data available for use by the public sector (B2G), explicitly also for public services such as mobility management.
- Data interoperability and quality issues "which impede the combination of data from different sources within sectors, and even more so between sectors. The application of standard and shared compatible formats and protocols for gathering and processing data from different sources in a coherent and interoperable manner across sectors and vertical markets should be encouraged".
- Data processing capacities and essential technological infrastructures are missing in the EU, making it dependent on external providers, subject to foreign legislation, and more vulnerable to cyberattacks.
- In the pursuit of the Single EU market for data nine EU-wide common, interoperable data spaces in strategic sectors and domains of public interest, which "aim at overcoming legal and technical barriers to data sharing across organisations, by combining the necessary tools and infrastructures and addressing issues of trust, for example by way of common rules developed for the space"[32] shall be developed. One of these data spaces will be a **Common European mobility data space**, comprising an intelligent transport system, including connected cars as well as other modes of transport. The Commission hopes that this data space "will facilitate

[29] cf. also 5G Action Plan of the European Union.
[30] SSMS, para. 70.
[31] Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions, "A European strategy for data", COM(2020) 66 final ("EU Data Strategy").
[32] EU Data Strategy.

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access, pooling and sharing of data from existing and future transport and mobility databases."[33]

4.2 The Combined Transport Directive as a legal driver for intermodality

One major initial driver for intermodality in the European Union has been the **Combined Transport Directive**.[34] It has as its main objective the "further development of combined transport as an alternative to road transport"[35] and shift road freight to lower emission transport modes (inland waterways, maritime transport, and rail). It, hence, promotes intermodality for the **transport of goods** for three modal combinations:

- road and rail
- road and inland waterway
- road and maritime services.

It applies to ***"Combined transport"***, characterised as following:

- The initial or final leg of the journey are on **road**, and
    - Takes place between the point where the goods are un-/loaded and the nearest suitable rail un-/loading station or
    - Within a radius not exceeding 150km as the crow flies from the inland waterway port or seaport of un-/loading
- The other leg is on **rail/inland waterway/maritime services** and exceeds a distance of 100km as the crow flies.[36]

For these cases of intermodal/combined transport, **liberalisation rules** apply.

Quantitative restrictions are eased or set aside, i.e.

- National road **taxes** on the use or possession of commercial vehicles (listed in Art. 6(3) of the Directive) must be reimbursed
    - either by a standard amount, or in proportion to the extent that they are carried by rail and
    - on the basis of the rail journeys effected within the state or also the rail journey partially/wholly outside the MS (Art. 6 of the Directive)
- Initial or final road haulage legs are exempt from compulsory **tariff** regulations (Art. 8 of the Directive)

Administrative constraints, notably transport documentation obligations (Art. 7 of the Directive), are eased, too. National restrictions on authorisations, tariffs and quotas are forbidden (Art. 2 of the Directive).

The Directive was transposed in all Members States.

In the Sustainable and Smart Mobility Strategy (cf. Section 4.1) the Commission announced a new proposal to amend the Directive intending to make combined transport more attractive by means of

[33] EU Data Strategy.
[34] Council Directive 92/106/EEC of 7 December 1992 on the establishment of common rules for certain types of combined transport of goods between Member States, OJ L 368 ("Combined Transport Directive").
[35] Combined Transport Directive.
[36] Art. 1 of the Directive.

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economic incentives. The adoption of the proposal is planned for the third quarter of 2022. Its contents are still vague. However, an extension of support to a wider set of operations and increased levels of support can be expected.[37]

From a legal point of view **three core issues** for the development of an MTME have been identified in our research. These issues partially reflect the European Unions' priorities of actions.

- The first and major issue involves the role that **data** – and data access and sharing in particular – will play in the MTME.
- Secondly, a MTME will have to comply with existing legislation on **Cybersecurity** as well as **product security and liability.**
- Thirdly, **competition law** considerations must be kept in mind when exchanging information through a MTME.

4.3 Shared data

ORCHESTRA aims at researching a system that ensures the effective exchange of information between key stakeholders such as infrastructure managers, logistics companies, IT companies and other private and public sector companies. Shared data will hence be the backbone of the MTME which shall be developed throughout the project. The MTME will have to collect and manage personal, traffic and road safety data from the different stakeholders.[38] At the same time, data will be shared by the MTME with other networks and stakeholders. **Data creation and collection, data access and data exchange** will thus be the core issues the MTME will have to grapple with.

The following sections will provide an overview of the issues connected to multimodal traffic data. Data collection and processing regulations will be discussed (Section 4.3.1) just like data access (Section 4.3.2), data standards (Section 4.3.5), and the necessary physical and digital infrastructure (Section 4.3.6).

4.3.1 Data collection & processing

Data collection and processing are densely regulated on the EU level. A MTME developed in ORCHESTRA must factor in the provisions which will be presented in this section.

General Data Protection Regulation (GDPR)

The EU Charter of Fundamental Rights as well as the European Convention on Human Rights protect the right to privacy. The European Union has, hence, developed the GDPR as the main safeguard for the protection of privacy and of personal data. The GDPR will apply to all **personal data** collected and processed through the MTME which will be developed in ORCHESTRA.[39]

Regulation on a framework for the free flow of non-personal data (FFD)[40]

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[37] "Sustainable transport – revision of Combined Transport Directive", European Commission, available at: https://ec.europa.eu/info/law/better-regulation/have-your-say/initiatives/13010-Sustainable-transport-revision-of-Combined-Transport-Directive_en, accessed 23.11.2021.

[38] cf. Deliverable 2.1.

[39] The requirements established by the GDPR are detailed in the *Data, Ethics and Gender Balance Plan* (Deliverable 1.3).

[40] Regulation (EU) 2018/1807 of the European Parliament and of the Council of 14 November 2018 on a framework for the free flow of non-personal data in the European Union, L 303/59.

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For **non-personal** data the Regulation on the FFD aims at removing barriers to the free movement of non-personal data, such as **aggregate and anonymised datasets used for big data analytics,**[41] in the EU. These data can be processed and stored anywhere in the EU (i.e., prohibiting all data localization requirements put in place by national authorities, Art. 4), and shall be accessible by competent public authorities all over the EU. The FFD thus allows for increased mobility of non-personal data.

4.3.2 Data access & merging

Access to data is strategic for the development and the functioning of a MTME. Data generated by different actors, especially private ones, will have to be provided to and processed by the ecosystem. Whilst the raw data by itself is only of no to little value, the merging of data in the ecosystem could generate considerable social, environmental, and economic value.[42]

Data access and sharing can take place on different streams between administration(s) and businesses:

A2A and A2B data sharing

The public sector has historically been more active in sharing data with other public authorities or even the private sector. This is also reflected in existing and proposed regulations:

- *Open Data Directive*[43]*:* This Directive aims to make **government-held data** (public sector information, PSI) more easily accessible. Existing documents[44] held by public sector bodies of EU Members States or by certain public undertakings must be **re-usable, and available free of charge for commercial or non-commercial purposes**. Specific rules apply to **"high-value datasets", including mobility data sets** (see Annex I to the Directive), which shall be available free of charge, machine readable, provided via APIs, and provided as a bulk download, where relevant (Art. 13ff). Dynamic traffic data collected by government-held enterprises could thus be subject to these access provisions and make Europe-wide real-time timetable information for local public transport available.[45]

- *Data Governance Act (proposal)*[46]*:* In November 2020, the Commission adopted the proposal for a Regulation on data governance, which shall strengthen data sharing across sectors and the EU through increased trust in data sharing, data availability and eased reuse of data. Most importantly, the proposed Act will – if enacted – enable the **re-use of public sector data by natural or legal persons**, and for commercial or non-commercial purposes other than the initial purpose within the public task for which the data were produced. In contrast to government-held data in the Open Data Act, public sector data is such data held by public sector

[41] Regulation (EU) 2018/1807 of the European Parliament and of the Council of 14 November 2018 on a framework for the free flow of non-personal data in the European Union, L 303/59, rec. 9.
[42] SuM4All, "Sustainable Mobility: Policy Making for Data Sharing", 2021, p. 9.
[43] Directive (EU) 2019/1024 of the European Parliament and of the Council of 20 June 2019 on open data and the re-use of public sector information, L 172/56.
[44] "any content whatever its medium (paper or electronic form or as a sound, visual or audiovisual recording)" and "any part of such content" (Art. 2(6) of the Directive).
[45] Palmetshofer, "Open Data: EU öffnet Datensilos des öffentlichen Sektors", netzpolitik.org, available at: Open Data: EU öffnet Datensilos des öffentlichen Sektors (netzpolitik.org), accessed 2.11.2021.
[46] Proposal for a Regulation of the European Parliament and of the Council on European data governance (Data Governance Act), COM/2020/767 final.

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bodies that is subject to rights of others (i.e. IPR, personal data protection, commercial/statistical confidentiality) and therefore falls outside the scope of the Open Data Act.[47] Data held by public sector bodies, according to the Data Governance Act, cannot be made subject to exclusive arrangements (Art. 4(1)), except in limited circumstances. The Act also aims at making data sharing services more trustworthy by introducing a notification obligation and other requirements for specified services (Art. 10f.).

B2A and B2B data sharing

In the private transport sector, on the other hand, the interviews conducted with practitioners and researchers in the field of (multimodal) transport as well as the literature review have shown that there is great hesitancy to share data with public or other private entities. This can be attributed to various reasons. First, companies have significant expenses when collecting, processing, and cleaning data. In return they expect high returns, lowering incentives to share the valuable data. Data is considered an asset and, in the long run, a competitive advantage. Most interviewees, therefore, expect that companies would tend not to share their data voluntarily. At least for business-critical data, forecast data, and real-time data significant reluctancy on part of the companies can be expected, whereas statistical data might be shared more willingly.[48] Asked for means that could be established to convince companies to share data, the practitioners showed doubts as to the effectiveness of monetary incentives such as tax reductions and remuneration. Instead, regulation is broadly seen as the solution for issues involving data access and use (see the answers to question 3.4 in Annex 1: Interview Protocols). To incentivise companies to participate, enough data must be fed into the ecosystem in order to create an added value through considerable efficiency gains for them. Through regulation the threshold between "not enough data, ergo not enough efficiencies to incentivise companies" and "enough data makes the ecosystem more efficient than transport outside the ecosystem and incentivises companies to participate" could be crossed.

With the ITS Directive[49] and its supplementing delegated regulations, the EU has made an initial step in the regulation of certain sets of mobility data to promote access and interoperability in road transport. They provide a framework for the **acquisition, the processing, and the transmission of mobility data** necessary for the development of Intelligent Transport Systems (ITS).[50] The Commission has termed the ITS Directive "an enabler for increased modal shift and the promotion of sustainable modes of transport"[51]. The Directive is applicable in the field of **road transport** as well as to **interfaces between road transport and other modes of transport**.

The ITS Directive empowers the Commission to adopt delegated acts[52] to implement the technical, functional, and organisational specifications for pre-defined priority actions (Art. 7):

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[47] Council of the EU Press Release, 30 November 2021, available at: https://www.consilium.europa.eu/en/press/press-releases/2021/11/30/promoting-data-sharing-presidency-reaches-deal-with-parliament-on-data-governance-act/, accessed 08.12.2021.

[48] cf. answers in the interviews, Annex 1.

[49] Directive 2010/40/EU of the European Parliament and of the Council of 7 July 2010 on the framework for the deployment of Intelligent Transport Systems in the field of road transport and for interfaces with other modes of transport, available at: https://eur-lex.europa.eu/legal-content/EN/TXT/HTML/?uri=CELEX:32010L0040&from=DE#d1e735-1-1.

[50] Jochum, "Verkehrsdaten für intelligente Verkehrssysteme. Rechtsrahmen und (noch) offene Fragen", ZD 2020, p. 497.

[51] Commission Staff Working Document SWD (2017) 324 final, "The provision of EU-wide Multimodal Travel Information Services – ITS Directive", p. 2.

[52] Art. 290 TFEU.

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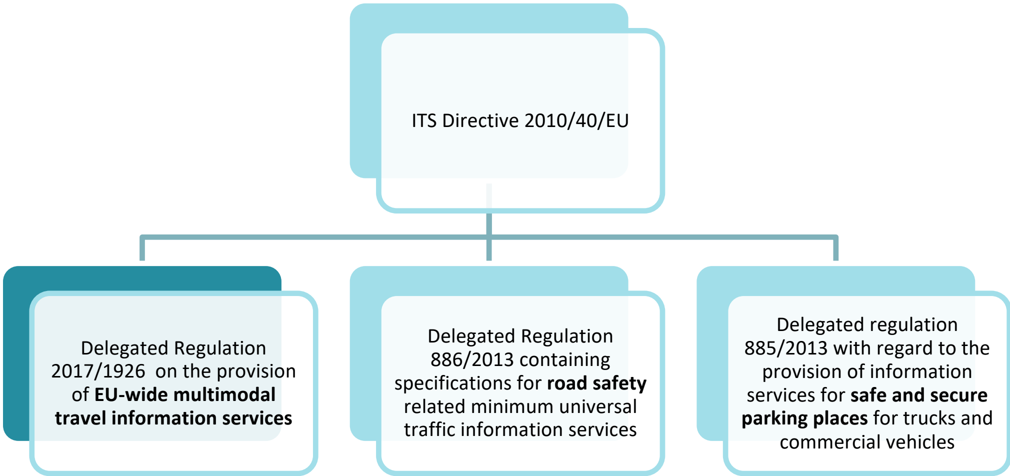

Figure 2: ITS Directive and Delegated Regulations

Most importantly, Delegated regulation 2017/1926 to the ITS Directive "on the provision of EU-wide multimodal travel information services"[53] establishes the necessary technical, functional, and organisational specifications to ensure that EU-wide multimodal travel information services are accurate and available across borders to ITS users (Art. 1). It corresponds to priority action (a) of the ITS Directive[54] and applies to the entire transport network of the EU and aims to support the **interoperability, compatibility, and continuity of multimodal information services** across Europe.[55] The Regulation intends to enable the cooperation between the relevant stakeholders along the travel value chain.[56]

Delegated regulation 2017/1926 introduces a distinction between two data categories:

- **static** travel and traffic data (defined in pt. 1 of the Annex to the Regulation);
- **dynamic** travel and traffic data (defined in pt. 2 of the Annex to the Regulation).

Depending on the data category and the transport mode, standards for data provision are defined (cf. Section 4.3.5). In addition, at least *static travel and traffic data* and *historic traffic data* (Art. 3) must be transferred by the stakeholders to **national access points (NAPs)**, which provide access to these data to users.[57] *Dynamic travel and traffic data* can be provided on a voluntary basis.

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[53] Commission delegated regulation (EU) 2017/1926 of 31 May 2017 supplementing Directive 2010/40/EU of the European Parliament and of the Council with regard to the provision of EU-wide multimodal travel information services.
[54] Priority action (a) comprises the provision of EU-wide multimodal travel information services.
[55] Commission Staff Working Document SWD (2017) 324 final, p. 2.
[56] Commission Staff Working Document SWD (2017) 324 final, p. 2.
[57] A list of national access points is available at: https://ec.europa.eu/transport/sites/default/files/its-national-access-points.pdf.

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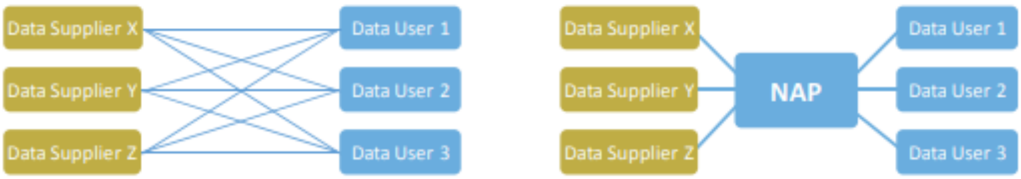

Figure 1: Concepts of data exchange without a NAP (left) and with a NAP (right)

Figure 3: Concepts of data exchange without a NAP (left) and with a NAP (right) (Jorna/Hendriks/Barr/Lubrich)

The relevant **stakeholders** are transport authorities[58], transport operators[59], infrastructure managers[60]**,** and transport on demand service providers[61]**.**

However, the delegated regulation **does not provide for a duty to actively collect and digitalise** the data.[62] *Whether* this data must be collected in the first place, *what* data is collected and *who* collects it is not determined. Only ***existing*** digital travel and traffic data corresponding to one of the data categories must be exchanged and updated. Moreover, mainly static data and only a small fraction of dynamic data, namely road status data, but no data collected by private companies such as private motion profile data collected by online mapping providers or car manufacturers, is incorporated in the regulation.[63] Only travel information service providers, defined as "any public or private provider of travel and traffic information, excluding a mere conveyer of information, to users and end-users", take up a unique role. They may have to provide to another information service provider static and dynamic routing results. For 2021 and 2022 the European Commission has announced the **revision** of the regulation to include greater and obligatory accessibility of new dynamic datasets (see SSMS).

Further delegated regulations based on the ITS Directive include:

- Delegated regulation **No 886/2013**[64] on **road safety related minimum universal traffic information services**: Information on certain road safety-related events shall be collected, made available, exchanged and reused, using the DATEX II (CENT/TS 16157) format or any fully compatibly and interoperable machine-readable format through a NAP.
- Delegated regulation **No 885/2013**[65] regarding the provision of information services **for safe and secure parking places for trucks and commercial vehicles**: There is an obligation to

[58] any public authority responsible for the traffic management or the planning, control or management of a given transport network or modes of transport, or both, falling within its territorial competence (Art. 2).
[59] any public or private entity that is responsible for the maintenance and management of the transport service (Art. 2).
[60] any public or private body or undertaking that is responsible in particular for establishing and maintaining transport infrastructure, or part thereof (Art. 2).
[61] any public or private provider of transport on demand service to users and end-users, in-cluding travel and traffic information thereof (Art. 2).
[62] Jochum, "Verkehrsdaten für intelligente Verkehrssysteme. Rechtsrahmen und (noch) offene Fragen", ZD 2020, p. 499f.
[63] Jochum, "Verkehrsdaten für intelligente Verkehrssysteme. Rechtsrahmen und (noch) offene Fragen", ZD 2020, p. 501.
[64] Commission Delegated Regulation (EU) No 886/2013 of 15 May 2013 containing specifications for road safety related minimum universal traffic information services.
[65] Commission delegated regulation (EU) No 885/2013 of 15 May 2013 supplementing ITS Directive 2010/40/EU of the European Parliament and of the Council with regard to the provision of information services for safe and secure parking places for trucks and commercial vehicles.

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collect, share and exchange data on safe and secure public and private parking areas describing the parking facility. Its objective is to optimise the use of parking places and to facilitate drivers' or transport companies' decisions about when and where to park.[66] DATEX II profiles or other internationally compatible formats shall be used.

- Delegated regulation **2015/962**[67]: Establishes a framework for the accessibility, exchange, re-use and update of road and traffic data by road authorities, road operators and service providers by means of national access points. According to the SSMS the regulation will be revised to extend geographical coverage and datasets.

According to its SSMS Action Plan the Commission has initiated the **revision** of the ITS Directive. The adoption of the proposal is planned for the third quarter of 2021.[68] It will assess infrastructure and traffic/travel data across the EU transport network and aims to also cover new developments in connected and automated mobility as well as online transportation platforms. It shall also include a multimodal ticketing initiative.

4.3.3 Intellectual property rights and ownership of data

For the most part, the attribution of the rights to access and use of (mobility) data is still left to private contract. This is also due to uncertainty regarding intellectual property rights and ownership of data, which restrict access to data on legal grounds. Intellectual property rights and questions regarding the ownership of data can be a big hurdle when trying to gain access to data of stakeholders.

An exclusive property right as such that protects data in general does not exist.[69] Although the notion of "data ownership" exists, it only refers to the de facto holder of data who can decide on its use and trade. Data access and exchange, currently, are largely dominated by a **network of highly individualized contractual agreements** rather than by common rules.[70]

Only for some (sets of) data, specific rights exist that may be utilized to refuse access to data. This is the case for data that fulfils the requirements of traditional intellectual property rights.

- *Copyright law*[71]*:* Since copyright law applies to information created by humans, and which is vested with a minimum of creativity of individuality[72] it does cover raw data collected through sensors or other monitoring mechanisms and will be of little to no relevance for a MTME.
- *Database Directive*[73]*:* Gatekeepers who own databases of transport and traffic data could claim sui generis database protection under the Database Directive, preventing a MTME's access to the data. Only data originating from a protected database, i.e. data emanating from

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[66] Commission delegated regulation (EU) No 885/2013 of 15 May 2013 supplementing ITS Directive 2010/40/EU of the European Parliament and of the Council with regard to the provision of information services for safe and secure parking places for trucks and commercial vehicles, rec. 2.
[67] Commission Delegated Regulation (EU) 2015/962 of 18 December 2014 supplementing Directive 2010/40/EU of the European Parliament and of the Council with regard to the provision of EU-wide real-time traffic information services
[68] no adoption yet (as of 07/12/2021).
[69] Kerber, "Governance of Data", IIC 2016, p. 759; Wiebe, "Protection of industrial data – a new property right for the digital economy?", GRUR Int. 2016, p. 877.
[70] Wiebe/Schur, „Protection of Trade Secrets in a Data-driven, Networked Environment – Is the update already outdated?", GRUR Int. 2019, p. 746, 747.
[71] Kerber, "Governance of Data", IIC 2016, p. 759.
[72] Wiebe, "Protection of industrial data – a new property right for the digital economy?", GRUR Int. 2016, p. 879.
[73] Directive 96/9/EC of the European Parliament and of the Council of 11 March 1996 on the legal protection of databases.

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a "collection of independent works, data or other materials arranged in a systematic or methodical way and individually accessible by electronic or other means" (Art. 1(2)), is protected by copyright. It is the selection and arrangement of its contents which constitutes the author's own intellectual creation and shall be protected. Data that first comes into existence through measurements made by sensors or machine-production and has not (yet) been integrated into a database, on the other hand, is not protected.[74] Insubstantial parts of a database, i.e. parts that did not require substantial investment, also do not fall under the Database Directive's protection unless the taking is repeated and systematic (Art. 7(1)). Additionally, a relevant investment into setting up the database and maintaining it must have been made.
For instance, the CJEU has decided in the *Esterbauer* case[75] that all single elements of a street map constitute relevant elements of a protected database.
The Database Directive is intended to be **reviewed**. The Commissions has set as objectives to clarify the coverage of machine-generated data and correspondent requirements as well as to modify the provisions so to ensure that the Directive does not impede cross-border data flows and data sharing.

- *EU Trade Secrets Directive*[76]*:* The Directive protects know how and trade secrets. Where "reasonable steps under the circumstances" have been taken to keep an information secret, which due to its secrecy has commercial value, factual secrecy must be preserved, and disclosure is precluded.[77] Reasonable steps to assure secrecy include, for instance, encryption measures. The Directive does not protect the data itself though, so that legal protection will dissolve as soon as secrecy is lost.[78] The holder of the secret is the person who has lawful control over it (Art. 2(2)). In a Network industry it will become more and more difficult to determine who is the holder. An information does not automatically lose its secrecy when it is transferred to a third party, as long as the number of people who have knowledge of it is limited and controllable.[79] This would, for instance, be the case where corresponding contractual precautions, such as non-disclosure agreements, have been agreed on. Gatekeepers could, thus, claim that the datasets they collect are trade secrets and cannot be accessed by the MTME.
- *Data protection:* Data protection requirements can also be a barrier to data access (cf. Section 4.3.1).

[74] Wiebe, "Protection of industrial data – a new property right for the digital economy?", GRUR Int. 2016, p. 879.
[75] Case C-490/14, *Freistaat Bayern v Verlag Esterbauer GmbH* [2015].
[76] Directive (EU) 2016/943 of the European Parliament and of the Council of 8 June 2016 on the protection of undisclosed know-how and business information (trade secrets) against their unlawful acquisition, use and disclosure (Text with EEA relevance), OJ L 157.
[77] Wiebe, "Protection of industrial data – a new property right for the digital economy?", GRUR Int. 2016, p. 880.
[78] Wiebe, "Protection of industrial data – a new property right for the digital economy?", GRUR Int. 2016, p. 880.
[79] Wiebe/Schur, „Protection of Trade Secrets in a Data-driven, Networked Environment – Is the update already outdated?", GRUR Int. 2019, p. 746, 747.

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4.3.4 Data Act (Inception Impact Assessment and Consultation)[80]

However, a big amount of data is not protected by traditional IPR law. Especially machine-produced data, such as sensor data which will supposedly be processed in the MTME, and data used in machine-to-machine communication, may not be covered by the above provisions.[81] The European Commission is trying to intervene in this field now through a new Data Act which shall revolutionise B2B and B2A data sharing in the EU Digital Market. It will complement the Open Data Directive and proposed Data Governance Act in creating a fair data economy through **substantial rights on access and use of data**.[82] The Data Act will likely respond to a number of issues which we have identified for the development of an MTME, such as the lack of economic incentives for data holders to share data, the lack of trust between businesses, and the lack of legal clarity on ownership, control and use of data.[83] Observers expect the Data Act to introduce (among other things):

- Requirements on data sharing and transparency in the B2A sphere;
- **B2B transparency obligations** for manufacturers of connected objects on rights to access and use;
- **B2B data access and use rights** potentially on the basis of fair, reasonable, proportionate, transparent and non-discriminatory terms for non-personal data;
- Harmonising horizontal modalities for B2B access to data, which could apply to data access rights established in specific sectoral rules, possibly on fair, reasonable, proportionate, transparent and non-discriminatory terms.[84]

4.3.5 Data standards

Data standardisation has emerged as one of the biggest operational bottlenecks for multimodal traffic management. A lack of interoperability means, users are unable to exchange data in real time, making real-time traffic management impossible. One additional consideration is that standardisations must be widely accepted and implemented.

With ***Delegated regulation 2017/1926*** on the provision of EU-wide multimodal travel information services to the ITS Directive (see above, Section 4.3.2), the EU has already defined some standards for data provision which apply to road transport, the spatial network and other modes of transport:

[80] "Public consultation on the Data Act", European Commission, 3 June 2021, available at: https://digital-strategy.ec.europa.eu/en/consultations/public-consultation-data-act, accessed 23.11.2021; the first proposal is expected to be published in late 2021 (no proposal as of 7.12.2021)
[81] Kerber, "Governance of Data", IIC 2016, p. 759, 760.
[82] "Public consultation: Data Act", available at: https://data.europa.eu/en/news/public-consultation-data-act, accessed 23.11.2021.
[83] Hidaka/Modrall, "EU's possible Data Act: What can we anticipate from the Inception Assessment and the Consultation?", Data Protection Report, available at: https://data.europa.eu/en/news/public-consultation-data-act, accessed 23.11.2021.
[84] Hidaka/Modrall (n 84).

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Table 3: Data standards

	Road transport	Spatial network	Other transport
Static data (Art. 4)	See Art. 4 of Delegated Reg 2015/962: • a standardised format, if available, or • any other machine-readable format	Art. 7 of Directive 2007/2/EC (implemented in Regulation (EU) No 1089/2010)	choice between • NeTEx CEN/TS 16614 and subsequent versions, • technical documents defined in Regulation (EU) No 454/2011 and subsequent versions, • technical documents elaborated by IATA • any machine-readable format fully compatible and interoperable with those standards and technical specifications
Dynamic data (Art. 5)	See Art. 5, 6 Delegated Reg 2015/962: - DATEX II (CEN/TS 16157 and subsequently upgraded versions) format or - any machine-readable format fully compatible and interoperable with DATEX II	-	• SIRI CEN/TS 15531 and subsequent versions, • technical documents defined in Regulation (EU) No 454/2011 or • any machine-readable format fully compatible and interoperable with those standards or technical documents

4.3.6 Data infrastructure

Finally, the lack of physical and digital infrastructure was also highlighted as one of the biggest operational bottlenecks for the development of a MTME. For a MTME to be capable to collect, process, access and distribute data, infrastructures such as towers, cables, servers, networks, and software systems (networking, compute, storage, flow, analytics, AI)[85] must be built, maintained, and protected. In particular, the interviewed practitioners identified 5G and satellite data as core technologies that will have to be deployed.

With the **TEN-T Regulation**[86] the EU has taken first steps to develop the infrastructure for a trans-European transport network (TEN-T). It develops guidelines and requirements for the infrastructure of two intertwined networks:

- the comprehensive network, and
- the core network of highest strategic importance which will be established on the basis of the comprehensive network and its management.

The TEN-T comprises the transport infrastructure and telematic applications as wells as their management and use. Articles detailing infrastructure components for each transport mode and maps annexed to the Regulation specify the network.

[85] SuM4All, "Sustainable Mobility: Policy Making for Data Sharing", 2021.

[86] Regulation (EU) No 1315/2013 of the European Parliament and of the Council of 11 December 2013 on Union guidelines for the development of the trans-European transport network and repealing Decision No 661/2010/EU.

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According to Art. 2(2) of the Regulation, the transport infrastructures of the trans-European transport network also include **multimodal transport**. Multimodal transport is defined in the Regulation as "the carriage of passengers or freight, or both, using two or more modes of transport" (Art. 3 lit. (n) of the Regulation). Sections 6 and 7 of the Regulation define guidelines and individual objectives for the infrastructure for multimodal transport (more details in Annex II). However, provisions on the concrete design, the achievement or requirements of multimodality are not given in the Regulation. The Regulation includes mainly statements of targets and calls to actions targeted towards the EU Member States.

A **revision process of the TEN-T Regulation** was started by the European Commission in 2021, and should end with the adoption of a new legislative proposal, planned for the third quarter of 2021.[87] In its Inception Implementation Assessment for the revision, the Commission made out the Regulation's lack of preparedness for the digital transition in transport as one of three main issues because the Regulation mainly focuses on the development of a physical infrastructure network.[88] The Commission, accordingly, defines as an objective to "[advance] the framework for the digital dimension of TEN-T infrastructure within and between all transport modes" and "[accommodate] infrastructure needs to enable automation and innovative technologies in transport".[89] It can, hence, be expected that multimodality will play a more prominent role in the revised TEN-T Regulation.

4.4 Cyber- and product security law

A MTME will have to comply with a number of cybersecurity provisions while also considering general liability questions. The pertinent Cybersecurity policies and legislative acts will, hence, be introduced and assessed in this section as well as liability considerations.

4.4.1 Cybersecurity

Cybersecurity has emerged as a central issue for the design of an MTME in the interviews and research conducted by IKEM. The MTME must be a reliable digital tool in which consumers like businesses can put their trust.

These finding go hand in hand with the ***EU Cybersecurity Strategy***[90] the EU has adopted in December 2020 and which recognizes the importance of resilience against cyber threats in the EU digital market. The Strategy not only aims at further strengthening cooperation between Member States in the field of cybersecurity but also declared the Commission's objective to enact a number of regulatory and policy measures to

- enhance resilience, technological independence and leadership through broad IT security in both the private and public spheres for the entire EU;
- build operational capacity for prevention, deterrence and response;
- promote a global open cyberspace through enhanced cooperation, also with third countries.

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[87] Dinu, "Revision of the TEN-T Regulation", Implementation Appraisal, European Parliamentary Research Service, June 2021; not yet adopted (as of 07/12/2021).
[88] Dinu (n 88), p. 3.
[89] Dinu (n 88), p. 4.
[90] Joint Communication to the European Parliament and the Council, "The EU's Cybersecurity Strategy for the Digital Decade", JOIN(2020) 18 final.

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A joint **cyber union** is proposed to build the operational capacity for prevention, deterrence and response to cyberattacks. This union would close gaps in intergovernmental cooperation without undermining the competences of the Member States.

Critical Infrastructure Resilience Directive (ECI Directive)[91] Review

One element of the Cybersecurity Strategy is a review of the ECI Directive. The technical challenges of recent years have been found to have outdated the Directive. Hence, a directive replacing it and addressing and building on other existing and planned instruments has been initiated.[92] In great contrast to the ECI Directive, it

- shall not only apply to the energy and transport sectors, but to many more sectors of the economy;
- shall provide a procedure for identifying and designating critical infrastructures using common criteria based on a national risk assessment and through a cross-border dialogue; and
- shall impose obligations on Member States and the critical facilities they identify, which would then be subject to specific oversight.

Network and Information Systems (NIS) Directive[93]

The NIS Directive is intended to achieve a high common level of security of network and information systems in the Union in order to improve the functioning of the internal market. Above all it defines **security requirements and reporting obligations** for

- **operators of essential services**, defined as public or private entities of a type listed in Annex II to the Directive that provides services that are essential for the maintenance of critical social and/or economic activities; the provision of that service must be dependent on network and information systems; a security incident would cause a significant disruption in the provision of that service (Art. 4);
- **providers of digital services**, defined as legal persons who provide a service, usually for remuneration, at a distance by electronic means and at the individual request of a recipient, and which corresponds to a type listed in Annex III to the Directive.

Annex II of the NIS Directive defines various facilities falling under the transport and traffic sector as critical infrastructure (CRITIS). MTM systems are not explicitly described. However, considering the purpose of the provision, a MTME would presumably fall within the scope of CRITIS. The MTMEs will be created as a digital infrastructure through which traffic management between the modes of transport can be made more efficient and coordinated. An attack on this infrastructure would very likely have disruptive effects on the coordination of traffic flows, movement of persons and supply of goods. Member States shall ensure that **operators of essential services** take appropriate and proportionate technical and organisational measures to manage the risks to the security of the network and information systems they use for their activities (Art. 14, 15). Those measures shall ensure a level of security of the network and information systems appropriate to the risk presented,

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[91] Council Directive 2008/114/EC of 8 December 2008 on the identification and designation of European critical infrastructures and the assessment of the need to improve their protection (Text with EEA relevance), OJ L 345.

[92] available at : https://ec.europa.eu/home-affairs/whats-new/evaluations-and-impact-assessments/european-critical-infrastructure_en, last accessed 08.12.2021.

[93] Directive (EU) 2016/1148 of the European Parliament and of the Council of 6 July 2016 concerning measures for a high common level of security of network and information systems across the Union, OJ L 194.

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considering the state of the art. Furthermore, Member States shall ensure that **operators of essential services** take appropriate measures to prevent or minimise the impact of security incidents affecting the security of the network. This obligation also applies to information systems the operators of essential services apply in order to ensure the availability of those services.

4.4.2 Liability framework

The European legal framework for product liability is formed by the ***Directive on the liability of products***[94], as well as a non-harmonised EU-wide regime of **national regulation**.[95] However, emerging technical development may reduce the effectiveness of the existing liability regime, which is not tailored specifically to apply to artificial intelligence (AI) and the Internet of Things (IoT).[96] In regard of the emerging importance of AI the European Commission has issued a White Paper on the topic.[97]

The Commission has, equally, issued a ***proposal for an Artificial Intelligence Act***[98]. The proposal defines AI as software that uses, amongst other possible features, knowledge-based approaches, or optimisation methods[99], which generate outputs (content, predictions, recommendations, decisions influencing the environment they interact with) for a set of human-defined objectives (Art. 3(1)). Software used for the technical tools which will be developed in ORCHESTRA, in particular the decision support Tool[100] but also other tools, might fall within this definition. These tools will have to take into account the following provisions to be adopted:

- Certain **practices of the use of AI will be prohibited** (Art. 3). However, the use of AI for the implementation of MTMEs, as foreseen through the ORCHESTRA concept, does not include any of the prohibited methods listed in the proposal at this stage.
- Certain **high-risk AI systems** are identified (Art. 6). For instance, any AI systems used for the management and operation of critical infrastructure are high-risk AI systems (Annex III). This is particularly relevant for AI systems intended to be used as safety components in the management and operation of road traffic.[101] Accordingly, AI systems developed in ORCHESTRA must meet special requirements applicable to high-risk AI systems, such as the implementation of risk management systems, training and validation methods in connection to data and data governance, technical documentation, record-keeping, transparency and provision of information to users, human oversight, as well as accuracy, robustness and cybersecurity (Art. 9-15). Before entering the market high-risk AI systems must undergo a conformity assessment, where the compliance with the relevant requirements is demonstrated (Art. 43).

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[94] Directive (EU) 85/374/EEC of 25 July 1985 on the approximation of the laws, regulations and administrative provisions of the Member States concerning liability for defective products, 7.8.1985, OJ L 210, 7.8.1985.
[95] EC, Report on the safety and liability implications of Artificial intelligence, the Internet of Things, and robotics, 19.02.2020, COM(2020) 64 final, p.12.
[96] ibid., p.13.
[97] EC, White Paper – On Artificial Intelligence – A European approach to excellence and trust, 19.02.2020, COM /2020), 65 final.
[98] Proposal for a regulation of the European Parliament and of the Council laying down harmonized rules on artificial intelligence (Artificial intelligence Act) and amending certain Union legislative acts, 21.04.2021, COM(2021) 206 final; presumably to be adopted in the third quarter of 2022.
[99] Artificial Intelligence Act, Annex I – Artificial Intelligence Techniques and Approaches.
[100] Decision support based on arbitration models which assist the result of the arbitration, with a priority sequence as outcome.
[101] Artificial Intelligence Act, Annex III, High risk systems referred to in Art 6 (2) Nr. 2 a).

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- Furthermore, **obligations for different actors** involved in the use of high-risk AI systems are proposed. It distinguishes between the obligations for providers of high-risk AI systems (Art. 16), product-manufacturers (Art. 24), obligations for importers (Art. 26), obligations of distributors (Art. 26), users and other third-parties (Art. 28, 29).

4.5 Competition law

Although research into competition law in the data economy is still in its early stages, some initial ideas, which should be factored in when developing a MTME shall be presented in this section.

On the one hand, the sharing and trading of data can have significant pro-competitive effects, increasing efficiency and encouraging innovation as well as preventing the tipping of markets towards data-monopolists.[102] On the other hand, anti-competitive effects could materialize. Participating entities may use the shared data to collude, to abuse the market position they have obtained by accessing or holding vast amounts of data, and even to use the data to exclude competitors, when access to information in the pool becomes indispensable to be able to enter the market.[103] Agreements as to the sharing of digitalized information of the transport sector within a MTME and co-operation between actual or potential competitors can thus become a problem from a competition law perspective.

The exchange of data in the MTME is not anti-competitive from the outset. In particular, it will probably be compatible with European competition law depending on the type of information exchanged. Whereas the sharing of strategic data (e.g., pricing, output and innovation data) between competitors likely amounts to concertation, "because it reduces the independence of competitors' conduct on the market and diminishes their incentives to compete"[104], exchanges of non-individualised data or data where the recognition of individual company level information is sufficiently difficult as well as more technology-oriented data[105], will less likely lead to restrictions.[106] The Commission's Horizontal Guidelines also find that: "The exchange of historic data is unlikely to lead to a collusive outcome as it is unlikely to be indicative of the competitors' future conduct or to provide a common understanding on the market".[107] Finally, public exchanges of information may also be less likely to impede competition, although not excluded.[108] This may be the case if the exchanged data is equally accessible to all competitors and customers.

Companies should share their data anonymously in the MTME and the MTME will have to return aggregated data with no indication of the company it comes from.[109] The participants in the MTME should contractually restrict themselves from exchanging any information that could be competition sensitive, notably strategic information regarding price and innovation.[110]

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102 Communication from the Commission — Guidelines on the applicability of Article 101 of the Treaty on the Functioning of the European Union to horizontal co-operation agreements ("Horizontal Guidelines"), para. 2.
103 Horizontal Guidelines, para. 3
104 Horizontal Guidelines, para. 61.
105 Lundqvist, „Competition and Data Pools", EuCML 2018, p. 146, 149.
106 Horizontal Guidelines, para. 89.
107 Horizontal Guidelines, para. 90.
108 Horizontal Guidelines"), para. 94.
109 this has, for instance, been proposed by Margrethe Vestager, see Lundqvist, „Competition and Data Pools", EuCML 2018, p. 146, 152.
110 Lundqvist, „Competition and Data Pools", EuCML 2018, p. 146, 149.

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5 Results: Economic and Market Perspective

This chapter summarizes the main results from the economic and business perspective concerning the status quo of MTME. First, literature results are presented, followed by a summary of the undertaken interviews.

5.1 Literature review

For the literature review from a business and economic perspective, an in-depth literature analysis is done. As a first step, a Google Scholar search is performed, where the key word "multimodal traffic management" is applied individually and connected to relevant business or economic terms. This offered the advantage of a broad search covering publications of the last 5 years which included not only papers, but studies as well(results can be seen in Figure XYZ). Furthermore, relevant sources of these publications (related primary sources) were checked and additionally literature from partners was added. Lastly, the literature search was more widened to "traffic management" in general, to include general aspects of MTM into the economic and business review since only a limited number of sources focusing on MTM exist. For identifying current drivers, alongside the listed drivers in the existing publications, additional research aimed at current "mega trends" is performed and linked to multimodal traffic management when relevant.

As seen in the graph below, the importance of MTM is growing over time, however, the amounts of publications related to MTM remains low. Nevertheless, for 2021 an increase in the economic and business-related publications are visible. In particular, within the last 5 years (data from 2016-21) no hits for "multimodal traffic management ecosystems" are found.[111]

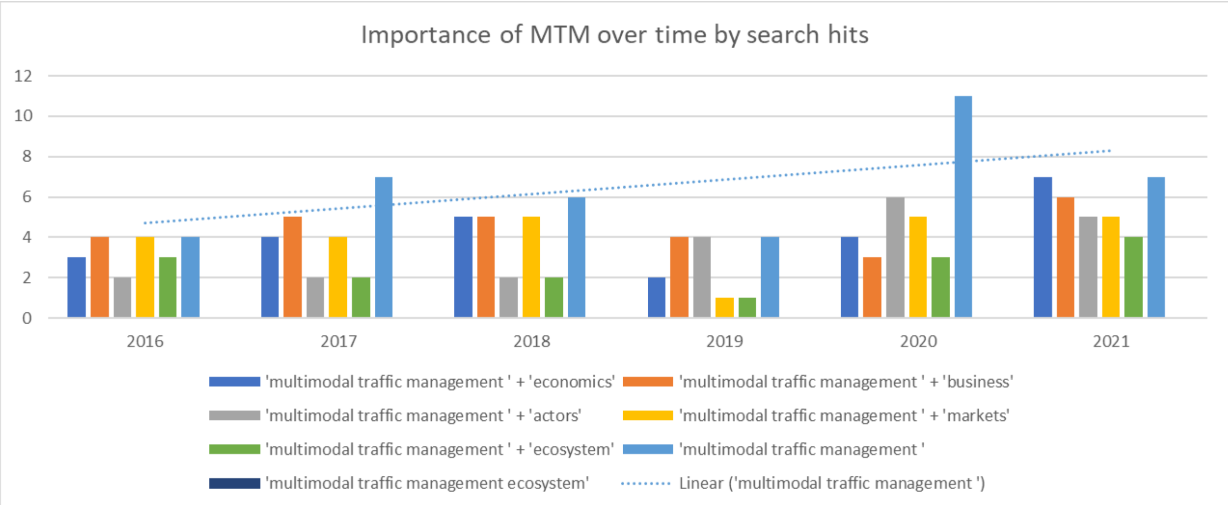

Figure 4: Analysis of importance of multimodal traffic management form an economic perspective by hits

In the following first the current status quo regarding multimodal traffic management (environments) is presented. This includes obstacles for the implementation of MTM(E), current developments and business models (opportunities). Following drivers for MTM(E) named in the literature are presented.

[111] The overview analysis is based on a key word search in google scholar (status November 2021)

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5.1.1 Business and economic status quo of multimodal traffic management

The following briefly presents the status of multimodal traffic management from a business and economic perspective in general and some of the basic problem areas/barriers associated with it. One of the main problems addressed in this context are the economic effects of traffic congestion, which significantly limit traffic efficiency and can be minimized through well-orchestrated traffic management. The costs that arise in this context are numerous. Connections to air and noise pollution, stress, and quality of life can be made. However, the primary costs can be broken down to the time of the people directly or indirectly involved and the operating costs of the vehicles.[112] Currently, traffic congestion is composed of physical bottlenecks (40%), traffic incidents (25%), bad weather conditions (15%), work zones (10%), poor traffic signal timing (5%) and special events (5%).[113] Today, traffic management is related to silo mentality, not taking advantage of the potential benefits of using the entire possible traffic network of all modes. For example, road and railway managers optimize their performance separately, the complementarity and possible synergy of the modes is ignored in most traffic control approaches.[114] As transportation of persons and goods (especially in urban areas) has become increasingly complex, a need for managing diverse transportation modes, interactions between them and the traffic they cause emerged.[115] Here, MTME comes into play to overcome these barriers and open new business opportunities for several different actors. Making optimal use of existing transport corridors and modes, the overall efficiency of traffic flow can be improved. In doing so, the MTME seeks to "[…] exploit the full potential of deployed intelligent transport technologies to improve not only the operation and performance of the network but also the demand traveling in the network, influenc[ing] the mode choice, travel time, delay, fuel consumption and emissions."[116] In the following, the relevance of an MTME is examined more specifically for both the passenger and freight transport sectors.

5.1.1.1 Business and economic relevance of MTMEs in passenger transport

The current and arising business opportunities related to multimodal mobility and thus multimodal traffic management are manifold. MTME can especially be linked to the Mobility as a Service (MaaS) concept, which can be described as the "integration of various forms of transport services into a single mobility service accessible on demand."[117] These services help support individuals to find the fastest and most convenient transport connection with the most suitable mode of transport in a specific

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[112] Alberto Bull, United Nations, and Deutsche Gesellschaft für Technische Zusammenarbeit, eds., *Traffic Congestion: The Problem and How to Deal with It*, Cuadernos de La CEPAL 87 (Santiago, Chile: United Nations, Economic Commission for Latin America and the Caribbean, 2003), p. 39, https://repositorio.cepal.org/bitstream/handle/11362/37898/1/LCG2199P_en.pdf.

[113] Allan De Souza et al., 'Traffic Management Systems: A Classification, Review, Challenges, and Future Perspectives', *International Journal of Distributed Sensor Networks* 13, no. 4 (1 April 2017): 14, p. 2, https://doi.org/10.1177/1550147716683612.

[114] Zahra Ghandeharioun et al., 'Integrated Multimodal Network Management: An Agent Based Approach' (Swiss Transport Research Conference, Monte Verità / Ascona, 2020), p. 16, http://www.strc.ch/2020/Ghandeharioun_EtAl.pdf.

[115] Ivana Semanjski and Sidharta Gautama, 'Big Data-Driven Multimodal Traffic Management: Trends and Challenges', in *Proceedings of the 7th International Conference on Data Analytics 2018* (IARIA, 2018), p. 150.

[116] Ivana Semanjski and Sidharta Gautama, 'Big Data-Driven Multimodal Traffic Management: Trends and Challenges', in *Proceedings of the 7th International Conference on Data Analytics 2018* (IARIA, 2018), p. 150.

[117] Stephanie Leonard, Laura Coconea, and Vassilis Mizaras, 'Traffic Management 2.0 – Mobility as a Service Task Force', Final Report, June 2019, https://tm20.org/wp-content/uploads/sites/8/2019/08/TM2.0-TF_MaaS_Final_Report_v3.0.pdf.

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situation through a single service[118] and contributing to a smooth traffic flow[119]. The combination of MaaS and (multimodal) traffic management enables road operators "to optimize the multimodal network capacity thanks to the use of all vehicles and transport modes"[120]. So, the efficiency of the overall network can be increased by avoiding congestions and increasing vehicle utilization. Another service closely linked to the implementation of multimodal traffic management and MaaS is to find the most suitable path to every user of the MTM system. To do so, "the real time situation of the selected modes of transport"[121] need to be considered. This opens business opportunities to software companies as well as to traffic and transportation planners, as the results of the route analysis can be again an input for further planning of multimodal traffic systems. Other options include optimization of parking (not only for private users, but as well for freight transport on highways) or traffic management.[122] Furthermore, a demand for "advanced transportation analysis tools to estimate and predict network performance under different strategies and analyze the network for different tactical purposes"[123] might emerge, ideally leading to a self-learning system with several business opportunities.

The economic relevance of MTME results directly from the problem areas addressed. If the commute in passenger transport is particularly long for (utility-maximising) individuals due to traffic congestion, this can play a role in the decision of total working time, since more time is spent in traffic, which at the same time means less leisure hours and less pay for time spent. This can be interpreted as an effective reduction in the individual's hourly wage and could accordingly shift their decision towards less working time and more leisure time. In macroeconomic terms, this would represent a reduction in productivity.[124] Moreover, additional attrition of the mobility objects (car, train etc.) would occur and additional units of fuel such as electricity or petrol would be consumed, further enhancing (external) costs.

5.1.1.2 Business and economic relevance of MTMEs in freight transport

The same applies to freight transport. Complex manufacturing processes require extensive transport of goods in different modes of transport. Unforeseen delays can negatively affect the manufacturing process and negatively affect supply chains, which can also have a direct impact on product prices.

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[118] Laura Coconea et al., 'Insights on Traffic Management in the MaaS Value Chain' (13th ITS European Congress, Eindhoven, Netherlands, 2019), p. 9, https://pure.tue.nl/ws/portalfiles/portal/146413392/ITS19_Brainport_Paper_Turetken.pdf.

[119] Susanne Boll-Westermann et al., 'AI Business Models for Travel and Transport', 2020, p. 5, https://en.acatech.de/publication/ai-business-models-for-travel-and-transport/download-pdf?lang=en_excerpt.

[120] Laura Coconea et al., 'Traffic Management: The Invisible Actor in the MaaS Value Chain' (International Scientific Conference on Mobility and Transport Mobil.TUM 2019, Munich, Germany, 2019), p. 2, https://webarchiv.typo3.tum.de/BGU/mobil-vt/fileadmin/w00bqi/www/mobilTUM2019/Sessions/Posters/6052_abstract.pdf.

[121] Mohamed El moufid et al., 'An Architecture of an Interactive Multimodal Urban Mobility System', *International Journal for Simulation and Multidisciplinary Design Optimization* 10 (2019): A13, https://doi.org/10.1051/smdo/2019015.

[122] Mohamed El moufid et al., 'An Architecture of an Interactive Multimodal Urban Mobility System', *International Journal for Simulation and Multidisciplinary Design Optimization* 10 (2019): A13, https://doi.org/10.1051/smdo/2019015.

[123] Zahra Ghandeharioun et al., 'Integrated Multimodal Network Management: An Agent Based Approach' (Swiss Transport Research Conference, Monte Verità / Ascona, 2020), p. 16, http://www.strc.ch/2020/Ghandeharioun_EtAl.pdf.

[124] OpenStax, '6.3 Labor-Leisure Choices', 2016, https://opentextbc.ca/principlesofeconomics/chapter/6-3-labor-leisure-choices/.

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The fragility of this system at certain bottlenecks was demonstrated in 2021 when a container ship got stuck in the Suez Canal and blocked it, obstructing the passage of around USD 10 billion worth of goods over the course of a few days.[125] In summary, the economic relevance of an efficient traffic flow can be attributed a high value. MTME can be a possible solution to many of the problems named in order to make traffic management more holistic and efficient.

Currently, international logistics chains across multiple modes of transport in their various individual stages and with their different operating actors within these stages are characterized by a lack of (real-time) information on the other phases of the whole logistic chain.[126] This leads to considerable inefficiencies due to e.g., waiting times, interrupted schedules, and traffic routes etc. One promising technology to support freight transportation and logistics chains in a more reliably, cost-effective, and energy-efficient manner are artificial-intelligence-assisted (AI-assisted) logistics and transport systems, which are expected to be feasible in about five years.[127] Different actors of logistic chains (carriers (air, maritime, rail, road) / handling agents / forwarder / express courier (last mile)) themselves could optimize their services via AI and therefore improve efficiency and sustainability of freight transport.[128] However, this implies the need to real time data from multimodal traffic management. Also, data management service provider can improve nodes in-between actors within logistic chains and therefore improve the whole system of freight transport.

5.1.2 Summary of Gaps and Barriers

The following main gaps/barriers for the current state of traffic management can be summarized:

- Poor traffic efficiency due to lack of orchestration of different modes of transportation (traffic management in silos) in both passenger and freight transport.
- Reduction in productivity due to commuting times (caused by congestion).
- Increase of external costs due to inefficiencies.
- Lack of (real-time) information for various dependent actors in logistic chains leading to inefficiencies in freight transport (and passenger transport).
- Forecast of future weather or traffic events and their impact on traffic insufficiency (forecasting capacities).

It can be expected that these gaps/barriers could be filled/overcome by the implementation of a multimodal traffic management network.

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[125] Mary-Ann Russon, 'The Cost of the Suez Canal Blockage', *BBC News*, 29 March 2021, sec. Business, https://www.bbc.com/news/business-56559073.

[126] AHM Shamsuzzoha and Petri T Helo, 'Real-Time Tracking and Tracing System: Potentials for the Logistics Network', in *Proceedings of the 2011 International Conference on Industrial Engineering and Operations Management* (Kuala Lumpur, Malaysia, 2011), http://www.iieom.org/ieom2011/pdfs/IEOM038.pdf; Zhaojing Wang et al., 'Blockchain-Based Framework for Improving Supply Chain Traceability and Information Sharing in Precast Construction', *Automation in Construction*, no. Volume 111 (March 2020); Frederico Capello, Marco Toja, and Natalia Trapani, 'A Real-Time Monitoring Service Based on Industrial Internet of Things to Manage Agrifood Logistics', in *Proceedings of the 6th International Conference on Information Systems, Logistics and Supply Chain* (Bordeaux, France, 2016), http://ils2016conference.com/wp-content/uploads/2015/03/ILS2016_FB01_1.pdf.

[127] Susanne Boll-Westermann et al., 'AI Business Models for Travel and Transport', 2020, p. 2, https://en.acatech.de/publication/ai-business-models-for-travel-and-transport/download-pdf?lang=en_excerpt.

[128] For details on respective actors see: Susanne Boll-Westermann et al., 'AI Business Models for Travel and Transport', 2020, p. 3-4, https://en.acatech.de/publication/ai-business-models-for-travel-and-transport/download-pdf?lang=en_excerpt.

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5.1.3 Techno-economic challenges of MTMEs

Different technical challenges are related to (a possible implementation of) multimodal traffic management ecosystems affecting an economic implementation as well as offering new business opportunities.

Among many other areas of application, especially Big Data has also brought disruptive changes to Intelligent Transportation Systems (ITS)[129] and traffic management in general. Various sources of data like Global Navigation Satellite Systems (GNSS) data, mobile network data and mobile sensed data obtained from ubiquitous digital devices and connected technologies offer new possibilities to replace "traditional data collection methods for mobility studies"[130] on the one hand and at the same time open opportunities to enhance the performance of traffic management immensely[131]. Big Data in traffic management offers business opportunities due to the value of movement patterns and at the same time can be a threat to privacy when personal data and individual mobility is evaluated.[132]

Inherent to Big Data are technical challenges regarding capturing, storage, analysis, and visualization of data[133] which seem to hinder its exploitation for traffic management and until now allow for so called "shallow traffic prediction models" that focus on traffic flow of motorized transportation only[134]. Existing procedures in ITS seem to be incapable to utilize Big Data comprehensively due to its sheer magnitude and heterogeneity.[135] This must apply even more for multimodal traffic management (ecosystems) with sets of data from various modes of transportation and even more individual sources of data within them. Therefore, new tools and systems are needed to control and direct the flood of data to bring actual benefits in traffic management.[136]

In order for the system to be introduced, all necessary information regarding traffic (in different modes), anticipated traffic development, weather, etc. must first be collected in an initial information gathering phase (1). Since this information comes from different sources, it must be further combined

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[129] Sasan Amini, Ilias Gerostathopoulos, and Christian Prehofer, 'Big Data Analytics Architecture for Real-Time Traffic Control', in *Proceedings of the 5th IEEE International Conference on Models and Technologies for Intelligent Transportation Systems (MT-ITS) 2017* (Naples, Italy, 2017), https://doi.org/10.1109/MTITS.2017.8005605.

[130] Ivana Semanjski and Sidharta Gautama, 'Big Data-Driven Multimodal Traffic Management: Trends and Challenges', in *Proceedings of the 7th International Conference on Data Analytics 2018* (IARIA, 2018), p. 149.

[131] Sasan Amini, Ilias Gerostathopoulos, and Christian Prehofer, 'Big Data Analytics Architecture for Real-Time Traffic Control', in *Proceedings of the 5th IEEE International Conference on Models and Technologies for Intelligent Transportation Systems (MT-ITS) 2017* (Naples, Italy, 2017), https://doi.org/10.1109/MTITS.2017.8005605.

[132] Ivana Semanjski and Sidharta Gautama, 'Big Data-Driven Multimodal Traffic Management: Trends and Challenges', in *Proceedings of the 7th International Conference on Data Analytics 2018* (IARIA, 2018), p. 150.

[133] Fernando Almeida and Catalin Nicolae Calistru, 'The Main Challenges and Issues of Big Data Management', *International Journal of Research Studies in Computing*, no. Volume 2 Number 1 (April 2013): 11–20 (16ff.), https://doi.org/10.5861/ijrsc.2012.209.

[134] Ivana Semanjski and Sidharta Gautama, 'Big Data-Driven Multimodal Traffic Management: Trends and Challenges', in *Proceedings of the 7th International Conference on Data Analytics 2018* (IARIA, 2018), p. 150.

[135] Sasan Amini, Ilias Gerostathopoulos, and Christian Prehofer, 'Big Data Analytics Architecture for Real-Time Traffic Control', in *Proceedings of the 5th IEEE International Conference on Models and Technologies for Intelligent Transportation Systems (MT-ITS) 2017* (Naples, Italy, 2017), https://doi.org/10.1109/MTITS.2017.8005605.

[136] Sasan Amini, Ilias Gerostathopoulos, and Christian Prehofer, 'Big Data Analytics Architecture for Real-Time Traffic Control', in *Proceedings of the 5th IEEE International Conference on Models and Technologies for Intelligent Transportation Systems (MT-ITS) 2017* (Naples, Italy, 2017), https://doi.org/10.1109/MTITS.2017.8005605.

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into a functioning data set in an information processing phase (2). In the final phase (3), the service must be provided, i.e. it must reach the end user.[137]

5.1.4 Techno-economic gaps and barriers

Comparing today's status quo with MTME's vision for the future, some challenges emerge. In phase 1, the necessary infrastructure, i.e. sensors, chips, cameras, etc., must first be installed on a large scale, leading to an intensive demand of investment. In phase 2, the collected data derives from a variety of different sources, which brings up the problem of integrating heterogeneous data. Data standardization and compatibility is thus a prerequisite for the functioning of the system and can be considered a (financial) challenge. Further, different agencies may collect their real-time data asynchronously, which can lead to an incomplete or time-delayed real-time data evaluation. The sheer size of the data collected also poses a problem, as processing it requires enormous computing power and thus leads again to investments needs and additional operation costs. In addition, the algorithms used must be able to classify and weight the collected data appropriately in order to realistically depict the traffic profile. These algorithms must also take into account the traffic flows on the alternative routes when re-routing suggestions are made, so that no undesired traffic congestion forms on the alternative routes.[138]

In conclusion, there are still some serious challenges to the implementation of such a system, from a technical as well as from an economic perspective. However, overcoming them seems worthwhile when considering the negative economic effects of inefficient traffic flow and the positive effects of optimized traffic flow and new, data driven business opportunities. Even more so if autonomous vehicles are to be integrated in existing traffic flows in the future.[139]

5.1.5 Drivers to multimodal traffic management from an economic perspective

The literature shows two main sources for economic drivers for multimodal traffic management. On the one hand, technological developments (e.g., increasing amounts of data[140], type of data creation[141], but as well increasing computation power) can be named, on the other hand, sustainable

[137] Allan De Souza et al., 'Traffic Management Systems: A Classification, Review, Challenges, and Future Perspectives', *International Journal of Distributed Sensor Networks* 13, no. 4 (1 April 2017): 14, p. 3, https://doi.org/10.1177/1550147716683612.

[138] Allan De Souza et al., 'Traffic Management Systems: A Classification, Review, Challenges, and Future Perspectives', *International Journal of Distributed Sensor Networks* 13, no. 4 (1 April 2017): 14, p. 11f., https://doi.org/10.1177/1550147716683612.

[139] Ivana Semanjski and Sidharta Gautama, 'Big Data-Driven Multimodal Traffic Management: Trends and Challenges', in *Proceedings of the 7th International Conference on Data Analytics 2018* (IARIA, 2018), p. 152.

[140] Krispin Raich et al., 'Spatial Extension Model for Multimodal Traffic Management', in *Proceedings of the 2020 4th International Conference on Vision, Image and Signal Processing* (ICVISP 2020, Bangkok Thailand: ACM, 2020), 1–6, https://doi.org/10.1145/3448823.3448854.

[141] Ivana Semanjski and Sidharta Gautama, 'Big Data-Driven Multimodal Traffic Management: Trends and Challenges', in *Proceedings of the 7th International Conference on Data Analytics 2018* (IARIA, 2018), p. 149.

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efforts for the mobility sector[142] (leading for instance to new business models like shared services[143]) must be accounted. Both lead to economic shifts within the transport sector, from a car-centric traffic management[144] to a multimodal mobility and thus the demand for multimodal traffic management.

Modern business models often emerge at the boundary of modes of transportation and represent a key driver. This includes for instance "Mobility as a Service" (MaaS) concepts and is based on the combination of new technologies and the goal of more sustainable transport. MaaS is a rapidly growing market with an estimated volume of over 450 billion US dollars in 2030 in the European Union alone[145]. By applying MTM(E) in combination with Mobility as a Service (MaaS) approaches, added value can be already created e.g., by using a "sole payment channel instead of multiple ticketing and payment operations", leading to a "more efficient use of the [city] transport system"[146]. The combination of new technologies and the goal of more sustainable transport can as well be seen in the freight sector, where big data solutions allow for a better forecast of traffic and "intermodal freight options have the potential to provide significant community benefits"[147] which includes emission reductions.

Furthermore, external factors are driving the need for multimodal traffic management from an economic perspective. Thus, increasing urbanization[148] will lead to an increase in mobility demand in cities, demanding for an efficient passenger transportation and multimodal traffic management. Additionally, social aspects, for instance the increase in the e-commerce market[149] leads to a higher demand of freight transport within cities and with this to the need of a sustainable, multimodal traffic management.

In a nutshell, technology and the need for sustainable transportation is driving the need for an efficient, multimodal traffic management system. External factors do strengthen this process. New business models are already taking advantage of this development, and from an economic perspective,

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[142] Casper Van Gheluwe et al., 'Geospatial Dashboards for Intelligent Multimodal Traffic Management', in *2020 IEEE International Conference on Pervasive Computing and Communications Workshops (PerCom Workshops)* (Austin, TX, USA, 2020), 1–3, https://doi.org/10.1109/PerComWorkshops48775.2020.9156231; Stephanie Leonard, Laura Coconea, and Vassilis Mizaras, 'Traffic Management 2.0 – Mobility as a Service Task Force', Final Report, June 2019, https://tm20.org/wp-content/uploads/sites/8/2019/08/TM2.0-TF_MaaS_Final_Report_v3.0.pdf.

[143] TM2.0. 'Task Force 21: TM2.0 - Multimodal Mobility'. Final Draft V 3.1, 7 September 2020. https://tm20.org/wp-content/uploads/2020/10/TM-2.0-Maas-Alliance-report-for-Task-Force-on-Multimodal-mobility-final....-4.pdf.

[144] Delphine Grandsart et al., 'TMaaS: An Innovative, Multimodal and User-Centred Approach to Traffic Management', in: Beate Müller and Gereon Meyer, eds., *Towards User-Centric Transport in Europe 2*, Lecture Notes in Mobility (Springer International Publishing, 2020), 102–116 (102).

[145] Statista Research Department, 'Market Size of Mobility-as-a-Service (MaaS) in the European Union (EU) in 2017, with Forecasts for 2025 and 2030', 14 March 2021, https://www.statista.com/statistics/1002916/mobility-as-a-service-eu-market-size/.

[146] Laura Coconea et al., 'Insights on Traffic Management in the MaaS Value Chain' (13th ITS European Congress, Eindhoven, Netherlands, 2019), p. 10, https://pure.tue.nl/ws/portalfiles/portal/146413392/ITS19_Brainport_Paper_Turetken.pdf.

[147] Laura Coconea, 'FENIX Network: Deliverable 6.2.1: Definition of Scenarios for Coordination of Multimodal Traffic Management Plans, at Cross-Border and Urban/Interurban Integration', Final Version, 31 March 2020, p. 13, https://fenix-network.eu/wp-content/uploads/2020/07/FENIX_Deliverable-6.2.1_FINAL.pdf.

[148] Statista Research Department. 'Prognose zum Anteil von Stadt- und Landbewohnern in den Weltregionen bis 2050'. Statista, 17 February 2021. https://de.statista.com/statistik/daten/studie/870960/umfrage/prognose-zum-anteil-von-stadt-und-landbewohnern-in-den-weltregionen/.

[149] Statista Research Department. 'E-Commerce Revenue in in Europe 2017-2025'. Statista, November 2020. https://www.statista.com/forecasts/715663/e-commerce-revenue-forecast-in-europe.

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the need of internalization of external costs from emissions supports the development of a sustainable, multimodal traffic management as well.

5.1.6 Environmental-economic and social-economic relevance of MTME

The implementation of MTME can significantly contribute in making the (urban) mobility sector more sustainable by offering solutions that are environmentally friendly and socially inclusive, thus leading to a reduction of external costs. This is especially true for urbanized cities, which cover 2-3% of the earth's landscape[150], and are responsible for two-thirds of the world's energy consumption, generating about 70% of the global carbon emissions[151]. The primary sources of CO_2-emissions in cities are fuel emissions from combustion in on-road traffic vehicles as well as in residential or commercial buildings[152]. Furthermore "road transport activity is a significant source of emissions"[153] including, next to CO_2-emissions, nitrogen oxides and/or particulate matter.[154] One can estimate the CO_2-emission related costs to being at least 195€$_{2020}$/t$_{CO2\text{-}eq}$.[155]

Regarding passenger transportation, (external costs from) noise and air pollutants (CO_2, but as well NO_x, SO_2, particulate matter) are especially related to car travels, while bus or train transportation are significantly less harmful. Similar accounts for freight transport, whereas clear sustainability advantages are related to the use of rail and sea transport.[156] Implementing MTME paves the way for increasing the efficiency of transportation on the one hand (e.g. in public transportation[157]), and reducing the barriers to a multimodal transportation on the other, which results in less environmentally harmful traffic and transport overall. In addition, the costs from air pollutants are strongly associated with health problems for the adjacent population. For instance, the Department for Environment, Food and Rural Affairs (UK) found in 2007, that "air pollution is currently estimated to reduce the life expectancy of every person in the UK by an average of 7-8 months" [158]. Still today, the reduction of air pollution could prevent the premature death of people in several (European) cities[159]. Thus, a more efficient and multimodal transportation based on effective traffic management can help to improve public health.

From a social-economic perspective, MTME can help to bridge another existing problem of traffic management. Today, traffic planning is often car focused.[160] However, this excludes a significant group of the population that do not have access to cars, specifically from the lower income quantile

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[150] Ulrike Weiland, 'Stadt im Klimawandel | bpb', bpb.de, 9 July 2018, https://www.bpb.de/politik/innenpolitik/stadt-und-gesellschaft/216883/stadt-im-klimawandel.
[151] UN-Habitat, ed., *The Value of Sustainable Urbanization*, World Cities Report 2020 (Nairobi, Kenya: UN-Habitat, 2020), 20.
[152] based on C40 Cities Climate Leadership Group, 'C40 Greenhouse Gas Emissions Dashboard Data', Version 07.07.2021 (London, UK, 2020), https://c40.ent.box.com/s/piq83gmxl8vbbvd1mkoi5tsg1kvd2i74.
[153] Department for Environment, Food and Rural Affairs, 'Emissions of Air Pollutants in the UK - Summary', GOV.UK, 26 February 2021, https://www.gov.uk/government/statistics/emissions-of-air-pollutants/emissions-of-air-pollutants-in-the-uk-summary.
[154] Department for Environment, Food and Rural Affairs.
[155] Astrid Matthey and Björn Bünger, 'Methodenkonvention 3.1 Zur Ermittlung von Umweltkosten - Kostensätze', Bericht (Dessau-Roßlau: Umweltbundesamt, December 2020), 8, https://www.umweltbundesamt.de/sites/default/files/medien/1410/publikationen/2020-12-21_methodenkonvention_3_1_kostensaetze.pdf.
[156] Matthey and Bünger, 39.
[157] Nicos Komninos et al., 'Towards High Impact Smart Cities: A Universal Architecture Based on Connected Intelligence Spaces', *Journal of the Knowledge Economy*, 4 March 2021, https://doi.org/10.1007/s13132-021-00767-0.
[158] Department for Environment, Food and Rural Affairs, 'The Air Quality Strategy for England, Scotland, Wales and Northern Ireland', in partnership with Scottish Executive, Welsh Assembly Government and Department of the Environment Northern Ireland (London, July 2007), 7, https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/69336/pb12654-air-quality-strategy-vol1-070712.pdf.
[159] Sasha Khomenko et al., 'Premature Mortality Due to Air Pollution in European Cities: A Health Impact Assessment', *The Lancet Planetary Health* 5, no. 3 (March 2021): e121–34, https://doi.org/10.1016/S2542-5196(20)30272-2.
[160] Sandjai Bhulai, Dimitris Kardaras, and Ivana Semanjski, *Proceedings of the 7th International Conference on Data Analytics 2018* (IARIA, 2018), p.150 ff.

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of the population[161]. For this group, an increase in efficiency (and possible reduction of transportation costs) by implementing MTME is highly relevant. For example, a more efficient public transportation system leads to better inclusion of the society, and therefore can reduce health problems (e.g. less isolation) as well increase economic welfare.

All in all, MTME creates the possibility of a more sustainable traffic management approach. This is done by considering and including all types of transportation vehicles (cars, bicycles, scooters, trains, trams, planes, ships, etc.) and further offers perspectives of sustainability by increasing efficiency, reducing (external) costs, and allowing an integrated multimodal traffic.

5.2 Primary data collection via interviews

This section focuses on the economic and technological interview results recorded by eight interview partners from the following companies and institutions: European Road Transport Telematics Implementation Coordination Organisation (ERTICO), Technical University of Berlin (TUB), Jelbi (funded and managed by the Berliner Verkehrsbetriebe - BVG), Mobility Inside (MI), Verkehr Mobilität Zukunft (VMZ), Bocconi University Milan (UB), Det Forenede Dampskibs-Selskab (DFDS), and Trondheim Kommune. Following a brief round of introductory questions asked to the interview partners, the results are split into three categories: general, economic, and discussion.

Under the general questions category, the current problems in traffic management planning mentioned were primarily the silo mentality of operation of traffic routes, congestion, interlinking different digital transport services, and an overlapping administrative authority. In this context, an integrated and unified traffic management platform is seen as a central part of the solution, but only when it is in harmony with other factors such as further physical infrastructure development, economic viability, and an increased shared economy. Within the context of MTME, key drivers that motivate the work of universities and public transport companies include a need for public financing, ongoing research projects on efficient and sustainable transportation development, and the continuous analysis of existing and new markets in mobility. As for private companies, the key drivers include technological innovation and interoperability, digitalisation, data standardisation of the public transport sector, and making freight transport more sustainable. Statements regarding future technologies of smart infrastructure were of particular interest, most of the interviewees responded with IoT (Internet of Things), increased satellite data, smartphone - road infrastructure communication, smart grids, machine learning via AI, and real-time data use. Interviewees stressed on the idea that a successful unified traffic management platform requires further smart infrastructure developments and expansion to accommodate the use of such technology. Autonomous driving and uniform data standards were also mentioned by a few respondents.

The second category of questions were dedicated to understanding the status quo from an economic and business operation perspective. To be able to effectively manage traffic for multimodal transport, it is essential to pinpoint the current issues and bottlenecks that exist along with future technologies and strategies that aid in solving these problems. When the interviewees were asked about how traffic routes are presently planned for their transport operations, their answers all included using an automated software. All interviewees who were able to respond to the question use various platforms or software. Some traffic-related data is shared in this context in a limited bidirectional exchange between the interviewed business partners. None of the interviewees currently use a unified and

[161] see Roger L. Mackett and Roselle Thoreau, 'Transport, Social Exclusion and Health', *Journal of Transport & Health* 2, no. 4 (December 2015): 4, https://doi.org/10.1016/j.jth.2015.07.006.

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integrated traffic management platform, but some intend to do so in the future. One of the most critical issues that most interviewers believe a digitalised MTM network would solve is the first mile/last mile problem. A variety of systems were identified in terms of the navigation systems used by the companies and institutes the interviewees represent, however only Google Maps/Google Data and TomTom were both mentioned twice, otherwise different systems were used. Regarding the tracking of the transport vehicles, most of the vehicles related to the interviewee's companies are already being tracked in real-time. When asked about the biggest operational bottleneck, a wide variety of answers emerged, which mainly involve the lack of physical and digital infrastructure, data standardization, and a range of socio-economic factors.

Two important economic theories that focus on the possible effects of road infrastructure expansion and technological improvements in efficiency were highlighted in an interview with the Technical University of Berlin. The first theory (Braess's Paradox) states that adding more roads to an existing road network could slow down traffic flow through it, and vice versa. The second theory (Jevon's Paradox) states that although efficiency improvements due to technological advancement may seem to reduce the overall consumption of a natural resource, the reality is that the rate of consumption increases due to an increasing demand. According to this theory, the increasing efficiency of road vehicles does not necessarily solve the problem of resource depletion and road emissions, and hence must be carefully taken into consideration when assessing new technological innovations. Moreover, according to the interviewees, autonomous driving does not yet play a significant role at the present time. Some are involved in pilot projects in this regard, but beyond that it appears to be a future topic. With regards to sustainable transition in the transport sector, the stakeholders surveyed take different approaches. In general, electrification is given a high priority, as is the reduction of private transport and the expansion of public transport. Efficiency improvements through energy management, technological advancements, and smarter digital platforms are also rated highly.

With regards to the technological analysis of MTME, three companies contributed to providing answers that help in understanding the current and future ecosystem from a technical perspective. DFDS stated that monetization is not a barrier in sharing V2X data that support in logistics planning of sea-to-road-to-rail transport. The main issue is to guarantee control on who accesses the data, currently the necessary interfaces and standards are still missing. According to ERTICO, industry proprietary data sharing is still complicated since competitive use of data, and trust on how data is used, remains a barrier. Public authorities want to keep control on the shared data and make sure it remains the same after being transferred. Monetary value is important and can be a barrier for sharing data, since the control over the data and the value associated with that is lost from the data owners once it's shared. However, collaboration is possible even before the value becomes a problem and businesses can still be competitive, generating added value not from a single data but by combining them. Transport providers that operate under the MaaS ecosystem need to work with transport management systems. The TM2.0 is an example of a platform that can help with traffic management and facilitates the required work between public authorities and service providers. However, there is a conflict of interest on how shared data should be used. The service providers want to sell the service to bring customers from point A to B, while public and transport authorities want to avoid congestions first and foremost. Each stakeholder prefers to have their own platform because they need to feel in control of the data. According to statements from Trondheim Kommune, most of the transport data is available when a platform for integration is offered. The problem is about partnerships and interest for service providers to provide an integration platform (i.e., Google/Google Maps). Transport providers ideally want to avoid disturbances and be the only ones providing the service, hence they prefer to collect and manage data all in-house.

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The discussion section was the final category of questions and mainly revolved around the potential benefits and challenges of implementing an MTM network. It became evident that almost all interviewees viewed MTM as part of the solution to current traffic problems, while a few viewed it as a general solution. All interviewees who commented on these questions considered an MTM network to be beneficial to their institution or company. Regarding main concerns related to MTME, a variety of different responses emerged. Security aspects were mentioned twice, while acceptance, standardization, a sufficient legal framework, the transition phase, and the distribution of competencies around the network were mentioned once each. The most important technical features that MTME should have according to the interviewees are data interoperability, security, real time monitoring, standardized protocols, machine learning via AI, and integration of 5G networks. There was considerable disagreement among interviewees regarding the platform in terms of the role of public and private stakeholders. Some clearly oppose government stakeholders because they have inadequate experience with AI and generally operate inefficiently, whereas others favor government control over critical infrastructure for funding and security reasons. Different ideas and opinions emerged when asked about how private stakeholders could account for MTME. Some interviewees remain against the idea of a private funding strategy. The most prominent ones, on the other hand, amounted to having a membership fee or a cost per transaction. As for the discussion on final challenges for MTME, interviewees mentioned planning, transparency, cybersecurity, impact on power consumption, cost-effectiveness, building physical infrastructure, legal requirements, and opposition from economic stakeholders to sharing their data.

To conclude, there is a high level of (economic) interest in an MTM network as described in ORCHESTRA, but many barriers are associated with the introduction of such a network. On the techno-economic side, the integration of many future technologies such as 5G networks, quantum computing, self-learning algorithms and cybersecurity is a priority. On the infrastructural side, the physical requirements of a road, rail and waterway network designed to meet future needs must be established, thus, investments must be taken. On the administrative side, it is vital to create clear and efficient distributions of competencies without conflicts of interest. In this respect, it also plays a role whether the system is financed by taxpayer money and operated by the state as a critical infrastructure, or whether it should be placed in private-sector hands for economic and efficiency reasons.

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6 Results: Safety and Security Perspective

In this chapter, the results from safety and security perspective concerning the status quo will be summarised.

6.1 Literature review

The literature review was based on three primary types of content: Articles providing general information on safety, security, and cybersecurity topics; Articles provided by the European Union (or related institutions); and the regulations themselves.

The main search terms used were “Security”, “Safety”, “Cybersecurity”, “Passenger”, “Freight”, “Transport”, “European Union”, “Standards, “Automotive”, “Maritime”, “Rail”, “Aviation”, and any combination thereof.

6.2 Security and safety

This section provides an overview of the different Transport modes which are considered in this pre-study. For each of these modes, some relevant information is given, which may include a short description, associated challenges, reasons why safety and security are important, amongst others.

6.2.1 Road traffic[162]

The transportation of people or goods by road is by far the most widely used, and is also the primary cause of accidents. Because of this, a lot of time and resources are still being invested to promote rules and standards which aim to increase the safety of road transport, even though European roads are already the safest in the world. The EU even aims to completely eliminate deaths and serious injuries on roads, by adopting the so-called "Vision Zero".

Moreover, there are two prominent safety regulations in the European Union, with which all motorised vehicles must comply in order to legally be sold within the EU. These regulations are the General Safety Regulation (GSR - Regulation (EC) No 661/2009) and the Pedestrian Safety Regulation (PSR - Regulation (EC) No 78/2009). The GSR specifies the general safety requirements for the approval of motor vehicles and all components related to them. The PSR is similar but specifies the safety requirements of motor vehicles in regard to the safety of pedestrians. Technical advancement related to safety features is regularly reported to the European Parliament and Council so that these can be considered possibly included into the regulations. Some of the safety measures are:[163]

- Advanced Emergency Braking Systems
- Driver Monitoring
- Driver Drowsiness and Attention monitoring and Warning
- Advanced Distraction Recognition
- Driver Readiness Monitoring for Automated Driving
- Event Data Recorder
- Emergency Lane Keeping System
- Frontal Full-Width Impact

[162] European Commission, ”Road Safety”, EC Europa, https://ec.europa.eu/transport/road_safety/ , accessed on 09.11.2021.

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- Pedestrian and Cyclist Enlarged Head Impact Zone
- Intelligent Speed Assistance
- Reversing Safety
- Tyre Pressure Monitoring (heavy duty vehicles
- Direct Vision & Pedestrian and Cyclist detection (heavy duty vehicles)

6.2.2 Air traffic

Aviation is one of the fastest growing, but at the same time one of the safest modes of transport. The air safety policy within the EU promotes cost efficient rules, facilitates the movement of products and people, while simultaneously ensuring a high level of safety for the passengers. The aviation safety system in Europe based on common safety rules which are overseen by the European Commission, the European Aviation Safety Agency (EASA), and the National Aviation Authorities. These safety rules cover everything, including airworthiness, aircrew, and aerodromes. Accident investigation, which aims to avoid reoccurrence of accidents by thoroughly investigating, is also a key part of these rules. However, the European airspace is used extensively by non-European air carriers which need to provide the same level of safety as European carriers.

6.2.3 Maritime security[164]

The objective of the EU's maritime security policy is to protect the citizens and economies from unlawful intentional acts against shipping and port operations.

The EU legislation provides a regulatory framework to protect the maritime transport logistics against threats and attacks and consists of two parts: The regulation on enhancing ship and port facility security, which contains preventive measures; and the directive on port security. The application of this legislation and its effectiveness is monitored by the European Commission with regular inspections.

Even though this framework goes beyond international obligations, it still ensures that the promotion and pursuit of international trade is not hindered.

6.2.4 Rail traffic

The railways in Europe are one of the safest in the world and the EU aims to improve the safety and simplicity by establishing an integrated European railway area. This will align safety requirements and rolling stock authorisation procedures within the EU, and will thus facilitate the maintenance of high safety standards. The European Railway Agency (ERA) is working with railway companies and national authorities to develop common approaches to safety.[165]

Improving Passenger Rail Security using stakeholder consultation:[166] While EU legislation to protect aviation and maritime transport is developed, there are no corresponding measures at EU level on rail security. Even though some Member States have already strengthened their national security measures, these measures have been carried out in an uncoordinated way, therefore they need to be harmonised on an EU level. To achieve this, a variety of different stakeholders, like for example

[164] European Commission, ”Maritime Security“, EC Europa, https://transport.ec.europa.eu/maritime-security_en , accessed on 09.11.2021

[165] European Commission, ”Railway interoperability“, EC Europa, https://transport.ec.europa.eu/transport-modes/rail/interoperability-safety/interoperability_en , accessed on 09.11.2021

[166] European Commission, ”Improving Passenger Rail Security“, EC Europa, https://transport.ec.europa.eu/transport-themes/security-safety/land-transport-security/improving-passenger-rail-security_en , accessed on 09.11.2021

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citizens and associations of Rail Users, as well as technology providers, as well as transport authorities are consulted, to capture as best as possible the interests of everyone

6.3 Transport Security

Everyone needs to be able to travel without fear of being a victim of some sort of attack. At the same time, it is important that security is as unintrusive as possible, to avoid making travelling an unpleasant experience. The scope of transport security is broad because it can cover everything from terror attacks to graffiti. However, most of the effort and time is invested into the prevention of crimes, like theft or stowaways. As the transportation of people and goods is an international affair, it is important to have a coordinated approach within the EU, which is being developed by the ICAO (International Civil Aviation Organisation) and the IMO (International Maritime Organisation). This coordination within the EU is complemented by cooperation with other countries by exchanging experiences and best practices.

Maybe a bit surprisingly, there exists currently no EU legislation which addresses the security of land transport, except to some extent in the transport of dangerous goods because of some overlap between safety and security. This is despite the fact that the number of deaths due to terror attacks on land transport are higher than those of air and water transport, and despite the fact that theft of cargo on land transport is estimated to cost of €8 billion annually. The diversity of land transport and the different needs of different operators in different locations, massively complicates the implementation of security measures. Due to this, unlike security in aviation, it is undesirable to have very detailed and prescriptive rules and there is no "one-size fits all" solution.[167]

All these points mentioned above make it clear that it is of utmost importance to include security aspects in MTMEs, and this should be done from the beginning. Doing this, will allow operators to have a common framework to include the security into their service, making it as seamless and unintrusive as possible. Using this approach, it will be easier for operators integrate and coordinate security measures, people will feel safe, and the security of cargo will be ensured. The focal points of security (and safety) are passenger and freight terminals, i.e. locations where large amounts of freight and people come together and get distributed. To simplify, passenger and freight transport are generally separated. The physical security of passengers is secured by extensive measures, such as screening and the channelling of movements. Since 2020 and the Covid 19, epidemiological security is also an issue, which requires additional measures.

In the freight sector, most security concerns are directed to either workers safety or theft. One of the mitigation measures of the latter, is the restriction of access to port terminals. Other important concerns are illegal immigrants, smuggling, custom duty evasion, piracy, etc. The airline freight industry is thus facing stringent security requirements, as the screening of all cargo is required and the costs have to be borne by airlines, freight forwarders, and shippers themselves. This naturally causes additional costs, delays, and disruptions, causing operational effectiveness to decrease. The parallel to these security measures in the maritime fright industry (in the United States), is the Maritime Transportation and Security Act, which has three important requirements:

[167] The Geography of Transport Systems, "Transport Safety and Security", TransportGeography, , 09.11.2021https://transportgeography.org/contents/chapter9/transport-safety-security/ , accessed on 09.11.2021

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- Presence of an Automated Identity System (AIS) for all vessels between 300 and 50,000 dwt (deadweight tonnage, carrying capacity of a ship), which requires a permanently marked and visible identity number.
- Port security assessment which involves the assessment of its assets and facilities, as well as the assessment of the effects of potential damages. The port must then evaluate the risks, and identify the weaknesses of its physical security, communication systems, utilities, etc.;
- Customs clearance of all cargo destined for the US before the departure of the ship.

In most cases, these measures are also applicable, maybe with slight variations, in the European Union. This is due to the fact that the EU needs to comply with these measures to be able to trade with the US, and as a result adapts them to fit the European market.

6.4 Cybersecurity

Cybersecurity is the protection of IT systems and networks from a multitude of threats which can either originate from an external or an internal source. These sources can have a malicious intention but they can also simply be a careless actor, unintentionally exposing or exploiting a threat. More information on different types of threats and exploitation strategies can be found in section technical aspects. Due to the ever-growing reliance on IT systems and the steadily increasing number of devices connected to the internet, cybersecurity has (or will) become one of the most important aspects of nearly every company, individual, or nation.

6.4.1 Goals and challenges

Three important aspects of cybersecurity are:

- upholding confidentiality
- preserving integrity
- providing availability of data and systems.

While trying to reach these goals stakeholders face a variety of issues, e.g. the exploitation risk of software, hardware, personnel to compromise any system, as well as the increase of wireless communication.[168] Cybersecurity is relevant, regardless of the activities of a company, but these risks are of a major importance for the transport sector, especially the public transport of people. This is due to a very rapid expansion of the use of mobile and connected systems, such as traffic signals, online fare payment, and vehicle surveillance. This, combined with the risk that human lives are potentially at stake in the event of an attack, increases the importance of cybersecurity in the public transport sector.

There are several problems identified for the topic of cyber security especially in intelligent public transport. These are, amongst others, limitations of cybersecurity expertise in the companies, due to other core activities, as well as the connection of different systems risking the entire transportation system, if only one is attacked.[169]

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[168] Sarah Harvey, "Secure Your City: Public Transit", KirkPatrickPrice, 09.05.2019, https://kirkpatrickprice.com/blog/secure-your-city-public-transit/.

[169] By Cédric Lévy-Bencheton and Eleni Darra, " Cyber security in intelligent public transport: challenges and solutions", IntelligentTransport, 20.06.2016, https://www.intelligenttransport.com/transport-articles/19618/cyber-security-intelligent-public-transport/

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6.4.2 Public transport specific information

IT systems, which include computers, embedded and mobile systems, hardware, software, and the networking between them, are highly complex and differ vastly between different areas of application. On a high-level overview, the IT infrastructure of a typical public transport organisation[170] derives out of operational systems, enterprise information systems, as well as customer facing and external systems.

6.4.3 Maritime Cybersecurity[171]

To address increasing cyber threats to maritime operations and mitigate new cyber risks, the resolution MSC.428(98) (encourages administrations to ensure that cyber risks are appropriately addressed in existing safety management systems), and the guideline MSC-FAL.1/Circ.3 (Provides recommendations for cyber risk management to safeguard shipping from cyber threats and vulnerabilities) were adopted by the IMO and added to the International Safety Management (ISM) Code.

There are three pillars, which are addressed by the guideline:

- The assessment of cyber risks across processes, technology and staff.
- A secure cyber architecture should be designed, which incorporates cyber risk management into the safety management of the organisation.
- Technology and staff should be incorporated in the risk management on a continuate basis in order to protect the vessels and operations functional elements, such as processes

6.4.4 State of the Art and best practices to improve cybersecurity[172] [173]

Cyberattacks and cybercrime are increasing, and this trend is expected to grow further in the future.. Despite this, many operators still lack sufficient measures to protect their systems, like encryption and appropriate access control. And a single attack successfully compromising for example the ticketing system of an operator, can shut down the whole operation for hours or days.[174]

The most important threats for cybersecurity are[175]:

- (D)DoS, (Distributed) Denial of Service: This either limits or entirely interrupts the access to data and services by overloading a target with requests.

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[170] UITP, ”Action Points: Cybersecurity in public Transport“, CMS UITP, https://cms.uitp.org/wp/wp-content/uploads/2021/02/Action_Points_Cyber_Security-v2.pdf , accessed on 09.11.2021

[171] Mission Secure, ”Complying with the IMO 2021 Cybersecurity Regulations“, MissionSecure, https://www.missionsecure.com/hubfs/Assets/Collateral/complying-with-imo-cybersecurity-overview-mission-secure.pdf , accessed on 10.11.2021

[172] National Highway Traffic Safety Administration, “Cybersecurity Best Practices for the Safety of Modern Vehicles”, NHTSA, https://www.nhtsa.gov/sites/nhtsa.gov/files/documents/vehicle_cybersecurity_best_practices_01072021.pdf , accessed on 09.11.2021

[173] Intelligent Transport, “Cyber security in intelligent public transport: challenges and solutions“, IntelligentTransport, https://www.intelligenttransport.com/transport-articles/19618/cyber-security-intelligent-public-transport/ , accessed on 09.11.2021

[174] ISA Cybersecurity, ”Cybersecurity for the transportation sector“, ISACybersecurity, https://www.isacybersecurity.com/cybersecurity-for-the-transportation-sector/ , accessed on 09.11.2021

[175] European Commission, ”Transport Cybersecurity Toolkit“, EC Europa, https://transport.ec.europa.eu/transport-themes/security-safety/cybersecurity_en , accessed on 09.11.2021

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- Malware: This implies malicious software, which can derive in various forms and in various ways, e.g., trojans, viruses amongst others.
- Unauthorised access, data theft, software manipulation providing access to protected systems and data.

However, there are various practises, that exist in order to improve cybersecurity. The practises either focus on reactions during incidents, whereas others address recovery and future improvement once an incident has been solved.

Overall best-practise examples can be listed in three groups:

- Technical features in order to secure systems and technologies
- Policies and standards, which employ security by design making sure that the organisations need to implement cybersecurity during the whole life cycle of a product
- Organisation, staff and processes, which focus on the internal process of organisations

To conclude, (intelligent) public transport operators need to integrate cybersecurity in their governance in the following ways:

- Define a Cybersecurity structure (specific to each operator)
- Make training and awareness programmes available to people working in the company
- Identify critical assets (business, society, etc.)
- Define key performance indicators to protect the organisation, the provided service, the passengers.

One method, that addresses shortcomings on the growing concerns around cybersecurity is the Transport Cybersecurity toolkit, which provides tips and recommended practices for enterprises of the transport sector.[176] The Transport Cybersecurity Toolkit defines potential threat actors, awareness profiles for transport staffs, as well as guidelines for decision makers on how to identify, protect, detect and respond to cybersecurity issues. Some good practices, which should be implemented to improve the cybersecurity are the following:

- Creation of cybersecurity culture by training the personnel and improving the awareness of cybersecurity risks and their potential sources.
- Develop a cybersecurity response plan and hire an external cybersecurity expert which provides support in implementing measures and staying up-to-date on potential risks.
- Employ a zero-trust model, meaning that systems and their access is subdivided, and people only receive access to the systems which are necessary for them.
- User and entity behaviour analytics should be used to rapidly detect (and react to) abnormal behaviour of the systems which could impact the safety of the operation.

[176] European Commission, ”Transport Cybersecurity Toolkit“, EC Europa, https://transport.ec.europa.eu/transport-themes/security-safety/cybersecurity_en , accessed on 09.11.2021

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- Physical protection of critical hardware is also of utmost importance, to avoid unauthorised people physically accessing and damaging or compromising systems.[177][178]

6.5 Security and Safety Standards

This section provides insight into some of the most relevant standards regarding safety and security aspects for the different transportation industries. Usually, only the standard which are directly applicable in the European Union are mentioned and described, but for some of the sections, notably for the aviation and maritime sector, some US standards are also given. This is because they either need to be followed by European companies, if they wish to trade with the US, or these standards have a direct European equivalent. If the latter is true, both standards are mentioned.

Following is a list of these standards (further insight is provided in the annex in Section 10.3):

- ISO 26262, ISO 21448, EN 50126, EN 50128, EN 50129, EN 50159, EN 50657, IEC 62443, ARP 4754, ARP4761, RTCA DO 178C/254/160/297/331/355, ISO 21434, ISO 27000 series, ISO 15408, PD CLC/TS 50701, EUROCAE ED-202.

These standards are already important now to guarantee a minimum amount of safety in all the modes of transportation. However, in the context of MTMEs, these standards get even more important, due of the highly interconnected nature of MTMEs, which aggravates the impacts of single failures. The standards are often not directly required by law, but the law states that safety and security relevant systems need to follow the state of the art of the respective domains. Which translates to a certification of processes and/or products for these standards by an accredited certification body. E.g., TÜV and CertX in Europe. To implement these standards as effectively as possible, people need to be made aware of their importance, which can for example be done by including this topic in mandatory trainings.

Keen readers might notice that the list of standards provided does not include any concrete standardisation of autonomous vehicles and the communication between them and the infrastructure. This is one of the topics which still have to addressed, as the percentage of automation in everyday vehicles is steadily increasing.

6.5.1 Primary data collection via interviews

The main take away from the interview answers is that some organisations are already implementing some cybersecurity, weather in the form of training of employees or the application of some standards. But what became apparent, is that in most cases the organisations are currently not particularly interested in further and more in-depth implementation of cybersecurity. When they were asked what their incentives are for cybersecurity, the response was usually that there are none. The goal is that the system has to function, whereas generally safety and cybersecurity is only implemented when it is required. This shows that cybersecurity measures might only be widely implemented when they are mandatory.

[177] UITP, "Action Points: Cybersecurity in public Transport", CMS UITP, https://cms.uitp.org/wp/wp-content/uploads/2021/02/Action_Points_Cyber_Security-v2.pdf , accessed on 09.11.2021

[178] ISA Cybersecurity, "Cybersecurity for the transportation sector", ISACybersecurity, https://www.isacybersecurity.com/cybersecurity-for-the-transportation-sector/ , accessed on 09.11.2021

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7 Results: Psycho-Sociological, acceptance and ethical perspective

In this chapter, the results from psycho-sociological and acceptance perspective concerning the status quo will be summarized.

7.1 Literature review

The literature review was based on scientific articles. The search terms used for this work were "UTAUT" (Unified Theory of Acceptance and Use of Technology (UTAUT)[179], "Transport", "Acceptance", "Freight" and "passengers". Google Scholar and Elsevier were used as databases. The first keyword was "transport managing system", however the results only focused on one particular mode without taking into account other modes and did not necessarily address the acceptance dimension. Therefore, the search was extended to include other keywords. The literature review focuses on the acceptance of integrated systems, the acceptance of CAV, which is an integral part of ORCHESTRA and is the subject of a large literature debate, and finally the UTAUT model. The literature on MTM is very poor or even non-existent concerning its acceptance. It is therefore essential to rely on a solid theoretical model applicable to all kinds of objects.

7.1.1 Acceptance of integrated system by actors other than end-users

The issue of traffic management is dealt with in the literature, albeit rarely and only considering one mode (e.g. air transport). As indicated, the research was therefore extended to **integrated transport systems**, defined as "the organizational process, in which the elements of transport system (network and infrastructure, fares and ticketing, information and marketing, etc.) served by different operators, who use different transport modes, interact more efficiently and closely"[180].

In the field of passenger transport, the literature on the acceptability of traffic management tools remains scarce. It mainly focuses on the perception of tools by end-users[181] but not at all from the point of view of the various stakeholders outside end-users. As far as freight is concerned, the main obstacle to the implementation of a MTME, as defined in ORCHESTRA, is the large number of actors involved, which requires interaction and exchange of information, and the need to integrate different transport modes. The difficulties lie in the low compatibility of tools and perceived benefits.[182] In addition, implementation and maintenance costs are barriers. Another point is the difficulty in quantifying the benefits which can lead to inappropriate or insufficient use of the tool.[183] The size of the company seems to have an impact, and a high level of implementation seems to be linked to the size

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[179] Venkatesh, Morris, Davis, Davis (2003). User Acceptance of Information Technology: Toward a Unified View, MIS Quarterly, 27.

[180] Stopka, Bartuška, Kampf, Passengers' evaluation of the integrated transport systems, Nase More, University of Dubrovnik, 2015, vol. 62, Special issue.

[181] ibid.

[182] Cooper, Schindler, Business Research Methods, New Delhi, Tata McGraw, 2013; Marques, Villate, Vaz Carvalho, Applying the UTAUT Model in Engineering Higher Education: Teacher's Technology Adoption. 6th Iberian Conference on Information Systems and Technologies, 2011.

[183] Pokharel, Shaligram, Perception on Information and Communication Technology Perspectives in Logistics. Journal of Enterprise Information Management, 18(2), 2005.

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of the company.[184] Regarding the context, competition from actors and policies in different countries may affect the acceptance of ICT.[185] However, a number of positive points can be highlighted such as real-time data sharing, and better adaptability in unexpected situations.[186] In sum, the existing barriers are mainly technological, environmental, and organisational. The managers' perspective assumes a vital role in ICT adoption among intermodal companies, too.[187]

7.1.2 Acceptability/acceptance of autonomous vehicles

Research on autonomous vehicles and their acceptance by users has been a major research theme for the last five years, particularly in European projects (My Smart Life and CityMobil2).

The model used remains the UTAUT, which will be presented in detail in the rest of the document.

7.1.2.1 Acceptability of autonomous shuttles

Autonomous shuttles are being studied as prototypes in several projects.[188] The shuttles, which are currently in operation, run at relatively low speeds and can carry 8-10 people. They usually require supervision, for example by an on-board operator.

Much research has attempted to investigate the acceptability of the autonomous shuttle; users had to give their opinion on this mode of travel **without having been a user of this type of transport**, having no actual experience with the object. According to research conducted by Nordoff, De Winter, Kyriakidis, Van Arem and Happee[189], the main aspects mentioned by respondents relate to the safety of the shuttle. In addition, the authors discuss the impact of the media on the attitudes of respondents who reported an accident involving an autonomous shuttle that hit a parked delivery car. Participants responded that the presence of an on-board operator would reassure them, especially if the shuttle was able to travel at the same speed as other vehicles. In addition, they mention other factors such as the possibility for an outside human operator to remotely regain control of the shuttle, the possibility of reserving the shuttle via their smartphone and the reduction of waiting time at the stop compared to other transport offers. Perceived benefits are also the possibility to enjoy the "landscape" and to

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[184] Davies, Mason, Lalwani, Assessing the impact of ICT on UK general haulage companies. International Journal of Production Economics, Volume 106, 2007; Pokharel, Shaligram, Perception on Information and Communication Technology Perspectives in Logistics. Journal of Enterprise Information Management, 18(2), 2005.

[185] Huckridge, Bigot, Naim, ICT in multimodal transport operations: a framework for future research. In Proceedings of 17th International Annual EuroMA Conference, Portugal, 2010.

[186] Dürr, Giannopoulos, SITS: a system for uniform intermodal freight transport information exchange. International Journal of Transport Management 1 (3), 2013; Gunasekaran, Koh, Interlocking of information systems for international supply and demand chains management. International Journal Production Economics. 122 (1); Perego, Perotti, Mangiaracina, ICT for Logistics and freight transportation: a literature review and research agenda. International Journal of Physical Distribution & Logistics Management Vol. 41 No. 5, 2011; Prajogo, Olhager, Supply chain integration and performance: the effects of longterm relationships, information technology and sharing, and logistics integration, International Journal of Production Economics, 135(1), 2012.

[187] Madhavi, What should managers of Intermodal Freight Transport companies consider before adopting Intelligent Transportation Systems (ITS)? Emerging Environmental Technologies and Health Protection, Volume 1, 2018.

[188] Drive Sweden, Sweden mobilizes for piloting future transportation solutions, 28.09.2017.

[189] Nordhoff, de Winter, Madigan, Merat, Van Arem, Happee, User acceptance of automated shuttles in Berlin-Schoneberg : A questionnaire study. Transportation Research Part F 58, 2018.

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chat with other passengers. Few respondents mention the possibility of working. However, in another study, respondents mentioned activities such as resting, watching movies, sleeping, or reading.[190]

An acceptability/acceptance study, based on a qualitative and quantitative approach, was carried out by Moneger[191]. Its objective was an autonomous electric shuttle, travelling at 20 km/h and capable of carrying up to 6 passengers. Concerning the acceptability phase (focus groups were carried out), 48% of the respondents considered that the use of the shuttle would reflect a positive image of its user as being someone who is keen on innovation. It is considered useful and practical (14%). 37.5% expressed confidence in the shuttle. 25% of respondents stressed the need to maintain human contact through voice announcements or remote monitoring. Testing a new mode of travel, linked to the curiosity factor, would be a motivation to use the shuttle (13%). Reluctance emerges from the analysis concerning the loss of drivers' jobs (10%). Fear of the unexpected and malfunctions (25%) as well as a feeling of insecurity resulting from the absence of a driver (13%) are evoked by the respondents. A positive aspect is, that the shuttle represents an alternative to walking, especially for people with reduced mobility, or more generally for people with difficulties in getting around (63%), it is time saving (13%) and its environmental benefits (15%). Reservations regarding new technologies are reported by 33% of respondents refusing to use the shuttle. On the other hand, 27% of respondents said that the shuttle would be easy to use.

The above research presented does not distinguish between respondents who intend or do not intend to use the autonomous shuttle, yet in our research the respondents we call non-users do not have experience with the autonomous shuttle because they could not or would not use it.

7.1.2.2 Acceptance of autonomous shuttles

On the other hand, some research has focused on the acceptance of autonomous shuttles **by users** once they have had the opportunity to travel by autonomous shuttle.

Ease of use, usefulness, reliability, sense of safety and comfort are elements that contribute to a good acceptance of the autonomous shuttle[192]. Other research confirms these results, at least partially, with comfort and the feeling of safety emerging as determinants of acceptance.[193] On the other hand, waiting time at shuttle stops does not seem to play a central role in acceptance.[194] While overall, studies show good acceptance of autonomous shuttles, the negative points concern the limited space for luggage, their lower efficiency compared to their usual mode of travel and their relatively low speed.[195] With respect to the latter point, for some respondents, because of its low speed, autonomous shuttles

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[190] Cyganski, Fraedrich, Lenz, Travel-time valuation for automated driving: A use-case-driven study. In: Proceedings of the 94th Annual Meeting of the TRB. 94th Annual Meeting of the Transportation Research Board, 11.-15. Januar 2015, Washington, USA.

[191] Moneger, Conception d'un service de transport par navettes autonomes acceptable et sécurisé : approche ergonomique par l'analyse des expériences vécues et des valeurs en acte. Education. Université Clermont Auvergne, 2018.

[192] Gorris, De Kievit, Solar, Katgerman, Bekhor, CityMobil. Towards advanced transport for the urban environment, Deliverable D5.4.1Assessment of Automated Road Transport Systems contribution to Urban Sustainability, 2011.

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[195] Nordhoff, de Winter, Madigan, Merat, Van Arem, Happee, User acceptance of automated shuttles in Berlin-Schoneberg : A questionnaire study. Transportation Research Part F 58, 2018.

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are expected to cause traffic congestion.[196] Moreover, a qualitative study[197] based on semi-structured interviews shows that shuttle users have what the authors describe as high expectations. Thus, users regret that the shuttle cannot go around obstacles and that an on-board operator has to step in to carry out this type of manoeuvre. However, 20% of those interviewed said that they would prefer a shuttle with an on-board operator or remote control of the shuttle to a shuttle without any of these devices. Other research confirms this result, e.g., 90% of respondents would like autonomous vehicles to be able to be driven manually when needed, and 92% of respondents would like to know when and how automatic functions are activated.[198] The quality of service also emerges. If used as a "door-to-door" service difficulties with the implementation arised. However, the service was very attractive to respondents.[199] The low speed of the vehicles (8km/h) remains too low and hinders the regular use of the shuttle.[200]

On the other hand, its beneficial impact on road safety, in that it would reduce the number of road accidents, is an element that is also found in other research.[201] A negative point would be that due to its small size, the shuttle leaves little privacy. Therefore, performing complex cognitive tasks such as working seems unthinkable in such a context. However, the infringement of freedom seems to be a problem that is mainly found in developed countries. The authors question the impact of such a factor in developing countries.[202] Here too, the focus of this analysis is on the end-user.

7.1.3 UTAUT: Mobilised Model

UTAUT is the most comprehensive model of the acceptability of new technologies at present (see Figure 1). It is also the most reliable model. In longitudinal field studies of employee technology acceptance, UTAUT explained about 70 percent of the variance in behavioural intention to use a technology and about 50 percent of the variance in technology use. Since its original publication, UTAUT has served as a baseline model and has been applied to the study of a variety of technologies in both organizational and non-organizational settings.

- Performance expectancy:

Performance expectancy, defined as "the degree to which using a technology will provide benefits to consumers in performing certain activities" is the strongest factor and is significant both in a free choice context and in a constrained context. It is moderated by gender: men are very task-oriented

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196 Eden, Nanchen, Ramseyer, Evéquoz, On the road with an autonomous passenger shuttle: Integration in public spaces, In Proceedings of the 2016 CHI conference extended abstracts on human factors in computing systems.

197 Nordhoff, de Winter, Payre, Van Arem, Happee, What impressions do users have after a ride in an automated shuttle? An interview study, Transportation research part F: Traffic Psychology and Behaviour, Volume 63, 2019.

198 Liljamo, Liimatainen, Pöllänen, Attitudes and concerns on automated vehicles, Transportation Research Part F: Traffic Psychology and Behaviour, 2018, Volume, 59.

199 Shen, Zhang, Zhao, Integrating shared autonomous vehicle in public transportation system: A supply-side simulation of the first-mile service in Singapore, Transportation Research Part A: Policy & Practice, 113, 2018.

200 Nordhoff, Kyriakidis, Van Arem, Happee, A multi-level model on automated vehicle acceptance (MAVA) : a review-based study, Theoretical Issues in Ergonomics Science, Volume 20, 2019, Issue 6.

201 Bansal, Kockelman, Singh, Assessing public opinions of and interest in new vehicle technologies: An Austin perspective. Transportation Research Part C: Emerging Technologies Volume 67, June 2016; Portouli, Karaseitanidis, Lytrivis, Amditis, Raptis, Karaberi, Public attitudes towards autonomous mini buses operating in real conditions in a Hellenic city. In Proceedings of the 2017 IEEE intelligent vehicles symposium, Los Angeles, CA, 2017.

202 Nordhoff, Kyriakidis, Van Arem, Happee, A multi-level model on automated vehicle acceptance (MAVA) : a review-based study, Theoretical Issues in Ergonomics Science, Volume 20, 2019, Issue 6.

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and therefore performance-oriented whereas young people are more sensitive to extrinsic motivations.[203]

- Effort expectancy:

"Effort expectancy is the degree of ease associated with consumers' use of technology."

More salient for women, older with little experience with the system Venkatesh and Morris 2000; Venkatesh et al. 2000; Older men.[204]

- Social influence:

"Social influence is the extent to which consumers perceive that important others (e.g., family and friends) believe they should use a particular technology."

None of the above defined constructs are significant in a non-binding context. In a compulsory context, social norms have an impact on stage 1 and become insignificant in later stages. For women, the impact of this norm is most significant in the early phase and decreases later with experience.

7.1.4 Facilitating conditions

Facilitating conditions are defined as the degree to which an individual believes that an organizational and technical infrastructure exists to support use of the system. Self-efficacy and anxiety have been modelled as indirect determinants of intention fully mediated by perceived ease of use. These constructs are significant when the expected effort and expected expectation are not present in the model.

[203] Morris, Venkatesh, Age Differences in Technology Adoption Decisions: Implications for a Changing Workforce. Personnel Psychology , 53 (2), 2000.
[204] ibid.

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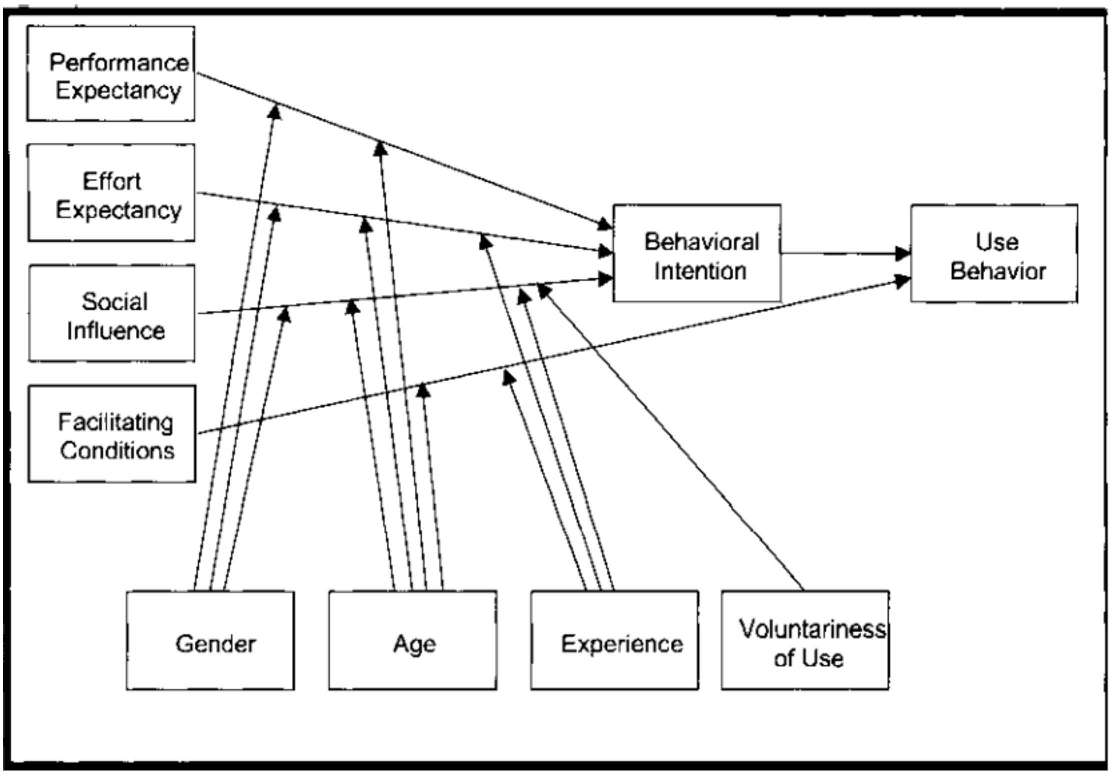

Figure 5: UTAUT (Venkatesh, Morris, Davis and Davis, 2003)

7.1.5 Issues concerning the findings

The evidence from the literature remains underdeveloped. However, the work of Mahdavi[205] offers some interesting starting points. Indeed, as this author points out, the decision to implement an intelligent transport system (ITS) involves a combination of technological, environmental, organisational, and individual factors. ITS offers similarities to MTME in the sense that the bottlenecks in the implementation of a data sharing tool by different operators in the freight sector arise as well. The technological factor (cost-benefit analysis, technological risk, suitability of the tool for the task it is supposed to help with) is in line with the UTAUT factors. However, the technological specificities such as the type of data collected, their standardisation, etc., should be taken into account. Just like the acceptance of ITS occurs at different levels, the level of acceptance for MTME does. Companies have to decide whether or not they see an interest in MTME themselves. Concerning individuals, the decision lays upon who will be in charge of using the technical tool and who will be able to judge the usability difficulties that it represents. Moreover, at this stage of the project, it seems difficult to study the acceptance of MTME at an operational level, so this work focuses on acceptance at a management level. We will therefore study the UTAUT factors but also other factors in order to see what difficulties are currently encountered and to what extent MTME could help them, as well as the difficulties that could arise.

[205] Madhavi, What should managers of Intermodal Freight Transport companies consider before adopting Intelligent Transportation Systems (ITS)? Emerging Environmental Technologies and Health Protection, Volume 1, 2018.

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7.2 Primary data collection via interviews

Five semi-directive interviews were conducted, each about 45 minutes. In the first instance, the interviews were transcribed in their entirety. Secondly, the UTAUT model was used as an analysis grid, i.e. for each of the elements of the UTAUT model, the corresponding statements were filled in:

- Effort expectancy
- Performance expectancy
- Social influence
- Facilitating conditions
- Moderating factors

The results of the interviews are presented below according to the perceived effectiveness, perceives effort, social influence and facilitating conditions of an information sharing system between actors. A particular focus is given on disrupted situations.

7.2.1 Effort expectancy

The expected efforts concern several areas, data but also the difficulty of interconnection between modes.

- **Data:** It will be necessary but difficult to have access to all the data of ALL the actors. Moreover, the mass of data, even for a single actor, remains very large (customs documents, health documents, etc.). The data must be anonymised, secure and standardised. As far as the Lemans Express is concerned, the operators realised that there were a lot of interconnection problems between the French and Swiss systems, and it was therefore necessary to make their two passenger systems compatible (e.g. train cancellations, delays, etc.).
- **Difficult interconnection between modes for infrastructure reasons but also legal and health reasons.** The difficulties encountered in each mode are presented below:

  Air transport: The complexity is such, especially at large airports which have, for example, an airfield control tower and an air traffic control tower, that interconnection is difficult. As far as freight is concerned, only fresh or high value-added products (with high margins) and for which customers are in a hurry are transported by air.

  Road transport: Compares to road transport, rail remains more expansive.

  Sea transport: Depending on the nature of goods, they may be allowed in one mode of transport and not in another. For example, goods may be considered dangerous in maritime transport, but not in rail transport. In order to accept the goods in the port, the trailers must sometimes be left on the train, even though the train may arrive in the port. The regulatory inflation is a problem, which leads to difficulties for the management. Moreover, the silo organisation is an issue.

  Waterway transport: This mode of transport still needs development. Certain obstacles are needed to be overcome, e.g. the tidal range of more than 5 m in some waters. Moreover, there is a big difference between the various players in urban logistics. However, the could complement each other. For example, a large international road transport company may choose to coordinate with three-wheeler for the final delivery of the goods (e.g. Schenker in Nantes).

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7.2.2 Expected performance

The expected effects are cooperation between service operators, reduction of greenhouse gas emissions, and new transport modes. The Maas is the model most often mentioned.

- **Better flow management:** Concerning passenger rail transport, the Lemans Express is an example, which serves several French and Swiss stations. Therefore, Switzerland and France have succeeded in sharing information in the field of rail transport. The difficulties, which arised due to the lack of data standardisation have been overcome. However, only one mode of transport is used in this case.
- **Help in setting targets:** Local authorities find it difficult to set targets for urban freight transport, but the problem is likely the same for other types of transport, as they do not have access to data on flows. This point goes back to the interest of having a strong regulatory authority. In any case, the various players agree on common objectives, which are fluidity, reduction of polluting emissions, speed, etc.
- **Maas:** Maas is cited as a system similar to the MTME to the extant that it allows all passenger information to be pooled and sent to the customer, and interconnections between a TER and a regional bus (sufficient connections, etc.). One of the essential elements of the success of public transport is the availability of its transport offer.
- **New modes of transport:** New modes of transport have to be taken into account, such as:
    - **Drones or CAVs**: According to one of our interviewees, drones and CAVs could remains a polluting mode of transport and therefore not very effective. On the contrary, "green" vehicles should be developed for efficient and non-polluting delivery.
    - **Micro-delivery sites**: Micro-delivery sites should be developed in the city. An example of efficient transport management, could be the use of driving school cars to transport parcels

7.2.3 Social influence

The main obstacle remains competition between operators, both in passenger and freight transport.

- **Passengers**: Competition improves the quality of customer service but results in great difficulty in interconnecting passenger information systems. For example, the Ile-de-France region is divided into twenty or so lots distributed among four operators. Each operator is assigned to a lot following a response to APP for a period of nine years. The competition between these operators means that they do not wish to communicate specific types of data to other competitors.
- **Freight:** Freight has a very strong competitive logic, which leaves little space for interconnection. Therefore, an example cannot be provided. On the other hand, as far as the network is concerned, no competition arises. The natural monopoly leads to an exception for competition.

7.2.4 Facilitating conditions

The implementation of an MTME requires the establishment of governance, more specifically, a strong transport regulatory authority at the European level when it comes to the transport of goods or passengers between countries.

- **Regulatory authority of transport (RAT) and organising authority:**In order to function, there is a need for a regulatory authority with strong competences, which will require operators to make data available. This type of operation exists in each country, but the influence of these authorities on the operators differs from one country to another. They have strong competences in the UK, but much less powerful enforcement in France. The idea of an European regulatory authority is being studied, but it remains quite national. However, regulations in the intergovernmental level exist. Still, there is a lot of diversity in the network, as well as the regulations, which little cross-boarder influence.

The two actors who must impose the pooling of their data for better passenger information are:

- **The Transport organising authority:** This is the agency or department of a city or region (for TERs) that is responsible for defining and financing urban transport policy, or TERs, in short public transport in a given area.
- **The Transport Regulation Authority (RAT in France)** functions at a higher level, with one authority per state. The RAT is responsible for ensuring the application of sound liberalisation in the transport sector, avoiding for example discrimination in access to infrastructure or platforms for new entrants' train companies. In France, it oversees almost the entire transport sector: motorways, airports, railways, urban buses, etc. It also carries out studies and is independent of monopolies, especially the National Company of French Railways (SNCF).

Other elements must be taken into account as well:

- **Sanitary context:** Sanitary control, for example, can impact boarding times. For the moment there is no impact as traffic has not returned to normal since 2019 although airlines ask passengers to arrive earlier than usual. Control measures need to be done by the airport and airline staff.
- **Regulatory inflation:** According to one of the respondents, in France, the trend development is to implement more controls. After the attack of September 11 the trend is increasing. First, ISPS controls were imposed as part of port and maritime security. Later, the Touquet treaty with migratory controls was implemented. It requires, that 100% of freight traffic is controlled, which leads to one million controls on heavy goods vehicles during the year. These control measures are time consuming.

7.2.5 Disruptive situations

The issue of disruptive situations was addressed in the interviews. Disruptive situations can be broken down into two different categories, which are unexpected situations and predictable situations.

- **Unexpected situations:** Two types of accident on airports can happen. First, an accident which involves pedestrians. This involves a fatal, and a material risk. A damaged aircraft is a high financial risk, as this could lead to several million Euros loss for an airline. The second type is a strike. In the case of maritime transport, the dockers may be on strike and might block the port. In this case, the customer is obliged to pay parking fees at the port for the duration of the strike.
- **Expected:** Bad weather conditions could be an expected disruptive situation. Airports are usually warned in advance of extreme weather events and have a winter maintenance plan. These disruptive situations can have an impact depending on the mode of travel, like flight or maritime and are an important management aspect. In case of an accident, the airport capacity, in other words the flow management, is impacted. If an aircraft is stuck on the ground, it takes

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up a parking space, which therefore cannot be used by other aircraft coming to that airport. Regarding maritime transport, in case of strikes the dockers block the port, but charging fees still apply. If the event of a strike is known to the ship before it arrives, it might be possible to reroute the ship to another port. However, this leads to additional costs. For the flight sector rerouting of planes is possible at large airports, but rather difficult at smaller ones.

7.3 Ethical aspects for MTME

The disregard of ethical aspects can function as a barrier for the implementation of the target vision for MTME.

Some ethical aspects are already covered in the legal and safety and security perspective of this report, such as data protection requirements for MTMEs, the liability framework for artificial intelligence, as well as security requirements. More detailed information on other ethical aspects, which are influencing the implementation concepts of ORCHESTRA are covered in D1.3 “Ethics, security and gender balance plan.” The potential ethical issues include the discriminatory use of technical tools, whereas recommendations for the development process of technical tools and the arbitration processes are provided. Moreover, the topic of gender and MTMEs and the risk of excluding transport solutions for vulnerable users is addressed in D1.3 “Ethics, security and gender balance plan”, providing inputs on mobility of care, as well as the possibility for safer transport through ITS solutions.

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8 Conclusion

The last chapter summarises the results and shows common findings as well as special distinctions between the perspectives. Finally, common drivers will be presented.

8.1 Business and techno-economic perspective

From a business and techno-economic perspective the silo mentality has especially been identified as a barrier, preventing a holistic optimisation and leading to efficiency losses. These inefficiencies, along with traffic congestion, lead to direct as well as indirect (external) costs, for instance by increased fuel consumption and related emissions. MTME and an integrated and unified traffic management platform is seen as a central part of the solution, but only when factors such as physical infrastructure (development), economic viability, and an increased shared economy are taken into consideration. A main issue for implementing a data-sharing platform is to guarantee control over accesses and permissions to the data. Further, a conflict of interest exists on how shared data should be used between the stakeholders. While service providers want to sell the service to bring customers from point A to B, public and transport authorities want to avoid congestions first and foremost. Nevertheless, several processes foster the development of MTM(E). In particular, technology as well as the need to increase efficiency and sustainability of transportation drive MTME. For private companies, the key drivers include technological innovation and interoperability, digitalisation, data standardization, whereas for the public transport sector the goals of making (freight) transport more sustainable is crucial. These drivers are already influencing the industry. In addition, new business models integrating MaaS concepts are driving the development of MTME. It should be emphasized, that none of the economic interviewees currently use an integrated traffic management platform. However, various interview partners stated that this would be (economical) beneficial. In order to finance MTME, a combination of public and private financing (e.g. by membership fees or at cost per transaction) is required and thus mentioned.

8.2 Legal and regulatory perspective

From a legal point of view, there are four benchmarks of relevant legislation for the implementation of MTME. Firstly, European legislation targeting transport and its multimodal aspects. In this regard, the Combined Transport Directive is a driver, creating incentives for companies to use multimodal transport. However, the incentives are quite minor. Secondly, the other relevant legislation strand focuses on general data protection, access and exchange of data within the EU, which might have significant implication for multimodal transport and can both function as drivers and barriers. The TEN-T regulation mainly calls in action to installed required infrastructure for mono-modality and only partly for multimodality. However, digital aspects for the development of a multimodal network are absent within the TEN-T regulation. Furthermore, the ITS Directive supports access to and interoperability of road mobility data, as well as data on the intersection of road transport and other transport modes. However, the scope of application does not foster inter-modality between all kinds of modes. Therefore, even though the ITS Directive enables multimodality to a certain degree, the approach is still fragmentary and merely a limited driver for the implementation of MTME. Thirdly, the legal framework of cyber- and product security law can function both as an enabler and a barrier for the implementation of MTME's. They could be enabling, since the compliance with cyber- and product security law fosters acceptance from users. However, they could also function as a barrier, as the implementation of certification processes and IT-security measures is time-consuming and requires financial and human resources. Fourthly, regulation on competition law could be a barrier for

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the implementation of MTME. However, the aspects could be solved through contractual agreements between users.

8.3 Psycho-sociological and acceptance perspective

From the psycho-sociological and acceptance point of view, the results show that the freight transport sector is much less advanced in terms of information sharing than passenger transport. This difference can be explained by a very aggressive competitive environment for freight transport which makes information sharing more difficult to accept. Concerning the expected effort, the large volume of data that needs to be collected, as well as the need to standardise and anonymise it are needed to be taken into account. Moreover, the interconnection between different modes of transports, notably for health reasons or economic reasons remains difficult, e.g. road transport remains cheaper than rail transport. However, the respondents are sensitive to environmental issues. In any case, the different actors agree on common objectives: fluidity, reduction of polluting emissions, and speed. In order for MTME to be achieved, two bodies remain indispensable: a strong regulatory authority associated with an organising authority. At present, regulatory authorities have been set up in the various countries. However, their weight differs from country to country. The idea of a European regulatory authority is under consideration. Regulatory inflation remains a contextual element that must be taken into account. The evaluation of the acceptance of an information sharing system at the level of the different actors is focused on the management level.

8.4 Security & safety perspective

In regard to the security and safety perspective, one of the main drivers is the EU policy goal to improve safety in the road traffic sector and to achieve the Vision Zero. A variety of standards exist in order to increase safety for different transport sectors. These are relevant to take into account for certification processes. The implementation of a certification process can be a driver for acceptance, but might also be seen as a barrier, where requirements are strong. Management measures may vary in order to respond to the different issues that may potentially arise per sector. The importance of cybersecurity rises and is of high relevance for the implementation of the MTME due to the connection of all transport modes. The connection risks the entire transportation system if one is under cyberattack. Special knowledge toolkits already exist. However, the implementation of cybersecurity is often-limited due to the missing expertise in companies with different core activities. Nevertheless, the interviews showed that some organisations already implement cybersecurity measures. In most cases the organisations were not particularly interested in in-depth implementation of cybersecurity and only decide to invest in measures when this is required.

8.5 Synthesis – Similarities and differences

This section provides an overview of the similarities and differences between the drivers and barriers of the legal, economic, security & safety, as well as psycho-sociological and acceptance perspective.

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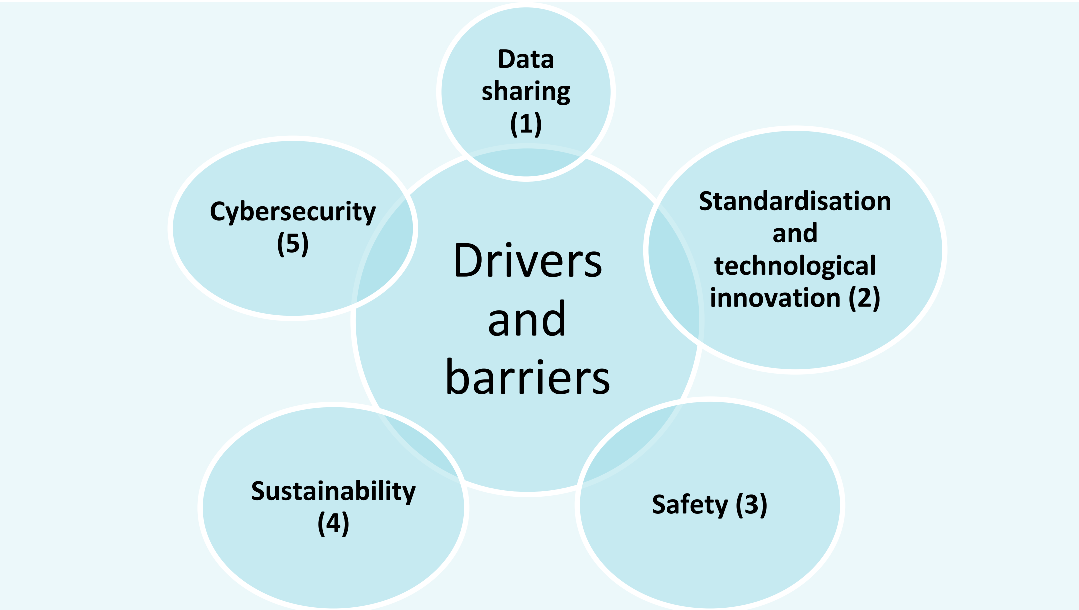

Figure 6: Overview - Common drivers and barriers

(1) <u>Data Sharing</u>

In order to implement MTME, data sharing between stakeholders is essential. However, the conflict of interest is a common barrier from an economic, as well as an acceptance perspective. From a legal point of view, the incentives to share mobility data are rather minor. Moreover, the regulation distinguishes between data sharing models, like data sharing A2A, B2A, or B2B. The existing hesitancy from private stakeholders to share data with competitors has economic reasons, as data might be a competitive advantage in the long run. However, this assessment might vary depending on what types of data are shared, e.g. statistical data might be shared more willingly, than real-time data. The public sector is already more active in sharing data, which is reflected in the legal framework. In order to solve the conflict of interests, which arise from an economical perspective, contractual agreements on what types of data are shared and how they should be used by stakeholders might be a solution. From an acceptance perspective, there is a need for a regulatory authority with strong competences, with a mandate to manage mobility data.

(2) <u>Standardisation and technological innovation</u>

The need for standardisation is a common driver shared by the economical, acceptance, as well as security and safety perspective. It is interlinked with technological innovation, which is a driver for both, the economical, as well as the safety and security perspective. The link exists e.g. through certification processes of newly developed technologies, in which cases applied standardisation functions as a threshold for certification authorities. Certification processes or conformity assessments by authorities might also apply for software used within MTME due to the characterisation as essential infrastructure, as well as high-risk AI systems. The applicability of both categories depends amongst other requirements on the link to potential disruptive effects on the coordination of traffic flows, movement of persons, and supply of goods.

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(3) Safety

Another policy goal and driver are the safety aspects of road traffic and the transport sector in general. The potential increase in safety is achieved through faster management and an improved forecast of disruptive effects through the implementation of MTME. This driver is shared from the legal, economical, as well as the acceptance perspectives. Disruptive events might cause harm to people and goods, and should be prevented or, in case where a prevention is not possible due to outside effects, such as extreme weather events, they must be at least efficiently handled.

(4) Sustainability

A shared driver between the legal, economical, as well as the acceptance perspectives is the goal of sustainability within the transport sector. This goal is reflected in the European regulatory framework, like the European Green Deal, as well as the Sustainable and Smart Mobility Strategy issued by the Commission. Moreover, from an economic-environmental and economic-social perspective, sustainable transport is important due to the external costs related to Co2 emissions, as well as policy goals for air quality. The latter is especially important in urban areas. If the increase of efficiency leads to a reduction of transportation costs, this could lead to better inclusion of society, also leading to the improvement of health of citizens through active participation in societal events.

(5) Cybersecurity

The topic of cybersecurity is a common driver between the legal and regulatory perspective, and the safety and security perspective. The link to acceptance is provided through the need for regulation in order to achieve a high protection level, since companies often do not implement protection measures on a voluntary basis. From an economical perspective, cybersecurity functions as a barrier due to cost-intensive resources needed for the implementation. However, it can also function as a driver for the economical perspective, due to the prevention of breakdowns of systems leading to potential financial loss.

Contribution to the objectives of ORCHESTRA

The findings of the deliverable contribute to the understanding of the drivers and barriers for a future implementation of the MTME target vision by analysing the status quo.

The results are relevant for the following objectives of ORCHESTRA:

- *O1: Establish a common understanding of multimodal traffic management (MTM) concepts and solutions.* The further work on the scenarios in WP2 and the roadmap for policy makers must take the identified drivers and barriers into account.
- *O2: Define 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 work in WP3 on the polycentric and multimodal traffic management architecture must take the social dimension and the ethical issues of digitalization into account.
- *O3: Support MTME realisation and deployments.* The work in WP3 must take the barriers and drivers into account. The results from the legal and economical perspectives are relevant for the future work on the business, market, and organisational models in WP4.
- *O4: Validate and calibrate MTME with respect to organisational issues, functionality, capability and usability*. The roadmap in WP2 will take into account the findings on barriers and drivers of this pre-study to analyse how policy-makers could foster usability of MTME.

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10 Annex

10.1 Annex I: Interview Protocols

10.1.1 Legal and Economic Interviews (IKEM)

Section 0: Addressing and personifying the interview partner / general introduction to the interview partner (open part)

Interviews with Berliner Verkehrsbetriebe (BVG), European Railway Agency (ERA), European Road Transport Telematics Implementation Coordination Organisation (ERTICO), Mobility Inside (MI), TU Berlin (TUB), Universidad Nacional de Educación a Distancia (UNED), Uni Jena (UJ), Uni Bocconi (UB), Uni Roma (UR) and Verkehr Mobilität Zukunft (VMZ) from end of August 2021 to mid of October 2021 - If answers are missing, it is because the interviewee was not able to give input on the respective question

	Structure	
Introduction	**Question**	**Answer**
• Introduction of the interviewer • Usage of the findings (We would like to record) • Topic presentation • Structure of the interview	0.1 None	Presentation of the project and person of the interviewer
• Introduction of the interviewee partner • Introduction of the company/institution. • Status of the company/institution. • Field of expertise of the company/institution.	0.2 To begin, could you please briefly introduce yourself? 0.3 What is the name of your organization or company? 0.4 Are you a subsidiary of a group? 0.5 What is your status: public, private, private-public partnership? 0.6 What is your field of competence?	[individual answers]

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Section 1: General questions

	Structure	
Introduction	**Question**	**Answer**
• Every company/institution has key motivators which act as drivers to carry out their daily tasks.	1.1 What would you describe as the key drivers for the work your company/institution does?	Publicly financed (Unis, public transport) x5 Research (projects) - efficient and sustainable development issues, continuous innovation, analysis of technological operation, evolution of existing and new markets in mobility x4 (Unis) Making urban/freight transport more sustainable by connecting them – "sustainable transport design" (VMZ) Establishing single European railway area (as opposed to national ones) (ERA) Innovation and interoperability (ERTICO) Digitalization and data standardization of public transport sector (MI)
• Traffic plays an integral part in every company/institution and often companies/institutions deal with traffic across various modes of transport in their daily operations.	1.2 How is your company/institution related to multimodal traffic?	Connecting transport via train in a multimodal way (ERA) Creating solutions for advanced interactive traffic management (corridor/traffic/cross border information system) (ERTICO) Cooperative, connected automated Mobility (CCAM), Horizon 2020 Projects (TUB) Teaching about multimodal transport law (UR) Analysis of infrastructure, determination of demand, creating digital mobility platforms, providing intermodal route planning (VMZ) Creating an all-in-one app for MaaS, including multimodal transport (MI) Research on EU regulations regarding multimodality and digital platforms (UNED) General research (UB, UJ)

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• Consequences arises whenever traffic management isn't done efficiently. However, every organization have their unique approach towards its solution.	1.3 In your experience, what are the effects of poor traffic management planning?	Poor services, Disruptions, Bad reputation, Lack of capacity, Revenue loss (ERA) Traffic jams (ERTICO) Congestions, traffic jams (TUB) Most companies monomodal → inefficient planning (Uni Roma) No interlinking of different digital public transport services → less use → more emissions/jams etc. (MI) Sharing of competencies on governmental level → Inefficiencies, lack of multimodal governance (UB) Transport modes working in silos → Efficiency loss First/Last mile issues not optimized (UNED)
	1.4 Do you think that current traffic problems can be solved by an integrated and unified traffic management platform?	Hollistic approach: Infrastructural measures (reduction of parking space, expanding sharing economy) → private car must be made less at-tractive, "shared use" more attractive (BVG) multi-modal platform cannot solve certain structural problems, such as cross-border operations, flow management between modes etc → only part of solution (ERA) Yes, especially when focusing on standardization and unifying (Ertico) Only in combination with infrastructural measures, technology can only support (TUB) Can help as a part of solution (UR) Central part of solution, but infrastructure needs to be expanded, too (VMZ) Part of the solution, other factors e.g. infrastructure also important (MI) Can help, but economic viability is vital (Uni Jena) Part of the solution (Uni Bocconi) Platform has potential, but doubts about it being unified/integrated (UNED)

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• Smart Infrastructures has the potential to transform the way we plan and manage infrastructure. New developments in technology and software can increase the overall productivity and efficiency.	1.5 Which future technologies and functions from smart infrastructures would be of interest to your company/institution?	serving gaps/bottlenecks in transport systems in real time (BVG) Automated train operation (ATO), Smart grids, Future Railway mobile com. System (FRMCS) (ERA) IOT, autonomous driving/shuttles, 5G, Machine learning/AI, Quantum computing(ERTICO) AI use of satellite data, Integration of 5G (Uni Roma) V2X (e.g. traffic light – smartphone real time info), City tolls (VMZ) Digitization of tariffs, unified standards, real time data (MI) Real-time holistic data exchange, vehicle and infrastructure monitoring (satellites) (UB) Sensors – Infrastructure – Smartphone, Networking (5G), Machine learning/AI (UNED)

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Section 2 Economic focus

Interviews with BVG, ERTICO, TUB, VMZ, MI, UB

	Structure		
Introduction/Address	**2**	**Question**	**Answer**
• When it comes to the planning of traffic routes and schedules, companies operate quite differently.	2.1	How are traffic routes and schedules currently planned in your company's/institution's transport operation?	• Tools AEOLIX/FENIX are able to calculate estimated time of arrival, rerouting, planning (ERTICO) • In Berlin: several mobility services, but no integrated network routing/planning (TUB) • Integration of public transport info on platform, modelling of traffic flows, demand planning, traffic modelling (VMZ) • Offering App, that shows cheapest/fastest mean of transport, use of DELFI (platform of German federal states) for uniform traffic data (MI) • Current problems for most companies probably still lie in the last mile concerning digitalisation and that a MTME would be especially useful for that last mile (UB)
• There are various digital solutions available in the market.	2.2	What kind of digital solutions does your company/institution use and/or offer?	• A digital cloud Marketplace and Innovative services (ERTICO) • Using: VISUM Software: modelling and planning e.g. parking data, sharing economy, intermodal route planer, monitoring (VMZ) • Offering: White label app: Sales background system for digital processes (MI)
• Sharing the traffic routes and/or schedules of your company's transport fleet with business partners could be mutually beneficial.	2.3	Are traffic routes and schedules for your company's transport operation shared with the logistics/freight companies that you are in business with?	• Timetables and real time data shared via VBB data hub (BVG) • Data sharing enhances efficiency. With margins of 2-5%, freight companies will have to share data to survive (ERTICO) • MI = data hub and data connector (MI)
	2.4	Do the companies you are in business with also share similar data with you?	• E.g. provision of the route planner, which can be integrated into the company-specific app as a ser-vice (VMZ) • Provision of routing for customers (data management as the main task of Mobility Inside) (MI)
• Choosing the best traffic routes and best time for doing the transport operation while updating your business partners can create difficulties.	2.5	Is there an integrated traffic management platform/system that is currently being used between your company and other logistics/freight companies?	• Jelbi App: Marketplace for mobility as intermediary between mobility providers and customers (BVG) • Project Fenix: proposal to integrate traffic management services across the trans-European network to integrate all over Europe (ERTICO)

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	2.6 If not, what is the current mode of communication fortraffic and route planning? [dismissed]	• No integrated traffic management program, Current mode of communication: API Channel or API connection (TUB)
• There are different navigation systems available in the market which includes traffic forecasting too.	2.7 What type of navigation systems (incl. traffic forecast systems) does your company use, if any?	• Currently no use of such a program by Jelbi, other sources: Traffic data of the MIV via Google data/ Maps for optimizing timetable information (BVG) • Using Cooperative IT services helping to navigate, booking parking slots, rerouting option, showing estimated time arrival of vehicle → important to make RDS-TMC available for everyone (ERTICO) • Open street map, Google. TomTom (TUB) • Use of own route planning through in-house development, Purchase of floating car data (travel data) and forecasting tools from provid-ers such as tom tom or inrix • Not at the moment, (consideration of these aspects in the 3 to 5-year planning (MI)
• Many companies prefer monitoring their vehicle fleet in real-time or at regular intervals throughout an operation.	2.8 Are your company's transport vehicles (fleet) monitored in real-time throughout the entire operation? 2.9 If not, at which points do you get updates on the operation and where the vehicles are? [dismissed]	• Location data of sharing partners transmitted in real time, Tracking of buses in real time, no tracking for subway (BVG) • Companies involved with Ertico track in 30s-intervalls (ERTICO) • No transport vehicles, but real-time monitoring and routing of other vehicles by customers (VMZ) • MI does not own any vehicles, but real-time data is a requirement for participation for customers (MI) • Real-time monitoring is a widespread activity for security and fleet performance reasons (UB)
• With your company's/institution's experience, you must have identified what the main operational bottlenecks are with managing traffic routes/schedules.	2.10 What, in your professional opinion, is the main traffic-related operational bottleneck that exists in your current operation? 2.11 Can you give an example of a specific scenario where this bottleneck happened?	• enormous area and long distances; growing urban center, Commuter problem: core approach to reducing car traffic (BVG) • Physical Network capacity, technical difficulties in monitoring real-time data and lack of quantum computing power are major bottlenecks (ERTICO) • Technological advancement is necessary but not enough, essential to consider customers' behavior and needs as socio-economic factors (TUB) • Market: lack of software developers (VMZ) • Small-scale nature of public transport and lack of standardization, different technical and especially organizational systems everywhere, organizational area is strongly influenced by political interests (MI)

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		• Traffic jam and lack of digital infrastructure → improvements in digital infrastructure also need improvements in physical infrastructure in order to make sure there is an optimised traffic flow (UB)
• Companies use different approaches to manage multi-modal transport operations.	2.12 If an operation requires multi-modal transport, how does your company manage the link between the modes of transport?	• Solution: optimize traffic flow and estimate time of arrival of each segment in multimodal transport (ERTICO) • By complex algorithms with appropriate configurations, real-time data is crucial to offer realistic options and to check the viability of transport offers, For each mode there are separate route planners that calculate the optimal result for the user by means of a multi-criteria algorithm (e,g, time, distance, GHG) (VMZ) • Deep link is used for sharing offers to the app of the transport partner = interconnection of different transport modes (MI)
• Autonomous and connected vehicles/fleets could offer many advantages for transport operations.	2.13 Do you use/intend to use in future, autonomous and connected vehicles in your transport operations?	• **Discussion**: self-driving subway, **Pilot projects**: self-driving mini-buses (e.g. Tegel, Charité Campus), **Goal**: widespread use of autonomous shuttles (BVG) • **Plan**: connect hub to hub e.g. port or airport **Option**: Last mile delivery by autonomous vehicles **Currently**:, use of autonomous vehicles more of a legal framework and policy issue than technology issue (ERTICO) • CAVs need to be integrated in all modes of transport (TUB) • Cooperation with Siemens, where apps for autonomous shuttles are being developed, also research projects e.g., Shuttles & Co. by BVG, Easy Ride in Munich by MVG (VMZ) • No concrete planning for autonomous driving (MI)
• The Paris Agreement sustainability development goals aim for the transport industry to heavily reduce or eliminate carbon emissions.	2.14 Is sustainability an important topic on the agenda of your company? If so, what steps have been taken in order to reduce emissions?	• Conversion of bus fleet from combustion engines to electric motors by 2030 (BVG) • If there are different multimodal segments integrated into projects, the segments can be optimized and aggregated for a reduction of CO2 of up to 32 percent (ERTICO) • Preferable steps: Advancement in technology, Regulations – controlling and considering interaction or dynamics between transport modes, Consideration of socio-economic parameters (TUB)

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		• Development of numerous master plans for cities and municipalities, Designing the implementation of necessary measures and mobility information services (VMZ) • Primary goal: Reduce MIV and motivate previous car users to switch to public transport, Simplification of the ticket systems (MI) • electrification, efficient management of energy in public transport infrastructure → flexibility and integration are key (UB)

Section 3 Legal Focus

Interviews with ERA, UNED, UR, UJ

	Structure	
Introduction	**Question**	**Answer**
• When it comes to data sharing, it is necessary for companies/institutions to share some data with national authorities.	3.1 Is there a national authority in your EU member state to whom companies working in the traffic sector must provide data on their traffic / logistic flows?	• As EU institution: only establishing technical specifications for interoperability and delivering authorization (ERA) • No (Spain), due to complex political structure. Transport ministry working on implementation of ITS directives and implementing regulations. Problem: complex administrative system, tension between state and regions – regional policies need to be coordinated through a national one. Therefore, mainly implementation of EU legislation (UNED) • Italy has various regulatory bodies, authority on transport based in Turin and mandated by EU law • Certain degree of data transparency in public transport, but not in other areas (UJ)
	3.2 What kind of data do relevant stakeholders currently share with authorities / private stakeholders to foster intermodal traffic management?	• Timetable info, tariffs, road & rail network description, pedestrian & cycling network real-time data, network description, consignment notes, operational information (ERA) • Companies provide complex raw data, which is statistical data of the past → for functioning of multimodal system real time data must be provided (UR)

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	3.3 Are relevant stakeholders obliged to share any data / provide any access to public authorities within your (EU member) state? If yes: Under what regulation / circumstances?	• Silo system: e.g. airlines have to provide financial data to EU Airspace safety authority (UR) • Other interviews: answered in 3.1/3.2

• Some data may be too critical for stakeholders to share with authorities or other actors. In the absence of a legal basis, for example, incentives could convince these stakeholders to share such data.	3.4 What kind of incentives are needed to convince stakeholders to share data concerning their traffic flows with authorities/other stakeholders for traffic management reasons?
	A. Tax reduction?
	B. Remuneration?
	C. No incentives would be needed, other than improvement of efficiency that comes with it?
	
	3.5 Would your previous assessment on question 2.4 differ concerning separate types of data categories, such as real-time data on traffic flows, forecast data on traffic as well as statistical data?
		• D)
		  ○ Enforced regulation for data sharing, especially for multimodal transport; experience has shown that voluntary things do not develop as quickly as needed
		  ○ Standardised data descriptions and protocols
		  ○ Financial incentives: public subsidies are possible in case stable business do not develop; data sharing obligations with authorities
		  ○ monitoring implementation to enforce it (ERA)
		• B) They need certainty, a win-win solution: Exchange data as an incentive option, i.e. bilateral exchange (for instance, ports giving data to vessels and vessels to ports) (UNED)
		• Companies only afraid to share critical business data, as long as it´s protected it´s ok (UR)
		• C) does not believe in tax reductions and remuneration
		
		• Yes, with each data category you might have different requirements for data sharing (ERA)
		• Transport industry is very conservative for data sharing.
		  ○ Statistical data – Yes, for regulation purpose.
		  ○ Forecast data – No, because it is more accounted into business.
		  ○ Real time data source – No. (UNED)
		• Real time data needed (UR)
		• No, crucial for each kind of data: is it something the company is giving out voluntarily? if not, are there reasons for it? (UJ)

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		• Reluctance to share customer-related data (ERA)
• There are differing opinions when it comes to cybersecurity requirements, some see it as driver whereas some as barrier.	3.6 Are cyber security requirements seen as a barrier for collaboration amongst stakeholders? A. No, because stakeholders implement cyber security on a high-level on voluntary reasons. B. Yes, because the legal requirements deriving from e.g., essential service protection requirements can only be implemented with high effort / the use of expensive resources? C. Other?	• D) Cyber security requirements are a mandatory basis because it is required by certain regulation, e.g. telematics (ERA) • Yes, they are a barrier, but not the main one. installment for devices/services are pre requirement for traffic management which will cost energy and time as the main issue will be how to distribute them (UNED) • B) Very expensive to keep data thoroughly protected, but it´s mandatory (UR) • C) Energy sector: Stakeholders care too little about cybersecurity, will take time until appropriate standards develop, not seen as a real barrier though, legislator should create regulations (UJ)
• The NIS II Directive defines what essential digital infrastructures are.	3.7 Would you share the assessment that potential digital infrastructure for MTMEs would be considered essential infrastructure under the NIS II Directive?	• Yes, see also 2.6 (ERA) • Not currently, but **yes** because their role will increase in future. Platforms will become system coordinators, "brain of the system" (UNED) • No precise answer, but it is surely strategic and requires very much attention; it should fall among those sectors (UR) • No precise answer, but it is surely strategic and requires very much attention; it should fall among those sectors (UJ)
• When creating an MTME network, personal data protection requirements must be adequately considered.	3.8 Do you think personal data protection requirements are hard to implement for specific MTME tools in the passenger sector? A. No, because anonymisation and pseudonymization techniques can be implemented easily. B. Yes, because anonymisation and pseudonymisation techniques need to be further developed	• No (ERA) • Yes, for anonymization purposes (UNED) • Anonymisation does not exist, only written in law, but data is saved somewhere (UR) • In Germany, people are treated quite anonymously. As things stand, there should be few problems with this (UJ)

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• The "data mobility spaces" is defined be the EU data strategy.	3.9 Are you familiar with the concept of "data mobility spaces", which will be implemented in accordance with the EU data strategy? Do you think relevant stakeholders would be willing to participate by providing data to the "data mobility spaces?	• Aware, but not familiar in detail (ERA) • Familiar with the concept as much as possible because it is not yet clear how it is going to work, but Transport Service providers are not willing to provide the data sets to "data mobility spaces" (UNED) • EU has implemented a Directive on flow of data, as data can have strategic importance (UR) • Not familiar (UJ)
• Different EU member states have different legal frameworks for integrating CAVs.	3.10 How is the national legal framework in your (EU member) state concerning CAV shaped? To what extant is the use possible on public grounds?	• No specific regulation in Italy yet, doesn´t consider it a top priority (UR) • There is a new regulation in road traffic law, but it is not comprehensive and without preconditions (GER) (UJ) • ERA/UNED no reply
	3.11 How is data ownership deriving from CAV's allocated within your national legal framework?	• National legal framework does not exist (UR) • Others cannot answer

• There are different possibilities available for interoperable data exchange. Some of them are relevant for MTME.	3.12 Are there standardization norms already applicable?	• Passenger transport: CEN developed
		  ○ Netex: umbrella interface where everybody can plug-in and find their "comfort zone", very easy to give information to public authorities and to understand it
		  ○ Transmodel-Siri (included in Netex): description of real-time information in a multi-modal environment
		• Freight: COM developed
		  ○ eFTI - aim to ensure that consignment node and consignment order messages between different actors in intermodal manner (ERA)
		• Example of data standardization in LA (UNED)
		• difficulties on EU level for exchange of information between public authorities (UR)
		• No answer (UJ)

	3.13 If not, do you think interoperability for the data exchange would be an issue?	• Many challenges, but standards will be developed (ERA) • Will be an issue for different geographic regions (UNED) • Interoperability always a problem, at least fundamental regulations necessary (UJ)

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		• No answer (UR)

Section 4 Discussion questions

	Structure	
Introduction/Address	**4 Question**	**Answer**
• The current challenges in traffic are multifaceted and can be addressed in a variety of ways.	4.1 Do you believe that the traffic issues that currently exist can be solved via an integrated and unified MTME network?	• No answer (BVG) • A multi-modal platform cannot solve certain structural problems, such as cross-border administrative problems, flow management between modes (ERA) • Yes (ERTICO) • cannot be solved by this, but it can make a contribution (MI) • Yes (TUB) • Network and platform will work. Still not sure about the integrated and unified network (UNED) • It wouldn't do any harm, it will already give a push in the right direction. But one cannot see the solution to all problems here (UJ) • Important tool, but needs fair and transparent sharing of info and foster growth of intermodal services (UB) • MTME might be helpful to eliminate some problems but can't solve all of them (UR) • No, because it is not sufficient on its own to solve the traffic prob-lems, Tougher factors such as fiscal measures are also needed (VMZ)
	4.2 Do you think the MTME network as described by ORCHESTRA would be useful to your company/institution?	• Key: Depth integration, real time planning and availability, one-in-all-solution e.g. app (BVG) • Yes with enforced regulation (ERA) • Yes, especially for TM2.0 (ERTICO) • Yes, especially when working with real time data (MI) • Yes, because connected and integrated data can be used for better analysis. (TUB) • No answer (UNED) • No answer (Uni Jena) • Yes, enables many chances to support change in public institutions, companies and to embrace development of different generation of services, exploiting the benefits of an effective and open informative ecosystem (UB) • No answer (UR)

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		• Yes, as networking is the key to inter-modality and monopolarity is not conducive (VMZ)
• The introduction of a highly data-intensive network such as the MTME network entails risks as well as great opportunities.	4.3 What would be your main concern in MTME, if autonomous/connected vehicles were integrated into the system?	• Acceptance and standardization (ERA) • Legal framework and libability (ERTICO) • Might push car transport instead of public transport (MI) • Cyberattacks (TUB) • Safety (UNED) • Difficult from technical perspective (UJ) • Transition phase difficult (UB) • Technological problems can be handled (UR) • Competencies and authorities must be carefully considered in order to avoid conflicting goals (VMZ)
• Especially with regard to technical features, such a network could be designed in a variety of ways.	4.4 Can you describe some of the technical features that would be important for your company/institution on the MTME network?	• Ensuring data interoperability & security (ERA) • Real time monitoring as well as integration of different multimodal segments for transport or logistic service providers (ERTICO) • No answer (MI) • Providing standardized protocol: real-time, on-demand, and high technology for MTME network (TUB) • Control over sensors, algorithms/AI and networks (UNED) • No answer (UJ) • Planning support (UB) • Integration of 5G technologies and European Union project of control of Road traffic through satellites and movement (UR) • Open Interfaces (VMZ)
• When establishing a data management system as described in ORCHESTRA, there are many possibilities to divide the scope of tasks between public and private stakeholders. This also applies to a possible monetization of the system.	4.5 What could be the respective role of public versus private sector in funding, developing, and operating a digital infrastructure enabling the above data management and or value transfer/payment functions?	• Public sector (infrastructure manager, public RU, PSO) should be the driver for the data management system while sharing information with private sector (ERA) • No concrete answer (ERTICO) • Strong doubts on public authorities – Lack of knowledge with respect to AI in order to operate system. They have a very important role in terms of enabling and incentivizing the growth of this systems and they have a very strong role in the control of how these systems operate, but should not operate (UNED) • In no case primarily a state task, because the state does not manage better. The bottom line is that companies generate our prosperity (UJ)

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		• No answer (UB) • It is imperative that public sectors oversee and coordinate infrastructures like ports, airports, railways, motorways, as well as digital cables and satellites and databases (UR) • Both need to be harmonized – public sector not efficient but powerful, private efficient but lacks some powers (TUB) • Financing by the public sector so that the project is sustainable -Otherwise, the added value is too low to refinance the costs for the platform (VMZ)
	4.6 If the MTME network were to be monetized: How could we monetize the data and/or the data access in real time? (e.g., towards scalable automated processes)	• Membership fees (ERA) • Similar to navigation systems: pay for updates received (ERTICO) • Either create flat access or pay by data volume (MI) • No concrete answer (TUB) • Public support for starting the platform, then numerous ways for monetization (unspecific) (UNED) • No answer (UJ) • Membership fee (UB) • Monetization wrong approach, public investment in critical infrastructure will boost economic welfare (UR) • Transaction based model, licensing (VMZ)
• In this short interview, we certainly did not discuss all aspects related to MTME.	4.7 What further challenges do you see regarding the MTME network? 4.8 Would you be interested to use an MTME network as described in ORCHESTRA?	• Overcome stakeholders reluctance to share data (ERA) • Cyber security, lack of information on how the implementation of this might further develop, impact on energy consumption (ERTICO) • Cost-effectiveness and incentives (MI) • See above (TUB) • Overcoming silo structure, as companies in one silo partly profit from this and will be reluctant to change (UNED) • No answer (UJ) • Planning on regulatory level, transparency (UB) • Creating smart and digital infrastructures (UR) • Legal requirements and who has competencies, fairness (no one overly disadvantaged), data transfer and protection, standardization, data quality (VMZ) • Yes (BVG) • Yes (ERTICO) • Yes, definitely (MI) • Yes (TUB) • Yes (UB)

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		• Yes (VMZ) • Rest was not asked

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10.1.2 Security & Safety Interviews (HES-SO)

Conducted Interviews:

- **12.10.2021:** Project Manager for innovation in public transport from Transport publics fribourgeoise (TPF)
- **05.11.2021:** Project Manager at Verkehrsbetrieb Zürich (VBZ)
- **12.11.2021:** Professor of Computer Science at HES-SO Valais (HES)
- **18.11.2021:** Employee at Institut für Verkehrsrecht und Verkehrsverhalten (IfVV)
- **18.11.2021:** Business Developer at YUnex AG (YUnex)
- **24.11.2021:** Project Coordinator at Swiss Transit Lab (STL)

Section 0: Addressing and personifying the interview partner / general introduction to the general attitude of the interview partner to the topic (open part))

Research question		**Structure**	
	Introduction/Address	**Question**	**Answer**
Intro	• Introduction of the interviewer • Usage of the findings (We would like to record) • Topic presentation • Structure of the interview	None	Presentation of the project and person of the interviewer
Which industry/research project do interview partners belong to? In which industry/research project do interview partners work?	• Introduction of the interview partner	0.1 Name and surname 0.2 Name of your organization 0.3 What is the status of your organisation ? 0.4 What is your organisation's area of competence ? 0.5 What is your role in your organisation ?	[individual answers]

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Section 1: General questions

This section contains questions to be asked to ALL CoP-members

	Question	Answer
Every company/institution has key motivators which act as drivers to carry out their daily tasks.	1.1. What would you describe as the key drivers for the work your organisation performs?	• Customer satisfaction (TPF) • We are public transport provider for Zurich and operate a mobility platform for Zurich area (VBZ) • Achieving impact in society (HES) • Legal framework for road traffic; actual prerequisites for safe traffic flow for people, means of transport and in the traffic area. (IfVV) • Traffic, general need of travelling (Yunex) • It is enthusiasm of the members for the topic of future mobility. (STL)
Traffic plays an integral part in every company/institution and often companies/institutions deal with traffic across various modes of transport in their daily operations.	1.2. How is your organisation related to multimodal traffic?	• We are a company of public transport, and we work on multimodal projects. (TPF) • We have a platform with which you can plan multimodal journeys (VBZ) • Many of us work far away from where they reside (HES) • Through various research papers and subsequent publications (IfVV) • Solution provider for multimodal traffic (Yunex) • It is our vision to bring further the multimodal traffic (in opposite to individual traffic). currently we are working on first/last mile solutions for public automated transportation (STL)
Consequences arises whenever traffic management isn't done efficiently. However, every organization have their unique approach towards its solution.	1.3. In your experience, what are the effects of poor traffic management planning?	• Our buses are stuck in traffic jam. Our routes are not always optimized. (TPF) • Customers are not satisfied and switch to usage of own cars (VBZ) • Long commute times, poor use of public transport (HES) • Shortcomings in road safety (IfVV) • Congestion and longer travel time in general (Yunex) • Traffic jams, bad service level in public transport and in consequence less people using public transport. (STL)

	1.4. Do you think that current traffic problems can be solved by an integrated and unified traffic management platform?	• A part yes. But people have to change their habits. (TPF) • probably yes, but the public has to define, what kind of traffic they want to have and how they want to regulate it (VBZ) • Yes, in part (HES) • No (IfVV) • Not as the sole measure, just a part of the solution (Yunex) • Some of them, yes. but probably not just one platform... (STL)
Smart Infrastructures has the potential to transform the way we plan and manage infrastructure. New developments in technology and software can increase the overall productivity and efficiency.	1.5. Which future technologies and functions from smart infrastructures would be of interest to your organisation ?	• Intelligent Traffic light, informations about the traffic in real time to anticipate decisions (for example : to add a bus if the others are too late) (TPF) • Digital swiss map with realtime information of mobility demands and prediction of future demand including current road usage and occupation (VBZ) • Smart safety systems (HES) • All (IfVV) • AI (Yunex) • Automated driving, digital platform services like shared services or MAAS (STL)
MTME Networks have the potential to vastly improve public transport and the transport of goods, but they do not come without any challenges.	1.6. What would be your main concern in the MTME if autonomous/connected vehicles were integrated into the system?	• Cybersecurity (TPF) • Increasing traffic due to empty rides, no ridepooling (VBZ) • None (HES) • Increasing road safety (IfVV) • No concerns (Yunex) • that they can be used easily on-demand and that they are bound to the bigger system (STL)
	1.7. If the MTME network were to be monetised, how could we monetise the data and/or the data access in real time?	• Difficult to answer. As a partly state-owned company, politicians should be included in the discussion (TPF) • Our data has to be open data therefore no monetising will be possible (VBZ) • Pay-per-access (HES) • N/A (IfVV) • Good question. At the moment it is hard to earn money with traffic data (Yunex) • good question, that's for you to answer (STL)
	1.8. What further challenges do you see regarding the MTME network?	• Guarantee equality but also guarantee the survival of local businesses (example: Google uses the data to put into service an autonomous vehicle service and endangers the local transport company) (TPF) • Organization, legal, data quality, financing and delivery of data by all suppliers (VBZ) • Integration and coordination among different operators (HES)

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		• Networking and interconnection with analogue traffic (IfVV) • Authorities. At the moment this is a task from the authorities. Further-more, the disrupting development of the car industry gives a uncertainty of the future technology (Yunex) • what's the business model? who is going to pay for your service? (STL)
	1.9. Would you be interested in using or participating in such an MTME net-work?	• Why not (TPF) • Yes (VBZ • Yes (HES) • Yes (IfVV) • Yes (Yunex) • yes, of course! (STL)
	1.10. Could you describe some of the technical features that would be important for your organisation on the MTME (Multimodal Traffic Management Ecosystem) net-work?	• having strong & secure datahubs (in-ternally), homogeneity, ITxPT com-patibility, handling of master data, enabling open-data access for public and other hubs (TPF) • N./A. (VBZ) • N./A. (HES) • N/A (IfVV) • We intend to build the MTME, not to use it. (Yunex) • N/A (STL)

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Section 4 Security and safety focus

	Question	Answer
When it comes to safety/cyber-security, companies have different methods regarding implementation and incentivising.	1.11. How is safety/cybersecurity currently treated and implemented within your organization?	• IT and OT worlds are separated. OT world (including critical infrastructure) is handled by a dedicated department, they take best practices and regulations from the railway industry. (TPF) • IT world is managed by the IT department, we followin the minimal security standard from Switzerland. however we don't have a iSMS system yet (management of information security) (TPF) • N./A. (VBZ) • N./A. (HES) • N/A (IfVV) • Highest priority (Yunex) • N/A (STL)
	1.12. What are some incentives that push the organisation and its employees to improve safety/cybersecurity?	• (TPF) • compliance with regulators in Switzerland (and sponsors) (TPF) • None; only that the systems work (VBZ) • lowering costs of attacks (HES) • Increasing road safety (IfVV) • There are no incentives. it's just that it has to be done (Yunex) • N/A (STL)
	1.13. What Safety and Cybersecurity threats do you think remain, even when implementing all necessary measures?	• ALL of them still remain, however the risk is reduced. (TPF) • N./A. (VBZ) • N./A. (HES) • N/A (IfVV) • This is an ongoing process with new threads and new countermeasures. (Yunex) • N/A (STL)
	1.14. Are there any Safety and Cybersecurity standards/regulations you are already following?	• working toward ISO27002 for IT + minimal standard from Switzerland (public transport - based on NIST) (TPF) • Other regulations (railway) are coming from the industry and the partners. (TPF) • N./A. (VBZ) • N./A. (HES) • N/A (IfVV) • Yes, e.g. ISO27001 (Yunex)

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		• N/A (STL)
Considering the current scenario, digitisation is critical. It is important to have a good cybersecurity culture and management of cybersecurity incidents within the organisation.	1.15. Are there currently any programs to improve the cybersecurity culture in your organisation ?	• Yes, training for all employees, phishing campaigns, partner management (TPF) • Yes, there is a central cyber security initiative by the IT department of the city of Zurich (OIZ) (VBZ) • Yes (HES) • Yes, implementing standards such as ISO27001 (Yunex) • yes, we are adressing it when tackling the challenge of teleoperating. (STL)
	1.16. How cybersecurity incidents currently handled within the company?	• The IT department takes care of this problem. Internal information has been put in place for all employees. Security has been improved. (TPF) • External SOC + internal response team (IT permiter). OT = we rely on partners (TPF) • There is a central process within the IT department (VBZ) • The system admin issues emails with warnings and indications (HES) • There are none (IfVV) • Analyse, react, and implement (Yunex) • we are an association, not an employer (STL)
The implementation of cybersecurity measures can be carried out internally or by a third party.	1.17. How are critical elements regarding Safety and Cybersecurity, and their associated risks, currently identified? Is it conducted internally or outsourced externally?	• internally, risk analysis from the IT. however the OT world is not really taken into account as of today, although we know it's important. security should be organized at the company level, not only for 1 IT perimeter and 1 department. (TPF) • We are lacking staff as of today + visibility, budget to improve the iSMS system (TPF) • N./A. (VBZ) • N./A. (HES) • N/A (IfVV) • Internally (Yunex) • badly, not handled. (STL)
	1.18. How are Safety and Cybersecurity measures currently chosen and implemented? Is it conducted internally or outsourced externally?	• internally + external audits. (TPF) • N./A. (VBZ) • N./A. (HES) • N/A (IfVV) • Internally (Yunex)

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		• N/A (STL)
	1.19. If a third party is involved in Safety and Cybersecurity, what is their role? (Training, creation or review of documentation, etc.)	• partners - for all of these tasks. (TPF) • Internal training is also given to all employees (by the IT department) (TPF) • N./A. (VBZ) • N./A. (HES) • N/A (IfVV) • N/A (Yunex) • N/A (STL)
There are several tools available on the market for the implementation of cybersecurity infrastructure.	1.20. Are you currently using any tools to support the implementation of Safety and Cybersecurity? If yes, which tools are used and for what are they used?	• vulnerability scanners, risk analysis systems (TPF) • N./A. (VBZ) • N./A. (HES) • N/A (IfVV) • Yes, common tools as available on the market (Yunex) • N/A (STL)
	1.21. If tools are used, of what type are they? (open-source/free, proprietary/non-free, custom)	• non-free and opensource. a mix ! (TPF) • N./A. (VBZ) • N./A. (HES) • N/A (IfVV) • Different. Whatever is the best tool, type is of minor importance (Yunex) • N/A (STL)
Data security is expected to be a top priority when establishing a data management system. Therefore, it is important to understand which methods are currently used to secure critical data and which could be used in the future.	1.22. Sharing data in a multi-stakeholder ecosystem poses risks of data being used by malicious parties. How can we guarantee that data is accessed by authorised parties only? And how can we ensure trust between data providers and consumers?	• DLP policies, SLAs, NDAs, ITIL practices + partner management, based on security best practices. (TPF) • N./A. (VBZ) • N./A. (HES) • N/A (IfVV) • This is a part of cybersecurity. There is no simple answer. But all the mentioned risks mentioned above are part of a decent cybersecurity implementation at not a new problem or thread (Yunex) • N/A (STL)
	1.23. Some data is generated by critical infrastructure. How can we guarantee the proper functioning of this infrastructure and the accuracy of the data?	• very complicated question / no solution yet in place (TPF) • N./A. (VBZ)

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		• N./A. (HES) • N/A (IfVV) • Again, there is no simple answer but this is part of a cybersecurity system as ISO27001 or similar. These risks are covered by implementing such a system, the level of security must be adapted to the application (Yunex) • N/A (STL)
The preferences of individual stakeholders with regard to data sharing play a central role in this context.	1.24. Is your organisation currently sharing any data with third parties? If yes, what type of data and how is it shared?	• yes e.g. live traffic data, datahubs are collecting real-time data (national data hubs) (TPF) • N./A. (VBZ) • N./A. (HES) • N/A (IfVV) • Sure we are sharing data, all different kinds of data with all different kinds of technologies (Yunex) • N/A (STL)
	1.25. What type of data would your company share on an MTME (Multimodal Traffic Management Ecosystem) platform?	• The number of people on the buses, their punctuality. We can imagine putting different sensors on the buses to collect data (Pavement condition, air pollution information, etc.) (TPF) • Public transport data (VBZ) • Data about commuting paths of employees (HES) • None (IfVV) • We are just providing the system, the data belongs to our customers, we don't share any data (Yunex) • where vehicles are and how they are accessible (STL)

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10.1.3 Acceptance Interviews (CEREMA)

Interview 1: Manager of Strategy and Development, Port of Calais 18 October 2021, 11h-12h.

The port of Calais is specialised in passenger and freight transport, which is accompanied traffic, i.e. passengers are accompanied. The container is handled, it doesn't move by itself, there is a docker who will move it, the port doesn't have to manage the docker but only to manage the information of the goods. This is a specificity of Calais, we are on an accompanied traffic.

Massified traffic, i.e. 95% of our traffic goes to the United Kingdom and we have quite considerable volumes of traffic, since in 2017 it was 2 million HGVs. On very active days, we will be doing 7,500 HGVs for export, but we will have to control the information chain. But we have the same thing for imports. So it should be noted that in Calais, you have private vehicles, goods and people who will travel with all sorts of cases: intra-EU, extra-EU, nationals of more or less exotic third countries, live animals. So the diversity of what there may be to control, the related regulations, that makes a lot of regulations. We have to manage dangerous goods in the sense of the SOLAS convention, so the safety of goods, we have to manage goods in terms of customs, and even in terms of health, and I'm only talking about exports. The goods must be declared to customs, they must be linked to the vehicle registration and the ship's manifest. For the goods, you have European authorities. But in Calais, you have a little peculiarity that you don't find anywhere else in the maritime world, to my knowledge, we have juxtaposed management offices. It's a bit complicated to say that all the controls are done at the departure terminal. You take the boat, you cross the border, for example the exit from the Schengen area. You are checked in Calais and then you declare your goods for export from the European Union, but at the same time they enter another customs territory. There will be a specific procedure for British customs or for the Ministry of Agriculture to check the sanitary state of the goods entering the customs territory. So there you have it, goods and people are checked and there is a transport vehicle, a ferry, which will take on another, a HGV, a light vehicle or a bus. There is also the vehicle to be managed on a commercial and operational level. A vehicle has to be assigned to the right place and therefore assigned to the right boat. So you can imagine that every time we have to look for goods or a person, we have to look for the vehicle, so we have to manage a large number of goods, people and vehicles for customs, health, safety and operational reasons. And all this in a minimum of time, in a fluid manner, because fluidity is the heart of our activity. We have to do this for both borders. When I tell you that the controls are done at the entry terminal and that it's free at the exit, that's not quite true. What is done at the departure terminal is the first part of the journey, that's where the carrier of the goods will transmit the information to the authorities. You can be turned back immediately. For example, if you are of a certain nationality, for example if you are an Albanian truck driver, the British don't let Albanians in, so you will be turned back in Calais. But for all the rest, you will be allowed to pass, the control will be done during the sea crossing and you will be caught by the patrol at your destination. It's the same for both directions for people and goods, tomorrow I'm going to the UK if the UK borders want to control me in the UK, they will let me board but the UK border force will wait until I'm under British jurisdiction to apply the British rules.

Let's imagine that the agri-food products that have been shipped to Calais are subject to a control, they will not be subject to a control in Calais but to a control in the United Kingdom if the goods cannot obtain a sanitary status, it will be in the United Kingdom that it will be decided. And conversely, goods that come to the port of Calais will declare, the sanitary control is done at the borders, at the entry of the territory.

We have a complex territory because we manage two borders in both directions for people and goods with completely different regulations, with information that has to circulate, a physical flow. What

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we have in common is the driver's registration and all that. We have to manage the circulation of information and the physical flow at the same time, so when you have a driver, it's more or less fine. Even the least clever driver is able to show his passport or his CMR to the checker. Things become more complicated when you talk about intermodality, where you no longer have the driver to manage but the transfer of information between the different stakeholders, so for example, let's imagine a train arriving with trailers to be loaded onto a ferry. There is a lot of information to manage, the port rail network must be aware of the train's arrival, the junction with the national network must be made when the train arrives at the port, the terminal, it will be necessary to manage its handling, the placement of all the trailers, to know which trailers are leaving by boat and which trailers are leaving in another way. We'll have to manage the border crossing, the customs and even the sanitary clearance for the British and French borders, we'll have to transfer the trailers that are going well to the maritime handling yard for maritime transhipment to the right ship, we'll have to send them to the right yard with an access control that will take place, and check the condition of the trailer. Does it have all the documents, does it have a check? If only one of these pieces of information is missing, the operation cannot succeed, we will check the overall state, the physical state of the trailer, we will park it in a precise place, it will be traced in our computer system so that the handler can come and get the right trailer and put it on board the right boat. So that would be the difficulty of the operations, apart from the right know-how, the right teams: a huge management of information.

Do you have common information management tools? How does it work?

The Port of Calais has a very particular governance, we are not a port authority but a terminal. We are a dedicated terminal, we are not the owner of the port in the two ports of Calais and Boulogne. In most ports, you will have tools piloted by the port authority, which is not the case in Calais.

We have developed a tool based on a bus architecture, an IMO bus which allows us to integrate APIs between the systems of the various stakeholders. We're going to suck in data from shipping companies, and we're going to process this data in our own system. GATE will control the inputs and outputs; GOST will control the handling. These two systems will enable us to collect information from the shipping companies and to know, for example, when we are going to read a number plate. The system will do consistency checks, it will check that the registrations, the status, the location... it will check that the voyage is going as the standardised voyage defined in the system...

A trailer comes from Orbastiano by train, the train is going to tell me that it is coming, it has to tell me how many trailers are on its train. So I have to have the identity of the train, the operation, the timetable, the destination of the train. All the operational conditions, how many trailers, where they are parked. All the information will be stored in our system and when they enter an area that is under my control for handling, I will redo the operation, I will check by reading the plate or querying a Pin code, the trailer is going to the company in question on which departure, are there any dangerous goods on board, if so what class, have the documents been properly transmitted, if not approved by the harbour master's office, I cannot let the trailer pass. The same goes for the customs part, the customs documents must have been transmitted to customs. If this is done, the goods are exportable and can therefore enter my fleet. The system will automatically tell it, depending on the status of the trailer, that it must be parked in place 48. And when the ship arrives, about 20 minutes before the ship's departure, I have a driver who will receive an order on a tablet, he will say the registered trailer is parked in place 48, you put it on board the Spirit of Britain at 10.10am post 7.

And the system will take pictures, and will trace the information and will report to our services, to the authorities and to the customers that everything went as planned. The same thing happens at import, 20 minutes before the arrival of the ship, the drivers will be informed that the trailers are arriving,

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they will know what they have to unload from the ship, they will unload, they will indicate where they are parking the trailers if the trailers are under customs or sanitary control, they know that they cannot leave, they know that they will have to take them to the controls, and this will be done and automatically the system will check that the goods in the trailer have a customs status at import. If they don't have a customs status, they can't leave the park. After 24 hours, the goods will be placed on consignment with a very specific regime and then after 90 days, if there is no news from the consignee, they will be destroyed. All this information is managed, we need to know "what, when, where, how and why" for everything: handling, maritime transport, the application of the transport of dangerous goods, for the customs part, for the sanitary part, and for the border crossing of people.

We are going to have a major difficulty in the future, as a consequence of Brexit, the application of an EES and ETIAS regulation. This is a Community regulation. Third-country nationals will have to be authorised to enter the Schengen territory, but also on a Schengen basis and not on a French border police basis. They will have to pre-declare themselves before arriving at the border crossing point and when they pass this point, they will have to undergo an automated biometric check. The problem is that in Calais the travellers are in vehicles. With the Covid, there are no more travellers, there are more than 3.5 million passengers. An empty port is still 3.5 million people. In 1997, it was the time when duty free was the joy of the port of Calais and duty free had 21 million passengers.The passengers are essentially non-EU citizens, but even if there are 10 million, a biometric control in the cars in addition to the customs part will become very complicated, especially if there are stages with load breaks. If people have to stop at a terminal to pre-declare themselves, it is always complicated. In France, we are only moving towards more controls, it's a basic trend, since the September 11 attacks it's only increasing. First, ISPS controls were imposed on us in the context of port and maritime security, then we had the Touquet treaty with migratory controls that require us to control 100% of freight traffic, 1 million controls on heavy goods vehicles during the year. It takes time! All these migratory security controls, border controls, migratory controls, all that for 2 borders, that's a lot. From year to year we ask for more and more. We ask for more but we also ask for it in a not very happy way. The people who draft regulations for us are people who take the plane, not the ferry. Often the European Commission transfers to us texts that are made for the airport world, for example, ETIAS is not a problem in an airport. If you have PARAFE airlocks, it is not a problem at all. PARAFE airlocks for bus passengers, ETIAS will not change the control process, but for people who do not get out of a vehicle it is more complicated. And the commission did not think about it. In general, in Paris at the Ministry of Transport, they don't think about it. They don't come to the field to see how things are going. We are an exception in the landscape.

For ETIAIS and EES, the British announced a reciprocity measure since the control of the 2 borders on our port is systematic. It's not going to get any better, any move by the EU brings an opposite reaction from the UK which means EES and ETIAS controls on third country nationals, which means that the French border will essentially control British nationals. The British will control third country nationals and for them it will be mainly HGVs, so we will risk a clash if we are not able to manage the information prior to the physical passage of people. The difficulty is that we have regulatory inflation, we have many many control authorities. All these authorities work in silos, all the more so as they are nationals of other states and obey different rules, even in terms of intermodality, the regulations are quite complex.

Some goods disembark from the train that cannot be accepted by sea and are considered dangerous, but not by rail. To accept them in the port, we have to leave the trailers on the train, the train is in the port. It's an absurdity that is difficult to manage, but this regulatory inflation is a real problem. These silo organisations are also a problem.

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1/ an IT layer that allows information to be captured on a one-stop shop principle (tell me once!) and that the information that circulates in a secure and unique way is transmitted to the services so that they can make their control, take their decision according to the problem and give us an answer.

All this can be done in hidden time and this is difficult because the difficulty in Calais is that not everyone works with reservations.

The tourist traffic works with reservations so we can imagine that as a traveller tomorrow I take the boat, I have 2 borders to cross, I give the registration of my vehicle to the shipping company and a proof of my identity and travellers. I should be able to scan the passports, pass them on to the shipping company who need them to issue their manifest. Then they can pass this information on to the police authorities, the PAF having my passport number could very well query the database and check if I am wanted in the Schengen area, how long I have stayed, where I have been. If I am the owner of the passport that I am going to present, these things can be checked at the last moment, the biometric check takes less time.

We would like to have this computer layer, it's always a BUS that allows us to get information from the system that is accessible to whom it may concern, with sensors that read the number plate and say that we have passed at such and such a place, with a consistency check (are we where we should be?) and the information is sent to whom it may concern.

For a check to be carried out without disrupting the flow, it would have to be done in hidden time and be invisible to the passenger. The difficulty is that freight is not pre-registered. The freight arrives as it goes along, the transport companies have an account with the shipping company and the driver does not know where it will go. Depending on the logistical conditions, he will go to the ferry or to Eurotunnel... as he doesn't know 15 minutes beforehand where he is going, there is no information to pass on in advance to anyone.

Interview 2: Directorate General for Civil Aviation , Project manager, on the security aspect, Monday 18th October, 10h - 11h

In an airport, there is a city side, which is where passengers arrive and do all the check-in procedures, plus the waiting within the airport. On the airside, it's all the aircraft manoeuvres, the exchange zones from the airport to the aircraft, but also the transport of goods from the airport to the aircraft, so on this airside, there are many exchanges which are formalised via safety rules, to avoid safety problems between actors.

Cargo transport, maintenance and servicing agents, the baggage transporter, various people who control the aircraft during its parking phase, pedestrians, various vehicles, baggage tractors, paraffin tractors, freight tractors, various vehicles with different functions and different dimensions, vehicles with mobile gangways that allow the aircraft to connect to the airport. There are many users and uses on the airside airport platform and therefore a risk of accident between these different users.

We are working on this risk analysis and we are trying to improve airside traffic management, we are trying to improve safety on the apron.

On the apron, where the aircraft will park and where all the exchanges between the aircraft and the airport will take place.

An operator, airport management airlines, who manage the planes and the passengers

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Subcontractors: work for the big airlines, they will manage the various flows between the airport and the aircraft. When there is going to be baggage transport, there will be staff with baggage tractors, baggage towards the plane and it is subcontracted.

Coordination between the different actors in a rather restricted environment, there are different vehicles with different cabins and risk of accident with the plane and a person on the ground.

- Aircraft may be damaged and therefore a high financial risk, loss of several million euros for an airline

- person on the ground: fatal risk

Airport capacity corresponds to the management of flows, if a plane is blocked on the ground, it takes up a parking space and this parking space cannot be used by other planes coming to that airport and as long as there is no control of the plane, it is blocked and cannot leave. So passengers who can't take their plane and are stuck on standby at the airport are sent home to wait for a new flight. At big airports they manage to be rerouted, because there is enough space and enough traffic to manage to be rerouted to a flight quickly enough. At smaller airports, this can be a problem for passengers who might be stranded at the airport and could be rerouted to other modes of transport (train or bus to make the connection).

Each operator is responsible for ensuring safety on its platform. There is an operating document that defines all safety measures and the single documents that define the activities that take place on the airport and the associated risks.

This single document is shared by all the players and it is the responsibility of the operator to set up its document and share it with the various players.

There are permits to circulate on the platform. The aircraft always has priority. An aircraft that is taxiing on the platform has its anti-collision lights on and vehicles must let it pass. The same applies to people walking around the plane, to avoid the risk of blowing up, there is a safety perimeter. When the aircraft is stopped, it is in a ZEC, you must have the approval of a ground staff (baggage tractor, all maintenance staff). The direction of travel is clockwise. When the tanker is connected to the aircraft, the other actors must not park near it. All these rules must be mastered by the people. There are different codes and signs on the platform. If someone has had an accident and if there is an obvious mistake, the person may have to take the P permit again (P for runway).

You have to imagine the airside airport as a very regulated area with specific rules that aim to ensure the safety of the people involved, that aim to avoid accidents in terms of accidents and airport capacity management area. This whole chain of information is managed with centralised management systems. For small airports, sometimes there is not even a control tower. For large airports, there are several control towers.

A control tower for the management of air traffic, a control tower for the management of ground traffic. The vehicles are equipped with transponders, transmitting information to the tower and the tower sees the traffic flow. By radio, it can get in touch with the different actors, it can alert them about lane closures... There can be a dynamic management of the airport area.

If there is an unforeseen accident, measures are put in place in an appropriate manner.

Bad weather, it is almost predictable. So the airports have winter viability plans to deal with the different routes, so there will be a quasi-organised management despite bad weather that is almost programmable.

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All airports must inform about the state of viability and traffic (e.g. closed due to bad weather). The information is on AIS. When making their flight plan, aircraft have to warn the different aerodromes that their aerodrome will be overflown or that they will be landing.

All aerodromes are supervised by the DGCA. It will collect the information reported by the operators, and the pilots will be informed by radio by air traffic controllers who work for the DGAC. This management is also done at international level, all international aircraft are also monitored when they fly over French territory. The air navigation managers will be aware of this flight and will be able to follow the aircraft in question and inform it of particular problems.

Several levels of information management

- airport on the ground for flow transfers airport aircraft
- aircraft to ensure its landing and take-off
- when in flight

International coordination

Before the flight, an airline will book slots on different routes, the sky highways. Air navigation will control the flow of traffic in coordination with the different states (each country has its own DGAC). These different countries are in contact to monitor these international flights.

The safety rules are common at European level. The EASA defines the regulations to be put in place, with safety objectives to be achieved. Each country must transcribe these rules into their national laws. Safety management is done at European level.

Even at the international level, ICAO does not advocate any obligation, but generally, the various countries will take this into account in their regulations.

Intermodal exchanges, at the moment, I am not sure that we have an exchange platform with different partners. Maybe things at the local level, CDC with the RATP or the SNCF, the possibility of rerouting people via the RER or the TGV, maybe this is done at the local level, at the national level, I don't think there is anything. But it could be useful.

The opposite case, TGV blocked and rerouted passengers by plane or by bus. Management in both directions, now it's piecemeal but there's nothing formalized;

Transport of dangerous goods, cannot be transported by plane, rerouting not always possible via plane. There are different rules for the transport of goods by air and by rail. On the other hand, for what is common, ... Define what can be mutualised and what cannot be and on the goods that can be mutualised, there could be rerouting. Different rules, tonnage weight management...

Brexit exit: No feedback on the impact in terms of time;

Sanitary control: It takes more time but as less traffic so it passes.

Airlines ask to come much earlier to anticipate this extra time

Health pass:

boarding: flight entrance and responsible for security on their flight

Operator: at airport entrance

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Interview 3: Professor, University of Cergy-Pontoise. Rsearch topics : Transport Science, Planning, European Integration, Franco-German Cooperation, Monday 25th of October, 11h-12h.

My latest work is on Le Lémans express, the ferry system between France and Geneva. There is information sharing between operators. It is cross-border. They realised that there were many problems with the French and Swiss interconnections.

They had to make their two passenger systems compatible, train cancellations, delays, etc.

This is central to the quality of service, the compatibility of systems between various operators to ensure a quality of service, which is what we have in the Maas. This is an essential element.

Portability on all applications and at the same time compatibility between operators.

When we make a public transport offer, we should think very early on about this platform connected between different operators.

The Maas, the ability to pool all this passenger information to send it to the customer, the interconnections between a TER and a regional bus (sufficient connections...). An essential element of the success of public transport is the availability of a transport offer.

There can be tensions when the operators are different, e.g. Kéolis and Transep. Each company is proud of its information system and does not want to be dominated by the other. Difficulty in interconnecting strong company information systems. Each one withdraws. Germans defend a collective interest, to make the public system work.

Competition improves the quality of customer service, difficulty in interconnecting passenger information systems.

IDF Mobility will demand a quality of passenger information, an availability of passenger information for itself. But operators drag their feet, especially if they have to provide unpleasant information, poor quality of service, etc.

The need for a very powerful regulatory authority or a need for a transport authority that will demand data availability from operators. Everyone has their secrets about their passenger information system.

The Ile-de-France (IDF) has been divided into about 20 lots and each zone is assigned to a carrier. IDF votes and sometimes a carrier is dismissed and assigned to another zone. 6 to 9 years per zone.

In the UK, the Office of Right Regulator (ORR) required the transport plans. The most important thing is the regulator.

The regulator is going to require at such and such a date: communication of transport plans, passenger information systems, etc. It is going to require experts to see how things are going.

The ORR has enormous sanctioning possibilities, it does not pay the operator.

The regulatory authority is strong, IDF Mobilité is strong, very demanding.

European regulatory authority, it remains quite national. It's regulated inter-governmentally. There is too much network diversity, regulation... There is very little cross-border.

It remains quite national.

This is something that is being studied: a European regulatory authority? On freight, there is nothing. Because there is a logic of very strong competition with a very strong road system that does not want to connect its information system to remain autonomous from the train, they do not want their shipper

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to remain connected on rails. They don't want to put their HGV on the train if there is a strike and the HGV is blocked on the train.

Progress to be made for freight. Freight trains are never on time, 20 km/h is the average for freight traffic. There is no interconnection for freight.

Interconnection between AirFrance and TGV, problematic. You do a Lyon-Paris by Airfrance which is in fact a TGV ticket and then you take your plane. But it didn't work very well. The TGV was late but you couldn't get on another TGV because of the Air France TGV.

When a train is delayed you can't access the Air France information system, it's something internal to the SNCF.

Airfrance wanted to launch a TGV company. Competition contributes to collective well-being, both on the producer's side, a reduction in inefficiencies, and on the consumer's side, we will go to the operator that suits us best.

In a network, there is no competition, it is a natural monopoly. This is the exception to competition.

In two weeks, there will be Italian TGVs. But there are already Ouigo at 19€ so I pity the Italians for making their TGVs profitable.

Freight, I have no example. Competition between rail operators, truckers can't stand rail... Airline, no information on air freight, no information on the pooling of freight data, there is too much competition, when you have competition, there are trade secrets. You are obliged to communicate your customers, it is a real problem. Because freight is about tenders. If it is very competitive and there is no strong regulation, there is no interconnected information system.

On the other hand, the traveller as well as the final customer, the regulatory authorities and the transport organising authorities like France Mobilté.

The availability of self-service bicycles, on the same application number of bikes, train, scooter, scooter, . Knowing the availability of the next mode of transport to avoid wasting time at stations, which is the most annoying. Seam less! Without a break, a waste of time, if there is luggage, I do not say the mess...

People jump on the metro when there are buses from station to station, you avoid the stairs. With an app, we'll know which way to go with or without luggage.

An application in Paris tells you where to stand in the RER to take your exit and your connection.

For freight, it's very complex. You hide your customers from the competition.

The planes are managed by air traffic control. They are the ones who give the agreement. As soon as they are in the air, they are tracked. Air travel is so complex that there is total independence between air travel and the rest of transport. Between plane connections, they don't wait. Airports close at night, the plane has to take off before a certain time.

Organising authorities and the ART are the two players who must impose the pooling of their data for better passenger information.

In a competitive situation, things get tense. The operators are losing lots, they don't want to give away their internal software. There is a lot of tension. If you are no longer retained on a network, you leave the older coaches and keep the old ones. The new operator comes in, they only see old buses.

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The other operator has to give back their electric buses, they are afraid they don't know where to put the staff. The drivers are taken back, but the management is not. They are waiting to be retained on another batch, they are floating. There are 28/32 or 24 lots in IDF. 4 operators (Teolis, RATP dev, TRANSCITE, LACROIX SAVAC.

The size of the lots can vary from one call for tender to another. All other countries do this. There is an adaptation time... Everyone must expect to have a lot but to change the scope.

Strike, change of operator has an impact on their pay.

Interview 4: International Manager, Food company, Saturday 31st October

We ask for a quote. How much does it cost to go to Moscow? The company insures the truck and we give you a deadline.

We need to know what it will cost you, we need to have a fixed price. The customer will not accept an extra cost.

20 tons, how much will it cost me? Then we contact the customer to find out where the goods are. They tell you if it is direct or if there is a transhipment.

The shipping company says where the ship is. If the ship is blocked by a strike, you can't turn to a carrier.

If there is a storm, the container falls overboard. Incoterms, ex works, the truck loads at the factory. The truck just goes to the dock. Free on board, the container lowers the bastengage. Cost and freight, you sell until the ship arrives at the dock, delivered to warehouse until the container arrives at the factory. There are liability risks. Generally, you sell cost and freight.

We can sell against documents, when the customer goes to collect the documents, he pays and gets the goods back. This is a security.

Air freight is for fresh or high value-added products, which are very expensive with high margins and the customer is in a hurry. I have never used the train because the truck is cheaper.

If there is a strike, the dockers block it and you have to wait until the strike is over, the port charges you for parking.

The boats don't go to the port any more and therefore change port and this has an impact on the cost. But the customer refuses to pay more. It's the forwarder who informs me.

The forwarder gives you a price and the validity of your price is three months.

You sell in dollars and the dollar fluctuates. You make a forward sale, what will be the cost of the dollar on such and such a date, you have a range. You are covered on a forward basis, so when you sell your dollars you know your margin.

We know each other's customers, exclusive contracts.

With each new shipment, contact all the forwarders (4 or 5) and see which one is the cheapest. There are 2 or 3 shipping companies each time. It's easier to go through a forwarder, he has much more weight, if there is a lot of volume, much easier to get a price.

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Obligation to consume Algerian durum wheat, if you consumed durum wheat in France, more expensive than international durum wheat. To avoid this, Brussels retrocedes the price difference. Refunds fluctuate according to the price of world wheat;

We have the right to set 3000 tonnes, Brussels set your refund rate and your goods were in a bonded warehouse and as you sold them you had to charge them and you had a deadline.

I sold rice on Reunion Island and there were refunds on Reunion Island. Even if I had only charged for transport, I would have made money. 10 cents per kilo.

Buy rice before the end of the refunds and we'll pre-fix it, and we'll sell it.

Refunds could be abolished overnight, we lost the Algerian market because of that.

In France, the price of chicken is too high compared to the world price, so there was aid. The refund no longer exists. For durum wheat, there is aid but for large producers.

Interview 5: Project manager - Strategy and Studies Mobility Department, Nantes metropole, Interview Thursday 4th November, 10h - 11h

The city of Nantes is conducting an urban logistics project, within the framework of a pact to be signed in 2022, between the various public and private stakeholders. This is a novelty, as the topic of urban logistics does not fall within the traditional competencies of a French metropolis.

The advantages of such a pact are that the players will have a more precise vision of the traffic situation and will be able to secure deliveries. Being able to book a parking space for deliveries would be an easy solution to put in place, with the technical tools already available.

City centre customers include households, restaurants, commercial companies, and a few industries (in some urban areas).

In order to manage urban logistics issues, it would be necessary to have access to flow data, but this is very difficult, because commercial data are privately owned. Models such as the Freturb model supply the data currently used ; but electronic commerce is not included in this model. It is therefore very difficult to assess the share of freight traffic in urban traffic.

It is then very difficult to define objectives without reliable data; in order to communicate their data, the stakeholders should find an interest, and it should be possible to guarantee the anonymisation of their data.

Mr Khouri is not convinced that the use of autonomous vehicles and delivery by drones are ideal solutions for urban deliveries. He said that these solutions consume a lot of energy for a not necessarily convincing result.

Freight distribution hubs exist or are planned for final delivery in the city centre. Two of them are already the starting points for bicycle deliveries.

The metropolis is planning to set up urban logistics facilities; the elected representatives are now mobilising on this type of project.

In 2030 or 2050, we could have good vehicles, for efficient and non-polluting delivery, improve the working conditions of delivery drivers or cyclists, and make their work visible to the city dwellers who benefit from it and develop micro-delivery sites, as they exist in Japan, and integrate these sites inside the city.

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The use of waterway to serve the city centre has not been overlooked, but there are currently many obstacles to this (tidal range in excess of 5 metres, existing quays in very poor condition). The Loire is not very long, and offers fewer logistical solutions than the Seine in Paris, for example. In the end, the use of river transport may remain anecdotal in terms of urban logistics for the city of Nantes.

There has been some thought of using driving school vehicles to deliver parcels (not implemented).

The different actors are beginning to have common objectives: fluidity, reduction of polluting emissions. All actors accept the idea of ecological transition.

Professionals are critical of private delivery solutions (a private individual picks up a parcel in his car, via a specialised application, to deliver it to another private individual). Private companies invest in the long term to optimise deliveries. The use of collaborative solutions via service platforms involves speed but also poorer social conditions (e.g. Uber). In Nantes, all meal deliverers to citizens have adopted the scooter, a polluting thermal solution. In March 2021, the Nantes metropolis banned scooters from the city centre.

There is a big difference between the different players involved in urban logistics ; but they may complement each other. For example, a large international truck company may choose to coordinate with three-wheelers for final deliveries (e.g. Schenker in Nantes)

10.2 Annex II: TEN-T Directive

Section 6: Guidelines for the infrastructure for multimodal transport

For example, the Member States shall ensure in a fair and non-discriminatory manner that

- the different modes of transport are interconnected to enable multimodal passenger and freight transport;
- freight terminals and logistics platforms are equipped to ensure a flow of information within the infrastructure and between the modes of transport along the logistics chain, in particular through the provision of real-time information on available infrastructure capacity, traffic flows and positioning, tracking and tracing, and safety topics;
- that continuous passenger transport is facilitated throughout the network by appropriate equipment and provision of telematics applications in stations and ports (Art. 28 of the Regulation).

According to Art. 29 of the Regulation, priority is given to ensuring effective interconnection and integration of the infrastructures of the comprehensive network, to removing the main technical and administrative obstacles hindering multimodal transport, and to establishing a smooth flow of information between modes of transport and the possibility of providing multimodal and unimodal services throughout the trans-European transport system.

Section 7: Individual objectives

- Telematic applications are to be designed in such a way that traffic management and information exchange with a view to multimodal transport operations enable improvements in safety, security and environmental compatibility. These telematic applications include in particular ERTMS (for railways), RIS (for inland waterways), ITS (for road transport), VTMIS and e-Maritime services (for maritime transport), and air traffic management systems (for air transport) (Art. 31).

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- Member States shall take into account, in particular, projects aimed at facilitating the operation of multimodal transport services (Art. 32 lit. c) of the Regulation).
- The aim is to improve the multimodality of the network, for example through multimodal ticket sales and coordination of schedules, and to promote efficient ways of providing information on multimodality (Art. 33 lit. d, e).

According to Art. 43, the corridors of the core network are multimodal and open to the inclusion of all modes of transportation.

10.3 Annex III: Overview of security and safety standards for transport industries

10.3.1 Automotive

- **ISO 26262: Road vehicles - Functional safety**[206]

This standard is based on the older standard IEC 61508 and defines functional safety for the entire lifecycle of automotive systems which are relevant to the safety of the vehicle.

- **ISO 21448: Road vehicles — Safety of the intended functionality**[207]

The meaning of Safety of the intended Functionality (SOTIF) is defined as: The absence of unreasonable risk due to hazards resulting from functional insufficiencies of the intended functionality, or by reasonable and foreseeable misuse by persons.

10.3.2 Railway

- **EN 5012x: Functional Safety Standard for the Rail Industry**

This series of standards also fallows a risk-based approach like the automotive standard ISO 26262, and therefore aims to reduce the risks resulting from hazards which are caused by malfunctioning systems.

- **EN 50126 (IEC 62278) – Reliability, Availability, Maintainability, and Safety (RAMS)**[208][209]

Covers the generic aspects of the lifecycle, defines a process to specify RAMS requirements, and to demonstrate the satisfaction of them.

- **EN 50128 (IEC 62279) – Software (Signalling Systems)**[210]

Covers the requirements for developing, deploying, and maintaining the software of signalling systems. This standard also defines Software Safety Integrity Levels, similar to ASIL of the automotive sector, which go from SIL 0 (lowest) to SIL 4 (highest).

[206] ISO 26262, https ://www.iso.org/obp/ui/#iso:std:iso:26262:-1:ed-2:v1:en , 09.11.2021
[207] ISO 21488, https://www.iso.org/standard/70939.html , 09.11.2021
[208] EN 50126-1, https://standards.cencenelec.eu/dyn/www/f?p=CENELEC:110:::::FSP_PROJECT,FSP_ORG_ID:60236,1257173&cs=1A3B6674FAB882FA61D09955EF5DFF303 , 10.11.2021
[209] EN 50126-2, https://standards.cencenelec.eu/dyn/www/f?p=CENELEC:110:::::FSP_PROJECT,FSP_ORG_ID:60237,1257173&cs=19A24D348DF24C78E2B1CD2FC1F1369BE , 10.11.2021
[210] EN 50128, https://standards.cencenelec.eu/dyn/www/f?p=CENELEC:110:::::FSP_PROJECT,FSP_ORG_ID:43626,1257173&cs=1D08CFCB1437DD03F4B6F8799117C2A1B , 10.11.2021

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- **EN 50129 (IEC 62425) – System safety (Subsystem Software)**[211]

Covers systems and equipment which was designed and manufactured for railway signalling applications. This standard applies to the entire lifecycle of electronic systems which are safety-relevant.

- **EN 50159: Railway applications - Communication, signalling and processing systems - Safety-related communication in transmission systems**[212]

This is a standard which is applicable to safety-related systems which are using communication systems which were not necessarily designed for safety-related applications, and provided basic requirements to achieve safe communication between safety-related systems.

- **EN 50657: Railways Applications. Rolling stock applications. Software on Board Rolling Stock**[213]

The EN 50657 standard specifies the process and technical requirements for the development of software for electronic systems which are used for rolling stock applications and does not consider signalling equipment (even if installed on trains) or does not contribute to operational functions of the rolling stock.

- **IEC 62443: Industrial communication networks - IT security for networks and systems**[214]

Describing technical and process-related aspects of industrial cybersecurity and using a risk-based approach, this standard aims to secure industrial automation and control systems through their entire lifecycle.

10.3.3 Aviation

- **ARP 4754: Guidelines for Development of Civil Aircraft and Systems**[215]

This guideline, and the equivalent EU guideline ED-79, addresses the complete development cycle of aircraft by dealing with the certification support development processes.

- **ARP 4761: Guidelines and Methods for Conducting the Safety Assessment Process on Civil Airborne Systems and Equipment**[216]

This guideline (in conjunction with ARP 4754 and 4761), is used to demonstrate compliance with the U.S. Federal Aviation Administration (FAA) airworthiness regulation, and with harmonised international airworthiness regulations like the European Aviation Safety Agency (EASA).

- **RTCA DO 178C/254/160/297/331**[217]

[211] EN 50129, https://standards.cencenelec.eu/dyn/www/f?p=CENELEC:110:::::FSP_PROJECT,FSP_ORG_ID:43189,1257173&cs=1DCCE376EBEF75D87EEF17B045C4CEB8F , 10.11.2021
[212] EN 50159, https://standards.cencenelec.eu/dyn/www/f?p=CENELEC:110:::::FSP_PROJECT,FSP_ORG_ID:55462,1257173&cs=16E71291D601166FC0632F53830F7C983 , 10.11.2021
[213] EN 50657, https://standards.cencenelec.eu/dyn/www/f?p=CENELEC:110:::::FSP_PROJECT,FSP_ORG_ID:61081,1257173&cs=1BBC9EC922AB97226B550F1C598F5BE6D , 10.11.2021
[214] IEC 62443, https://www.iec.ch/blog/understanding-iec-62443 , 09.11.2021
[215] ARP 4754, https://www.sae.org/standards/content/arp4754a/ , 09.11.2021
[216] ARP 4761, https://www.sae.org/standards/content/arp4761/ , 09.11.2021
[217] RTCA DO-160G: https://do160.org/rtca-do-160g/ , 09.11.2021

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The regulation of Environmental Conditions and Test Procedures for Airborne Equipment provides standard procedures and environmental test criteria to test airborne equipment used in all types of aircraft, such as light aircraft, helicopters, and jumbo jets.

- **RTCA DO-178C**[218]

The Software Considerations in Airborne Systems and Equipment Certification, and its equivalent ED-12C, is used by certification authorities (EASA, FAA, etc.) to approve all software-based aerospace systems used in commercial aircraft.

- **RTCA DO-254**[219]

This document, Design Assurance Guidance for Airborne Electronic Hardware, and the EU equivalent ED-80, provides guidance in the development of airborne electronic hardware and classifies this hardware into simple or complex categories.

- **RTCA DO-297**[220]

The Integrated Modular Avionics Development Guidance and Certification Considerations contains guidance for Integrated Modular Avionics (IMA) developers, integrators, certification applicants, and those involved in the approval and continued airworthiness of such systems in civil certification projects.

- **RTCA DO-331**[221]

Model-Based Development and Verification Supplement contains modifications and additions to DO-178C and DO-278A that should be addressed when model-based development and verification are used as part of the software life cycle.

10.3.4 Maritime Sector

- **Ship Safety Standards**[222]

The European Maritime Safety Agency (EMSA) aims to improve the safety of commercial shipping in EU waters.

- **Maritime Safety**[223]

Shipping is one of the most international industries of the world, as well as one of the most dangerous.

10.3.5 Cybersecurity Standards

- **ISO 21434: Road vehicles — Cybersecurity engineering**[224] [225]

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[218] RTCA DO-178C, https://www.sae.org/learn/content/C1410 , 09.11.2021
[219] RTCA DO-254, https://www.sae.org/learn/content/c1703/ , 09.11.2021
[220] RTCA DO-297, https://global.ihs.com/doc_detail.cfm?item_s_key=00472618 , 09.11.2021
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[224] ISO 21434, https ://www.iso.org/standard/70918.html , 09.11.2021
[225] UN Regulations on Cybersecurity and Software Updates to pave the way for mass roll out of connected vehicles, https://unece.org/sustainable-development/press/un-regulations-cybersecurity-and-software-updates-pave-way-mass-roll , 09.11.2021

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Similar to ISO 26262, the new ISO/SAE 21434 looks at the entire development process and life cycle of a vehicle. It follows the V-model.

- **ISO/IEC 27000-series: ISMS Family of Standards**[226] [227]

This is a series of standards providing recommendations for best practices on the management of information security, in the context of an Information Security Management System (ISMS).

- **ISO 15408: Information technology — Security techniques — Evaluation criteria for IT security**[228]

This standard, also called "Common Criteria" (CC), is a framework which allows customers to specify their needs (in the form of security functional and assurance requirements) in a so-called security target.

- **PD CLC/TS 50701: Railway applications - Cybersecurity**[229]

This standard provides guidance and specifications to the railway operators, system integrators and product suppliers, on how cybersecurity is managed in the context of the EN 50126-1 RAMS lifecycle, but this standard document can also be applied to the security assurance of systems and components which are developed independently of EN 50126.

- **RTCA DO-355: Information Security Guidance for Continued Airworthiness**[230]

This standard, or its EU equivalent ED-204, provides guidance for the operation, support, maintenance, administration, and decommissioning stages of the life cycle

- **EUROCAE ED-202: Airworthiness Security Process Specification**[231]

This standard, and its US equivalent DO-326, provides additional guidance for aircraft certification to handle the threat of intentional unauthorized electronic interaction, which are actions that can potentially affect the security of the aircraft (e.g. unauthorized access, use, disclosure, denial, disruption, modification, or destruction of electronic information or systems).

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[226] ISO 2700, https://www.iso.org/standard/54534.html , 09.11.2021
[227] ISO 27000 Standard, https://standards.iso.org/ittf/PubliclyAvailableStandards/c073906_ISO_IEC_27000_2018_E.zip , 09.11.2021
[228] Common Criteria, https://www.commoncriteriaportal.org/ , 09.11.2021
[229] Railway Cybersecurity, https://www.en-standard.eu/pd-clc-ts-50701-2021-railway-applications-cybersecurity/ , 10.11.2021
[230] RTCA DO-355, https://standards.globalspec.com/std/14335560/RTCA%20DO-355 , 10.11.2021
[231] EUROCAE ED-202, https://standards.globalspec.com/std/9862360/EUROCAE%20ED%20202 , 10.11.2021

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