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Preliminary Concept of Operations for Total Traffic Management

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Abstract

The EU project X-TEAM D2D focuses on future seamless door-to-door mobility, considering the experiences from Air Traffic Management and the currently available and possible future transport modalities in overall multimodal traffic until 2050. This paper deals with developing a Concept of Operations of an intermodal transport system with special consideration of the passengers' satisfaction with up to 4-hour journeys. For this purpose, the influences of quality management systems and other organizational facilities on the quality of passenger travel in the transport system were examined. In the study, integration of various management systems, like resources, traffic information, energy, fleet emergency calls, security and infrastructure, and applications such as weather information platforms and tracking systems, is expected.

Keywords: Management systems; Mobility-as-a-Service; Multimodal transport; European strategic planning.

Overview and motivation

This paper aims to describe a Concept of Operations (ConOps) for a holistic traffic management system in which the main goal is to optimize users' satisfaction (e.g. reliability, safety, security, multimodal traffic). The system includes several management systems that help meet passengers' preferences on a 4-hour door-to-door journey for all modes of transport. The elaborated management systems and applications presented in this paper are intended to enable the passengers and all actors to have a comprehensive and intelligent traffic management system equipped for future developments.

1. Methodology and main contributions

This paper presents the first definition of the Concept of Operations (ConOps) of a multimodal network that covers not only urban but also sub-urban and up to the regional scale of passenger travel. For the first time, the ConOps were

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defined not only for the future time horizon (in the scope of this research - 2050) but also considered an evolution of transport systems in 2025 and 2035, thus, envisioning the passenger travel for the next three decades.

This research emphasizes a future seamless door-to-door mobility by the EUROPEAN COMMISSION (2011) and SESAR JU (2021) with the main focus on customer satisfaction (Lierop et al.2018). For this purpose, ConOps was defined based on experience from air traffic management (ATM) by SESAR JU (2020) and Günther et al. (2016). For developing these ConOps, global and economic trends, EC policies, future passenger needs and technologies for urban and sub-urban mobility by, general and traffic management systems and basic quality management principles were researched in the literature (Souza de et al. 2017; TrafficQuest 2012 and Djahel et al. 2015) summarized in an overall traffic management system – Total Traffic Management System. In addition to the sophisticated ATM by SESAR JU (2020), the ConOps considered, for instance, Mobility-as-a-Service (MaaS) in order to meet future passengers' needs and expectations.

2. Summary of Concept of Operations under study

In these ConOps, the focus is on the passengers so that sustainable success is achieved if this system attracts and retains the confidence of customers/passengers and other relevant interested parties. An increase in satisfied and loyal customers means a flourishing overall system and thus added value for the other stakeholders in the system. Every aspect of passenger interaction offers an opportunity to create more value for the customer. Efficient management and cooperation in the different areas enable optimization and harmonization of the overall system.

Therefore, the International Organization for Standardization (ISO) basic concepts and principles for Quality Management Systems (QMS) by ISO (2015) flow into these ConOps. They represent a modern form of work organization and corporate governance with which the management of any organization, including the transport sector, can achieve its goals. The management and service components of the preliminary definition of ConOps shown in Fig. 1 are briefly explained in the following context. Thus, resource management (Fig. 1: golden box in the bottom left) focuses on Quality-of-Service requirements, among others. Resource management should identify the resources required to achieve the organization's objectives. To ensure that resources are used effectively and efficiently, processes must provide, allocate, monitor, evaluate, optimize, maintain and protect these resources. For instance, an efficient vehicle resource management mechanism is essential to obtain the most valuable and complete traffic information, including location coverage. The exchange of information between the infrastructure and transport vehicles of all types, including air vehicles, is generally considered an enabling technology to reduce accidents, congestion, and peaks in the long term and improve traffic efficiency. Mobility-as-a-Service (Fig. 1: light red box in the upper right) can be provided by different suppliers and offered and billed as a combined, multimodal service and requires both joint route planning of the individual mobility services and their joint billing. Most users expect a seamless mobility experience on the ground, water, and air. To deliver this experience, providers and agencies will need to offer and implement an efficient MaaS (Jittrapirom et al. 2017) that can integrate all available modes of transportation. Energy Management (Fig. 1: light red box in the upper right) will play a key role in achieving efficient energy consumption of electric vehicle technology on the ground and air. A substantial issue is the charging infrastructure and power plants needed to support the electrical infrastructure.

For this purpose, all possible energy sources must be statistically recorded, planned and controlled from a coordination centre. The Fleet Management (Fig. 1: purple box in the bottom left), in turn, must ensure that all vehicles within the system and the integrated providers are used economically and that sufficient transport capacity is available for all processes. The Emergency management system must be in place so that the transport system is resilient and robust to react to failures and/or interruptions. This includes contingency measures to ensure continuity of operations in the event of major outages, natural disasters, security threats or other unusual circumstances. The Safety Management system (Fig. 1: golden box in the bottom right) is promoted using an integrated Safety Management System approach for identifying and managing potential hazards. This includes equipment, organizational, operational or systems problems. Secure infrastructure (e.g. train stations, terminals, airports and take-off-and-landing areas) must have an integrated facility security system adapted to different capacities, accesses and risk situations. Infrastructure Management system: intermodal ground access to all transport connection points is essential for intermodal networks. Functioning and passenger-appealing transitions in the form of transport interconnection points are needed to link transport networks within a regional system and enable more efficient traffic flow. Joint management of the infrastructure would bring clear quality control and set the standards in the system.

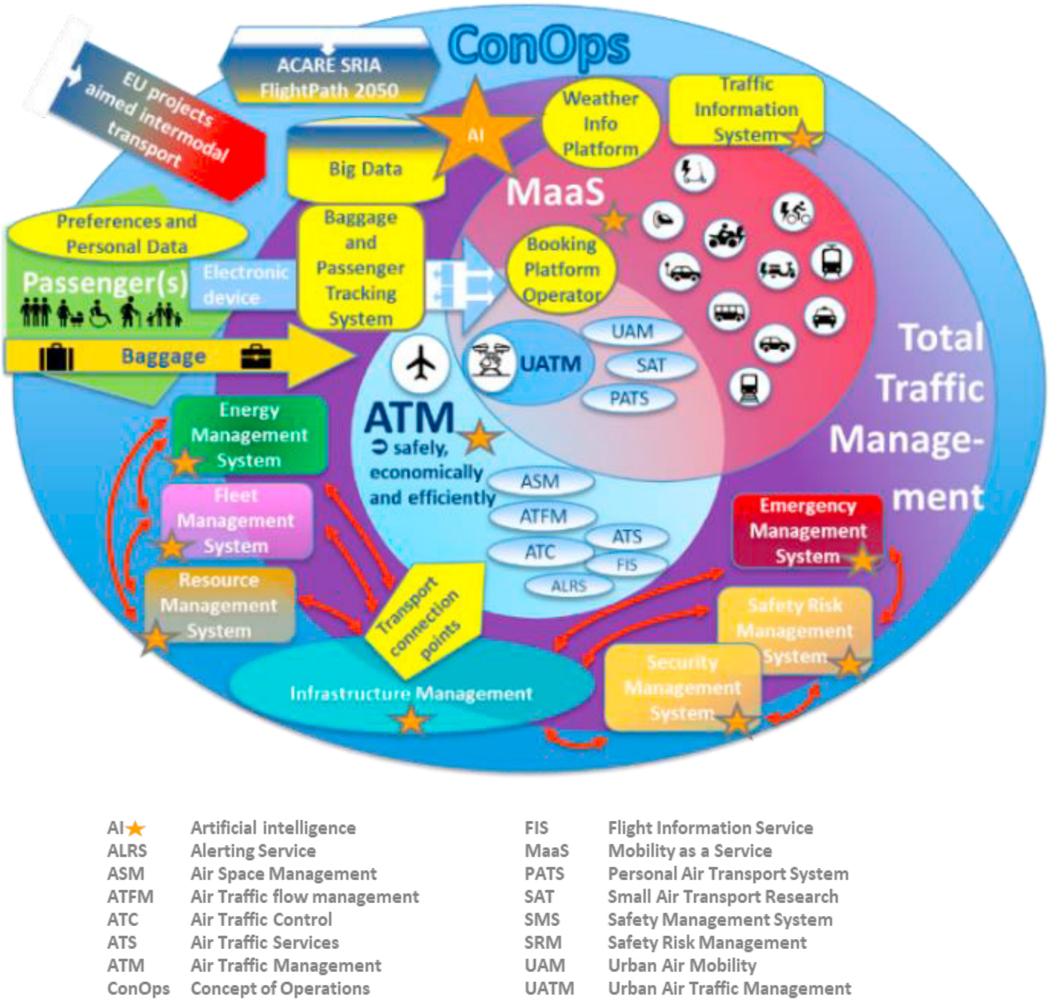

Fig. 1. Concept of Operations supporting the seamless integration of ATM and Air Transport into an overall intermodal network

2.1. Artificial Intelligence

The artificial intelligence (AI) component will be necessary for the operational concept of the ATM service for passengers in intermodal transport. Many AI application possibilities can make mobility safer, more ecological, more efficient, more comfortable, more intelligent and more resource-saving. Moreover, that means not only the development of autonomous means of transport but also the implementation and control of inter-and multi-modular networked management systems.

a. *Resource Management Systems*

Resource management focuses on Quality-of-Service requirements, among others. An efficient resource management mechanism for vehicular multimedia applications is essential to obtain the most valuable and complete traffic information, including location coverage. Resource management should identify the resources required to achieve the organizations' objectives. To ensure that resources are used effectively and efficiently, processes are required to provide, allocate, monitor, evaluate, optimize, maintain and protect these resources. For example, an efficient resource management mechanism for vehicular multimedia applications is essential to obtain the most valuable and complete traffic information, including location coverage. SESAR provides open information standards for a centralized wireless system to disseminate passenger flow information at major airports to include ground transportation connectivity, weather, delays, parking availability and check-in times within a single network.

2.2. Traffic Information System

The exchange of information between the infrastructure and transport vehicles of all types, including air vehicles, is generally considered an enabling technology to reduce accidents, congestion, and peaks in the long term and improve traffic efficiency. Under SESAR, it is expected that a more significant number of aircraft will operate with reduced separation thresholds between aircraft within a given airspace. The new concept of operations also allows aircraft the flexibility to change flight routes (or flight plans) in response to changing conditions. In addition, different aircraft would have very different navigation capabilities due to different equipment levels. With such complex scenarios in future air traffic control operations, it would be essential to have a compliance monitoring tool to monitor aircraft movements.

2.3. Mobility as a Service

The mobility services can be provided by different suppliers and are to be offered and billed as a combined, multimodal service. This requires joint route planning of the individual mobility services and their joint billing.

Most users will expect a comparatively seamless mobility experience on the ground, on the water, and in the air. To deliver this experience, providers and agencies will need to offer and implement an efficient Mobility as a Service (MaaS) that can integrate all available modes of transportation.

2.4. Energy, Fleet and Infrastructure Management Systems

Energy management will play a key role to achieve efficient energy consumption of vehicle technology on the ground and in the air. The provision of energy and renewable fuels for the expected future technologies within the transport network will be decisive (Schmutzler et al. 2012). An example of this is the electric charging infrastructure, which needs to be coordinated and managed nationwide. The fleet management of these ConOps must ensure that all vehicles within the system and the integrated providers are used economically and that sufficient transport capacity is available for all processes (Fotouhi et al. 2020; Rajsman and Pros 2014; Celiński and Sierpiński 2013). Intermodal ground access to all transport connection points is essential for intermodal networks. Functioning and passenger-appealing transitions in the form of transport interconnection points are needed to link transport networks within a regional system and enable more efficient traffic flow. Joint management of the infrastructure would bring precise quality control and set the standards in the system.

2.5. Emergency, Safety and Security Management System

The ConOps system must be resilient and robust to respond to failures and/or interruptions. This includes contingency measures to ensure continuity of operations in the event of major outages, natural disasters, security threats or other unusual circumstances. Following SESAR JU (2019), a balance of reliability, redundancy, and procedural backups should ensure security during a failure of individual systems or components. Ultimately, SESAR provides a high availability system and requires minimal time to restore functionality in case of disruptions.

Safety is promoted by using an integrated Safety Management System approach for identifying and managing potential hazards. This includes equipment, organizational, operational or systems problems. Specifically, SESAR uses a formal, top-down, business-like approach to manage safety risk, including systematic procedures, practices, and policies for safety management. Secure infrastructure (e.g., train stations, terminals, airports, and take-off-and-landing areas) must have an integrated facility security system that can be adapted to different capacities, accesses and risk situations (Golpayegani et al. 2021; Liu and Wang 2019).

2.6. Authoritative Weather Info Platform

This integration of weather information platform, combined with probabilistic forecasts to account for weather uncertainty and improved forecast accuracy, minimizes the impact of weather on traffic.

2.7. Baggage and Passenger Tracking System

The passenger and baggage tracking system allow baggage handling to be carried out in a remote area of the airport if required. This increases capacity, reduces check-in time, reduces staffing requirements, and enables transparency for passengers. This system aims to ensure that, by taking greater account of passengers' preferences, safety is improved, and capacity and operational efficiency are increased. This is achieved by building processes and systems to help passengers realize their preferences. In addition, information is collected, collated, monitored, evaluated, and shared through the management systems. Research and analysis will determine the appropriate division of tasks between systems. This will include determining when decision support is needed to assist humans and when functions must be fully automated.

2.8. Interactions and relations between the management systems

The management systems must interact, or the actors and systems must interact with one another. This interaction is closely linked to the concepts of communicating, acting, planning, working with each other and – finally – informing one another. For example, the infrastructure management system must work closely with the energy, fleet, and resource management systems since there are many relations, similarities and intersections that complement and overlap or influence each other. These interactions also apply to emergency, security, and safety management systems. This mutual interaction should be aimed for and used for all management systems in this overall system.

3. Extended ATM Concept of Operations for passenger service

This section describes the elements of the ConOps and their relationships according to the planned architecture of the intermodal transport system. The three-time horizons (2025, 2035, 2050) considered in the project are differentiated. The management systems, the tools, and the "intelligence" of the algorithms, which will become the intermodal system, play a decisive role in achieving the ambitious goal of providing complete traffic management for a door-to-door connection in up to four hours. The elements are to be viewed broadly, as service tools are also included, for instance. While new technologies will improve the means and infrastructures, it is also evident that the system's functioning depends heavily on service quality.

3.1. Architecture outline in the 2025 timeframe

In 2025, the implementation of electric vertical take-off and landing aircraft for Urban Air Mobility (UAM) operation will occur (Fig. 2). Only on some specific routes UAM will be implemented for testing and demonstration purposes. These UAM operations will be managed with procedures and technologies available within the current ATM paradigm (either local or international). New mobility services (NMS), i.e. car-sharing, ride-hailing, bike-sharing, e-scooters, e-bikes, will gain user interest and take a significant share in the transport system. Some possible services could have an important impact on multimodal mobility. First light MaaS activities, e.g., single ticket, pricing by optimizing travel costs of different modes, ticketing interoperability (flexible in case of disruptions) and integrated tickets will be available in some areas. There is still a high difficulty integrating the ATM and U-Space system.

There is still a lack of tools to exchange and use data between the different transport modes in the immediate future. In addition to the passengers, the whole system would benefit considerably from an improvement in this condition. The efficiency of the transport process still depends on the passenger's ability to manage their journey. Unfortunately, ATM operations have not yet become passenger-centric, partly because performance targets did not consider the impact on passengers. In addition, the complexity of the ATM network does not allow for the desired response in the event of a disruption. The existing ATM works with a well-established and proven safety management system, but it does not allow for rapid developments and implementations. In contrast, U-Space is innovative and fast, but its level of security and robustness is not defined/validated. The fact that airspace will be shared between manned and unmanned aircraft when U-Space is introduced makes it necessary to identify and confirm the roles of U-Space and ATM in terms of airspace and traffic management responsibilities and functions. Although these services will likely need to interact, there must be no overlap of conflicting or incompatible services or areas of responsibility.

During 2025, conformance monitoring will rely on current Air Traffic Management - Communication, Navigation and Surveillance (ATM CNS) capability and ATM and regulatory reporting mechanisms. In 2025, there will be an opportunity to increase surveillance and communications coverage by implementing systems such as Automatic Dependent Surveillance-Broadcast (ADS–B) and other communications infrastructures. ADS-B does not necessarily scale well with high traffic density, and coverage is possibly insufficient for all phases of flight. Onboard UAM vehicle systems will be able to collect and disseminate additional information that can be used to inform conformance monitoring. However, a data collection system will need to be implemented. It will be necessary to define where and/or under what scenarios Conformance Monitoring will be necessary. Scenarios could include adherence to routes in accordance with noise abatement procedures. Conformance Monitoring capabilities established in 2025 would provide evidence that would support the safety and/or community acceptance for moving UAM operations to 2035 (similarly between 2035 and 2050). MaaS will only be available in some regional areas for a part of the transport modes. The continuation of the C-ITS strategy for Cooperative Intelligent Transport Systems will promote international cooperation with other major regions of the world on all aspects of cooperative, connected, and automated vehicles and will decisively advance further development of a Traffic Information System. Urban transport (light rail, metro, but also trams and regional commuter trains) is still characterized by a highly diversified landscape. At least a certain convergence in architectures and systems can be observed. In some cases, these points are linked to the safety of urban transport systems. In this context, "safety" is seen as anything dealing with the methods and techniques to prevent accidents. "Security" is concerned with the protection of people and the system from criminal acts. State of the art has been brought together and extended in harmonized and agreed to standard security packages. Thus, a coherent and coordinated hazard and risk analysis were established, and agreed security requirements were defined for the security-relevant functions of an urban managed transport system. In order to achieve such an allocation of safety requirements, it is necessary to create a functional and object-related safety model for an urban guided transport system.

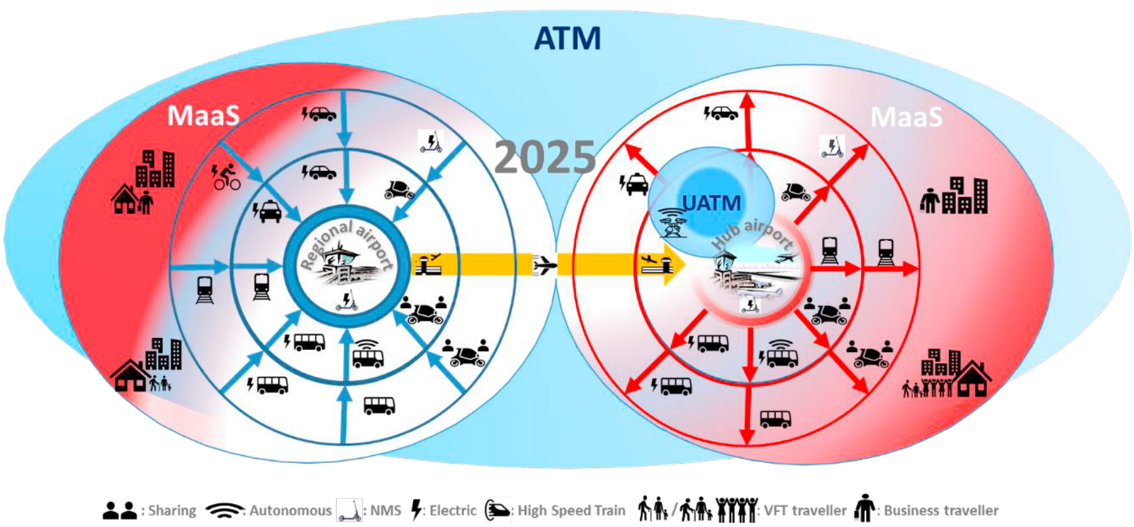

Fig. 2. Time horizon 2025 on the way to total traffic management

3.2. Architecture outline in the 2035 timeframe

Horizon 2035 requires new ATM procedures and/or technologies not currently used by ATM and will introduce Urban Air Traffic Management (UATM) Services to support UAM operations (Fig. 3). These services will vary in service type and maturity, from initial procedures and services to full implementation. Depending on the region, it will not be possible everywhere to reduce the workload of air traffic control (ATC) with the available resources. Trials of new procedures and technologies will be needed during 2025 to support the case for 2035 operations.

In 2035, a new ATM model will emerge with the support of new technologies and standards. Fundamental to this will be support for ATM Data Services Providers (ADSP). The terrestrial component of air-to-ground communications will require high bandwidths. The new architecture will allow resource sharing across the network and more stable service delivery to all airspace users. The Advanced U-Space services will be operational across Europe. In contrast to the time horizon 2025, a passenger preparing for an intermodal journey in 2035 will be able to use a U-Space for his or her journey. In 2035, Conformance Monitoring will provide an ongoing set of information to manage the operational safety risk of UAM operations. There will be an opportunity to increase surveillance and communications coverage for all stakeholders (including the pilot) by implementing current and new communications and surveillance infrastructure (e.g., new cooperative surveillance technology).

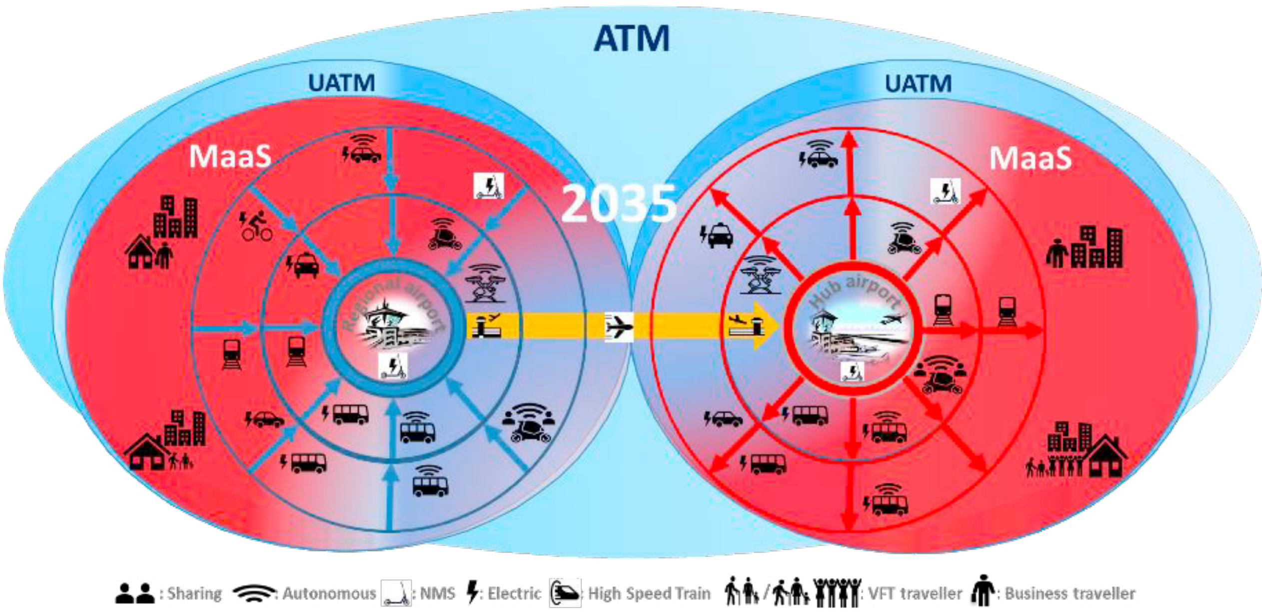

Fig. 3. Time horizon 2035 on the way to total traffic management

3.3. Architecture outline in the 2050 timeframe

For the 2050-time horizon, intermodal travel is characterized by a full range of services. The management systems will bring traffic management to a much higher level (Fig. 4). By the 2050-time horizon, a highly automated ATM system with an all-weather operation and a safety level above today's will be available. It will be service - and passenger-oriented management, relying on high connectivity, automation, and digitalization.

U-space complete services will be available. C-ITS traffic systems will use all aspects of cooperative, connected, and automated vehicles. The collected data will bring the traffic information system to an excellent level. In addition, strategic planning of traffic flows will be improved, reducing the imbalance between capacity and demand. Based on accurate and complete data, changes and disruptions can be resolved without loss of travel time. Mobility-as-a-Service will be possible for every traveller for door-to-door travel, including a flight segment. Figure 4 shows the optimal configuration of the ConOps with all their management systems, instruments, and applications as an extended ATM operating concept for passenger services, as described in this document.

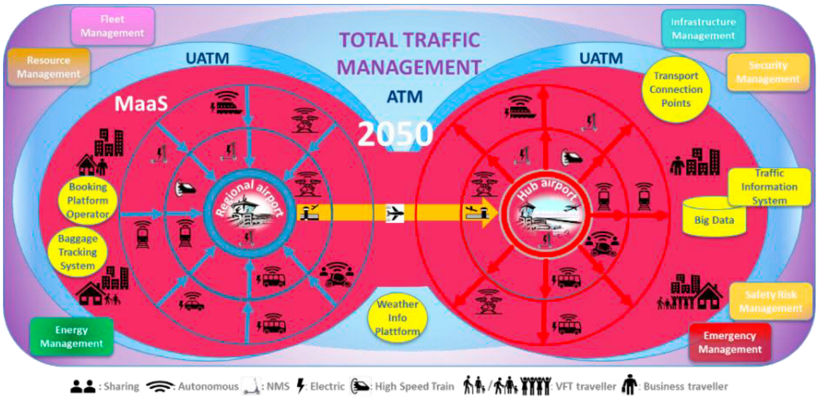

Fig. 4. Total traffic management in 2050

3. Conclusion and future work

In this paper, the first formulation of ConOps for Total Traffic Management was presented, which contains management and service applications that should pave the way to "seamless" goal for all modes of transport in which the travellers' preferences have a high priority. For future research, the management systems and applications described in the ConOps should be examined more precisely for possible synergies, interactions and points of friction in an intermodal transport system. To this end, it should be explored how these management systems should be implemented gradually over the time horizons 2025, 2035 and 2050.

Acknowledgements

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