Future Reference Scenarios and Barriers

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X-TEAM D2D

EXTENDED ATM FOR DOOR2DOOR TRAVEL

This deliverable is part of a project that has received funding from the SESAR Joint Undertaking under grant agreement No 891061 under European Union's Horizon 2020 research and innovation programme.

Abstract

X-TEAM D2D project aims at defining, developing and initially validating a Concept of Operations (ConOps) for the seamless integration of ATM and Air Transport into an overall intermodal network, including other available transportation means (surface, water), to contribute to the ACARE SRIA FlightPath 2050 goal. X-TEAM D2D project aims contributing to this goal by providing and preliminarily validating a ConOps for seamless door-to-door mobility in urban and suburban (up to regional) environment, i.e., X-TEAM D2D target scenario addresses the connection of a big metropolis with the surrounding area (up to country-wide level).

The project is focused on the consideration of ConOps for ATM integration in intermodal transport network serving Urban and Extended Urban mobility, taking into account the transportation and passengers service scenarios envisaged for the next decades, according to baseline (2025), intermediate (2035) and final (2050) time horizons.

The target ConOps will encompass both the transportation platforms integration concepts and the innovative seamless Mobility as a Service (MaaS) including ATM concepts. The ConOps will be preliminarily evaluated against already existing and specifically defined applicable KPAs and KPIs, implementing both qualitative and quantitative performances assessment approach.

The X-TEAM D2D project will develop a simulation-based platform for validating the proposed concept, considering the most relevant elements of the transport in the future such as interfaces mode-mode, high-level network model, passenger-centric paradigm.

This deliverable entitled *Future Reference Scenarios and Barriers* is aiming at definition and description of crucial specifications of systemic environment in which future integrated metropolitan and regional transport would operate. It will be a foundation for definition of Concept of operation defining role of ATM and air transport in three considered time perspectives: 2025, 2035 and 2050. Both in terms of physical and informational dimension. The deliverable consists of four main parts corresponding to the tasks in WP2 Future Scenarios and Barriers:

- Chapter *3 Reference Scenario Definition*. Task 2.1: *Urban and suburban mobility reference scenarios* Definition of reference scenarios reflecting dominating trends in urban and suburban mobility;

- Chapter *4 Technologies for urban/suburban mobility*. Task 2.2 of the same title. Analysis aiming at identification and evaluation of new technologies related to transport modes representing potential to significantly impact the intermodal mobility of people in three time horizons;
- Chapter *5 Use Cases*. Task 2.3 of the same title. Identification of specific use cases for the intermodal transport system including ATM and air transport with reference to the three considered timelines (2025, 2035, 2050);
- Chapter *6 Barriers against 2D and air transport integration.* Task 2.4 of the same title. Identification of barriers disabling efficient integration of vertical and surface modes of transport.

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1.2 Acronyms

X-TEAM D2D eXTEnded AtM for Door2Door travel

5G the fifth generation mobile communication
5Vs of BigData Volume, Velocity, Variety, Veracity, Valence
AAS Airspace Architecture Study
ABS Anti-lock braking system
ADS-B Automatic Dependent Surveillance–Broadcast
ADSP ATM Data Services Providers
AEB Autonomous (or active or automatic) emergency braking
AI Artificial Intelligence
AIM aeronautical information management
AIOTI Alliance for Internet of Things Innovation
AMC Acceptable Means of Compliance
APP mobile device internet-connected software application
ASBUs Aviation System Blocks Upgrade
ASD AeroSpace and Defence Industries Association of Europe
ASEAN + 6 Association of Southeast Asian Nations + 6 countries (China, Japan, South Korea, Australia, New Zealand, India)
ASG Annual Sustainable Growth, cyclical EU strategy
ATC Air Traffic Control
ATM Air Traffic Management
ATSU Air Traffic Services Unit
B2G Business-to-Government
BVLOS Beyond Visual Line of Sight, type of UAS operation
CAGR Compound Annual Growth Rates
CAM Connected and Automated Mobility
CANSO Civil Air Navigation Services Organisation
CEN European Committee for Standardization
CENELEC European Committee for Electrotechnical Standardization
CIRA Centro Italiano Ricerche Aerospaziali (Italian Aerospace Research Centre), beneficiary and Project Coordinator
C-ITS Cooperative Intelligent Transport Systems
CIV Contract for International Carriage of Passengers and Luggage by Rail
CJEU Court of Justice of the European Union
CNS communications, navigation and surveillance
CO2eq Carbon dioxide equivalent
ConOps Concept of Operations
COVID-19 Coronavirus Disease 2019
C-ROADS cooperation platform of Member States and Commission in implemneting C-ITS
CWP Controller Working Position
D2D Door-to-door
DAA detect-and-avoid

DAC	Dynamic airspace configurations
DG MOVE/E3	the Commission's Directorate-General for Mobility and Transport, Directorate E – Aviation, Unit E3 – Single European Sky
EASA	European Union Aviation Safety Agency
EASCG	European ATM Standards Coordination Group
EC	European Commission
ECTRL	EUROCONTROL European Organisation for the Safety of Air Navigation, non-EU
EGD	European Green Deal
EHPS	Electric and/or Hybrid Propulsion System
EIP-SCC	European Innovation Partnership on Smart Cities and Communities
EMF	Emerging Markets Forum
ENISA	European Union Agency for Cybersecurity
ENoLL	European Network of Living Labs
EOC	Essential Operational Change
ESOs	European Standards Organizations
ESP	Electronic Stability Program
ETSI	European Telecommunications Standards Institute, non-EU
EU	European Union
EUROCAE	European Organisation for Civil Aviation Equipment, non-EU
EUROCITIES	a community of more than 190 European cities
EUROSTAT	European Statistical Office
EV4SCC	E-Vehicles for Smart Cities and Communities
EVLOS	Extended Visual Line of Sight, type of UAS operation
FAA	Federal Aviation Administration
FL	Flight Level, hundreds of feet
Galileo	global navigation satellite system created by EU
GANP	Global Air Navigation Plan of ICAO
Gbps	Gigabits per second
GDP	Gross Domestic Product
GFC	Global Financial Crisis
GH	ground handling
GHG	Green House Gases
GM	Guidance Material
GUTMA	Global UTM Association, non-profit consortium of 25+ countries
GVC	global value chains
HFR	High level Flight Rules
HPC	High Performance Computing
ICAO	International Civil Aviation Organization, UN specialized agency
ICT	Information and Communications Technology
IFR	Instrument Flight Rules
IIASA	International Institute for Applied Systems Analysis
ILOT	Institute of Aviation in Poland
IMET	Intelligent Mobility for Energy Transformation
IoT	Internet of Things

ISO	International Organization for Standardization
IT	information technology
ITF-OECD	OECD International Transport Forum
ITS	Intelligent Transport Systems
JARUS	Joint Authorities for Rulemaking of Unmanned Systems
JRC	European Commission's Joint Research Centre
KPA	Key Performance Area
KPI	Key Performance Indicator
LDACS	L-band digital aeronautical communication system
LIFR	Low Instrument Flight Rules
MaaS	Mobility as a Service
MET	aeronautical meteorological services
ML	Machine Learning
NEB	National Enforcement Body
NGEU	NextGenerationEU, an EU financial instrument of the recovery package and EGD
NMS	New Mobility Services
OASC	Open & Agile Smart Cities
OECD	Organisation for Economic Co-operation and Development
PATS	Personal Air Transport System
PPP	Purchase Power Parity or public–private partnership
PRM	Person with Reduced Mobility
Q1,Q2,Q3,Q4	quarter of a year
R&D	Research and development
RDP	Rolling Development Plan for European ATM standardisation
RPAS	Remotely Piloted Aircraft
RVT	Remote Virtual Towers
SAT	Small Air Transport
SDGs	United Nations 2030 Agenda's Sustainable Development Goals
SDM	SESAR Deployment Manager
SERA	Standardised European Rules of the Air
SES	Single European Sky
SESAR	Single European Sky ATM Research
SJU	SESAR Joint Undertaking
SORA	Specific Operations Risk Assessment
SPO	Single Pilot Operations
SRIA	Strategic Research and Innovation Agenda
SUMP	Sustainable Urban Mobility Planning
SWIM	System Wide Information Management
TAM	Total Airport Management
TBO	Trajectory Based Operations
TEN-T	Trans-European Transport Network
TMA	Terminal Manoeuvring Area
UAM	Urban Air Mobility
UAS	Unmanned Aircraft Systems

UAV	Unmanned Aerial Vehicles, part of UAS
UN	United Nations
U-space	SESAR's set of new services to support access to airspace for large numbers of drones
UTM	Unmanned Aircraft Systems Traffic Management
VFR	Visual Flight Rules
VLOS	Visual Line of Sight, type of UAS operation
VoIP	Voice over Internet Protocol
VTOL	vertical take-off and landing
WBG	World Bank Group
WG	Work Group
WTO	World Trade Organisation

2 Project Objectives

High level aim of the X-TEAM D2D project is to define, develop and initially validate a Concept of Operations (ConOps) supporting the seamless integration of ATM and Air Transport into an overall intermodal network, including other available transportation means (surface, water), to contribute enabling the door-to-door connectivity, in up to 4 hours, between any location in Europe, in compliance with the target assigned by the ACARE SRIA FlightPath 2050 goals.

More in particular, the X-TEAM D2D project is focused on the detailed consideration of ConOps for ATM integration in intermodal transport network serving Urban and Extended Urban (up to Regional) mobility, taking into account the transportation and passengers service scenarios envisaged for the next decades, according to baseline (2025), intermediate (2035) and final (2050) time horizons.

The target ConOps provided and initially validated by the X-TEAM D2D project will encompass both the transportation platforms integration concepts and the innovative seamless MaaS including ATM concepts. The developed ConOps, then, will be also preliminarily evaluated against already existing and specifically defined applicable Key Performance Areas (KPA) and Key Performance Indicators (KPI), implementing both qualitative and, where possible, also quantitative performances assessment approach.

In the project activities, the integration of ATM and air transport into overall intermodal transport system will be considered not only with respect to currently available transportation alternatives on the surface and water but also with respect to emerging new mobility forms that are envisaged for the next decades. In particular, emerging innovative mobility paradigms will be considered, including extended urban and regional air transport (Small Air Transport (SAT), Personal Air Transport System (PATS), vertical urban mobility (Urban Air Mobility (UAM)), road autonomous mobility (autonomous cars and buses), high-speed rail mobility (including Hyper-Loop related concepts), water autonomous mobility (autonomous vessels). In addition, emerging disruptive concepts aimed to implement seamless mobility of passengers by using passengers' pods (e.g. "*Link and Fly*" concept proposed by AKKA Technologies and "*Clip-Air*" concept proposed by Switzerland's Federal Polytechnic Institute) will be considered from the perspective of ATM integration into intermodal transport. The X-TEAM D2D project, therefore, will analyse and review both the status quo of different transport modes present in Europe and the new emerging ones that new technology is developing, all of them immerse in the on-demand and shared economy which in combination with passenger-centric view will revolutionize the future transport modes.

While pursuing the above aim, the project will take into account the outcomes of other EU funded projects aimed to support the intermodal transport (e.g. BigData4ATM, DORA) and addressing not only air transport but also other transport means on ground and water (e.g. applicable projects addressing the impact of a new airport to the ground transportation in a certain area) and will also consider available studies in literature.

Under the above outlined overall objectives of X-TEAM D2D, one specific aim will be to develop a simulation-based platform for validating the concept proposed in the project. This platform will consider the most relevant elements of the transport in the future such as interfaces mode-mode, high-level network model, passenger-centric paradigm. The X-TEAM D2D proposed ConOps, therefore, will be validated with the simulation platform and a description of the semantic values of future KPIs and a diagnosis of the inefficiencies of the ConOps will be provided.

In order to better specify the scope of the X-TEAM D2D project in the wider framework of the FlightPath 2050 global target, it has been clarified in the X-TEAM D2D Kick-off Meeting, and it is here reported for the sake of clarity, that X-TEAM D2D does not address the complete FlightPath target of door-to-door travel between any location in Europe in up to 4 hours but X-TEAM D2D project aims *contributing* to this goal by providing and preliminarily validating a ConOps for seamless door-to-door mobility in urban and suburban (up to regional) environment: X-TEAM D2D target scenario addresses the connection of a big metropolis with the surrounding area (up to country-wide level).

In practice, it turns into the following assumptions:

- **Only passenger transport is taken into consideration as solely addressed by 4 hours door-to-door challenge.**
- **Urban and metropolitan areas are of main focus of X-TEAM D2D project. They are considered as a place where the main efforts oriented on ATM and surface transport integration should be allocated. It is assumed to be achieved through:**
    - **U-SPACE solutions in case of Urban Air Mobility development as a component of sustainable, integrated urban/metropolitan transport system**
    - **Airport, in the meaning of a access and regress point, indirectly connecting metropolitan transport system with at least European-range air connections. In X-TEAM D2D both hub and regional airports are considered.**
- **“Regional” scope (covering metropolitan, up to regional range) entails no need for implementation of European-wide ATM integration solutions (e.g. Single European Sky) as well as enable incremental/gradual deployment of particular solutions (both related to hardware and software solutions)**
- **The European urban and metropolitan areas are very diverse. Their development can be affected by numerous factors of various nature. Nevertheless, it was assumed that European cities will be favourable environment for realization of identified trends. However not all, not everywhere and not at the same time.**

3 Reference Scenarios definition

3.1 Introduction

A problem of scenario formulating to give a base for ConOps for ATM integration developing needs a multidisciplinary approach. In the following sub-chapters, drawing inspirations from social science theories, having identified institutionally recognized sustainable development measures and their trends, we prepared general assumptions. Using facts reported by key global institutional[2], business[3] and non-profit organizations[4], we took a picture of current global, economic and demographic developments and their future visions. We included potential ramifications of the European policy's circular economy paradigm and the COVID-19 pandemics recovery package instrument – NextGenerationEU – in sustainable transport, urban air mobility and urban infrastructure development vision. We surveyed current supply side approach to intermodality and passenger intermodality experiences. Finally, we presented scenarios envisaged for the next decades, according to baseline (2025), intermediate (2035) and final (2050) time horizons.

[2] institutional organisations: World Bank Group (WBG), Organisation for Economic Co-operation and Development (OECD) and European Union (EU)

[3] business organisations: The Economist Group, Mitsubishi Corporation

[4] non-profit organisations: The Emerging Markets Forum (EMF), EUROCITIES

3.2 Assumptions

3.2.1 Scenarios assumptions

Basing on the capabilities approach and, assuming (in alignment to the EU strategy) circular economy paradigm in 2025 and 2035 with a bit more of digitalization and automation in 2050, we developed scenarios. They are not alternatives, but subsequent possible future states – first in 2025, second in 2035 and third in 2050.

Since our focus is urban and peri-urban mobility, the scenarios goals are measured by economic, institutional, physical and human goals of a modern city development with respect to mobility given by United Nations[5]: SDG 2: Zero hunger, SDG 3: Good health and well-being, SDG 7: Affordable and clean energy, SDG 9: Industry innovations and infrastructure, SDG 11: Sustainable cities and communities, SDG 12: Responsible consumption and production, SDG 13: Climate action.

https://unhabitat.org/topic/mobility

Figure 1 – UN Human Settlements Programme SDGs for mobility

We selected main subindicators of the 7 SDGs and estimated their long-term values using Compound Annual Growth Rates (CAGR) presented by the EUROSTAT 2020 report [2]. Our synthetic interpretation of the results set a stage for the Urban Air Mobility (UAM) ConOps for ATM intermodal integration scenarios available in Chapter 3.7 Scenarios definition. More explanation on the XTEAM D2D scenarios assumptions is available in Appednix 1.

[5] UN Human Settlements Programme SDGs for mobility, accessed from: https://unhabitat.org/topic/mobility

3.3 Global and regional economic trends

The short-term trend is shaped by COVID-19 pandemic global impact, China's assertive policy and emerging technological transformations progressing the 4th industrial revolution (digitalisation, automation and AI).

The long-term trend's most important features are demography (ageing populations), urbanisation, globalisation, middle class importance, Asia's capital domination and consequences of the 4th industrial revolution on the job market as well as "green" polices effects in general sustainability.
More explanation on the XTEAM D2D scenarios geopolitical assumptions is available in Appednix 2.

3.4 Future Passenger needs (demography)

As literature presents, depending on the trip purpose (business, commuting, leisure, etc.), nowadays passengers, generally choose urban transport mode according to twenty factors [3]. Among them, the top ten factors belong to two groups – travel mode attributes[6] and traveller attributes[7]. Until 2035, this classic list will be extended by factors related to digitisation and automation of travel as well as urge for more individual and tailored experience. Personal perceptions of value of time savings, data security and ethical concerns, safety concerns, affinity to automation, to online services, to environmental awareness, to social media, to sharing and willingness to share will influence the needs of near future passenger. What will be passengers needs beyond 2035, we believe, is highly dependent on the demographic shifts and prerequisites the Inclusive Design paradigm.

3.4.1 Demography

In 2015, The Economist report [4] expected global population growth to see a dramatic decline from an average of 13% in the 1980-2014 period to 0.5% across the 2015-2050. In 2017, The Emerging Markets Forum [5] envisioned world population to peak in 2035 and begin to decline in 2050. Europe will be reduced to 11% of the world's population and Africa will account for 40%.

Evidence suggests that society is ageing. In 2017, the European Commission [6] forecasted that by 2050 the number of over 80 year-olds will have tripled, and about 25% of the population will be over 65 years old. Two years later, a report [7] collaboratively prepared by the Commission's Joint Research Centre and the International Institute for Applied Systems Analysis (JRC/IIASA) gave even more insights into demographic trends. All of the JRC/IIASA's three demographic scenarios expect significant enlargement of the EU population aged 65 and over. The central scenario presents 19% in 2015, through 25% in 2035 up to 32% in

[6] travel mode attributes : travel time, travel cost, mode access time and commute distance

[7] traveller attributes: income, gender, age, household composition, car ownership and education level

2050. The "zero international migration" scenario: 19%, 27%, 32% and the "high immigration" scenario: 19%, 24%, 27%.

A shrinking labour force means more non-working dependants on working people. JRC/IIASA examined potential remedies – migration, fertility programmes and increasing participation.

3.4.1.1 Migration

There are three types of migration – economic, seeking refuge and climate-related.

The economic migration is mainly within the EU as differences in wages and living standards continue to drive people westward or northward in spite of cohesion policies. A hypothetical case, inspired by the Spain's financial crisis emigration, indicated that such a relocation will deplete the working-age population of certain EU regions even by 50% until 2050, leading to a loss of a home-grown talent and innovation as well as having consequences for intergenerational replacements and ageing.

The refugees tend to settle for the long term and to age just as the native population does. Furthermore, to reach replacement levels from refugee immigration requires well-designed integration policies and successful job match. This is rarely the case. Promoting the prevention and reduction of conflict and violence, addressing human rights violations, and enforcing the rule of law will be key actions to reduce this type of migration pressure.

The climate-related migration, which is a real risk, is likely to involve a short-distance move within a country rather than a long-distance move across borders.

According to the report [7], neither economic, nor refugees, nor climate-related migration will reverse ageing trend in the EU.

3.4.1.2 Fertility programmes

Successful fertility programmes require substantial investment in work-life balance (tax incentives, child allowances, day-care access, family-friendly work). The France's policy created higher fertility close to the replacement levels. This model is not easily replicable according to the report [7].

3.4.1.3 Increasing participation, a remedy

A remedy to population ageing is neither focusing on higher fertility nor more migration, but rather increasing labour participation. Its first pillar will be equalisation of woman, but, still, it will not be enough. Only including constant elderly participation in labour generates scenario, where labour force dependency ratio is acceptable, i.e., similar to the one of 2015. Since young people are, nowadays, better educated than elder generations, they will offer higher human capital in 2050, provided they maintain and upgrade their skills constantly. This is in line with the Mitsubishi report [8] and the 2020 OECD report's post-COVID-19 recommendations [9] stating that active labour market programmes and enhanced vocational education and training are needed to create opportunity for all, facilitate possible job reallocation and prevent erosion of human capital.

3.4.2 Elderly passengers

Transport has an important role to play in helping governments to sustain their ageing populations. Good transport solutions are crucial for maintaining mobility understood as the ability to move oneself – either independently or by using assistive devices or transportation – within environments that expand from one's home to the neighbourhood and the regions beyond.

In 2002 the European Conference of Ministers of Transport [10] issued a report on elderly passengers' needs. It optimistically announced that future elderly will be generally in better health, they will have higher levels of education, better housing and higher incomes. The report stressed that older will retain levels of mobility, preferring to drive their own cars, longer trips, as long as possible. The 2013 European guidelines - TRACY [11] - offered a little more moderation and details. According to them, an average older person will be living alone, independently, away from inner urban areas, with no close family, vulnerable to social isolation and poverty. The two documents agree, however, that there will be an increasing number of people with some mobility problems. There will be elderly unable to meet transport needs, like people with serious physical and emotional difficulties and those without access to a car or other modes of travel or the means to pay for it. There will, also, be people who continue to drive to meet their needs, even though they are no longer competent drivers. Among them, the oldest women are the most disadvantaged and with limited financial resources. They will represent an important share of not homogeneous future elders.

Establishing the transport needs and behaviours of older people is a complex process. E.g., elderly have problem with stable position, that increases with age and limits cycling use. Older drivers tend to over-rate their driving ability ignoring gains and losses of ageing. Barriers and disruptive influences, also, may impact their fitness. Moreover, elders can be disinclined to use public transport due to lack of accessibility, affordability, and understanding. Any obstacle can make an older person unlikely or unable to complete a journey, especially if walking is a significant component of travel chain.

Researchers of the TRACY guidelines used the 2013 GOAL's project profiles[8] [12] to develop twelve transport system qualities for the elderly:

- **Affordable** - use of the transport and mobility system should be possible within the financial means of older people;
- **Available** - the mobility and transport system should exist in a way that makes it available to older people;

[8] The 2013 European project GOAL developed five profiles of people over the age of 50 identifying the characteristics that older people might exhibit in terms of living conditions and social networks, mental problems, residential area and mobility behaviour, access to technology and information. The youngest, healthiest and the most active group was denoted Fit as a Fiddle (FF). The profile named the Care-Full (CF) contained the frail, impaired and immobile very old ones, who are dependent on the help of others. The members of the profile an Oldie but a Goodie (OG) are quite mobile and independent despite their old age. In the Happily Connected (HC) group are the fit, active and satisfied elderly with excellent social networks, and the profile Hole in the Heart (HH) includes older people suffering from mental as well as severe physical problems in younger ages

- **Barrier free** - facilities that can be used by disabled persons without any specific difficulty and without assistance from third persons. It should be possible to use the transport and mobility system taking into account the physical, sensory and cognitive impairments more likely to be experienced by older people;
- **Comfortable** - the transport and mobility system should be designed or adapted to ensure that older people can use it without experiencing undue discomfort, pain, stress or anxiety;
- **Comprehensible** - information about the transport and mobility system should be communicated in a number of ways that make it easy for older people to understand about transport and mobility services;
- **Efficient** - it should be possible to travel to the required destination within a reasonable and suitable amount of time;
- **Friendly** - the transport and mobility system should be approachable for older people. Where applicable staff who are involved should be available in a number of ways (phone, face to face) and should be aware of the particular needs of older people;
- **Reliable** - the transport and mobility system should be delivered and should perform as it could reasonably be expected to allow for an element of unpredictability caused by unforeseen events, for example, by extreme weather;
- **Safe** - the transport and mobility system should not be dangerous for older people, with their specific needs, to use. They should not feel unsafe while using it;
- **Secure** – the transport and mobility system should be dependable and should not present unnecessary risks to older people. They should feel confident that they are not at risk when using it;
- **Transparent** - older people should be aware of the existence of the transport and mobility options available to them and understand how to use them;
- **Complementary** - the transport and mobility system should be supported by policies that work alongside it to further promote accessibility for older people.

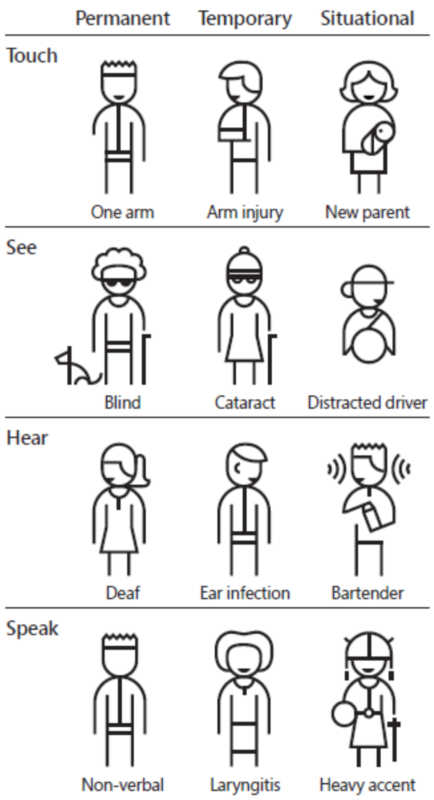
3.4.3 Implementation of passengers’ centeredness (and needs consideration)

To elicit, harmonize and appropriately consider the variety of passengers’ needs resulting from demographic change, from new technologies and transport services available in the 2025, 2035 and 2050 time horizons, as well as to accommodate the increasing awareness of multimodal passengers’ rights and expected services quality, a series of applicable concepts and approaches have been surveyed. In the purpose of X-TEAM D2D project, these concepts have been selected as guidance to ensure the:

- consideration of EU principles of equality and human rights to access public services
- achievement of a set of passengers’ related data to be combined with ATM and other transport means data for an affordable, accessible and seamless multimodal travel experience
- meaningful profiling of multimodal and air transport passengers

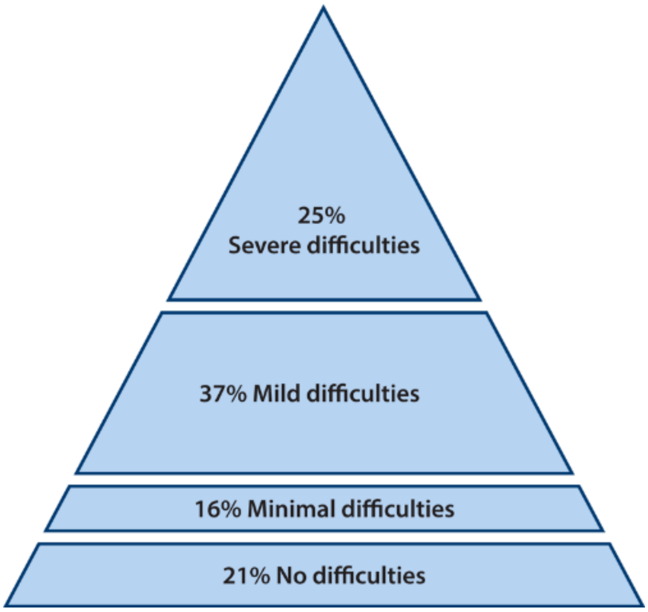
In this view, the key reference concept is the **Inclusive Design**. Inclusive Design is aimed at optimizing the use of a system or a service for a specific user with specific needs (usually this user is an extreme user, meaning that this user has particular needs) and, while focusing on the extreme users, many other users with similar or lighter needs will get advantage from the intended system or service, so that a wider diversity of people can make easy use of it [13][9]. Therefore, Inclusive Design results in a system and/or a service that is accessible to, and usable by, as many people as reasonably possible without the need for adaptation or specialised design for specific user categories [14]. The Inclusive Design framework embeds the concept of **Transgenerational design**, that is specifically aimed at making systems and services compatible with those physical and sensory impairments associated with human aging and which limit major activities of daily living [15]. In fact, the Inclusive Design approach allows to consider the full range of human diversity with respect to ability, language, culture, gender, age and other forms of human difference [16], supporting the elicitation of a wide range of human characteristics to cover permanent or temporary needs of every passengers.

[9] see also http://www.inclusivedesigntoolkit.com/whatis/whatis.html



Inclusive Design Toolkit, Microsoft, 2016

Figure 2 – Human diversity under the Inclusive Design perspective



The prevalence data and definitions of difficulty levels are drawn from the Microsoft (2003) survey [17]

Figure 3 – The pyramid model presents a continuum of population diversity

The table below provides some practical examples on how travel services can accommodate the needs of many passengers by addressing the specific need of a traveller with a disability, according to the Inclusive Design approach.

Table 1 – Examples of passengers' typology benefiting from inclusive solutions

Specific disability	Technical/organizational solution	Other passengers benefiting from the specific solution
Deafness	Subtitled video instructions on aircraft safety procedures	Not English speaking passengers Elderly with reduced auditory ability Passenger listening audio from his/her personal device
Arm/hand impaired	Luggage pick-up at starting door and delivery at arrival door	Parent holding a baby Elderly with reduced strength or osteoarthritis

	Long haul/long stay passenger (heavy luggage)

It is also clear that ability to access and use a seamless D2D multimodal journey depend not only on personal characteristics but, sometimes in greater extent, on the overall context where passengers act and behave during their journey. In this approach, eliciting passengers' needs requires that also context and situations are properly considered; to support these aspects, X-TEAM D2D project will refer to the Context of Use concept and Task Analysis technique.

The concept of **Context of Use** was firstly introduced in the context of digital interfaces usability [18] and is extensively used to represent the combination of goal, characteristics, task, objects and environment characterizing the situation in which the users will operate a system or service [19]. The Context of Use perspective will allow to consider the variety of real-world contexts, also under the three time horizon scenarios, with respect to which multimodal passengers must be enabled to travel, properly addressing their needs. The third component of X-TEAM D2D approach to users' needs analysis (and for Use Cases definition) is the adoption of **Task Analysis** technique to identify the main actions during the multimodal journey that the passengers must be able to carry out in the most efficient way. Task Analysis is a well-established human factors technique [20] that in X-TEAM D2D project can be used to break down the high level "multimodal journey" task into a sequence of smaller and more contextualized tasks, allowing to identify all the details of the context of use, from the environment (i.e. train station, moving bus, airport landside etc.), to the goal (change a reservation, drop off the luggage, etc.), to the passenger (age, impairments, scope of the travel, language etc.), to the objects/equipment (smartphone, credit card, suitcase, stroller, etc.).

Relying on the above conceptual references, a review of needs per passengers' characteristics and journey's, multimodal travel variables has been conducted taking into consideration:

- **multimodal travel variable (or travel indicator):** travel time, connections/modes, accessibility and comfort of each travel segment, cost and level and services provided, personal security, luggage security, environmental impact, ticketing, early and real time information provision;
- **personal characteristic of human variable per passenger:** visual impairments, auditory impairments, walking impairments, women travelling alone/family/group with children, business traveller, leisure traveller, people travelling for personal reasons other than leisure, not mother tongue/not speaking local language, low digital trust/personal devices availability, no enabled credit card holder (or no cash availability), no credit card/enabled card holder.

The full table showing the relevance of each multimodal travel variable or travel indicator, with the elicitation of lower level description or relating services or function sought, and personal characteristic of human variable per passenger is part of deliverable D4.1.

3.5 EC policy[10]

Policy makers of an ambitious and unfinished project [21], European Union, have to deal with most of the challenges and opportunities of the globalized world. On top of that, the Europeans have faced a series of high risk events[11]. Emergence of such situations is inevitable in future. The 2019 European Council strategic agenda [22] set out the priority areas that provide guidance for the work programmes of other EU institutions[12]. The European model for the future includes strengthening cohesion in the EU and incorporating all aspects of the digital revolution and AI for the benefit of the citizens. It also stresses importance of climate change managing (the Paris Agreement [23]) and globalisation while making sure that no-one is left behind and living in human-centred cities [24]. On a global stage the European model means promoting European interests and values through supporting the UN 2030 Agenda (SDGs), trade policy within World Trade Organisation (WTO) and security cooperation within NATO. The Council's, i.e., heads' of Member States guidance includes the recommendation for the EU to invest in solutions for the mobility of the future.

In December 2019, the new President of the European Commission, Ursula von der Leyen[13], and the new Executive Vice-President Frans Timmermans[14] presented ambitious plan – the European Green Deal (EGD) [25] – to make Europe the first climate-neutral continent by 2050, boosting the economy, improving people's health and quality of life, caring for nature, and leaving no one behind. One of the pillars of the EGD is the Clean energy ambition [26] that sets a plan of Net-zero emissions of Green House Gases (GHG) in 2050.

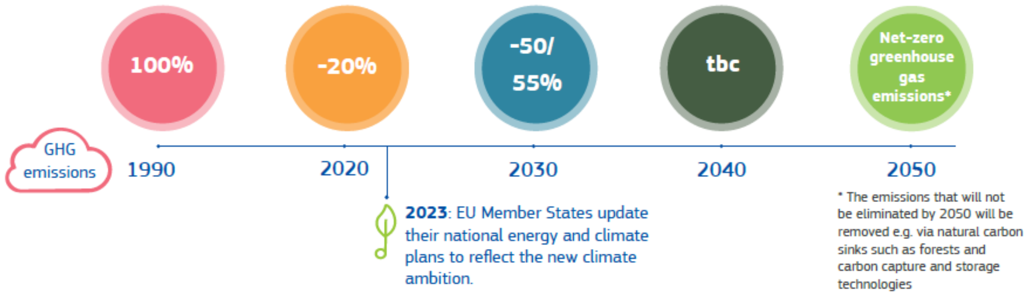
[10] EC policy - European Commission's policy

[11] The high risk events in Europe: the 2007 Global Financial Crisis (GFC), the 2008 global spread of avian influenza (H5N1), the 2009 swine flu pandemic in Europe (H1N1), Air travel disruption after the 2010 Eyjafjallajökull eruption, the 2010 European debt crisis, the 2014 Ukrainian Revolution and War in Eastern Ukraine, the 2015 European migrant crisis, Brexit in 2016, the Coronavirus disease (COVID-19) in 2020

[12] The 2019 European Council strategic agenda priorities: protecting citizens and freedoms, developing a strong and vibrant economic base, building a climate-neutral, green, fair and social Europe, promoting European interests and values on the global stage.

[13] Ursula von der Leyen, President of the European Commission, since 2019, accessed from: https://www.consilium.europa.eu/en/press/press-releases/2019/07/02/european-council-appoints-new-eu-leaders/

[14] Frans Timmermans, Executive Vice-President of the European Commission, since 2019, accessed from: https://ec.europa.eu/commission/commissioners/2019-2024/timmermans_en



https://ec.europa.eu/info/strategy/priorities-2019-2024/european-green-deal/clean-energy_en

Figure 4 – European Commission Clean energy ambition (2019)

In the Annual Sustainable Growth (ASG) 2020 Strategy [27], the Commission called to refocus the existing since 2010 process of Member States policy coordination in economic and social challenges, the European Semester, by complementing it with the environmental sustainability aspect. In addition to this new section, each country report will also include a new annex setting out the individual Member States' performance measured by 17 SDGs.

https://www.un.org/sustainabledevelopment/development-agenda/

Figure 5 – United Nations 17 Sustainable Development Goals (2015)

The Council adopted [28] these conclusions and the new annex will monitor each country's progress, based on the Eurostat's SDGs indicator set.

Concluding Special European Council [29] held in July 2020, President Charles Michel[15], announced agreement on a recovery package[16] of EUR 1824.3 billion that will help the EU to rebuild after the pandemic

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[15] Charles Michel, President of the European Council, since 2019, accessed from: https://www.consilium.europa.eu/en/european-council/president/biography/

[16] The 2020 EU recovery package includes two components – **the multiannual financial framework (MFF)** of EUR 1074.3 billion: single market, innovation and digital, cohesion, resilience and values, natural resources and the environment, migration and border management, security and defence, neighbourhood and the world, European public

and will support investment in the green and digital transitions. President von der Leyen called this agreement "a huge and historic step forward" [30] and welcomed approval for the NextGenerationEU (NGEU) instrument worth EUR 750 billion for the Member States to invest in the EGD - renewables, energy-efficient buildings, roll-out of 5G network, digitisation[17] and digitalisation[18] [31], sustainable transport, and AI & automation[19] [32].

Until September 2020, following the EGD Roadmap[20], the Commission has presented (or adopted) 10 proposals and strategies. One of the proposals included The Energy System Integration and Hydrogen Strategy. The strategy envisions hydrogen as an energy source for industry and greater direct electrification of end-use sectors including, among others, electric vehicles in transport.

Also in September, the Commission launched the next European Semester cycle with its publication of the ASG 2021 Strategy [33]. The Commission invited Member States to apply for funds of the NGEU's Recovery and Resilience Facility (EUR 672.5 billion) within a list of flagship areas[21] [34], prepared in line with the UN

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administration – and – a recovery fund, **NextGenerationEU (NGEU)** of EUR 750 billion, (EUR 360 billion to be repaid to capital markets until 2058): Recovery and Resilience Facility: EUR 672.5 billion (loans: EUR 360 billion, grants: EUR 312.5 billion), ReactEU: EUR 47.5 billion, Horizon Europe: EUR 5 billion, InvestEU: EUR 5.6 billion, Rural Development: EUR 7.5 billion, Just Transition Fund (JTF): EUR 10 billion, RescEU: EUR 1.9 billion, Special European Council, 17-21 July 2020

[17] Digitization is the process of changing from analogue to digital form, also known as digital enablement. Said another way, digitization takes an analogue process and changes it to a digital form without any different-in-kind changes to the process itself.

[18] Digitalization is the use of digital technologies to change a business model and provide new revenue and value-producing opportunities; it is the process of moving to a digital business.

[19] A consequence of the automation progress e.g. in agriculture is inevitable phasing out of the important Common Agricultural Policy (and similarly Common Fisheries Policy), which served, for many decades, as a means "to support farmers […] to make a reasonable living".

[20] EGD Roadmap timeline until September 2020. (January): European Green Deal Investment Plan and the Just Transition Mechanism, (March): European climate law, European Climate Pact, European Industrial Strategy, Circular Economy Action Plan, (May): 'Farm to fork strategy', EU Biodiversity Strategy for 2030, (July): **EU strategies for energy system integration and hydrogen**, (September): 2030 Climate Target Plan, accessed from: https://ec.europa.eu/info/strategy/priorities-2019-2024/european-green-deal_en

[21] Facility becomes operational as of 1 January 2021, the flagship areas: Power up – The frontloading of future-proof clean technologies and acceleration of the development and use of renewables; Renovate – The improvement of energy efficiency of public and private buildings; **Recharge and Refuel** – The promotion of future-proof clean technologies to accelerate the use of sustainable, accessible and smart transport, charging and refuelling stations and extension of public transport; Connect – The fast rollout of rapid broadband services to all regions and households, including fibre and 5G networks; Modernise – The digitalisation of public administration and services, including judicial and healthcare systems; Scale-up – The increase in European industrial data cloud capacities and the development of the most

SGDs, including, among others, the promotion of future-proof clean technologies to accelerate the use of **sustainable, accessible and smart transport** as well as **measures increasing participation of elderly in labour force**.

3.5.1 Sustainable Transport policy

The EU transport and storage is the largest economic sector in the world with 10 million employed and 5% of GDP. It is not integrated enough, not advanced in digitization (not to mention digitalization). Especially on roads, it generates huge congestion. The transport-related GHG emissions represent a quarter of the EU's total. The EU citizens spend an average of almost 10 hours per week using transport, they travel an average distance of 34.7 km per day and spend 13 per cent of their total consumption on transport-related items. They expect seamless shifts between transport modes. Renting and sharing mobility services are increasingly popular. Climate change awareness has become one of the transport mode choice factors. The European automotive sector may have to considerably reshape its value chain, investment priorities and technological choices. Engineering jobs are expected to continue but processes increasingly demand sophisticated IT skills. Moreover, automated driving may require further reskilling. New business models are emerging including new on-line platforms for freight operations, car-pooling, car or bicycle sharing services, or smartphone applications offering real-time analytics and data on traffic conditions. Automated vehicles will need secure data exchanges between vehicles and between vehicles and road infrastructure offered by fifth generation mobile communication (5G) and Galileo services[22] [35]. Transformation will not leave aviation sector untouched. It will change completely environment we live in, the city itself. All the most pressing challenges of mobility are (and have been) in focus of the European Commission. See table below, especially the latest - the 2020 mobility strategy.

Table 2 – High-level transport policy of the European Commission since 2011

Year	Title	Description
2011	White Paper [36]	40 concrete initiatives The White Paper was a roadmap to a Single European Transport Area adopted by the Barroso Commission[23], for the following decade to build a competitive transport system that would increase mobility, remove major barriers in key areas and fuel growth and employment. The document, also, set goals for 2050:

powerful, cutting edge, and sustainable processors; **Reskill and upskill** – The adaptation of education systems to support digital skills and educational and vocational training for all ages

[22] An expansion of the European Geostationary Navigation Overlay Service (EGNOS) service is planned to support Galileo.

[23] José Manuel Barroso, President of the European Commission, 2004-2014, accessed from: https://multimedia.europarl.europa.eu/pl/appointment-of-barroso-commission_12904_pk

Year	Title	Description
		- no more conventionally fuelled cars in cities - 40% use of sustainable low carbon fuels in aviation - at least 40% cut in shipping emissions - a 50% shift of medium distance intercity passenger and freight journeys from road to rail and waterborne transport - a 60% cut in transport emissions
2013	Trans-European Transport Network (TEN-T) [37]	Infrastructure investment The TEN-T guidelines are part of the EU cohesion agenda establishing a network to promote better accessibility of all regions and intermodality. TEN-T main focus is placed on closing gaps, removing bottlenecks and technical barriers. TEN-T comprises two network 'layers': - the Core Network[24] - including the most important connections linking the most important nodes (to be completed by 2030) - the Comprehensive Network – covering all European regions (to be completed by 2050) TEN-T has had two horizontal priorities – in rail[25] and in maritime[26] transport. Until 2017 67% of airports were connected to railway and road transport infrastructure [38].
2016	Strategy for Low-Emission Mobility [39]	Modernisation to clean and digital transport The Juncker Commission[27] mapped the areas for the initiatives planned in the following years:

[24] The Core Network is represented by nine Core Network Corridors, which were identified to streamline and facilitate the coordinated development of the Core Network.

[25] European Rail Traffic Management System - a single interoperable system to replace the more than 20 different national train control and command systems currently in operation throughout Europe, accessed from: https://ec.europa.eu/transport/themes/infrastructure/european-rail-traffic-management-system_en

[26] Motorways of the Sea (MoS) – a pillar of TEN-T, consists of short-sea routes, ports, associated maritime infrastructures, equipment, facilities and relevant administrative formalities. MoS contributes towards the achievement of a European Maritime Transport Space without barriers, connecting Core Network Corridors by integrating maritime links with hinterland, accessed from: https://ec.europa.eu/transport/themes/infrastructure/motorways-sea_en

[27] Jean Claude Juncker, President of the European Commission, 2014-2019, accessed from: https://multimedia.europarl.europa.eu/pl/appointment-of-juncker-commission_12903_pk

Year	Title	Description
		- making the most of digital technologies, smart pricing and further encouraging the shift to lower emission modes; - speeding up the deployment of low-emission alternative energy for transport reaching significant market share by 2030; - moving towards zero-emission vehicles.
2017 /2018	Europe on the Move [40]	Modernisation to clean and digital transport The Commission's plan shaped the beginning of an era of connected and automated vehicles, shared mobility, zero emissions, and easy shifts between transport modes, preparing the future of mobility in Europe. Due to unsatisfactory progress[28] [41], the plan reiterated the 2011 White Paper goal of reducing the transport-related GHG emissions by 60% by 2050. The Commission promised [42] to strengthen its support for large-scale cross-border projects[29] [43] for automated driving and cooperative intelligent transport systems by 2019 using the C-ROADS platform[30] [44]. It also promised to step up its work with stakeholders to support an industry-led initiative for research, development and manufacturing of the next generation of battery cells and battery packs.
2019	European Green Deal (EGD) [45]	Shift acceleration The von der Leyen Commission updated the 2050 goal of the White Paper to Net-zero emissions, which means reducing transport emissions by 90%. The priority, here, is a shift of a substantial part of the inland freight carried today by road onto rail and inland waterways.

[28] The White Paper goals status in 2016: "[…] the majority of stakeholders that provided their feedback to the Commission were not satisfied with the progress achieved [and] acts adopted by the legislator presented less ambition than the underlying Commission proposals and that non-legislatives initiatives such as guidelines, roadmaps or best practices were followed up rather slowly."

[29] For example, in 2016, the EU Member States signed the Declaration of Amsterdam on Cooperation in the field of connected and automated driving.

[30] C-ROADS platform – launched by the Member States and the Commission to link Cooperative Intelligent Transport Systems (C-ITS) deployment activities

<table>
<tr><th>Year</th><th>Title</th><th>Description</th></tr>
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EU inland waterways in 2017, European Commission, 2020
https://ec.europa.eu/transport/themes/infrastructure/news/2020-08-26-progress-ten-t-network_en
To reduce congestion and pollution, especially in urban areas, the EGD proposed funds[31] for developing smart systems and infrastructure for traffic management and Mobility as a Service (MaaS) solutions enabled by digitalisation. Fossil fuel subsidies are to be phased out by closing loopholes, reducing tax exemptions, EU Emissions Trading System allowances and extending emission trading in aviation and maritime. The EGD called to reconsider and adopt effective road pricing – the Eurovignette Directive. The document, also, called the Member States to install, with the Commission support, one million public recharging and refuelling stations by 2025. The Commission planned legislative options to boost the production, to uptake sustainable alternative fuels and to review the Alternative Fuels Infrastructure Directive 20, as well as the TEN-T Regulation to accelerate the deployment of zero- and low-emission vehicles and vessels.
</td></tr>
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[31] The EGD funds of the EU Innovation and Networks Executive Agency, such as The Connecting Europe Facility (CEF) for Transport, accessed from: https://ec.europa.eu/inea/connecting-europe-facility/cef-transport

Year	Title	Description
2020	Strategy (the mobility strategy) [46]	On track for future - 82 initiatives in 10 key areas (flagships)[32] Aligned to the EGD and the 2011 White Paper, the strategy details sector's fundamental transformation, including recovery from the COVID-19 downturn, "build back better" resilient mobility and leap forward to sustainable and smarter future accessible for all, including persons with disabilities. The strategy sets concrete milestones: by 2030 - at least 30 million zero-emission vehicles on roads - 100 cities will be climate neutral - high-speed rail traffic will double - scheduled collective travel of under 500 km should be carbon neutral - automated mobility deployed at large scale - zero-emission vessels ready for market by 2035 - zero-emission large aircraft[33] ready for market by 2050 - nearly all cars, vans, buses, new heavy-duty vehicles will be zero-emission - rail freight traffic will double - high-speed rail traffic will triple - the multimodal TEN-T equipped for sustainable and smart transport with high speed connectivity will be operational for the comprehensive network

3.5.1.1 Sustainable aviation policy

In line with the 2011 White Paper objectives, a long-term vision for the European aviation sector was outlined in the High-Level Group on Aviation Research report – **Flight Path 2050** [47]. It envisaged a passenger-centric

[32] 10 Flagships: (1) boosting the uptake of zero-emission vehicles, vessels and aeroplanes, renewable & low-carbon fuels and related infrastructure, (2) creating zero-emission airports and ports, (3) making interurban and urban mobility healthy and sustainable, (4) greening freight transport, (5) pricing carbon and providing better incentives for users, (6) making connected and automated multimodal mobility a reality, (7) boosting innovation and the use of data and artificial intelligence (AI) for smarter mobility, (8) reinforce the Single Market, (9) make mobility fair and just for all, (10) step up transport safety and security across all modes

[33] Aligned to the Commission's policy, the Europe's aeronautics industry and research community targets disruptive technologies by 2030. The focus is on hybrid-electric flying, ultra-efficient propulsion and aircraft configurations for the short and medium range, and also on hydrogen-powered aviation. Strategic Research and Innovation Agenda - Volume 2, accessed from: https://www.acare4europe.org/acare-db

air transport system integrated with other transport modes, taking travellers and their baggage from door to door predictably and efficiently, enhancing passenger experience and rendering the transport system more resilient against disruptive events. It paved the way for the launch of two major public-private partnerships: Clean Sky [48] and the Single European Sky ATM Research (SESAR) [49]. The initiatives were successful in advancing solutions in technology and navigation. In August 2020, the Commission invited the Clean Sky stakeholders to a new partnership, to contribute to the EGD goals under Horizon Europe[34] [50], the Clean Aviation [51]. In November 2020, Commissioner Vălean[35] and the EUROCONTROL officials confirmed the continuation of SESAR partnership in the next, SESAR3 JU with the same level of support [52]. Clean Aviation and SESAR3 are part of the 2020 mobility strategy – in the flagships[36] 1 and 6, accordingly.

Aligned to the EGD and the 2015 Aviation Strategy for Europe[37] [53], the 2020 European ATM Master Plan [54] seeks to make use of the SESAR technologies to create a 'truly' Single European Sky (SES)[38] [55] [56]. Its goals, among others are **to integrate drones into airspace, to rollout the future performance-oriented communications, navigation and surveillance (CNS) and to deliver a fully scalable system able to handle both manned and unmanned aviation (U-space) by 2040[39]** [57]. The U-space and the expected 'Drone Strategy 2.0' are in the flagship 7 of the 2020 mobility strategy. More details in Chapter 3.5.2.

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[34] Horizon Europe - the next EU research and innovation programme

[35] Adina Vălean, Commissioner for Transport in the von der Leyen's College since 2019, accessed from: https://ec.europa.eu/commission/commissioners/2019-2024/valean_en

[36] The 2020 mobility strategy in its part for aviation includes: (flagship 1) starting initiatives to improve the energy efficiency and reduce emissions of aircraft and launching of ReFuelEU Aviation, (flagship 2) creating of common criteria of sustainable transport including aviation and revising of the Airport Slots Regulation and the Airport Charges Directive, (flagship 3) revising competition law to incorporate requirements of selling increasing number of multimodal tickets by airlines, (flagship 4) transforming of urban mobility planning in freight dimension including unmanned aircraft, (flagship 5) revising of the EU Emissions Trading System (ETS), with respect to the ICAO's Carbon Offsetting and Reduction Scheme for International Aviation (CORSIA), (flagship 6) developing ATM and completing SES, (flagship 7) developing the relevant rules on the U-space and 'Drone Strategy 2.0', (flagship 8) revising of the Air Services Regulation, (flagship 9) promoting high social standards of work in aviation, (flagship 10) seeking authorisation form the Council on the new air transport agreements.

[37] Aviation Strategy for Europe – an outward-looking EC initiative for the sector expansion to the rest of the world

[38] Single European Sky (SES) – an EC initiative launched in 2004 to reduce fragmentation of the airspace over Europe, and to improve the performance of air traffic management in terms of safety, capacity, cost-efficiency and the environment. In the second attempt to upgrade SES, the Commission expects that by modernising of the airspace management and establishing more sustainable and efficient flightpaths it can reduce up to 10% of air transport emissions

[39] Experts opinions of the 2019 Delphi study diverge if urban air mobility is possible until 2035 (the projection 13 including urban air transport was excluded). They agree, however, that urban transport systems are likely to change before 2030 to more on-demand, personal, flexible, and adapted towards personal preferences D2D transport.

3.5.1.2 Cleaner and smarter mobility in cities

In January 2017, the Commission launched an urban partnership in the framework of **Urban Agenda for the EU**[40] beginning consultations on public transport and soft mobility, on accessibility of the disabled, the elderly and young children, on efficient transport with good local and regional connectivity, and on how urban mobility can be harnessed to ensure high air quality standards across cities in Europe. The consultations resulted in the Sustainable Urban Mobility Planning (SUMP) guidelines (version 2)[41] unveiled in October 2019 at the CIVITAS conference[42] [58]. The March 2020 Urban Agenda for the EU report [59] on New Mobility Services (NMS)[43] deployment status concluded, among other findings[44], that there is a need for opening up of all data from transport providers and making them available in computer-readable format to facilitate common intermodal planning.

In the 2020 mobility strategy, the Commission called to create a **European Common Data Space**, that will serve transport in a safe and trustworthy way (the flagship 7). Moreover, the flagship 3 points cities as the forefront of the transition towards greater sustainability through increasing shares of collective transport, walking, cycling and automated, connected, multimodal mobility enabled by digital solutions.

The automated digital solutions have been under examination since the 2016 strategy for the **deployment of cooperative intelligent transport systems** (C-ITS) that initiated the C-ROADS testing platform[45] [60]. It has served the Commission to collect experience of automated transport for adopting coherent set of rules basing on the 2010 ITS Directive [61]. The flagship 6 of the strategy sets a plan to seize opportunities

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[40] The Urban Agenda for the EU was officially established by the Pact of Amsterdam, agreed by the EU ministers responsible for urban matters during informal meeting of the Council of the European Union in 2016, https://ec.europa.eu/regional_policy/en/information/publications/decisions/2016/pact-of-amsterdam-establishing-the-urban-agenda-for-the-eu

[41] Guidelines for developing and implementing a sustainable urban mobility plan, 2nd edition, European Programme for Accelerating the Take up of Sustainable Urban Mobility Plans, SUMPs-Up project, H2020-EU.3.4, accessed from: https://www.eltis.org/sites/default/files/sump_guidelines_2019_interactive_document_1.pdf

[42] CIVITAS - a network of cities for cities dedicated to cleaner, better transport in Europe and beyond. Over 800 innovative urban transport measures and solutions in over 80 Living Lab cities across Europe since 2002 show why CIVITAS stands for City VITAlity and Sustainability, accessed from: https://civitas.eu/

[43] New Mobility Services (NMS) - car-sharing, ride-hailing, bike-sharing, e-scooters

[44] Some other conclusions include: a need for education to spread best practices in mobility, a need for navigation services to guide drivers to transfer points, to switch to a more sustainable modes, a need for phasing out motor scooters as too polluting, a need for car-free housing areas, ride-hailing is unfavourable because it substitutes public transport, bike-sharing free-floating companies have different interests than cities, Urban Agenda for the EU, Partnership for Urban Mobility, March 2020.

[45] Several Member States started Cooperative Intelligent Transport Systems (C-ITS) deployment under real life conditions on interurban road links and pilot plans for urban streets testing.

presented by connected, cooperative, and automated mobility (CCAM) through further research under Horizon Europe and large scale deployment by 2030. More details in Chapter 3.5.3.

3.5.1.3 Summary

The EC policy is aiming at multilateralism, the long-run sustainability (circular economy) while keeping freedoms and leaving no one behind. In transport, the EC focuses on connectedness, intermodality, using emerging technologies to the full and energy source shift.

Scenario for 2025:

- intensifying use of NMS (New Mobility Services), emerging of CCAM (connected, cooperative, automated mobility)
- further development of TEN-T (mainly rail and maritime), shift to rail and maritime logistics
- million public recharging stations and 500 hydrogen refuelling stations
- Eurovignette

Scenario for 2035:

- emerging of UAM (Urban Air Mobility), intensifying use of CCAM (connected, cooperative, automated mobility)
- the Core TEN-T Network completed, smart pricing, shift to lower emission modes
- 3 million public recharging stations and 1000 hydrogen refuelling stations
- intensifying intermodality among the soft modes of travel, mass transit, NMS, CCAM

Scenario for 2050:

- net-zero emissions in transport
- the Comprehensive TEN-T Network completed
- walkable cities, domination of soft modes, mass transit, NMS, CCAM, UAM

3.5.2 Urban Air Mobility regulatory framework

Urban Air Mobility regulatory framework topic as important from the EC policy and integrated transport system is described in D3.1 and D4.1. Here only the summary is included.

Scenario for 2025:

Standards, specifications and regulations to support the airspace re-configuration, capacity on demand service, drone accommodation, initial U-space services implementation, advance network operations and services, simulators and ATM Validation Platforms partially completed and under development. First certified UAS is operating in controlled airspace.

Scenario for 2030:

New ATM Data service provision model is implemented across Europe. The ATM improvements are focused on service-oriented architectures, relying on virtual centres associated to a sector-independent ATS framework. This will enable capacity-on-demand, more dynamic delegation of the provision of air traffic services to an alternate centre with spare capacity and will result in a substantial improvement in ANS operations and productivity. ADSPs will in that timeframe play an important role in supporting the transition towards a more resilient ATM system. In addition, all ADSPs are required to be interoperable to exchange information based on European or ICAO standards.

Increased automation and virtualization are effectively balancing supply (of ATC) and demand (for flights) while ensuring higher levels of resilience. "The resilience can therefore be addressed in several contexts [62]:

- at network level, it is expressing the capability to accommodate peaks of traffic with maximum capacity offered ensuring the minimum delays even with some possible disruptions (e.g. changing local weather conditions, rerouting of flows due to a crisis in an ATSU [Air Traffic Services Unit];
- at local level, (e.g., for low visibility conditions), it is to ensure the sustainability of the ATM operations, in support of the regularity and punctuality of the traffic at a given airport: the aircraft must be prepared and equipped to face adverse conditions (or system disruptions) while maintaining its schedule and final destination;
- for data exchanges and services over SWIM[System Wide Information Management]/internet, it is to ensure the security and integrity of the information provided to the customers. When adopting the service-oriented approach to their organization, each stakeholder needs to assess its performance in this area as well, in particular to ensure the acceptability of its customers."

According to SESAR Vision by 2050: "deliver a fully scalable traffic management system capable of handling growing air traffic, both manned and unmanned, manage safely the future traffic growth, while mitigating environmental impact, increasing numbers of aerial vehicles (conventional aircraft and unmanned aircraft) will operate seamlessly and safely in all environments and classes of EU airspace."

Scenario for 2050:
ATM is more advanced and air transport system is significantly more fitted to passenger's individual, temporary needs – improved flexibility, safety, security, predictability and reduced fuel consumption and emissions, facilitating and optimizing airspace user operations in all weather conditions. The delivery of the Digital European Sky should be completed by 2050 in order to address the challenges faced by aviation

infrastructure in Europe and deliver maximum benefits to EU citizens. Completed digitalisation of European Sky facilitates total system optimisation and management including unexpected disruptions in one of modes and provides zero inefficiencies due to ATM. System has the ability to adjust to expected and unexpected disturbances (staffing problems, weather disturbances, system failures, cyber-attacks, temporary surge in needed capacity) in order to safely sustain required operations and secure sufficient capacity. The new architecture enables resources (including data) to be shared across the network, supporting flexible and seamless airspace management to support airspace users/passengers as well as connecting many modes of transport into seamless door-to-door services for people.

3.5.3 Smart city, Internet of Things and access to information

All the components mentioned in the title of this section complement the ICT (Internet and Communication Technologies) - large industry sector. Driven by digital technology development ICT plays crucial role in the process of shaping the future in numerous everyday life aspects. In the European Union the increasing significance of this domain is reflexed by continuous policy since 2014 by issuing following regulations: *The Regulation on the free flow of non-personal data* [63] aiming at removing obstacles to the free movement of non-personal data across Member States and IT systems in Europe; *The Cybersecurity Act* [64] strengthening the European Union Agency for Cybersecurity (ENISA), *The Open Data Directive* [65] providing a common legal framework for a European market for government-held data and *The General Data Protection Regulation.* Further in 2018, the Commission presented an *AI strategy* [66] to boost Europe's competitiveness in this field and agreed a *Coordinated plan* [67] with Member States. In April 2019 the High-Level Expert Group on Artificial Intelligence proposed their *Ethics Guidelines on trustworthy AI* [68]. This was built upon the framework for AI presented on 19 February 2020. In 2019, also President von der Leyen in her *Political Guidelines* [69] indicated on the need to lead the transition to a healthy planet and a new digital world. It was resulted with setting a digital technology development (together with European Green Deal) as one of EC priorities for the period of 2019-2024 [70]. Within this priority the following actions were defined: *Artificial intelligence*, *Online platforms, European data strategy, Cybersecurity, European industry strategy, Digital skills, High Performance Computing (HPC) and Connectivity.*

<u>Role of Information and Communications Technology (ICT) for Transport Integration.</u> According to International Transport Forum (ITF-OECD)[46] digital technologies are considered as an enabler for disruptive improvements in the field of efficiency, safety or cost of operation in transport. They are a catalyst for smart-city and smart mobility (understood as mobility which is: *instrumented, computative, connective and reactive* [71]) applications and become inseparable component of smart-city policies. ICT is probably the strongest force transforming the logistics industry today [72]. According to the ITF-OECD Report [71]:

[46] The International Transport Forum at the OECD is an intergovernmental organisation with 62 member countries. It acts as a think tank for transport policy and organises the Annual Summit of transport ministers. ITF is the only global body that covers all transport modes. The ITF is administratively integrated with the OECD, yet politically autonomous, https://www.itf-oecd.org

"Taken altogether, the various intermeshed components of smart mobility have the potential to improve mobility outcomes and reduce negative externalities related to transport activity. As with smart cities, smart mobility connotes the beneficial application of (mainly digital) technologies to improve mobility outcomes."

In details, following the ITF-OECD Report [71], ICT can revolutionise transport by new, disruptive solutions allowing for deeper and more efficient integration of modes. The most significant progress/highest benefits can be expected in: travel time, ride quality, safety, efficiency, environment, travel cost as well as affordability. Within the complex scope of ICT field, a set of domains being of crucial significance for the mobility can be identified. They are: Internet of Things (IoT), Big Data, 5G and beyond communication technologies and Smart-cities concept.

3.5.3.1 Internet of Things

According to the CONNECT Advisory Forum[47] report definition [73]: Internet of Things (IoT) is a set of products, services and processes that virtualizes the real-world things for digital processing. The outcome of IoT is a digital representation of the real world that can interact with digital systems and applications and is susceptible to internet business models. From the multimodal transport system point of view IoT solutions allow operators for better planning and reacting on current needs and traffic conditions. IoT makes all persons and objects in the transportation system informed and creates conditions for automated and optimised decision making in order to improve process efficiency. For passengers IoT means more reliable tools for better decision making and reduction of time and effort related to transportation. They get more reliable knowledge about advantage of public transport over personal car. On the level of management and policy making city governments and managing bodies obtain data on real needs of transportation system needs and can build more sustainable, safer and environment friendly transportation.

According to EC [74], "a set of supporting policy actions have been adopted by the European Commission to accelerate the take-up of IoT and to unleash its potential in Europe for the benefit of European citizens and businesses." As it was stated by the 2014 CONNECT Advisory Forum document [73] IoT is envisioned as one of the most disruptive technological revolutions since the advent of the Internet. Moreover, it was noted that Europe is in an excellent position to become a global leader in IoT. Among main strengths of European ICT are business-to-business software and services, systems in automotive and aeronautics industries. The document contained a set of recommendations assuring meeting the goal of leading position of Europe in IoT field.

In May 2015, the *Digital Single Market Strategy* was adopted [75]. To meet the Digital Single Market strategy needs and inform about its upcoming policy, the European Commission published in April 2016 the EC staff working document entitled *Advancing the Internet of Things in Europe* [76]. This document is part of the Digitising European Industry initiative and specifies the EU's IoT vision which is based on three pillars: two-dimensional nature of IoT ecosystem, putting user in the center and establishing a single market for IoT. In

[47] The main task of the Advisory Groups is to give advice to the Commission services on relevant H2020 objectives and scientific, technological and innovation priorities as well as on broader policies issues related to the Digital Agenda for Europe, https://ec.europa.eu/digital-single-market/en/connect-advisory-forum-working-groups

the field of mobility applications, the document highlights that trust, security and convenience aspects should be considered as priorities for future mobile ecosystems (in order to ensure the security and convenience of consumer-centric transactions and services). In addition, IoT should be designed in a way which prevents the users from failing to use the services or being locked-in by service providers. It should not completely substitute face-to-face services and interactions. Also correct understanding of technology, its usefulness and impact on the main user and his/her environment and choices should be in focus. And finally mistrusting technology-based systems and services should be avoided. In 2015 the *Alliance for Internet of Things Innovation (AIOTI)*[48] was initiated by the European Commission to support the creation of an innovative and industry driven European Internet of Things ecosystem. Among several Working Groups the one WG9 dedicated to smart mobility was established. Aim of WG9 is support of development of solutions which allow for increased multi-modal mobility, more efficient traffic management, a dynamic road infrastructure, automated road tolling, usage based insurance and improved policy making by analysis of road data and smart vehicles.

In 2016 the *IoT European Platform Initiative (IoT-EPI)*[49] was launched in order to support IoT research and innovation and the idea of open and easily accessible IoT platforms. Seven research and innovation IoT projects funded by the Horizon 2020 programme were at the core of IoT-EPI. These projects were aimed to develop and validate innovative platform technologies, foster technology adoption through community and business-building and creating a new vibrant IoT ecosystem.

In 2017 five *IoT Large-Scale Pilots*[50] co-funded by the European Commission under the *Horizon 2020* programme [77] started with AUTOPILOT[51] - Autonomous vehicles in a connected environment project among others. The idea of IoT Large-Scale pilots was to support the testing and experimentation of new IoT related technologies, to accelerate the standards setting across different business sectors and create conditions for further boosting the IoT technology (topics like privacy and security, business models or usability were covered by LSP).

In 2018 the European Commission has launched a specific cluster of R&D projects to investigate new solutions for security and privacy by design and by default in IoT. Within the cluster a set of eight IoT security and privacy research projects with an EU budget of EUR 37 million were co-funded. Projects were devoted to exploration and answering the question how to enhance overall security and deploy new approaches for data privacy such as Distributed Ledger Technology/Blockchains. In the same year AIOTI issued document entitled

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48 The Alliance for Internet of Things Innovation (AIOTI) website, https://aioti.eu/

49 The European Platform Initiative (EPI) website, https://iot-epi.eu/

50 The European Large-Scale Pilots Programme - Driving IoT Innovation at Scale in Europe website, https://european-iot-pilots.eu/wp-content/uploads/2019/06/IoT-_European-_Large-Scale_Pilots_Programme_eBook_CREATE-IoT_V02.pdf

51 The AUTOPILOT - AUTOmated Driving Progressed by Internet Of Things website, https://european-iot-pilots.eu/project/autopilot/

Advancing EU IoT Research and Innovation - AIOTI's position on Horizon Europe and Digital Europe [78]. The document indicates on the need for new solutions for future mobility applications as a result of emergency of the Internet of Vehicles and autonomous vehicle applications combining mobility, AI, IoT, 5G and real-time data processing. AIOTI advised on the creation of a Mobility research priority that is separate from Climate and Energy.

Under new strategy set by President von der Leyen AIOTI elaborated another document titled *European IoT challenges and opportunities 2019–2024 – an IoT enabled future* [79] where the set of challenges identified and responding recommendations is included. They are (also adequate for mobility solutions): A human-centric approach (ensuring safety, security, privacy and trust), enabling cross-sectoral data marketplaces, progress in the digitisation of European industries according to market and societal needs, and establishing a cybersecurity strategy for safeguarding IoT technology and applications.

Perspectives and look into the future of IoT**.** The EU will invest almost EUR 500 million in Internet of Things-related research, innovation and deployment within the H2020 framework until 2021 [74]. In terms of future of IoT it should be noted that development of advanced platform architectures for smart objects, embedded intelligence and smart networks is enabler for future design of the Internet of Things applications (EU invests in the development of advanced IoT platforms).

Next EU Research and Innovation Framework Programme for 2021-2027 (Horizon Europe). The European Commission has published an ambitious proposal for the follow-up to Horizon 2020. Internet of Things will mainly be supported under the heading of Next Generation Internet. In details, according to the Horizon Europe Specific Programme proposal [80], the main areas of support are Technologies and Systems for trusted and energy-efficient, smart network, next generation internet application and services and software-based middleware covering distributed ledger technologies.

3.5.3.2 Big Data

The Three Vs of Big Data, according to Oracle [81]: Volume - related to the amount of data; Velocity - related to the fast rate at which data is received and Variety - referring to the many types of data to be processed. Traditional approach requires data types to be structured and fit neatly in a relational database. Additionally, the 3Vs were supplemented (to 5Vs) by Veracity – accuracy and applicability of data and Valence - Connectedness. According to Oracle main use cases for Big Data are the following: Product Development, Predictive Maintenance, Customer Experience, Machine Learning (ML), Operational Efficiency and Innovation.

Following the 2020 B2G Data Sharing strategy report[52] [82] A huge amount of data produced every day has potential to enable understanding patterns of human behaviour and activities and to serve the general public interest by informing, decision-making, providing new scientific insights and resolving policy issues.

[52] High-Level Expert Group on Business-to-Government Data Sharing was an independent expert group set up by the European Commission in November 2018. Its mandate ended in December 2019.

According to the European Commission strategy for data [83] there is a need to establish effective networks for development of trustworthy technologies and to give businesses the confidence and means to digitise [84]. Creation of a *public–private partnership (PPP) on data* [85] was a part of the 2013 EC strategic initiative on the data value chain. In 2014 the Communication *Towards a thriving data-driven economy* [86] *and its accompanying Staff Working Document* [87], was issued. It focused on the digital economy, innovation and services as drivers for growth and jobs and called for EU action to provide the right framework conditions for a single market for big data and cloud computing. In 2016 the document titled: *Digitising European industry* [88] was published where data technologies standards were considered as one of the five priority areas. Further connectivity details were addressed as essential enablers of the data economy in *Connectivity for a European gigabit society* [89]. In 2017, the European Commission issued, on the basis of the conclusions of the 2014 Communication on the data-driven economy [90], the following documents: a communication on '*Building a European data economy'* [91] and its details [92] (see below final version of *European Strategy for Data*).

The data strategy [93] and the *White Paper on Artificial Intelligence (AI)* [94] are the first pillars of the new digital strategy of the Commission. The documents focus on the need to put people first in developing technology and to defend and promote European values and rights in how we design, make and deploy technology in the real economy.

<u>The European Strategy for Data.</u> The European strategy for data issued in 2020 aims at creating a single market for data. It will ensure Europe's global competitiveness and data sovereignty. Creation of Common European data spaces will make data more available for use in the economy and society, while keeping companies and individuals who generate the data in control. Data is seen as essential resource for economic growth, competitiveness, innovation, job creation and societal progress in general. The document indicates on areas requiring actions in order to ensure EU's leadership in the global data economy. The goal of European strategy for data is to adopt legislative measures on data governance, access and reuse, to assure easy development of common European data spaces in crucial sectors such as industrial manufacturing, green deal, mobility or health and to enable access to secure, fair and competitive cloud services by facilitating the set-up of a procurement marketplace for data processing services. €2 billion is going to be invested in a European High Impact Project to develop data processing infrastructures, data sharing tools, architectures and governance mechanisms. In effect the EU will create a single market for data [95] where data can flow within the EU and across sectors, for the benefit of all with respecting of European rules, in particular privacy and data protection, as well as competition law and where the rules for access and use of data are fair, practical and clear. Together with the data strategy, in 2020 the European Commission has issued a report on Business-to-Government (B2G) data sharing [96] containing High-Level Expert Group recommendations contributing to making B2G data sharing in the public interest a scalable, responsible and sustainable practice in the EU. This topic can be considered as critical and potentially disruptive for transport domain. The experts advised to take policy, legal and investment measures in the field of governance of B2G data sharing across the EU, transparency, citizen engagement, ethics and operational models, structures and technical tools and private sector data sharing in B2G contexts.

With regard to mobility the *European Strategy for data* document highlighted the need of support in establishment of mobility data space, identified as critical enabler for future mobility systems (like connected cars) facilitating access, pooling and sharing of data from existing and future transport and mobility databases. Further the document indicated that digitisation and data in all modes of transport and in logistics become an essential component of further work on the '*European Transport System'* and in particular in the upcoming '*Smart and Sustainable Transport Strategy*' (planned on Q4 2020). This will include actions in all transport sectors as well as for cross-modal data sharing logistics and passenger ecosystems. Regarding the increasing role of data in transport, European Commission declared to review and amend regulatory in the area of data sharing in following areas: for motor vehicles (currently focused on wireless data sharing for repair and maintenance), to open it up to more car data based services (Q1 2021); ITS *Directive on harmonised river information services* [97] and the *Directive on Intelligent Transport Systems* [98], including its delegated regulations to further contribute to data availability, reuse and interoperability (both in 2021); for aviation a Regulation on the *Single European Sky* [99] to include new provisions on data availability and market access of data service providers in order to promote the digitalisation and automation of air traffic management (2020) and for rail transport (in 2022) and maritime and freight transport (*Regulation on Maritime Single Window* [100] and Regulation on electronic freight transport information regulations[53] in Q3 2021 and Q4 2022 respectively).

White Paper on Artificial Intelligence (AI) [101] highlights that data and AI can help find solutions to many of society's problems in many areas like health, transport, farming but also help to find solutions in the fields of security or manufacturing but earning of peoples' trust a key. Therefore, promoting excellence in AI, Building trust and awareness on benefits of artificial intelligence should of highest priority.

The European Data Flow Monitoring Initiative [102]. Monitoring of data flows across the EU's territory is considered as being of strategic importance to EU decision-making and investment choices in the area of cloud computing. It is also crucial for the process of assessment of the competitiveness of the European digital economy. Therefore, the issue of setting up the European Data Flow Monitoring which will map data flows across the EU territory is one of EC priorities.

Next EU Research and Innovation Framework Programme for 2021-2027 (Horizon Europe) [80] HPC and Big Data analytics are critical to support policy making, scientific leadership, innovation and industrial competitiveness, and to maintain national sovereignty. In details according to Horizon Europe Specific Programme proposal main areas of support are: HPC; next generation of key exascale and post-exascale technologies and systems; Big Data: Extreme-performance data analytics; "Privacy by design" in the analysis of personal and confidential Big Data and focus on reduction of carbon footprint of ICT processes, covering hardware, software, sensors etc.

3.5.3.3 Next generation of telecommunication technologies (5G and beyond)

5G wireless technology is developed to deliver higher multi-Gbps peak data speeds, ultra-low latency, more reliability, massive network capacity, increased availability. Following Qualcomm [103] predictions 5G telecommunication technologies will support transport integration process through two main use cases: Mission-critical communications (5G will enable new services that can transform industries) and massive IoT (5G is meant to seamlessly connect a massive number of embedded sensors in virtually everything).

[53] The negotiations with the co-legislators are concluded, adoption was foreseen mid-2020.

The European Commission sees 5G technology as eyes and ears of artificial intelligence systems. Future 5G infrastructure will serve a wide range of applications and sectors including (e.g. Connected Automated Mobility, eHealth, energy management, possibly safety applications, etc.) [104]. 5G standards are one of the five priority areas under the *Digitising European Industry* [105] initiative.

In 2013 the European Commission established a *Public Private Partnership on 5G (5G PPP)*[54]. The EU flagship initiative to accelerate research and innovation in 5G technology. In line with an international cooperation plan [106], the strategy for EU international cooperation in research and innovation [107] aimed at agreement on global vision for 5G. On the same level 5G spectrum identification (above 6GHz) officially started (at the *World Radiocommunication Conference 2015 - WRC-15* [108]). In 2016, in order to ensure early deployment of 5G infrastructure in Europe, the Commission adopted a *5G Action Plan for Europe* [109] aimed at enabling of start 5G services in all EU Member States by end 2020. The document was followed by a rapid build-up to ensure uninterrupted 5G coverage in urban areas and along main transport paths by 2025. Also in 2016, the Commission launched the *Action Plan* [110] setting out a clear roadmap for public and private investment on 5G infrastructure in the EU. In line with the Europe's 5G Research Plan was launched [111]. The 5G research was funded by the Horizon 2020 EU's research and innovation programme and is organised in 3 phases: **Phase 1:** The future 5G network architecture (2015-2017 with 22 projects funded [112]), **Phase 2:** Move towards demonstration and experiments with the involvement of the vertical industries (2017-2019 with 21 projects funded [113]) and **Phase 3:** End to end 5G platforms, connected and automated mobility. All phases exceed a total budget of EUR 400 million. **Phase 3:** were divided into four waves. The first wave of the *5G PPP* phase 3 consolidated the results of the previous phases through integration of an end-to-end 5G experimental network infrastructure. (3 EU funded projects have been launched in 2018 [114]). The second wave of phase 3 was devoted to support pilots over cross border corridors for *Connected and Automated Mobility (CAM)* [115]. Three research and innovation projects covering three of the cross-border corridors agreed by neighbouring Member States started in 2018 (*5GCroCo - Fifth Generation Cross-Border Control*[55], *5GCARMEN -5G for Connected and Automated Road Mobility in European Union*[56] and *5GMOBIX - Driving forward Connected & Automated Mobility*[57]). The main target of the projects was to leverage vehicle connectivity to create complete ecosystem around cars and vehicles, serving not only safety related use cases but also a rich set of applications including maintenance, insurance, infotainment, driver's assistance and autonomous driving. The third wave initiated in 2019 was going to support the implementation of trials and pilots, dedicated to demonstrate the applicability of 5G network for various vertical industries use cases (like media and entertainment, industry, health, transport and automotive, energy, …) running on top of the 5G end-to-end platforms from the first wave. Eight projects were launched mid-2019. Including related to mobility (*5GTOURS - Smart mobility, media and e-health for*

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[54] The 5G Infrastructure for Public Private Partnership (5GPPP) website, https://5g-ppp.eu/

[55] The Fifth Generation Cross-Border Control (5GCroCo) website, https://5gcroco.eu/

[56] The 5GCARMEN – 5G for Connected and Automated Road Mobility in European Union) website, https://5gcarmen.eu/about/

[57] The 5GMOBIX - Driving forward Connected & Automated Mobility) website, https://www.5g-mobix.com/

tourists and citizens[58], *5G!Drones - Unmanned Aerial Vehicle Vertical Applications' Trials Leveraging Advanced 5G Facilities*[59], *5G-HEART - 5G Health Aquaculture and Transport validation trials*[60], *5Growth - 5G-enabled Growth in Vertical Industries*[61] and *5G-VICTORI - Vertical demos over common large scale field trials for rail, energy and media Industries*[62]. In addition, in the meantime, in 2018, the *EU Electronic Communications Code* [116] was adopted by the European Parliament and the Council. It was within the scope of *Wireless Europe* policy [117] which aims at the harmonisation of spectrum access conditions across the Union's internal market, a more efficient use of spectrum and improved availability of information about the current use, future plans for use and availability of spectrum.

Beyond 5G. The last fourth wave of **Phase 3** of *Europe's 5G Research Plan* started in 2020. It addressed the long term evolution of communication systems, investigating technologies not yet, or not fully, addressed under the *5G PPP*, and paving the way towards smart connectivity systems beyond 5G. Within this wave 8 projects started in 2019 and 2020. Among them*: LOCUS – Localisation and analytics on-demand embedded in the 5G ecosystem for ubiquitous vertical applications*[63] *and TERAWAY - Terahertz technology for ultra-broadband and ultra-wideband operation of backhaul and fronthaul links in systems with SDN management of network and radio resources*[64]. Additionally, as indicated in *Council conclusions on shaping Europe's digital future* [118] the COVID-19 pandemic has demonstrated the need for fast and ubiquitous connectivity. The pressure for availability of good quality connections can be considered as extra driver for 5G and beyond network solutions development.

3.5.3.4 Smart city

With regard to transport, according to the Commission [119], a smart city is a place where use of ICT is employed for better resource use and less emissions through smarter urban transport networks. In details,

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[58] The Smart mobility, media and e-health for tourists and citizens (5G-TOURS) website, http://5gtours.eu/

[59] The Unmanned Aerial Vehicle Vertical Applications' Trials Leveraging Advanced 5G Facilities (5G!Drones) website, https://5gdrones.eu/

[60] The 5G Health Aquaculture and Transport validation trials (5G-HEART) website, http://5gheart.org/

[61] The 5G-enabled Growth in Vertical Industries (5Growth) website, https://5growth.eu/

[62] The VertIcal demos over Common large scale field Trials fOr Rail, energy and media Industries (5G-VICTORI) website, https://www.5g-victori-project.eu/

[63] The Localisation and analytics on-demand embedded in the 5G ecosystem for ubiquitous vertical applications (LOCUS) website, https://www.locus-project.eu/

[64] The TERAWAY project website, Terahertz technology for ultra-broadband and ultra-wideband operation of backhaul and fronthaul links in systems with SDN management of network and radio resources, https://ict-teraway.eu/

as given by the bee smart city[65], it means pursuing the following challenges with support of ICT technologies [120] especially in the area of design of effective, equitable, safe and secure public transport systems, integrated with MaaS and other platforms, adapting to vehicle innovation and adoption (autonomous, connected, electric, shared, dockless), crafting policies and strategies to promote adherence to air quality standards and other quality-of-life measures, development of PPP partner ships and collaborating with knowledge institutions to address air quality, traffic congestion, and sustainability issues and building sustainable infrastructure — physical and digital — to support innovative mobility solutions from public and private sectors.

According to the Commission [121], the following activities were set to achieve an interoperable smart-city ecosystem**:** *The European Innovation Partnership on Smart Cites and Communities* [122], *The Digital Transition Partnership of the Urban Agenda for the EU* [123], *H2020* projects, the *Digital Cities challenge conference*[66] and *Green Digital Charter*[67]. *The Community of Practice*[68] brings together part of the overall conversations. In addition, *The Join, Boost, Sustain* declaration[69], aiming to support the scaling up of open, interoperable, cross-sector and cross-border digital platforms and digital solutions across the EU, gathering mayors, presidents of regions as well as national ministers to pursuing a 'European Way' of scaling digital solutions. The movement is driven by *EUROCITIES*[70], European Network of Living Labs (ENoLL)[71] and Open & Agile Smart Cities (OASC)[72].

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[65] bee smart city - the world's largest smart city network & community, https://hub.beesmart.city/en/global-smart-city-knowledge-center

[66] Digital Cities Challenge: A strategy for EU cities in the 21st Century - initiative helping over 40 European cities to reap the benefits of advanced technologies, develop comprehensive strategies and thriving ecosystems and achieve smart and sustainable growth, https://2019.digitallytransformyourregion.eu/

[67] The Green, Digital Charter website, http://www.greendigitalcharter.eu/

[68] CoP-CITIES - an initiative of the EC, open to external stakeholders. It builds on and brings together ongoing work and expertise on cities by JRC and REGIO, https://ec.europa.eu/jrc/communities/en/community/cop-cities

[69] The declaration available at the Living-in.EU website, https://www.living-in.eu/

[70] EUROCITIES – network of 190 cities in 39 countries cooperating to ensure a good quality of life for all. Focus areas: Climate change and energy transition, Metropolitan areas governance, Gender equality, Citizen engagement, Green areas and biodiversity, Fight air, water & noise pollution, Food systems, New business models and trends, Circular economy and Poverty and social exclusion. https://eurocities.eu/stories/

[71] European Network of Living Labs - user-centred, open innovation ecosystems based on systematic user co-creation approach, integrating research and innovation processes in real life communities and settings, https://enoll.org/about-us/

[72] Open & Agile Smart Cities – network bringing together smart cities & communities worldwide to shape the global market for digital services, https://oascities.org/

European Innovation Partnership on Smart Cities and Communities (EIP-SCC) established in 2012, bringing stakeholders together in six action clusters (*Citizen Focus, Business Models & Finance, Integrated Infrastructures & Processes, Integrated Planning, Policy and Regulations, Sustainable Districts and Built Environment and **Sustainable Urban Mobility***). EIP-SCC has successfully contributed to and to generate a seven-year series of calls for Smart Cities Lighthouse projects under the Horizon 2020 Framework Programme (H2020). *Sustainable Urban Mobility*[73]: The *EIP-SCC* Action Cluster brings together cities and regions with companies to show-case innovative mobility solutions and support their replication at scale in key market segments. Within the scope of this cluster four initiatives dedicated to the specific components of urban mobility system were established: *E-Vehicles for Smart Cities and Communities (EV4SCC)*; *NMS; Intelligent Mobility for Energy Transformation (IMET) and UAM*.

Look into the Future. Towards climate neutral and smart cities**:** Under the newly proposed programme Horizon Europe[74], the Commission has initiated a mission on '*Climate neutral and smart cities'*, whereby support will consist of helping cities become more resilient and smarter by empowering citizens in digital social innovation and in policy making and blending together best practices with technology components (large-scale, cross-border, standardised solutions and digital infrastructure).

3.5.3.5 Summary

All the described solutions aim to enable smart city mobility – a way to meet urban transport challenges like congestion or improve efficiency but also to reduce its externalities. As it is indicated in ITF-OECD report [71] realising these benefits is not, however, straightforward. A number of complicating factors and feedback loops come into play, which may thwart, diminish, or even lead to overall losses. Nevertheless, all the called strategy documents issued in recent years with support of the European Commission rather undoubtedly indicate on the fact that ICT is considered as being of critical importance for the achieving significant progress and sustaining leading position of European industry in the future. Not only in transport sector. Some view on future role of data transport is included in *European strategy for Data* [93] issued in 2020 where EU is aiming to become an attractive, secure and dynamic data economy by setting clear and fair rules on access and re-use of data, investing in next generation standards, tools and infrastructures to store and process data and by joining forces in European cloud capacity, pooling European data in key sectors, with EU-wide common and interoperable data spaces as well as by giving users rights, tools and skills to stay in full control of their data. The indicated in the strategy the increasing role of data in transport (projected to grow by 35% during 2015-2050) enables considering future transport as integrated through free data exchange as fairly more sustainable. Additional fact allowing for expecting of dynamic development of ICT in near future is the COVID-19 pandemic demonstrating the need for fast and ubiquitous connectivity [118].

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[73] The Sustainable Urban Mobility (EIP-SCC) is now part of the Smart Cities Marketplace, https://smart-cities-marketplace.ec.europa.eu/

[74] Horizon Europe - the Commission's proposal for Horizon Europe, strategic planning, implementation, news, related links, https://ec.europa.eu/info/horizon-europe_en

Scenario for 2025: Very limited access to privately generated travel related data and underutilisation of potential of data generated and collected by transport operators (due to lack of appropriate tools to exchange and use the data) results with situation where particular modes are internally optimised and matched to assessed or expected passenger flow. High complexity of network and numerous other constraints of various nature (e.g. urban/regional rail network or airline operator) together with lack of tools prevents or strongly limit flexibility or dynamic reaction on disruptions (in relation to mass/public transport). From the passenger point of view it means that passenger/traveller however supported by mobile phone applications (gathering data provided by different operators and proposing optimal connection) is the only manager of his/her multimodal journey in case of disruption. Transport process efficiency (expressed by numerous individual features) relies only on traveller's ability of using available information (or availability/affordability of transport data integrating applications).

Scenario for 2035: Privately generated data concerning travels are gathered and freely disseminated and processed within European Union by approved organisations. Due to security reasons, it is not possible to use the data in real-time. The data are input for ITS (Intelligent Transport System) using ML (machine Learning) and AI (Artificial Intelligence) technologies to forecast transport system related data in day-scale (privately generated data allows for projection of demand for transport system instead of traffic as in 2025). It is ensured: by appropriated regulatory framework related to data access and processing and availability of 5G network in all European urban areas allowing for positioning inside buildings. Insufficient yet digitisation of all surface modes systems prevents from real-time reaction for disruption or changed demand. But it is possible to manage transport systems supply in day-scale (on base of privately generated data gathered, processed and shared to operators). Due to IoT applied to transport means it is possible to better manage of available resources and achieve higher reliability and lower number of internally generated disruptions. From passenger's point of view it means that he/she is still integrator of his/her multimodal journey, but available tools are more advanced and transport system is slightly more fitted to his individual temporary needs predicted by the system employing available mentioned solutions (it can be expressed by i.e. reduced waiting time, shorter travel duration or higher travel comfort). Privately generated data (by portable device – smartphone) enrich functionality of applications gathering data provided by different operators allowing for more conscious decision (including data about i.e., congestion-number of passengers occupied).

Scenario for 2050: Privately generated data concerning travels are gathered and freely disseminated and can be processed in nearly real time (not more than 1-hour delay) within European Union by approved organisations. More accurate and precise forecast of demand for transport is possible and allows also for mitigation of external costs resulting from disruptions or other external events. Completed digitisation of resources being in use by all transport operators allows for total system optimisation and management (driven among other by real-time data provided by users) and nearly real time reaction of system-of-systems on unexpected disruptions in one of modes (parallel, separated/independent organisational structure of particular transport systems (modes) enable nearly costless flexibility. From passenger's point of view it means that he/she is can be still integrator of his/her multimodal journey, but available tools are more advanced and transport system is significantly more fitted to his individual, temporary needs predicted (nowcasted) by the system employing available, mentioned solutions (it can be expressed by i.e. minimised waiting time, shorter travel duration or higher travel comfort). In addition, transport system as managed from the level of complex Ecosystem is able to deal with disruption in nearly real time. Travel features are effect of total system optimisation according to agreed criteria. Privately generated data (by portable device – smartphone) enrich functionality of applications gathering real-time data provided by different operators allowing for even more conscious decision (including data about i.e., congestion-number of passengers occupied or (cost) of carbon footprint).

3.6 Passenger experiences

This section reviews the current use of intermodality transport data by air passengers. It focuses on best practices, current air passengers' expectations, shortcuts and informal intermodality data integration implemented by air passengers, as well as barriers currently experienced by air passengers in intermodal transport.

3.6.1 EU regulations and projects relevant for passengers' experience

3.6.1.1 Relevant EU regulations

Below a list of the EU relevant legislation together with a short content description.

Regulation (EC) No 261/2004 establishing common rules on compensation and assistance to passengers in the event of denied boarding and of cancellation or long delay of flight

The Regulation set a minimum level of quality standards for passenger protection, adding an important citizen's dimension to the liberalisation of the aviation market.
Depending on the circumstances of the travel disruption, it requires air carriers to:

- provide passengers with assistance, such as meals, refreshments, telephone calls and hotel accommodation;
- offer re-routing and refunds;
- pay a flat-rate compensation of up to € 600 per passenger, depending on the flight distance;
- proactively inform passengers about their rights.

The airline is not obliged to pay financial compensation if it can prove that the cancellation or delay was caused by extraordinary circumstances. However, the obligations for care and assistance are upheld even in such situations.

The Regulation also requires Member States to establish National Enforcement Bodies (NEBs) to ensure the correct application of the Regulation.

The rights of passengers under the Regulation should not be confused with their rights under the Montreal Convention: whilst the Convention provides for individualised damage to travellers, assessed on a case-by-case basis depending on the individual circumstances of the passenger, Regulation (EC) No 261/2004 establishes standardized entitlements (with regard to assistance and care) applicable to all passengers, regardless of their individual circumstances.

Under the Montreal Convention (as translated by Regulation (EC) No 2027/972 into EU law), a passenger may be entitled to compensation in case of mishandled baggage (but with a limit of about € 1200), except if the airline can demonstrate it has taken all reasonable measures to avoid the damages or it was impossible to take such measures. Unlike Regulation (EC) No 261/2004, neither Regulation (EC) No 2027/97 nor the Montreal Convention requires the establishment of enforcement bodies to ensure their correct application.

Regulation (EC) No 1107/2006 of the European Parliament and of the Council of 5 July 2006 concerning the rights of disabled persons and persons with reduced mobility when travelling by air

This Regulation is part of the policy carried out by the European Commission in all areas of everyday life to combat discrimination against persons with disabilities and, more generally, with either permanent or temporary mobility problems.

The objective of the Regulation is to allow disabled persons and persons with reduced mobility (PRM) to have the same possibility to travel by air as other citizens. The Regulation seeks a balance between the need to combat discrimination and the need to meet operational requirements by laying down a general principle of non-discrimination and by, on the one hand, imposing on operators a set of obligations relating to the information and assistance provided to passengers and, on the other, requiring PRMs to provide pre-notification of the need for assistance and allowing for strictly defined derogations from the obligation to provide assistance.

The general principle is to ban the refusal of carriage, with some derogations and special conditions. There are rules on designation of points of arrival and departure, transmission of information, right to assistance (and responsibilities and quality standards), compensations for lost or damaged wheelchairs, other mobility equipment and devices), complaint procedure and penalties to be reported by Member States.

Regulation (EC) No 1371/2007 on rail passengers' rights and obligation

The Regulation aims to protect rail passengers in the EU. Like air, waterborne transport, bus and coach passengers, rail passengers have rights to information, reservations and tickets, assistance, care and compensation in the event of delay or cancellation, free-of-charge assistance (for persons with disabilities and for persons with reduced mobility), compensation in the event of an accident, a quick and accessible system of complaint-handling and full application and effective enforcement of EU law through National Enforcement Bodies (NEBs) designated by Member States.
The Regulation builds on an existing system of international law (the Uniform Rules concerning the Contract for International Carriage of Passengers and Luggage by Rail (CIV) and extends its scope to domestic rail passenger services.

In 2013, the Court of Justice of the European Union (CJEU) ruled that the current Article 17 of the Regulation does not allow for railway undertakings to be exempted from compensating passengers for delays caused by force majeure. This distinguishes rail from other transport modes.
The Member States may exempt the following domestic services from the application of the Regulation (apart from certain mandatory requirements):

- Article 2(4): Domestic rail passenger services for a maximum period of five years, renewable twice (with the exception of the provisions listed in Article (2)3 of the Regulation).
- Article 2(5): Urban, suburban and regional rail passenger services (with the exception of the provisions listed in Article (2)3 of the Regulation).
- Article 2(6): Rail passenger services or journeys of which a significant part is operated outside the EU for a maximum period of five years. This exemption may be renewed.

Article 2(7) invites the Commission to provide the European Parliament and the Council with a report on the exemptions granted by Member States pursuant to paragraphs 4, 5, and 6 of Article 2.

***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**

The ITS Directive provides for developing specifications for actions within the four priority areas referred to in Article 2, and for developing necessary standards. The Directive's four priority areas can be directly linked to the first four action areas of the ITS action plan, namely:

- Optimal use of road, traffic and travel data: many ITS applications rely on relevant information to support the safe and efficient management of traffic, including digital maps and real-time traffic information. Where road safety is at stake, it is vital that information is validated and made quickly available to all players on a fair basis.
- Continuity of traffic and freight management ITS services: this will support the development of measures to improve freight transport, co-modality and road-user charging. Seamless and dynamic traffic management systems are needed to cope with rising congestion and enable optimal use of existing capacity.
- Road safety and security: this will help to ensure the protection of vulnerable road users and provide services for safe and secure truck parking areas. Another challenge has been to ensure the full-scale roll-out of the interoperable EU-wide eCall
- Integrating/linking the vehicle with the transport infrastructure: the streamlining and integration of ITS applications and cooperative systems could improve efficiency, enhance usability and reduce costs.

The Directive has been supplemented by a number of Commission delegated regulations, each of which sets the specifications for one of the Directive's priority actions, necessary for the compatibility, interoperability and continuity of the respective services, as follows:

- Commission Delegated Regulation (EU) No 305/2013 establishes specifications for the upgrading of public safety answering point infrastructure required for the proper receipt and handling of eCalls in order to ensure the compatibility, interoperability and continuity of the harmonised EU-wide eCall service ('specifications d'). In this context, reference can also be made to Decision No 585/2014/EU on the deployment of the interoperable EU-wide eCall service, which mandates that Member States must deploy no later than 1 October 2017 the eCall PSAP infrastructure required for the proper receipt and handling of all eCalls.

- Commission Delegated Regulation (EU) No 885/2013 establishes specifications necessary to ensure compatibility, interoperability and continuity for the provision and operational use of information services for safe and secure parking places for trucks and commercial vehicles ('specifications e').

- Commission Delegated Regulation (EU) No 886/2013 establishes the specifications necessary to ensure compatibility, interoperability and continuity for the deployment and operational use of data and procedures for the provision, where possible, of road safety-related minimum universal traffic information free of charge to users ('specifications c').

- Commission Delegated Regulation (EU) No 2015/962 establishes the specifications necessary in order to ensure the accessibility, exchange, re-use and update of road and traffic data by road authorities, road operators and service providers for the provision of EU-wide real-time traffic information services ('specifications b').

- Commission Delegated Regulation (EU) 2017/1926 establishes the necessary specifications in order to ensure that EU-wide multimodal travel information services are accurate and available across borders to ITS users ('specifications a').

For the purposes of the adoption of certain acts under its terms, the Directive stipulates that the Commission is assisted by the European ITS Committee (EIC). A European ITS Advisory Group was also set up to advise the Commission on the business and technical aspects of the deployment and use of ITS in the Union.
The general objective of the Directive and the action plan is to put in place the necessary mechanisms to increase the deployment and use of continuous ITS services across the EU, to subsequently improve the functioning of the road transport system, including its interfaces with other modes, and in doing so reduce the negative external effects of road transport.

The specific objectives are to:
- increase interoperability and continuity of applications, systems and services;
- establish effective coordination and monitoring mechanisms between all ITS stakeholders;
- establish solutions for liability issues and for the sharing of data which supports ITS services in respect of legislation on privacy and data protection.
- The operational objectives are to:
- establish a clear EU policy agenda by defining priority areas and actions with a timeline;
- establish a legal framework to support coordinated and coherent deployment and use of ITS in the EU;
- adopt specifications and ensure that they are implemented when ITS are deployed;
- establish effective coordination and monitoring mechanisms.

The intervention logic in Annex I describes the links and causal relationships between the problems and needs, broader policy goals, the general, specific and operational objectives that the legislative framework was designed to address, and the specific actions for addressing those problems and needs.

Two key elements to support the coordinated and coherent deployment and use of ITS are the requirements on the Commission to (a) develop a working programme that includes objectives and dates for implementing the various actions, setting a clear policy agenda and timeline and (b) to work towards adopting specifications in the four priority areas, starting with the six priority actions, as identified in Articles 2 and 3 and Annex I of the Directive. According to Article 7, these should be adopted in the form of legally binding delegated acts where this is considered appropriate, and also be based on standards where appropriate (as set out in Article 8).

Regulation (EU) No 1177/2010 concerning the rights of passengers when travelling by sea and inland waterway;

The Regulation incorporates certain provisions of the 1974 Athens Convention (as amended by the 2002 Protocol) relating to the carriage of passengers and their luggage by sea. The Regulation applies to all carriers in international carriage, including carriage between EU Member States, and certain types of domestic carriage, provided that:

- the ship is flying the flag of a Member State or is registered in a Member State, or

- the contract of carriage has been made in a Member State, or
- the place of departure or destination or both, according to the contract of carriage, are in a Member State.

It covers liability of the carrier in respect of passengers, their luggage and their vehicles, as well as mobility equipment, in the event of accidents. This Regulation does not affect the right of carriers to limit their liability for accidents in accordance with the International Convention on Limitation of Liability for Maritime Claims of 1976, as amended by the 1996 Protocol in its up-to-date form. Accidents under the Regulation include both 'shipping' and 'non-shipping' incidents in the course of the carriage.

Rights of passengers are on:
- compensation for death or personal injury;
- compensation for loss of or damage to cabin luggage;
- compensation for loss of or damage to luggage other than cabin luggage;
- for loss of or damage to valuables;
- passengers with reduced mobility to compensation for loss of or damage to mobility equipment or other specific equipment;
- passengers with reduced mobility to compensation for loss of or damage to mobility equipment or other specific equipment
- an advance payment in the event of a shipping incident.

Regulation (EU) No 181/2011 concerning the rights of passengers in bus and coach transport;

It provides for a minimum set of rights for passengers travelling by bus and coach services within the European Union. In principle, the Regulation applies to "regular services" (in other words services provided at specified intervals along specified routes, passengers being picked up and set down at predetermined stopping points) for non-specified categories of passengers, where the boarding or alighting point of the passengers is situated in the territory of a Member State. The following core rights will be applicable to all regular services, irrespective of the scheduled distance of the service:
- non-discriminatory transport conditions,
- access to transport for disabled persons and persons with reduced mobility at no additional cost and the financial compensation for the loss or damage of their mobility equipment,
- minimum rules on travel information for all passengers before and during their journey as well as general information about their rights,
- a complaint handling mechanism by carriers available to all passengers,
- independent national bodies in each Member State with the mandate to enforce the regulation and where appropriate to impose penalties.

In addition, the following rights are applicable to regular services where the scheduled distance is 250 km or more (hereinafter long-distance regular services):
- provision of (electronic) tickets or any other documents giving entitlement to transport,
- compensation and assistance in case of death, injury, loss or damage caused by accidents,
- information when the service is cancelled or delayed in departure,
- right of reimbursement of the full ticket price or rerouting in case of cancellation or long delay,
- adequate assistance in case of cancelation or long delay (only applicable when the scheduled duration of the journey is more than 3 hours),

- compensation up to 50 % of the ticket price if the carrier failed to offer the passenger the choice between reimbursement of the ticket price or rerouting in case of cancellation or long delay,
- specific assistance at no additional cost for disabled persons and persons with reduced mobility both at bus terminals and on board.

However, Member States may, on a transparent and non-discriminatory basis, grant an exemption from these additional rights to purely domestic regular services for a period of no longer than four years, which may be renewed once (making a maximum of 8 years). Finally, Member States may on a transparent and non-discriminatory basis, grant an exemption from the application of the entire Regulation for a period of no longer than four years which may be renewed once (making a maximum of 8 years) in case of regular services where significant part of the service (including at least one scheduled stop) is operated outside the European Union.

Overview of the rights of passengers travelling by bus and coach transport:
- Right to non-discriminatory transport conditions
- Right to information
- Right of compensation and assistance in the event of accidents
- Right of continuation, re-routing and reimbursement in case of cancellation or long delay
- Right of assistance in case of cancelled or delayed departures
- Right of disabled passengers and passengers with reduced mobility
- Right to submit complaints to the carriers and national enforcement bodies
- Enforcement of passenger rights.

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

The Delegated Regulation 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 is an enabler for increased modal shift and the promotion of sustainable modes of transport. A market already exists for the delivery of travel information services to end users, but a number of gaps and barriers are still present limiting the full potential of such services. It expects to provide the necessary requirements to make EU-wide multimodal travel information services accurate and available across borders. It establishes the specifications necessary to ensure the accessibility, exchange and update of travel and traffic data and distributed journey planning for the provision of multimodal information services in the European Union. The Delegated Regulation intends to provide appropriate framework conditions enabling the co-operation of all the relevant stakeholders along the travel information value chain. The relevant stakeholders include transport authorities, transport operators, travel information service providers, infrastructure managers and transport on demand service providers etc. Such enabling conditions aim to support the interoperability, compatibility, and continuity of multimodal information services across Europe.

3.6.1.2 EU projects and best practices targeting passenger multimodality experiences

The analysis of best practices follows a supply side approach: it considers examples in which airports provide facilities, services and technologies improving seamless connections between airports and point of destinations, supporting in such a way the rational use of transport options by passengers in a door-to-door perspective (co-modality multimodal transport context).

In a later stage of the analysis, the best practices will be compared with a demand side approach, in which passenger demand requirements and expectations will be examined. Indeed, air passenger demand is evolving and therefore the risk of inappropriate assumptions about airport and/or passenger needs may be an issue, also in relation to radical changes emerging in the coming years, e.g., COVID-19 new requirements.

By considering the supply side approach, an analysis of the EU projects has been undertaken. Below, a list of the considered projects:

- ATTRACkTIVE Advanced Travel Companion and Tracking Services (https://cordis.europa.eu/project/id/730822);
- COACTIVE - CO-modal journey re-ACcommodation on associated Travel serVices (https://cordis.europa.eu/project/id/777522);
- CONNECTIVE - Connecting and Analysing the Digital Transport Ecosystem (https://cordis.europa.eu/project/id/777522);
- GOF4R - Governance of the IF for Rail and Intermodal Mobility (http://www.gof4r.eu);
- ICARUS Intermodal Connections in Adriatic-Ionian Region to Upgrowth Seamless solutions for passenger(https://www.italy-croatia.eu/web/icarus)
- IT2Rail - IT Solutions for Attractive Railway Services (http://www.it2rail.eu);
- LAIRA -Landside Airport Accessibility (https://www.interreg-central.eu/Content.Node/LAirA.html);
- MaaSive - Passenger service platform specifications for an enhanced multi-modal transport eco-system including Mobility as a Service (MaaS) (https://cordis.europa.eu/project/id/826385);
- MOBILITY4EU (https://www.mobility4eu.eu);
- My-TRAC (http://www.my-trac.eu/);
- RIDE2RAIL - Travel Companion enhancements and RIDE-sharing services synchronised to RAIL and Public Transport (https://cordis.europa.eu/project/id/881825);
- Shift2MaaS - Shift2Rail IP4 enabling Mobility as a Service and seamless passenger experience (https://cordis.europa.eu/project/id/826252);
- TRANSFORUM Transforming European Transport through an Active Actors Forum (https://cordis.europa.eu/project/id/321565/it).

In particular, the LAirA Interreg project (2017-2019) represents an excellent starting point. The following section indicates the best practices, and the section 3.6.3 draws conclusion in terms of emerging supply requirements. In more details. the LAirA project has reviewed best practices addressing seven thematic areas:

1. Electric Vehicles.
2. Air-Rail Links.
3. Active Travel (cycling).
4. Car Pooling and Car sharing.
5. Intelligent Transport Systems.
6. Wayfinding.
7. Road Based Public Transport.

For each thematic area best practices have been identified, on the basis of a desk-based research and interviews with stakeholders.
The following best practice have been identified, addressing airports in Europe and North America.

Electric vehicles	Air-rail links	Active travel	Carpooling and car sharing	ITS	Wayfinding	Road based public transport
• Amsterdam Schiphol • Stockholm Arlanda • Vancouver	• Manchester • London Stansted • Oslo • Stockholm Arlanda	• Geneva • Vancouver	• Brussels • London Stansted • Vienna	• Munich Airport • London Gatwick	• Catania • Toronto Pearson • New York JFK	• Helsinki • London Stansted • Paris Charles de Gaulle

Each best practice is illustrated with the indication of stakeholders involved, type of solution, critical and or success factors and impacts. A detailed analysis of each best practice may be conducive towards the identification of supply requirements in the direction of seamless connections through multimodal transport means.

A partial indication can be derived from the following box [124]. The potential supply' requirements are showed in bold characters.

Electric Vehicles: Electric vehicles are becoming increasingly practical in terms of their range, availability, cost and specification. Provision for these vehicles in terms of charging infrastructure is increasingly common at airports for **convenience for customers** and to support low carbon travel.

Air-Rail Links: **Easy access** to a **fast, frequent** rail link to the local city centre is an attractive alternative to road-based transport to/ from airports. Often faster services compete with cheaper slower rail or bus services, so Air-Rail services need to be **frequent, fast, high quality and well promoted**.

Active Travel: To encourage cycling to the airport, particularly for airport employees, good **supporting facilities** and incentives are required. This includes **good connectivity to bike paths** in the wider area, on-site facilities such as secure parking and showers, and incentives such as promotions and events.

Car Pooling and Car sharing: Car-pooling and car sharing offer alternatives to taxi, hire car and single occupancy car trips. Car sharing can be **more economical** than taxi or traditional car hire, depending on the

timescale of use. The shared cars themselves are often low emission models, including electric options. Car-pooling is particularly useful to reduce single occupancy commute trips.

Intelligent Transport Systems (e.g. apps): Traditionally airport apps have focused on parking and air-side information, however, modern best practice examples **provide detailed information for passengers on landside transport options.** Apps can also assist airport staff to provide high quality customer services to passengers by providing travel information, particularly at times of disruption.

Wayfinding: Airport terminals are complex buildings, often on multiple layers. Airports with multiple options for landside travel can have the associated issue of **providing information in a way which is intuitive** to an international and transient audience. Clear wayfinding to onward transport connections is vital to ensure these options are as easy to use as possible.

Road Based Public Transport: Bus and coach services often provide opportunities for **low cost, convenient** links to a wider range of destinations than rail services may provide. Special airport coaches, other coach operators and local bus services can provide excellent levels of accessibility. Local bus services also provide an important option for airport staff. Ensuring attractive and **easy to use ticketing options and information is important for both passengers and staff.**

The following mobile applications have been developed by 3 airports to implement the Intelligent Transport Systems: The Gatwick, Munich and FLYTOGET

GATWICK AIRPORT APPLICATION

The Gatwick app was introduced in winter 2017/18 and further updated in summer 2018.
Among the features of the application, the following ones play an important role in ensuring multimodality, in particular as far as travel time and connection/modes indicators are concerned.

- Direct links to Google's journey planner.
- Links to public transport timetable information.
- Live train times.
- Airport announcements (these include updates about landside transport issues).

Furthermore, a staff app was developed by Airport Labs, providing a mechanism for all airport staff to be able to be informed about airport issues, including any disruption to landside access such rail service interruptions. Recently, the introduction of augmented reality features makes possible for the app to shows a way to a needed gate, baggage carousels, check-in desks, specific food or shopping outlets.

MUNICH AIRPORT PASSNGR APPLICATION

The Passngr Application allows received the "Top App" award from Focus Money in the 14/2018 issue.
It is currently available for the airports of Hamburg, Düsseldorf, Munich and Muenster-Osnabrueck. With the apps such as «Passngr», users can receive information tailored to their personal needs along the entire journey chain:

- traffic updates and information on route alternatives,
- information on the availability and prices of parking, on the expected duration of check-in,
- waiting times at security and offers from their favorite restaurants and shops in the departures lounge.

The same applies for the destination airports, including the anticipated waiting time at the baggage carousel. The app interacts with popular route planners and navigation systems, integrating information on car sharing and taxi services. In addition, passengers can book services directly: the rental or car-sharing vehicle or washing, refueling, and repair services during their trip.

FLYTOGET AIRPORT-CITY RAIL CONNECTION

The "Flytoget" service covers the almost 50 km distance between Oslo Central Station and airport in only 19 minutes, with a frequency of one train every ten minutes.
The service continues beyond Oslo Central Station and serves nine further stops within Greater Oslo and takes up to 60 minutes.
In terms of multimodality, the service supports an easy access to airport and efficient connections with Oslo in terms of:

- Location (the rail station was originally part of the airport)
- High frequency;
- High speed;
- Services in the Greater Oslo urban area;
- frequency and journey time;
- ticket integration.

On the other site, an example of best practice in the field of integrated ticketing is given by the Tallinn city. The Estonian city of Tallinn implemented a payment system (ID tickets) whereby electronic tickets for both public transport and certain local attractions were carried on a personal ID card. The tickets were obtained through mobile devices and on a specific website. In January 2013, the Tallinn City Administration took the unprecedented step and of making public transport free for registered users. The 'green card' was introduced as an alternative to the ID card and is available to all registered citizens of the city. Non-residents can load the required amount of money on to the so-called 'green card' to get about the city too. Although the service is free, users are still required to touch card to reader when using services in order that the public transport authority can have a better idea about patronage of the network. See www.tallinnlt.ee/en

3.6.2 Current passengers' expectations

The overall goal is to make transport as efficient as possible. Passengers request fast, efficient and in many cases, environmentally friendly transport connections. The era of transport rivalry must become a thing of the past. If mobility is to be safeguarded in the long term, the modes will have to work together. In the long term, intelligent division of labor is indispensable, each mode covering that part of the transport chain for which it is best suited [125].

Multimodal infrastructure refers to the network of airports, seaports, roads, railways, public-transport systems, and human powered mobility options that are integrated and coordinated to form a transport system to move people or freight from one point to another. While a seamless multimodal experience, might include, for instance, travelling on two or more forms of transport with a single ticket (e.g. rail and air). In general, the more effectively these modes support and interconnect with one another, and the more seamless the intermodal connections (the movement of passengers or freight between modes of transport), the less congestion and stress there will be on any individual component. As air traffic is concentrated at hub airports, constraints come up, such as long walking distances and delays. Passengers must wait at the hub airports for the connection flight, mostly longer than it would be necessary, since the flight co-ordination is less efficient and minimum connecting time is higher, especially at main hubs like Paris CDG and London Heathrow. Large airports have longer waiting times than the smaller airports (Frankfurt Main, Amsterdam Schiphol), even though one would expect shorter waiting time. The availability of information about travel time and routing alternatives is considered equally relevant to ensure seamless door-to-door mobility, both for passengers and for freight. In order to promote public transport and increase its attractiveness, factors such as accessibility and reliability of services will become more and more important as well as frequency, comfort and intermodal integration.

For sure, what passengers ask and want depends on their specific needs. Meeting those needs will increasingly become a competitive factor. Therefore, timely providing of real-time data to the passengers is high on the list of transport providers [126]. As an example, Cokasova underlined *arrival delay* is quoted to be 20% more important to the passengers than departure delay. Final results have shown that passengers' expectations are higher than assumed by industry managers.

Smart intermodal ticketing with common EU standards that respect EU competition rules is vital. Online information and electronic booking and payment systems integrating all means of transport should facilitate multimodal travel. **No matter how sophisticated the system can get, it will hardly reach the desired success if not serving the passengers.** Having sound knowledge of passenger feedback is the first step towards well-organized and satisfactory inter-modal connection and interchange node with efficient baggage handling logistics and integrated ticketing, a foundation for successful transport inter-modality [127]. Passengers ask companies along the D2D air travel value chain to adopt measures aimed at the personalization and digitalization of journeys overall and to establish partnerships with other providers and tech companies.

To understand the passengers needs we should focus on the following indentified needs, as indetinfied in the LAiRa project:

- **Convenience**, the provision of services and facilities should be provided at affordable prices. Maybe demand market segmentation, e.g., business class travellers, may determine a less stringent requirement;
- **Easiness**, the options and solutions provided should be easy to use and easy to understand as far as it is possible;
- **Frequent and fast**, the provision of frequent rail links to the local city centre should be an asset in particular if an attractive alternative to road-based transport to/ from airports exists;
- **Exhaustiveness,** information provided should be exhaustive. Providing high quality customer services to passengers, particularly at times of disruption;
- **Reliability of services,** that should be guaranteed also by providing alternative solutions in the case of disruption.

The following table shows the user needs enlightened together with the related key aspects:

Table 3 – The user needs - key aspects

USERS Needs	Related Key aspect
Convenience	- Clear indication of costs - Services offered for the selected transport path, taking into account extra comforts asked for
Easiness	- Accessibility of information and data, facilitating electronic data exchange across borders, and timely updating of information - Simplicity in both booking and costs - Clearly identification of connections - Possibility to have integrated tickets - Simplicity in understanding how to purchase
Frequent and fast	- Integrated information about the whole journey, being aware about real-time data to know about strikes, disruptions and delays
Exhaustiveness	- Privacy and liability issues - High level of protection (rights, information, services, etc.) in case of multimodal products compared to mode-specific ones (single contracts versus separate contracts per mode) - Accessibility information regarding passengers permanent or temporary impairments - Luggage security (both in terms of lost luggage and purloining) - Accessibility of vehicles, streets and stations
Reliability	- Care and assistance to be provided in the event of travel disruption - Re-routing to be offered so that passengers may arrive at their destination, as soon as possible - Reimbursement and/or compensation to be paid, where relevant

3.6.3 Shortcuts and informal multimodality data integration implemented by passengers

Smartphones can be considered the key mean to implement Intelligent Transport Systems: 63 percent of the world's population is estimated to have a smart phone and apps are now a key method of accessing information on travel. APPs supporting air travel arrangements are either independent services offered by digital companies or official application covering one or more mobility need or step by transport service providers (i.e., airport parking, shuttle reservation/ticketing, taxi reservation/payment etc.)
The following table offers a synoptic description of some mobile applications (City Mapper, Moovit, Transit, Gatwick, Airport Munich, Airport Flytoget) used by passengers to reach airports. It is a methodological grid for demand side approach, showing what the analysed applications offers to the users and what is still missing but requested by passengers. The table below shows the extent on which each shortcut or best practice tool covers expected services and functions: the number of circles represents the number of identified services and functions per each travel variable, the full dots represent the number of matched services out the total ones. The full list of services and functions able to match passengers' needs per each multimodal travel variable is given in project's deliverable D4.1.

Table 4 – Coverage of passengers' needs by surveyed applications

Multimodal travel variable	Shortcut tool	Services/functions provided	Best practice tool	Services/functions provided
Travel time	City Mapper	●●●●●	Gatwick Airport	●●●●●
	Moovit	●●●●○	Munich Airport	●●●●○
	Transit	●●●●○	Flytoget (Oslo)	●●●●○
Connections and travel modes	City Mapper	●●●●○○○○○	Gatwick Airport	●●●●○○○○○
	Moovit	●●●●●●○○○	Munich Airport	●●●●●●○○○
	Transit	●●●●●●○○○	Flytoget (Oslo)	●●●●●●○○○
Accessibility and comfort of each travel segment	City Mapper	○○○○○○○	Gatwick Airport	○○○○○○○
	Moovit	○○○○○○○	Munich Airport	○○○○○○○
	Transit	○○○○○○○	Flytoget (Oslo)	○○○○○○○
Cost and level of services provided	City Mapper	●●○○○○	Gatwick Airport	●●○○○○
	Moovit	●○○○○○	Munich Airport	●○○○○○
	Transit	●○○○○○	Flytoget (Oslo)	●○○○○○
Personal security	City Mapper	○○○○	Gatwick Airport	○○○○
	Moovit	○○○○	Munich Airport	○○○○
	Transit	○○○○	Flytoget (Oslo)	○○○○
Luggage security	City Mapper	○○	Gatwick Airport	○○
	Moovit	○○	Munich Airport	○○
	Transit	○○	Flytoget (Oslo)	○○
Environmental impact	City Mapper	○○	Gatwick Airport	○○
	Moovit	○○	Munich Airport	○○
	Transit	○○	Flytoget (Oslo)	○○
Ticketing	City Mapper	○○○○○○	Gatwick Airport	○○○○○○
	Moovit	○○○○○○	Munich Airport	○○○○○○
	Transit	●●●○○○	Flytoget (Oslo)	●●●○○○
Early and real time information provision	City Mapper	●●●○○○○○	Gatwick Airport	●●●○○○○○
	Moovit	●●○○○○○○	Munich Airport	●●○○○○○○
	Transit	●●●○○○○○	Flytoget (Oslo)	●●●○○○○○

3.6.4 Barriers currently experienced by air passengers in multimodal transport

The following barriers to intermodality transport have been envisaged:

- Access to data is limited, difficult and time-consuming across the EU;
- Gaps in travel and traffic data interoperability across transport modes;
- Lack of interoperable interfaces;
- Lack of T&C provisions for public and private bodies;
- Multimodal systems integration at national, regional and EU levels.

Today even within individual Member States most metropolitan regions have proprietary systems. Harmonization and cross-regional coordination among these systems is crucial. It was stated that transport operators often resist a harmonized approach for reasons of data ownership. It was stated that transport operators often resist a harmonized approach for reasons of data ownership. Additional emphasis was put

on data and cyber security at national levels. Stakeholders signaled significant demand for a European "code of conduct" regarding the organization of open data access. At the same time data ownership of the private sector must be respected and data provision can only be on a voluntary basis.
In order to make the whole transport system greener, more sustainable and more efficient, the provision of seamless multimodal door-to-door mobility is crucial. Better information on availability increases the likelihood that a transport option will be used.

To start with a multimodal system framework represents a **legal** challenge. Existing legal obligations, requirements and restrictions vary between the European and the national policy level and across Member States, and they may sometimes contradict each other. Supposed obligations to open data sharing (in order to enable smart services) could interfere with requirements of data protection and control, considering the varying perspectives on the relative importance of an individual's privacy against other public interests.
With respect to **data availability**, the biggest challenge is to make transport data complete with regard to geographical coverage, real time, transport modes etc., and ensure high quality, reliability and validity as well as traceability and transparency. Apart from supporting the collection of missing data by the use of funding instruments, legislation and cooperation should lead the way. Social media to get users' feed- back and collecting missing data through social net- works and crowd sourcing will be increasingly relevant in the future.

Access to travel data, especially real time and fare data is another challenge. Further promotion of the PSI Directive as well as further legislative measures or other binding instruments will help to assure the sharing of travel data. It must be ensured that such measures do not harm commercial interests while keeping the public interest in mind, therefore viable, self-standing and sustainable business models to deliver are needed. Furthermore, principles of fair- ness and non-discrimination have to be applied, while clarifying liability and ensuring data protection.

The **lack of interoperable data formats, protocols and interfaces** requires the development or definition of data formats and standards, which should ideally be 'light' standards and usable to ensure flexibility and the promotion of interoperability.

In terms of **integrated tickets**, fare data is the most difficult to obtain, i.e., to get the price of a multimodal cross-border trip, particularly if reductions and 'last minute' price adjustments are involved. From the users' perspective a user-friendly system would make multimodal travel more attractive, and it might be a key towards modal shift and enhancing accessibility of public transport.

Trust between the different actors and of users (e. g. passengers) is another challenge. This challenge relates to the need for financial transactions when buying tickets, but also to payments between operators (related to services like data provision). Beyond the required trust to allow all necessary transactions, some operators and competitors may not be willing to share data and information in the first place because data ownership can also mean a competitive advantage that could require protection. As experience from local contexts shows, the required collaborative actor settings are sensitive and would be even more complicated on a European scale.

In order to make it public transport systems more efficient, integrated ticketing is increasingly important. In this regard, mobile phone operators and their billing systems are candidates for possible collaboration

Fare management is most complex, especially when combining different modes and operators. How to deal with promotions, group discounts, weekly or monthly passes, and so forth? Many actors are involved in setting up a multimodal payment and ticketing system, e. g. customers, public transport authorities and operators and the payment industry. For the transport industry, the long-term advantages would be that services would be more attractive to customers and should also lead to a reduction of costs. Integrated ticketing is beneficial for both daily commuters who have to use different modes of transport as well as for those who have varying or less frequent/regular travel patterns. Achieving these systems would mean changing many back-office processes. Public acceptance is very important, and the introduction of any new system will probably encounter resistance unless it is well-communicated. The awareness-raising related to privacy and security is also something to consider. In the field of ticketing, standards are already well-established, e. g. the ISO/IEC 24014-1 standards for fare management systems (implementation specification for the use of smart ticketing published in 2013) which is due to the high sensitivity of any payment and ticketing operation.

At the ITS European Congress Helsinki in 2014 a number of sessions covered this topic. There is a high demand to integrate smart ticketing infrastructure, as multimodal travel is a daily activity of most people. These systems must provide reliability, security, affordability, simplicity, speed of service and must focus on travelers and their demands. It is expected that a single system used by multiple operator and service providers can also pro- vide economies of scale. The integration of the existing system, methods and effective solutions should be preferred to establish completely new technologies [127].

3.7 Scenarios definition

In developing scenarios we generalized all the facts identified so far.

3.7.1 Baseline scenario (2025)

The COVID-19 will be already tamed until this year. A slow recovery will be hampered by a cold war between China and USA (the West) which will lead, most likely, to separate global digital spaces. The period will be characterized by shortening of supply chains, low interest rates, high debt, low trust, risk aversion and low oil prices.

The European Union will push to reduce Green House Gases intensity of energy consumption and emissions. The consumption of final energy by each inhabitant at home will somewhat decrease and impact primary and final energy consumption totals. It will bring first results, though insignificant. The subsidies for fossil fuels will end. The agricultural systems will make some slight progress on its sustainable path by decreasing ammonia emission and by reducing risk of severe soil erosion. A progress will be made in reduction of overcrowded homes and noise disturbance.

A little better handling of hazardous chemicals and moving away from smoking habits will contribute to general health extending lifespan. On the other hand, people in the EU will continue to be obese.

Transport planner and decision-makers will slowly begin to adapt to new paradigms, but they will continue to perceive typical passenger needs in the “classic” way, i.e., the needs derived from basic travel burden - travel time, travel cost, mode access time, commute distance – as well as the needs derived from travelers' social status – income, gender, age, household composition, car ownership and education level.

New Mobility Services (NMS) i.e., car-sharing, ride-hailing, bike-sharing, e-scooters will be fully present in European cities. The CCAM (connected, cooperative, automated mobility), like automated cars, trucks will begin to emerge. The EU will continue to improve transport accessibility and intermodality by further development of Trans-European Transport Network (TEN-T), mainly rail and maritime. Due to regulations pressure (Eurovignette), logistics will begin to shift to rail and maritime. A million of public recharging and 500 hydrogen refueling stations to will be installed.

The first certified ATM data service providers (ADSP) will begin advance network operations to test airspace for introduction of U-Space services. This will be enabled by airspace re-configuration, new capacity for on demand services, first harmonized standards for UAS and first certified UAS in controlled airspace accompanied by simulators and specifications for ATM Validation Platforms.

There will be no dynamic interaction among transport modes, yet. Hardly any privately generated data will be available for public use and modes will continue to be optimized internally. Applications will be collecting only some information from operators.

3.7.2 Intermediate scenario (2035)

Around 2035 global tensions will begin to ease as China and, most probably, India will be given their rightful status in the United Nations. This will lead to an era of China, India and the West uneasy normalization. Megacities will emerge. Global development will be accelerated by progress in healthcare, in agriculture, by reconversion of assembly lines and by the 4th industrial revolution. As a side effect some workers will lose their purpose on the market. These "non-productive" citizens will be pushed to slums and fuel global fundamentalism and, potentially, terrorism.

The EU will be advanced in shifting to circular economy paradigm. Average concentration of fine particulate matter in the air and waste per inhabitant will begin to decrease at a very slow pace. Increased government support spent on agricultural R&D will lead to some major breakthroughs like automated precise farming or resistant organic crops. Unfortunately, farmland birds will be harder to spot.

The lifespan will continue to extend and a growing number of 65-year-olds and 80-year-olds will begin to become a significant population share.

More people will walk, use bicycles, buses and trains. Due to growing traffic most cities will introduce car-free zones.

The mobility needs will be shaped by more personal perceptions, like those of value of time savings, those of data security and ethical (Orwellian) concerns, those of safety concerns, those of affinity to automation, to online services, to green awareness, to social media, to sharing and willingness to share. On top of that, the growing mobility needs of elderly or disabled passengers will be addressed by adequate supply and regulations

In this scenario we expect emerging of Urban Air Mobility (UAM) in experimental sites. The Core TEN-T Network (including recharging and refueling stations) will be completed which will enable more intermodality among soft modes of travel, mass transit, NMS and CCAM. The transport providers will use smart pricing and, due to regulatory pressure, will shift to lower emission modes.

The ATM will reach high level of automation with new ATM data service provision model, virtual centres, dynamic airspace configuration. Unmanned Airborne Systems (UAS) will be certified for all classes of airspace, airports will be integrated with UAS and into ATM network. The ADSP will allow for U-space testing of advance U-Space services.

Transport data will be more digitized. Transport service providers will begin implementing digitalization to shift their business models to make use of publicly available privately generated data and possibility to generate daily demand forecasts. Applications will collect more and more information from operators. Algorithmic transport governance will emerge.

3.7.3 Final scenario (2050)

The new world order will be characterized by domination of Asian capital. Megacities enhanced by Artificial Intelligence & automation will become 'smart' and they will the core of global economy. There will be arable land no more. Many inhabitants will solely rely on universal basic income, ensuring material existence and opportunity to participate in society. For some this will be excellent condition to live a calm life, but for others, the accelerating changes may be hard to adapt to. Cultural uprooting and riots, may occur, especially, in overcrowded Asia and Africa. Ageing populations will begin to decline globally.

Dominating part of the energy consumed in the EU will originate from renewable sources. This will lead to a new age of productivity which will grow substantially due to a shift from carbon-intensive energy carriers and a shift of consumption patterns to environmental goods and services. Farmlands area will be farmed organically and automatically, generating high income. Most of the land will be covered by settlements and the dominant share of people will be urban dwellers. Cities or megacities will deeply cooperate and coordinate using the algorithmic governance. Automatic AI-based municipal systems will take care of many aspects. Waste will be a key element of the materials reuse. The EU will spend a lot more in the sector of R&D, resulting in jobs, patent applications and opening the way for unimaginable, today, technologies.

Significant number of older inhabitants will perceive themselves to be in good or very good health. Due to complete digitization and advanced digitalization, AI & automation important amount of time will be spent for social, leisure and hobby purpose, mostly within the realm of virtual entertainment.

This final scenario expects full satisfaction of the "extreme" travelers' needs. This will be achieved by the Inclusive Design paradigm addressing artificial or natural limits of human senses like touch, see, hear, and/or speak.

The EU transport will reach net-zero emissions. The Comprehensive TEN-T Network will be completed, allowing for full intermodality. A policy of walkable cities will cause domination of soft modes, mass transit, NMS and, most likely, UAM. Intercity traffic will be supplied by high-speed rail transport, CCAM and zero-emission large aircraft.

By 2050, Europe's aviation infrastructure will be completely transformed to Digital European Sky, enabling to handle the diversity of air traffic safely and efficiently, while minimising environmental impact. All operations will follow the trajectory-based paradigm. Service-oriented ATM will be scalable and highly automated. Full U-space services are expected and deployed with shorter lifecycles.

Transport business digitalization will be completed allowing for system of systems level optimization and algorithmic governance. This will enable possible dynamic interaction among modes and costless reaction to disruptions – flexibility.

3.8 Summary and conclusions

The World will change much after COVID-19. Tough, it is not over, yet. In the 2020 springtime wave we saw vulnerability of societies and the UN's WHO scandal with unclear China's role [128]. The second wave of Autumn 2020 undermined trust in national governments' approach which seemed outdated and ineffective even before [129]. Coherence among the priorities, forces Western financial capitalism, stalled globally since the 2008 financial crisis, to give way to a new system, less individualistic, preserving public goods, economic security, and inclusion. If the third wave occurs due to vaccine programmes failure, liberal democracy will be no more, slipping to bureaucratic authoritarianism. Fuelled by global consumption, mind controlling through its "sincerity score", techno-totalitarianism in the East begin to outgrow the succumbing West [130].

Public hand, like in the EU, will lead climate action and reconstruction to more efficient industrial systems, buildings, and vehicles to reach net-zero emissions. To achieve this goal, experts suggest, a return of next generation nuclear as a low-carbon energy source alternative to fossil fuels [131] [132] [133]. Even now the nuclear represents a critical component in the energy mix of 13 of the 27 EU Member States.

In the transport sector, the EC policy follows its circular economy paradigm aiming to complete the networks, further the sustainability, redefine airspace management (Digital European Sky), and make use to the fullest of the emerging technologies (Internet of Things, smart city) while protecting freedoms and leaving no one behind.

A set of EU rules already addresses protection of passengers' needs traveling by road, air, rail or water including urban public transportation. One of newer regulations [134] provides a framework conditions enabling the co-operation in the EU-wide multimodal travel information exchange to support the interoperability, compatibility, and continuity of services.

We identified current best multimodality practices with respect to the following aspects:

- e-vehicles (Amsterdam Schiphol, Stockholm Arlanda, Vancouver) - convenience for customers
- air-rail links (Manchester, London Stansted, Oslo, Stockholm Arlanda) - easy access, fast, frequent
- active travel (Geneva, Vancouver) - connectivity to bike paths
- car-pooling and car-sharing (Brussels, London Stansted, Vienna) - more economical
- Intelligent Transport Systems (Munich Airport, London Gatwick) - detailed information
- wayfinding (Catania, Toronto Pearson, New York JFK) – intuitive information
- road public transport (Helsinki, London Stansted, Paris Charles de Gaulle, Tallin) – mass, low cost

No matter how sophisticated the system can get, it will hardly reach the desired effect if not serving the passengers' needs: convenience, easiness, frequency & speed of service, exhaustiveness and reliability. Moreover, for the active elderly, an expected large share of future passengers, some extra features will have to be added to the system: affordable, barrier free, comprehensible, friendly, safe, secure, transparent and complementary.

In this general context, our three scenarios (years 2025, 2035 and 2050) and conclusions of the current passenger experiences set external conditions for Urban Air Mobility ConOps for ATM intermodal integration in Europe which are input for the project's Use Cases described in next sections.

4 Technologies for urban/suburban mobility

4.1 Introduction

In this chapter we present aeronautical/vertical technologies related to the Urban Air Mobility and surface transport technologies (road, rail, inland water and multimodal transport modes) with their potential for integration with ATM.

4.2 Aeronautical/vertical technologies

4.2.1 Urban Air Mobility (UAM)

For the future of public transport, the *Door2Door* (D2D) paradigm represents the most innovative contribution, involving critical issues, both from the spatial point of view (the connection with rural areas and suburbs of the cities) and the temporal point of view, for example considering the evening and the weekend. It is necessary to expand the network with a modern transport on demand concept and integrate all existing offers for citizens, in order to obtain a wider coverage of public transport. A technology that can help bridge this kind of gap is by air. For this reason, the concept of Urban Air Mobility has emerged, defined by NASA as "safe and efficient air traffic operations in a metropolitan area for manned aircraft and unmanned aircraft systems". Below, some concepts of operations for UAM airspace integration at different stages of operational maturity are listed [135]:

- **Emergent UAM operations**: characterized by low-tempo, low-density flights along a small set of fixed routes between a few take-off and landing areas. **At present**, it is expected that the earliest UAM operations will be to demonstrate their potential benefits to the general public and metropolitan areas. These initial UAM flights will be used to gather preliminary feedback from surrounding communities (for example, on noise) and gain support for initial commercial operations.
- **Expanded UAM operations**: characterized by higher-tempo, higher-density flights in a small network of vertiports feeding a common hub location, managed by UAM operator and third-party services. Currently there are three fundamental bottlenecks during clear weather operations: gates, runways, and ATC workload. While UAM is unlikely to use conventional gates and runways, ATC workload may limit UAM if not properly designed. As such, developing the concepts, technologies, and procedures (**planned for the decade 2025-2035**) that will enable UAM to be integrated into the airspace system and managed without tactical intervention from ATC represents a significant portion of the effort toward achieving higher-density, higher-tempo UAM operations.
- **Mature UAM operations**: characterized by high-tempo, high-density flights in a network with multiple hub locations, potentially with orders of magnitude of more vehicles. **Starting in 2035**, UAM airspace integration effort will focus on exploring possibilities for the services, procedures and tools necessary to support high-tempo, high-density mature operations. Stakeholders will develop and refine the initial airspace integration concepts for both emergent and early expanded UAM operations just described.

It is necessary to consider that UAM flights have unique needs. They will take off and land from numerous skyports across a city. They will require smaller separation standards than those today to accommodate the anticipated high traffic volumes. They will carry passengers and goods, fly in closer proximity to buildings and other aircraft, rely more on data link rather than voice communications, eVTOLs will transition to autonomy and operate in airspace adjacent to fixed-wing commercial aircraft. UAM flights will spend most of the duration of flights over densely populated areas and they share airspace with traditional urban traffic. To accommodate for these new requirements, U-space concept has been introduced. U-space is a set of new services relying on a high level of digitalisation and automation of functions and specific procedures designed to support safe, efficient and secure access to airspace for large numbers of drones. As such, U-space is an enabling framework designed to facilitate any kind of routine mission, in all classes of airspace and all types of environment - even the most congested - while addressing an appropriate interface with manned aviation and air traffic control. In support of this initiative, in 2017 the SESAR Joint Undertaking drafted the U-space blueprint, a vision of how to make U-space operationally possible. The blueprint proposes the implementation of 4 sets of services to support the EU aviation strategy and regulatory framework on drones:

- **U1**: U-space foundation services covering e-registration, e-identification and geofencing.
- **U2:** U-space initial services for drone operations management, including flight planning, flight approval, tracking, and interfacing with conventional air traffic control.
- **U3**: U-space advanced services supporting more complex operations in dense areas, such as assistance for conflict detection and automated detect and avoid functionalities.
- **U4**: U-space full services, offering very high levels of automation, connectivity and digitalisation for both the drone and the U-space system.

In the following table (see [135], page 9) the potential hazards are listed that exist within and across the various UAM domains. Although some hazards may have few downstream consequences, many hazards may have cascading effects that interact with other hazards.

Table 5 – Examples of UAM Domains and Potential Hazards

UAM Domains	Potential Hazards
Vehicle, equipage, systems	Loss of electrical power to control systems Failure of GPS/Receiver Autonomous Integrity Monitoring
Vehicle servicing and maintenance	Unavailability of necessary replacement part
Communications (datalink, Command-and-Control link)	Command-and-Control link lost Degraded Quality of Service (QoS) for critical control commands
Aerial operations, flight procedures, flight management	Vehicle upset attitude Vehicle fly-away
Routing, airspace, air traffic management	UAM route conflicts with existing air traffic Loss of safety-critical functions on ground station
External environment (weather, obstacles, aerial traffic, birds)	Convective weather (hail, severe downdrafts) Buildings, power lines, airborne vehicles
Pilots (on-board and remote)	Inadequate pilot training for maintaining safety margins Loss of pilot situational awareness
Dispatch, control center, emergency pilots	Dispatch understaffed, flight planning delayed Loss or degradation of ground control station capability

Ground-based operations and infrastructure	Lack of vertiport availability (occupied, damaged, closed) Inadequate ground crew training for maintaining safety margins
Passengers	Passenger interference with pilot/vehicle operations Passenger illness during flight
Cybersecurity	Inadequate authentication of Command-and-Control link (undetected hijacking of link)

However, if a travel is defined from the door of origin to the door of destination, other transportation modes are part of the transportation chain. A Passenger Information System (PIS) should therefore cover every element of this chain. When applying this perspective, the passenger-centric concept emerges and the system must necessarily be intermodal, so the multimodality is a concept closely related to UAM. Furthermore, whenever the concept of multimodality is associated with the *Big Data* macro topic, both information from mobile phone records and those obtainable from services such as Uber are considered: in practice, by using geolocation data, the *strategies* of individual passengers are imported to attempt to fill the gaps in their *trajectories*. For example, see the BigData4ATM, a SESAR exploratory research project, designed to investigate how these data can be analysed and combined with more traditional demographic, economic and air transport databases to extract relevant information about passenger behaviour.

In particular, the main data sources useful for ATM socioeconomic and behavioural studies was analysed, assessing their strengths and weaknesses. Traditional sources studied were Sabre, IATA PaxIS, OAG, CODA and STATFOR public reports, EUROSTAT, national statistical offices and airport surveys. Novel sources included mobile phone records, Twitter, FlightRadar24, credit card transactions, public transport smart card data, Google Maps APIs, TomTom Traffic Services and mobile apps data.

Below, the passenger-centric data map created for the BigData4ATM project is reported, linking each of the novel data sources with the domains where they can provide insights.

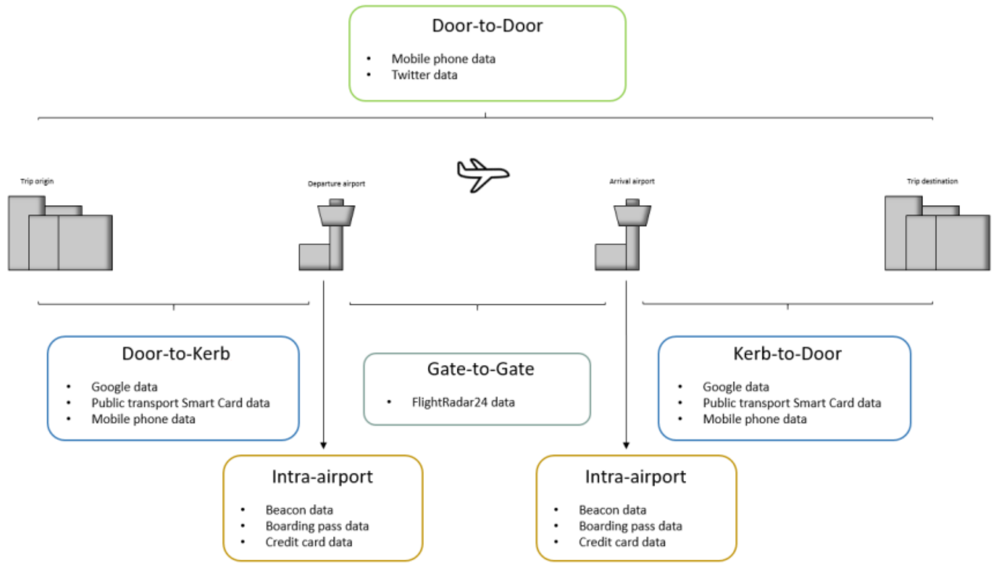

Figure 6 – Passenger centric data map

Extremely important will be the analysis of the infrastructures essential for the implementation of UAM and particular attention will be paid to the so-called vertiports. At present, there is no policy guidance governing vertiport operations and there are no mandatory design standards, fire codes, building codes or best practices for the "vertical" infrastructure and what will be required for a vertiport to be considered safe by an objective standard. The vast majority of recognized existing vertiports are privately owned. This allows owners considerable flexibility in their design and operation but it also provides stakeholders with few options for remedy should oversight or enforcement challenges arise. A particular example of relevance is the possibility of new building or tower construction in close proximity to a possible vertiport or within its approach and departure path.

Further relevant driver for UAM is the projection that global airline passenger traffic will hit 7 billion travellers by 2035 according to the International Air Transport Association (IATA). To minimize landside congestion, major infrastructure improvements need to be made to maintain efficiency and innovation for passengers and cargo. Airports would need to invest in infrastructure in the next years to be able to stay ahead of projected growth. Although the majority of the costs are attributed to terminal expansion and improvements, transportation to and within the airport complex remains one of the biggest challenges when it comes to streamlining the experience for passengers. The challenge is balancing the needs of passengers getting to and from terminals, offsite parking and public transportation, accommodating transportation plans under existing land constraints and find the funding to pay for these necessary investments. Airport access needs to be integrated into urban planning as it is an important connection that requires significant shrewdness. One of the most promising advancements in airport transportation is automated people movers. Operating on specific heavily travelled routes within and just outside the airport property, it helps alleviate traffic on roadways, reduce emissions, and provide reliable, punctual service. There must be an efficient connection to off airport facilities, such as consolidated rental hubs, public transportation, hotels and dining venues. New technology can alter rapidly the face of an industry while infrastructure change is relatively slow. To remain competitive, airport master plans should be flexible to allow for the assimilation of new technologies. Soon, passengers may schedule a personal driverless transport to get to and from the airport, which will shift infrastructure priorities from on and offsite parking facilities to developing larger vehicle staging areas. In conclusion, airports may need to modify infrastructure to accommodate future travel demand and deliver an efficient multimodal surface-moving experience for passengers.

4.2.2 Evaluation criteria for aeronautical/vertical technologies integration into multimodal transport system

In the next paragraphs, the following performances will be considered in relation to the analysed technologies and, based on literature analysis, a score will be assigned to each technology, according to each criterion, with respect to the possibility of integration into multimodal transport system. The score will be expressed in terms of stars, to be interpreted as follows: *one star* is a weakness, *two stars* is an acceptable level, *three stars* is a strength.

- **Integrability**: feature linked to the predictability of the flight time and the availability of operational services and dedicated infrastructures.
- **Endurance**: maximum length of time that an aircraft can spend in cruising flight.
- **Weather resilience**: ability to adapt its functioning following a weather change, in order to preserve correct functioning.

- **Manoeuvrability**: ability to perform manoeuvres with certain characteristics, for example by making safe trajectory changes.
- **Runway length**: length of the rectangular area prepared for the landing and take-off of aircraft on a land aerodrome.
- **Independency**: feature linked to the number of passengers on board the aircraft; the value is maximum for PATS aircraft as the user is less constrained to the needs of other passengers.

4.2.3 Small Aircraft Transportation System (SATS)

The Small Aircraft Transportation System (SATS) targets the stimulation of latent markets of consumers who make transportation choices based mostly on time considerations. The latent market for transportation is defined as trips not taken (for reasons of time, cost, convenience, comfort, or other factors), trips not imagined (because consumers have never been able to experience the service or product), and trips not possible (in the absence of enabling vehicles and infrastructure). This technology can be implemented through a hub-and-spoke accessibility to the smallest airports, without needing radar and control towers or more land for protection zones. SATS concept uses small aircraft for business and personal transportation, for on-demand, point-to-point travel between smaller regional, reliever, general aviation and other landing facilities, including heliports. SATS architecture contemplates near-all-weather access to any landing facilities. SATS would leverage Internet communications technologies for travel planning and scheduling, which would also minimize user uncertainty regarding destination services. The global SATS market size is expected to increase over the forecast period from 2020 to 2025. This vision was supplemented with a strategy for the development of technologies for the future SAT system within a time frame until 2020 and until 2035 [136]. The small-size aircraft operating on scheduled or non-scheduled flight will play important role as component of the Air Transport System to satisfy the Flight Path 2050 challenge. The goal for this time is that 90% of travellers within Europe will be able to complete their journey door-to-door within 4 hours.

The SAT system is designed to facilitate air transport by using small aircraft as alternative to traditional airline travel. For this purpose, technical capabilities need to be improved in the following areas (for example, see the SATS Project led by NASA): high-volume operations at airports without control towers; technologies enabling safe landings in almost all-weather conditions; integration of SATS into an air traffic control system capable of handling slower aircraft; improved single-pilot ability for an evolving complex airspace. The air taxi services can be considered a good example of SAT system: small commercial aircrafts which makes short flights on demand.

Below, categories and design characteristics for the small airplanes are listed[75]:

Table 6 – SAT aircraft categories and design features

Category	Design features
Commuter	Maximum take-off weight of 19000 lbs;

[75] The Federal Aviation Administration (FAA) website, www.faa.gov/aircraft/air_cert/design_approvals/small_airplanes/categories

	Maximum passenger seating capacity of 19; Multiple engines.
Gliders and Sailplanes	Maximum seating capacity of 2; If unpowered, maximum weight of 1654 lbs (750 Kg); If powered: ▪ maximum weight of 1874 lbs (850 Kg); ▪ single spark or compression ignition engine; ▪ maximum weight to wing span squared of 0.62 lb/ft2 (3.0 kg/m2).
Normal, Utility and Acrobatic	Maximum take-off weight of 12500 lbs; Maximum passenger seating capacity of 9.
Primary	Maximum take-off weight of 2700 lbs (3375 lbs if seaplane); Maximum seating capacity of 4; Unpressurized cabin.
Restricted	Maximum take-off weight of 12500 lbs; Operated under the limitations for the intended use (forest and wildlife conservation).
Very Light Airplanes (VLA)	Single spark or compression ignition engine; Maximum seating capacity of 2; Maximum take-off weight of 1654 lbs (750 Kg); Landing configuration stall speed not more than 45 knots; Limited to day-VFR normal category manoeuvres under 14 CFR part 91 operation.

By examining the peculiar aspects of D2D, the pros and cons of SAT technology under D2D perspective have been evaluated. The following table shows an analysis of D2D performance for a generic SAT aircraft, reporting a summary of the score achieved for the three time horizons under analysis, namely 2025, 2035, 2050 (*one star* is a weakness, *two stars* is an acceptable level, *three stars* is a strength).

Table 7 – D2D performance for a generic SAT Aircraft

Target	Score		
Horizon	**2025**	**2035**	**2050**
Integrability	★★☆	★★★	★★★
Endurance	★★★	★★★	★★★
Weather resilience	★★★	★★★	★★★
Manoeuvrability	★☆☆	★★☆	★★☆
Runway length	★☆☆	★★☆	★★☆
Independency	★☆☆	★★☆	★★★

Figure 7 – Exemplary pictorial view of SAT vehicle

However, these new aircraft will make the SATS vision for transportation available to the general public only if new concepts for airspace architecture and operations can be developed.

4.2.4 Short Take-Off and Landing (STOL) Aircraft

Short take-off capability promises operations from *micro airfields* with runways of less than 1000 feet that could open up new opportunities for regional point-to-point transportation. Many different definitions of STOL aircraft have been used by different authorities and nations. For example, in [137] the following definition is found: "STOL performance of an aircraft is the ability of aircraft to take off and clear a 50-foot obstruction in a distance of 1500 feet from beginning the take-off run. It must also be able to stop within 1500 feet after crossing a 50-foot obstacle on landing".

There is great interest for this technology in the next future and by 2025 the market will be enriched with aircraft of this category. The main development is also focusing on the environmental impact and, for this reason, hybrid STOL are planned. This trend will have an increasing weight over time: the forecasts for the 2035 market tends towards full electrification (in this case, the aircraft are known as eSTOL). For 2050 the scenario is twofold. On the one hand, the aim is to improve the technology itself, improving the environmental impact with sustainable technologies, as well as the aspects of autonomous flight, in order to completely replace the pilot with technology, unlike the previous period in which technology supports the pilot or in any case intervenes only in an emergency. On the other hand, it is necessary to consider that major changes have been required airside to overcome a doubling of traffic air every 12-15 years. In a still-growing number of countries, the capacity to build additional runways continues to be the critical obstacle to accommodating this growth, although advances in technology have partially compensated by enabling smaller aircraft (150-250 passengers) to take off and land on shorter runways, approximately 5000 feet long.

In the future UAM scenario, the number of small runways will grow and it will be needed to improve the performance of the current STOLs, because those available today oriented to meet the needs of the small runways of the present STOLports. The following table shows several private aircraft and their corresponding take-off and landing distances. The shorter take-off and landing capabilities of many private aircraft allow them to utilize a STOLport.

Table 8 – STOL performance comparison

Aircraft	Take-off to 50 ft (15 m)	Landing from 50 ft (15 m)
Just Superstol	550 ft (168 m)	450 ft (137 m)
Zenith STOL CH 801	400 ft (122 m)	300 ft (91 m)
ShinMaywa US-2	920 ft (280 m)	1080 ft (329 m)
Quest Kodiak	760 ft (232 m)	915 ft (279 m)
Australian Aircraft Kits Hornet STOL	656 ft (200 m)	623 ft (190 m)
Sukhoi Su-80	2686 ft (819 m)	1715 ft (523 m)
PAC P-750 XSTOL	1196 ft (365 m)	950 ft (290 m)
Slepcev Storch	126 ft (38 m)	110 ft (34 m)
Bounsall Super Prospector	300 ft (91 m)	250 ft (76 m)
PZL-105M	1109 ft (338 m)	1070 ft (326 m)
Peterson 260SE/Wren 460	1000 ft (305 m)	1000 ft (305 m)
Zenith STOL CH 701	1257 ft (383 m)	1257 ft (383 m)
AAC Angel	1404 ft (428 m)	1046 ft (319 m)
Spectrum SA-550	675 ft (206 m)	675 ft (206 m)

Antonov An-72	1312 ft (400 m)	1148 ft (350 m)
De Havilland Canada Dash 7	1200 ft (366 m)	1050 ft (320 m)
Maule M-5	550 ft (168 m)	600 ft (183 m)
CASA C-212 Aviocar	2001 ft (610 m)	1516 ft (462 m)
IAI Arava	984 ft (300 m)	902 ft (275 m)
Britten-Norman Defender	1050 ft (320 m)	995 ft (303 m)
SIAI-Marchetti SM.1019	1185 ft (361 m)	922 ft (281 m)
Conroy Stolifter	450 ft (137 m)	400 ft (122 m)
De Havilland Canada DHC-6 Twin Otter	1200 ft (366 m)	1050 ft (320 m)
De Havilland Canada DHC-5 Buffalo	2100 ft (640 m)	2100 ft (640 m)
Britten-Norman Islander	1100 ft (335 m)	960 ft (293 m)
Evangel 4500	1125 ft (343 m)	1140 ft (347 m)
Short SC.7 Skyvan	1050 ft (320 m)	1485 ft (453 m)
PZL-104 Wilga	625 ft (191 m)	780 ft (238 m)

For all these aircraft actual take-off and landing distance will vary with their conditions and the weight of the payload. So, fully loaded and heavier planes will require more distance to take off. For the future, it is necessary to further improve their performances in order to exploit their capabilities in the field of the D2D. Moreover, it should be noted that the STOL class excludes vertical take-off and landing (VTOL) types, rotorcraft, aerostats and most light aircraft.

The following table shows an analysis of D2D performance for a generic STOL aircraft. The score should be interpreted as follows: *one star* is a weakness, *two stars* is an acceptable level, *three stars* is a strength.

Table 9 – D2D performance for a generic STOL Aircraft

Target	Score		
Horizon	**2025**	**2035**	**2050**
Integrability	★☆☆	★★☆	★★☆
Endurance	★★☆	★★☆	★★★
Weather resilience	★★☆	★★☆	★★★
Manoeuvrability	★★☆	★★☆	★★☆
Runway length	★☆☆	★★☆	★★☆
Independency	★★☆	★★☆	★★☆

Figure 8 – Example of STOL aircraft: PZL-104 Wilga

4.2.5 Vertical Take-Off and Landing (VTOL) Aircraft

The flying car market is set to revolutionize the mobility concept and one of the major contributions will be made by VTOL aircraft. This is confirmed in the market analysis report by BIS Research [138], which shows in particularly that eVTOL aircraft market is estimated to be around 524 million dollars in 2025 and is projected to reach 1.9 billion in 2035, in terms of value. The market is anticipated to witness a CAGR of 13.75% during the forecast period from 2025 to 2035. This growth is further aided by factors such as increasing road traffic congestion in urban areas and a growing need for faster and efficient transportation. A further proof of the push to the development of this technology is given by Lilium, a company that attracts investors such as Amazon, Tesla, Airbnb, Spotify, SpaceX. Thanks to these reversals, they even have the ambition to be on the regional air mobility market with their electric aircraft as early as 2025 [139].

A vertical take-off and landing (VTOL) aircraft is one that can hover and land vertically. In addition to helicopter concept, many approaches have been tried to develop aircraft with vertical take-off and landing capabilities. For example, the following aerial vehicles should be considered:

Figure 9 – Uber Elevate eVTOL

Figure 10 – Lilium Jet

- Convertiplane: aircraft which uses rotor power for vertical take-off and landing, then converts to fixed-wing lift in normal flight (usually in tiltrotor configuration, that is the aircraft generates lift and propulsion by way of rotors mounted on rotating shafts at the ends of a fixed wing).
- Gyrocopter: type of rotorcraft that uses an unpowered rotor in free autorotation to develop lift. Forward thrust is provided independently by an engine-driven propeller.
- Quadcopter: main mechanical components are a fuselage or frame, the four rotors and motors. For best performance and simplest control algorithms, the motors and propellers are equidistant.

Thus, VTOL technology fully embraces the D2D paradigm, however it does not mean that they are free from defects or, in any case, do not need improvements.

Another generation of aircraft, called electric vertical take-off and landing vehicles (eVTOL), will help to redefine in particular the urban mobility experience. The concept of electric propulsion in aviation is nearly as old as aviation itself. The first electric-powered aircraft debuted in 1917 but, for a long time, electric aviation has been only a hobbyist's alternative. Now, with the advancements in multirotor distributed electric propulsion systems and the sophisticated controls to manage them, electric propulsion has finally become a viable alternative to hydrocarbon-based systems. Although some eVTOLs may look similar to a helicopter, they will be powered by batteries, hybrid engines or other new technologies that will make them much quieter than the helicopters of today. Advanced avionics will enable eVTOLs to navigate with high precision, exchange information digitally and respond to changes in flight conditions autonomously. At initial launch, many eVTOLs will have pilots on board. With time, however, these aircraft will mature to a stage where they will operate autonomously. In the report [140] various topics are discussed, such as: VTOL performance metrics, current eVTOL concepts, high performance batteries, electric motors, hybrid-electric. Furthermore, this document contains detailed information regarding many VTOL aircraft. In particular, see pages 7 to 17 of [140] where 55 aircraft are analyzed. The following table shows the design features and performances examined [140]:

Table 10 – Design features and performances examined for the 55 aircraft analysed

Fuselage length	Max Range	Maximum ceiling
Wingspan	Lift Propulsors (no.)	Maximum flight distance
Tip-to-tip distance (span)	Lift Propulsors (type)	Maximum flight time
Overall height	Fwd Propulsor/notes	Maximum speed
Empty weight	Motor (no.)	Maximum payload
Max gross take-off wt	Motor output	Acceleration to 100 km/h
Battery Weight	Power type	Full charging
Max altitude	Fuel volume	Minimal charging current
Useful load	Capacity (incl. pilot)	Maximum charge rate
Cruise speed	Maximum thrust (total)	Classification

Urban air taxi services will certainly be a challenge for these aircraft. For example, an aircraft designed with this mission in mind is definitely the Volocopter[76].

For what concerns, then, extended urban mobility, the Lilium project is very interesting (see the website[77]), since it well represents the concept of regional air mobility and because it uses electric propulsion very efficiently. The Lilium Jet is planned as a five-seater aircraft and is powered by 36 electric motors: six on each front wing and twelve on each rear wing. The propellers and engines are installed in twelve tilt able wing parts, so as to allow the vertical take-off and landing.

The following table shows an analysis of D2D performance for a generic VTOL aircraft. The score should be interpreted as follows: *one star* is a weakness, *two stars* is an acceptable level, *three stars* is a strength.

Table 11 – D2D performance for a generic VTOL Aircraft

Target	**Score**		
Horizon	**2025**	**2035**	**2050**
Integrability	★☆☆	★★☆	★★☆
Endurance	★☆☆	★☆☆	★★☆
Weather resilience	★☆☆	★★☆	★★☆
Manoeuvrability	★★☆	★★☆	★★★
Runway length	★★★	★★★	★★★
Independency	★★☆	★★☆	★★☆

[76] The Volocopter website, www.volocopter.com/en

[77] The Lilium Gmbh website, www.lilium.com

EASA expects VTOL operations to make use of existing runways and heliports, on one hand, but, on the other hand, the focus of these aircraft will be put on a vast number of future dedicated vertiports, although appropriate requirements do not yet exist. Furthermore, the current legal scope in European regulations usually refers to helicopters. So, from an airworthiness perspective, it was intentionally decided to classify the new entrants as a Special Class to provide them with an adequate set of regulations, considering their expected features and potential evolution.

The characteristics of the landing locations for VTOL aircraft are being identified, irrespective of whether it is located within an aerodrome or at a remote location. Considering that, in some phases, VTOL aircraft might have similar characteristics with rotorcraft, current heliports could be used as long as VTOL performance meet the design characteristics of the heliport. A detailed assessment of the EASA aerodromes and heliports rules should ensure that specifications can accommodate VTOL aircraft and, if necessary, develop new elements, in particular when these vertiports or landing sites are located in an urban environment. Currently existing aircraft infrastructure for VTOL technology within urban centres is very limited and that does exist is often reserved for medical uses or is unsuitable for UAM missions. Therefore, significant new infrastructure requirements will be necessary to make any UAM vision a reality. Moreover, such vertiports might also allow for take-off and landing of unmanned aircraft systems (UAS) of various sizes. This can enable cargo-UAS operations as well as to prepare the ground for operation of automated or autonomous VTOL in the future. While many manufacturers consider that VTOL operation anticipates IFR capabilities in the long term, such operations are expected to be limited to VFR conditions, at least for the initial launch. With growing procedures such as GNSS based, like PinS (Point in Space procedure used by helicopter pilots), future vertiports might be converted from VFR to IFR operation over the years.

4.2.6 Personal Air Transportation System (PATS)

PAT systems involve the use of personal air vehicles: an emerging type of aircraft proposed to provide aviation services on demand. This alternative to traditional land transport methods has been made possible by unmanned aircraft technologies and electric propulsion. Thus, this could be one of the solutions to avoid the typical problems associated with ground-based transportation, namely the creation of a personal air transport system capable of overcoming the environmental and financial costs associated with current methods of transport. Indeed, such a system could allow rapid city travel and eliminate the time loss connected with procedures such as check-in and security controls. Many prototypes have been built since the early 20th century, by using a variety of flight technologies such as distributed propulsion and some have true VTOL performance. The PAL-V Liberty roadable aircraft (see the website[78]) aims to become in 2021 the first flying car in full production. The times for a large-scale use of this technology are still not yet mature. In fact, today infrastructure is not currently capable of handling the increase in aircraft traffic that would be generated by PAT systems. Currently, the FAA plan that will form the Next Generation Air Transportation System is planned for 2025.

[78] The Pal-v website, www.pal-v.com

An example of personal air transport is provided by the use of quadcopter as passenger drone. On the website [141], there is a list of passenger drones, updated May 2020. The following table shows a list of most famous PAT aircraft, many of which are already D2D ready, whose peculiar characteristics are: less than 5 passengers, cruising speed of 150/200 mph, quiet, comfortable, reliable, able to be flown also autonomously, as affordable as travel by car or airliner, near all-weather capability enabled by synthetic vision systems, highly efficient (able to use alternative fuels, fuel cells or electric batteries), range of 800 miles and obviously D2D transportation solutions integrated.

Table 12 – List of most famous PAT aircraft

Model	Seats	Speed (km/h)	Range (km)
BLI Helodyne	4	230	1950
Lilium Jet	1	300	300
PAV-X	1	110	64
GEN H-4	1	200	60
Mosquito XE/XEL	1	130	240
Samson Switchblade	2	108	555
Terrafugia Transition	2	185	787
Samson Skybike	1	140	80
Parajet Skycar	2	160	320
VerdeGo Aero PAT200	2	240	32/64
PAL-V gyrocopter	2	180	350/500

Also the PAT aircraft were born to fully satisfy the D2D paradigm. However, there are many barriers to be evaluated. Indeed, it is necessary to consider usability, airworthiness, aviation safety, airspace integration, operating costs, aircraft noise and emissions. Many efforts will be needed to allow the necessary adaptation of infrastructures and services to the new emerging paradigm but as opportunities at stake concern both social and economic aspects it will only be a matter of time: personal air transport system is destined to become a reality that will irreversibly change both our cities and our way of life.

The following table shows an analysis of D2D performance for a generic PAT aircraft. The score should be interpreted as follows: *one star* is a weakness, *two stars* is an acceptable level, *three stars* is a strength.

Table 13 – D2D performance for a generic PAT Aircraft

Target	Score		
Horizon	**2025**	**2035**	**2050**
Integrability	N/A	★☆☆	★★☆
Endurance	N/A	★☆☆	★★☆
Weather resilience	N/A	★☆☆	★★☆
Manoeuvrability	N/A	★★★	★★★
Runway length	N/A	★★★	★★★
Independency	N/A	★★★	★★★

Figure 11 – PAL-V Liberty

It will be crucial to investigate the technologies needed to provide the operational infrastructure required for a PAT system to be used on a large scale, as this system will provide wider use of small aircraft, served by small airports, to create access to more communities in less time.

An important factor to consider are the main natural determinants of personal transportation system efficiency that are:

- traveling time as effect of speed, infrastructure, traffic management system and accessibility;
- energy used (fuel) on the realization of one passenger-kilometre at given speed;
- resources used for the transport and infrastructure production on one passenger-kilometre;
- impacts on ecology and environment.

The global determinant including all factors expressed in monetary form is the generalized cost of transport of one passenger-kilometre. These quantities will be used to evaluate the effectiveness of PATS and to compare it to others transportation modes.

Finally, the insertion of transports with PATS technology in a D2D path must be well evaluated, especially one must be careful about the distance to be covered. Moreover, a disadvantage of the system could be the time loss connected with procedures such as check-in and security controls, which can reduce the potential advantage of higher travel speed. It will be very important, therefore, to also look at these pre and after trip procedures.

4.2.7 Systems and Technologies Integrability considerations

UAM infrastructure requirements and customer demands provide an opportunity to build new businesses. The development of skyports/vertiports, across a wide metropolitan area will be critical to the growth of the UAM industry: the number and location of take-off and landing pads will drive the number of UAM flights that a city can accommodate. Skyport operators will provide eVTOL fleets with battery swap or recharging services and deliver transit services to UAM passengers. Fleet operators will be responsible for managing eVTOLs that will fly across cities. They will also interact with skyport operators and booking platforms that receive requests for passenger rides or cargo movements. These are only a few of the new opportunities that will be enabled by the growth of the UAM industry.

However, there is a danger that the industry will falter due to an inability to grasp the scope of future challenges and complexities. Communities will want assurances that noise from urban flights is acceptable. Regulators and air navigation service providers (ANSPs) will require that flights remain safe, orderly and efficient, while minimizing impact on airline traffic and ensuring no conflict with ATM/ATC operations. Operators of small drones will want access to low-altitude airspace, while fleet operators will need equitable access to urban corridors. General aviation pilots of fixed-wing aircraft and helicopters will want to fly above urban areas with the freedom they enjoy currently. The urban airspace needs to accommodate the needs of all these stakeholders.

A depth analysis of infrastructures and prices of public transport services is needed as the link between an optimal price and an optimal investment affect acceptability, in the sense that the price is lower queried if it reflects the existence of a related service. It is necessary to pay particular attention to the development of infrastructures because the greatest disadvantage of contemporary modes of high-speed transport (scheduled air, hi-speed train) are infrastructure development limitations and low nodes accessibility causing unbalanced regional development as a side effect.

Another critical problem to resolve is due to the economic environment of transport prices that is usually more difficult understand for the general public. For this region, a prerequisite for acceptable pricing policies is the effectiveness of the measures.

Indeed, a very important aspect to consider when trying to develop a new technology, is the general definition of air transport efficiency: on the system level, it is defined as energy consumption or cost needed to shift one passenger on representative (average) origin to destination great-circle distance in time according to a fixed plan and complying specifications requirements, also including safety and environmental costs.

As electric aircraft will dominate the urban areas in the future, a very important aspect of integrability will be their endurance. Thus, battery life will be crucial. There are many efforts that industry and scientific community are supporting in this direction. For example, paths characterized by the presence of inductive charging could be created: although futuristic, it is a possible scenario. In the automotive sector, it is almost a reality. In fact, recently ElectReon Wireless, an Israeli company specializing in inductive charging for electric vehicles, has signed an agreement with road construction company Eurovia to integrate wireless charging systems on the streets of Germany, France and Belgium. The system provides built-in charging coils eight centimetres below the road surface that are activated only when a vehicle passes over them. Within the Urban Air Mobility, after identifying the buildings most related to the trajectories of aircraft, similar *runways* could be created on their roofs. Consequently, it is obvious that the integrability of these systems will have a significant impact on the infrastructures of entire urban areas.

4.2.8 Conclusions

In this section, aeronautical/vertical technologies supporting the Multimodal Mobility have been analysed. Listed below are the highlights examined:

1) Time boundaries for the scenarios considered: **2025**, **2035**, **2050**.

2) Urban Air Mobility (**UAM**) concept defined by NASA in [135].

3) U-Space description and implementation of 4 sets of services:
   - 2020 → 2025: **U1**
   - 2025 → 2035: **U2**
   - 2035 → 2050: **U3** & **U4**

4) Technologies supporting the Multimodal Mobility:
   - **SATS** **S**mall **A**ircraft **T**ransportation **S**ystem
   - **STOL** **S**hort **T**ake-**O**ff and **L**anding
   - **VTOL** **V**ertical **T**ake-**O**ff and **L**anding
   - **PATS** **P**ersonal **A**ir **T**ransportation **S**ystem

5) Analysis of technologies and related performances, highlighting weaknesses and strengths.

Thus, considering the identified time boundaries and the analyzed technologies, the following technology roadmap has been drawn up:

Table 14 – Technology Roadmap

Technology	2020	2025	2035	2050
SATS				
STOL				
VTOL				
PATS				

- **SATS technology** is almost already available but other advances will still have to be achieved in an environment in which safety assurance and affordability are key and often conflicting constraints.
- **STOL technology** is partially available, since while aircraft development is now mature, short runways are still not very widespread in urban areas. Consequently, its potential cannot be fully exploited yet.
- **VTOL technology**, perhaps the most important element for Urban Air Mobility, is even less available, since there are few ready-made vehicles, and the biggest challenge will be building and managing the dedicated infrastructure.
- **PATS technology** presents the same problems mentioned in the previous item, but very more stringent regulatory aspects will have to be addressed.

Eventually, the following table summarizes the D2D performance for the technologies analysed. The score awarded should be interpreted as follows: *one star* is a weakness, *two stars* is an acceptable level, *three stars* is a strength. Moreover, the last column shows the rounded average score. This result, obtained considering the three time horizons (**2025**, **2035**, **2050**), indicates how ready the technology in question is to be integrated with other technologies within the Door-to-Door paradigm. It should be noted that for 2035 we have all four technologies considered fully operational and with a good average score while the only limit that affects the result are the **technological barriers** that will certainly influence their integration. Beyond 2050, when all the technologies considered will have reached the state of the art, we can note that some (especially the most futuristic such as VTOL and PATS) obtain a high score, an index that in the last decades examined there are good chances that technological barriers are mitigated.

Table 15 – D2D performance for the technologies analysed

Technology	Integrability	Endurance	Weather resilience	Manoeuvrability	Runway length	Independency	Mean score
Time Horizon 2025							
SATS	★★☆	★★★	★★★	★☆☆	★☆☆	★☆☆	★★☆
STOL	★☆☆	★★☆	★★☆	★★☆	★☆☆	★★☆	★★☆
VTOL	★☆☆	★☆☆	★☆☆	★★☆	★★★	★★☆	★★☆
PATS	N/A	N/A	N/A	N/A	N/A	N/A	N/A

Time Horizon 2035							
SATS	★★★	★★★	★★★	★★☆	★★☆	★★☆	★★☆
STOL	★★☆	★★☆	★★☆	★★☆	★★☆	★★☆	★★☆
VTOL	★★☆	★☆☆	★★☆	★★☆	★★★	★★☆	★★☆
PATS	★☆☆	★☆☆	★☆☆	★★★	★★★	★★★	★★☆
Time Horizon 2050							
SATS	★★★	★★★	★★★	★★☆	★★☆	★★★	★★★
STOL	★★☆	★★★	★★★	★★☆	★★☆	★★☆	★★☆
VTOL	★★☆	★★☆	★★☆	★★★	★★★	★★☆	★★★
PATS	★★☆	★★☆	★★☆	★★★	★★★	★★★	★★★

Such considerations also allow to identify the **barriers** that limit implementation and use of the technologies analysed. Indeed, the weaknesses in the above table constitute obvious limitations for **Multimodal Mobility**. Therefore, it would be necessary to at least increase to an *acceptable level* the performances listed above which currently are not.

Furthermore, considering that VTOL technology represents a key aspect for Urban Air Mobility, the ideal would be to transform its first three performances into strengths. Such an interesting goal already suggests possible enablers. In fact, it will be natural to try to increase the levels of integrability, endurance and weather resilience. In particular, improvements of endurance and weather resilience will depend on technological developments relating to vehicles. The **integrability** instead will represent perhaps the most difficult challenge, as it will involve regulatory aspects and urban infrastructures, such as the construction and management of the future urban vertiports. Some of the main stakeholders involved in the development of UAM solutions are: **Airbus**, **Boeing**, **Honeywell**, **Porsche**, **Hyundai**, **Uber Elevate**, **Volocopter**, **Lilium**, **Airborne**, **Rohde & Schwarz** (see the websites[79]). The concept of operations that these stakeholders support, or may support according to what they indicated about the intended use of their proposed technologies, will be analysed in the prosecution of X-TEAM D2D project and in particular in the Task 3.2.

[79] www.airbus.com/innovation/zero-emission/urban-air-mobility.html
www.newsroom.porsche.com/en/2019/company/porsche-boeing-collaboration-premium-urban-air-mobility-18880.html
www.honeywell.com/en-us/newsroom/news/2019/01/what-is-urban-air-mobility
www.rolandberger.com/en/Point-of-View/Urban-Air-Mobility-Shaping-the-future-of-mobility.html
www.uber.com/elevate.pdf
www.airborne.com/urban-air-mobility-the-rise-of-evtol-vehicles/
www.rohde-schwarz.com/us/solutions/test-and-measurement/aerospace-defense/avionics-navigation-test/hybrid-electric-aircraft-testing/hybrid-electric-aircraft-testing-overview_251206.html

4.3 Surface transport technologies

This section is dedicated to present and describe new hardware technologies and solutions representing potential to be used in the process of air and road transport means integration. The focus will be placed on urban, peri-urban and regional passenger transport. The following sections are devoted to road, rail and inland water and multimodal transport modes. In order to evaluate the potential for integration with air transport (mainly in the field of efficient information exchange) the following criteria were defined (they are equivalent criteria to air transport modes):

- **Functionality**: Feature linked to the punctuality of mode and predictability of riding time (including impact of weather) but also connected with ability to transport additional baggage.
- **Efficiency:** Measure proportional to the number of passenger kilometres which can be carried in one weighted unit of time and energy consumed. Related also to sustainability questions and resulted impact on transport system.
- **Flexibility**: Ability to adapt to changing conditions related to traffic and disruptions.
- **Integrability:** Availability of operational services, dedicated infrastructure (connected with investment and operational cost) and ability to be digitalised.
- **Independency**: Feature linked to the number of passengers on board; the value is maximum for personal car as the user is less constrained by needs of other passengers. Service personalisation ability.

In summary the **potential for integration with ATM services** will be calculated as average and rounded values: Understood as measure of system capability to be integrated with ATM services (exchange of information). For all surface modes the criteria will be ranked with regard to up-to regional transport (up-to few hundreds of kilometres). The study will take into consideration only technologies which:

- Provides new quality for movement efficiency from the passenger/user point of view will be taken into consideration.
- Achieved at least TRL 4 and represent significant potential in the area of expected progress with regard to above mentioned criteria (when compared to their today applications).

4.3.1 Road transport

4.3.1.1 Personal transportation

It covers highly personalised road transport modes like cars for exclusive use by owner/driver.

4.3.1.1.1 Electric car

Transition from fossil fuels to electric powered vehicles. The trend covers all road transport modes, both cars as well as public means of transport like buses. The change is driven mainly by the trend of COX, NOX emission reduction in densely populated urban areas in order to inhibit climate change and improve the air quality. There are several different electric vehicle types [142]:

- battery electric vehicles (BEVs) are powered solely by an electric motor, using electricity stored in an on-board battery;
- plug-in hybrid electric vehicles (PHEVs) are powered by an electric motor and an internal combustion engine that work together or separately;
- range extended electric vehicles (REEVs) have a serial hybrid configuration in which their internal combustion engine has no direct link to the wheels. Instead, the combustion engine acts as an electricity generator and is used to power the electric motor or recharge the battery when it is low. The battery can also be charged from the grid;
- hybrid electric vehicles (HEVs) combine an internal combustion engine and an electric motor that assists the conventional engine, for example during vehicle acceleration;
- fuel cell electric vehicles (FCEVs) are entirely propelled by electricity. The electric energy is provided by a fuel cell 'stack' that uses hydrogen from an on-board tank combined with oxygen from the air.

The most popular an intermediate form of electric cars is hybrid propulsion joining reciprocating engine with electric propulsion. Power differentiation allows for decreased fuel consumption and better performances in urban traffic conditions. In the area of public transport, the FCEV concept is also popular. The technologies are fully matured and introduced into the market. In 2020 there were more than 70 electric models available[80]. Among most popular were: Tesla Model 3 (about 645,000 cars sold since introduction[81]), Nissan Leaf (490,000 cars sold since introduction) and Tesla Model S (about 305,000). Electric vehicles (plug-in and battery electric) comprised around 1.5 % of all new car registrations in the EU-28 in 2017 [143]. In terms of performances electric engine powered cars can be considered as at least comparable with traditional cars in many aspects especially when strictly urban traffic conditions are taking into account. The electric cars potential and attractiveness for users seems to rely highly on cells performances limiting its functionality in the day of writing of this document. Among challenges/obstacles preventing electromobility to become more common is [144]: range, charging speed (currently it is about 20-30 minutes of charging to gain energy for about 100 kilometers), charging infrastructure, comparable to gasoline station network but also price of electric cars which is higher than conventional vehicles. Big industry effort directed on new fuel cells technology development driven by the needs of many branches (e.g. aviation, public transport) allows for expecting the increasing share of electric cars and buses. According to the *European Commission Staff Working Document* [145] by 2030, BEVs could be between 3.9% and 13.0% and PHEVs 6.7% to 22.1% of new car registrations, depending on the EU-wide fleet average CO2 target levels set for passenger cars in the future. With regard to buses and alternative propulsion systems (HEV is seen as one of most efficient) it was assumed that its introduction does not affect significantly the functionality and specification of road public

[80] https://en.wikipedia.org/wiki/List_of_electric_cars_currently_available

[81] https://en.wikipedia.org/wiki/Electric_car

transport services. It affects the operational costs and impact on environment which are out of the scope of this analysis.

The following table shows an analysis of Electric cars performance with regard to the potential of integration with ATM services. The score should be interpreted as follows: one star is a weakness, two stars is an acceptable level, three stars is a strength.

Table 16 – Potential for integration with ATM services for Electric Vehicles

	Criteria and Score					
Horizon	Functionality	Efficiency	Flexibility	Integrability	Independency	**integration with ATM services**
2035	★★☆	★☆☆	★★★	★★☆	★★★	★★☆
2050	★★★	★☆☆	★★★	★★☆	★★★	★★☆

It will be crucial to decrease the charging time as well as to extend the electric car range. Also dramatically higher demand for electric energy has to be addressed (e.g. by nuclear plants). It was assumed that better performances drive the users' interest, allow for more massive production and will lead to decrease the price of electric cars. As a personal mode of transport it allows for high independence and flexibility but poor transport efficiency. Due to high flexibility and level of independence Electric Car present high potential with regard to integration with ATM services and various air modes of transport both public/mass as well as personal like PATS. On base of Scenarios defined in section 3 as well as current TRL it can be assumed that full functionality and availability of transport potential of electric cars will be achieved in 2035. In addition, it has to be kept in mind that electrification will be followed by increasing automation but up to level 3 according to Figure 12.

4.3.1.1.2 Autonomous car (vehicle) (AV).

The most awaited disruptive technology dedicated to revolutionise the road transport. Being a continuation and in fact completion (finial) of the trend of improving safety of car driving. Under the notion of autonomous car, the complex and multicomponent system should be considered covering also ICT topic. Due to the fact that introducing of AV is a long time process with many intermediate forms (levels) of driving automation AV is included in this section. This section covers operational specification of AV. ICT section will cover issues related to communication (– an enabler for AV) as well as exchange of information with ATM.

According to *SAE International* there are 6 levels of driving automation [146]: It was assumed that only highest levels of driving automation have potential to introduce visible change in road transport efficiency. These are level 4 and level 5 which not require the driver to take over driving. The process of evaluation the potential of integration with ATM services will focus on this level. In addition, it should be noted that mode analysed in this section however expected to be fully electrified is devoted mainly to specific operational models like shared mobility.

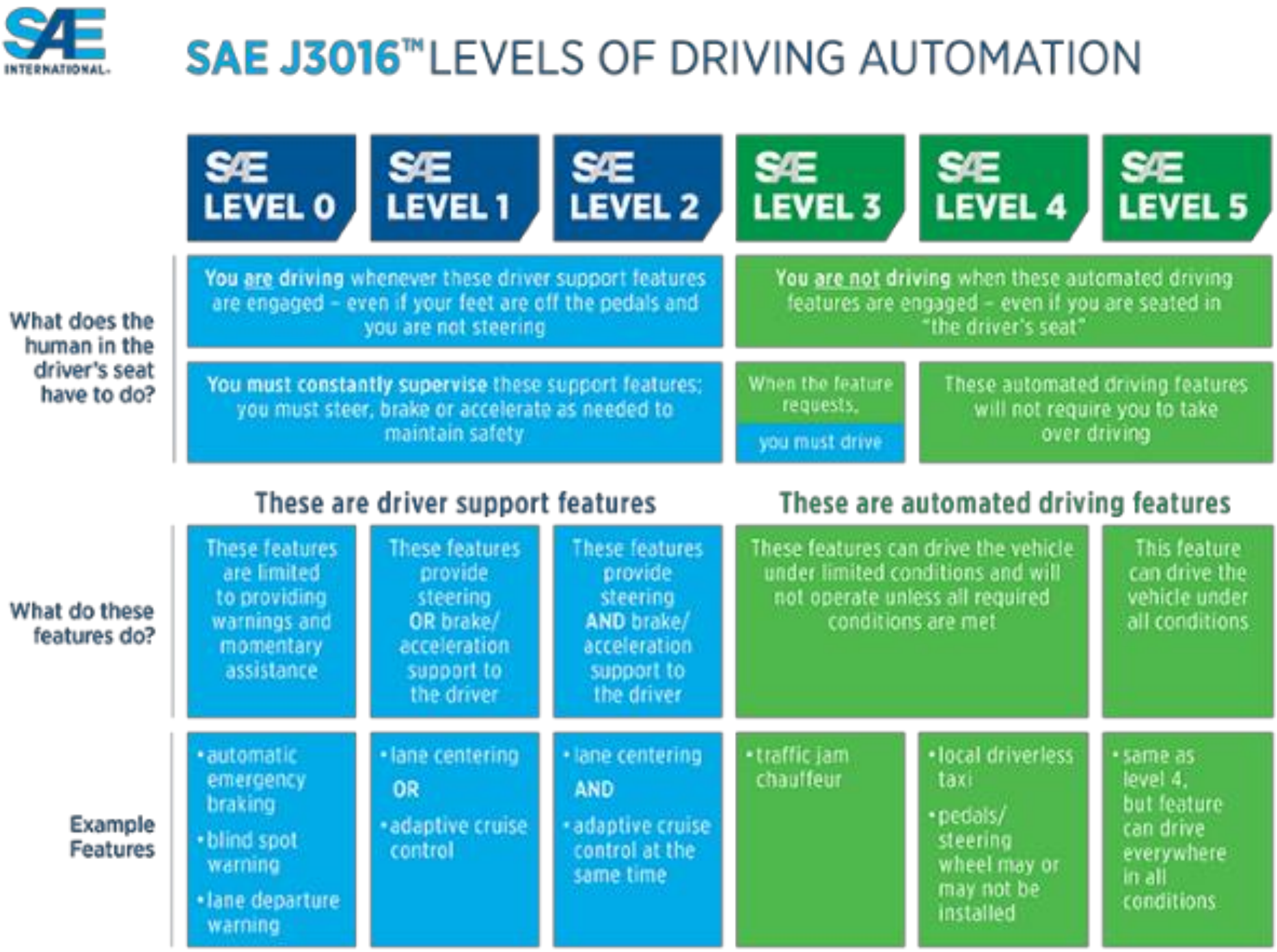

Figure 12 – Driving automation levels according to SAE

According to ITF-OECD report issued in 2018 [147]: Fully autonomous vehicles (AVs) are expected to be available in the early 2020s. Solutions available on the market in the time of writing of this document like Tesla Autopilot are classified on Level 2 - "hands-off" [148]). Going further requires deployment of necessary infrastructure assuring vehicle communication with other vehicles (V2V) and road infrastructure (V2I) or even introducing of IoT and V2X communication (Vehicle to Everything). Completed or nearly completed deployment of AV technology in relation to cars would bring the following benefits [149]:

- from the user/traveller perspective AV would allow for enhancing driving comfort and convenience, improving productivity or quality of life by freeing up time currently consumed by driving, reducing vehicle operational costs by more economic driving, improve safety or reduce travel time;

- from the transport system point of view common or sectoral implementation of AV mobility will lead to elimination of deficiencies related to limited human driving skills and will allow for reducing traffic congestion and more efficient use of existing road infrastructure, reducing energy use and pollutant emissions as well as for decrease the cost future infrastructure and equipment. In addition, resulting with enhancing and broadening mobility options, giving users more flexibility.

The significant expected improvement of safety (with regard to probability of accident)[82] as well as different than in case of manned cars mission/operational profile (closer to the public means of transport or shared mobility) will entail the need for redefinition of design requirements. The International Transport Forum document summarising all crucial issues related to AV indicates on following common specifications of AV [150]: electric propulsion, light weight as required by safety reasons, design tailored to operational profile (e.g. shared mobility), advanced electronic, communication and detection equipment in order to enable operation in mixed-use environment. The same report highlights that advanced solutions in the field of AV require implementation of Operational Design Domain (ODD) restrictions in place to mitigate system and/or vehicle limitations. The ODD constraints include geography, road type, speed, and weather conditions. In addition system capability and maturity will also be dependent on supporting infrastructure for safe operation (like communication infrastructure or dedicated roads or lanes). The following table shows an analysis of Autonomous Cars performance with regard to the potential of integration with ATM services. The score should be interpreted as follows: one star is a weakness, two stars is an acceptable level, three stars is a strength.

Table 17 – Potential for integration with ATM services for Autonomous Vehicles

	Criteria and Score					
Horizon	Functionality	Efficiency	Flexibility	Integrability	Independency	**integration with ATM services**
2035	★★☆	★☆☆	★★☆	★★☆	★★★	★★☆
2050	★★★	★☆☆	★★★	★★☆	★★★	★★☆

Autonomous cars achieved very good scoring. But turning the vision into reality requires making a big effort in numerous areas. Further research is necessary in the fields of ICT. For these reasons, but not exclusively a transition from marginal use of AV to mass use of AVs that are able to operate on a broad range of public roads is expected to take decades. Due to very high functionality, flexibility and level of independence Autonomous Car presents very high potential with regard to future integration with ATM services and various air modes of transport both public/mass as well as personal like shared mobility. It can include using of one traffic management system opening possibility for roadable aircraft. On base of scenarios defined in section 3 as well as current TRL it can be assumed that described functionality and availability of transport potential of autonomous cars will be achieved in 2050 (but still operating in mixed environment). Nevertheless, sectoral implementation covering some specific, separated routes/lanes (e.g. connecting airport with city center) will be available in 2035.

4.3.1.2 Public/mass transport

This section focuses on new technologies in public, road transport covering buses.

[82] According to The US National Highway Traffic Safety Administration (NHTSA) the driver is the critical cause of 94 percent of crashes: Critical Reasons for Crashes Investigated in the National Motor Vehicle Crash Causation Survey, NHTSA 2018, https://crashstats.nhtsa.dot.gov/Api/Public/ViewPublication/812506

4.3.1.2.1 Autonomous (electric) bus

The questions related to development of autonomous car are described in previous section. Most of them are adequate and can be easily shifted on the field of public transport and autonomous buses. Similarly, as in case of autonomous cars autonomous buses are introducing market. As it is indicated in ITF document [72] the technologies for trucks achieved automation level 5 (Figure 12) and Technology Readiness Level 7. In applications dedicated to public buses technology advance is lower but more and more pilots were being deployed in Europe. Among numerous examples are: The *H2020 FABULOS* project bringing self-driving buses in five European cities [151], Volvo Buses, Scania (Figure 13), ADL and Stagecoach, and IVECO bus making their demonstrations around the world between 2018 and 2021 [152].

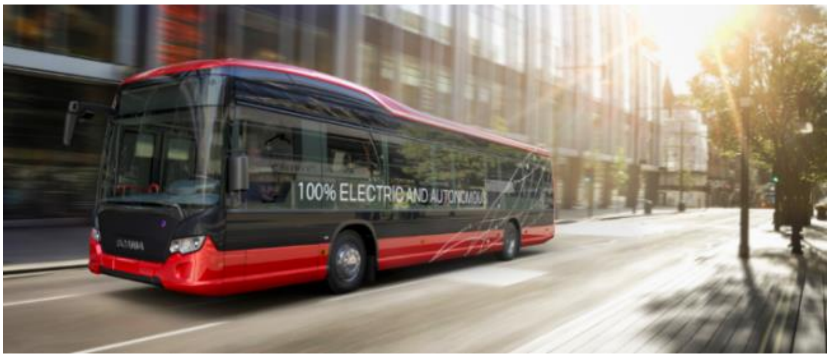

Figure 13 – Scania trial of autonomous buses on regular routes in Stockholm area from 2020

Besides higher service reliability, improved safety, efficiency and lower cost of vehicle operations Introducing of autonomous bus will allow for decrease the cost related to drivers and will enable higher utilisation factor without human driving time limitations. More common implementation of autonomous buses requires the same elements as in the case of autonomous cars (implementation of Operational Design Domain – ODD – see section entitled AV).

The following table shows an analysis of Autonomous Bus performance with regard to the potential of integration with ATM services. The score should be interpreted as follows: one star is a weakness, two stars is an acceptable level, three stars is a strength.

Table 18 – Potential for integration with ATM services for Autonomous Buses

	Criteria and Score					
Horizon	Functionality	Efficiency	Flexibility	Integrability	Independency	**integration with ATM services**
2035	★★☆	★☆☆	★★☆	★★☆	★☆☆	★★☆
2050	★★☆	★★☆	★★☆	★★☆	★☆☆	★★☆

Autonomous buses achieved good scoring. But the same as in the case of autonomous cars turning the vision into reality requires making a big effort in numerous areas. Further research is necessary. For these reasons, but not exclusively a transition from marginal use of AV (here buses) to common use is expected to take many years. Main strong areas of autonomous bus is good scores in nearly all criteria. The most significant weakness is the level of independence – natural feature of public transport. Nevertheless, the good scoring in the field of range, flexibility and integrability allows for considering autonomous bus as valuable component of future integrated transport system. Especially with connection to air modes characterized by high independence (e.g. PATS) and higher flexibility factors. On base of scenarios defined in section 3 as well as current TRL it can be assumed that full functionality and availability of transport potential of autonomous bus will be achieved in 2050 (e.g. extended with route flexibility). Nevertheless, sectoral implementation covering some specific, separated routes (e.g. connecting airport with city center) will be available in 2035.

4.3.1.2.2 Transit Elevated Bus (TEB)

The TEB is a bus that straddles traffic by driving over the top of it, running along fixed tracks. Its main compartment is elevated, leaving the street clear for cars underneath. The design also incorporates solar panels on the roof and at bus stops to partially power the vehicle[83]. The idea is interesting as enabling public bus transport operations independently on traffic situation and can be considered as relevant solution for today cities. It is much larger than conventional bus (capable to transport up-to 1200 passengers) and does not require expensive dedicated infrastructure (except elevated bus stops).

Figure 14 – Visualisation of the system

After building a prototype and testing it on 300 meter long test track the project was abandoned, probably due to technical problems. Nevertheless, due to potential and interest expressed by few European cities the TEB is considered as feasible and rationale solution for future urban road transport. The following table shows an analysis of Autonomous Cars performance with regard to the potential of integration with ATM services. The score should be interpreted as follows: one star is a weakness, two stars is an acceptable level, three stars is a strength.

Table 19 – Potential for integration with ATM services for Transit Elevated Bus

	Criteria and Score					
Horizon	Functionality	Efficiency	Flexibility	Integrability	Independency	**integration with ATM services**
2035	★★★	★★☆	★★☆	★★☆	★☆☆	★★☆
2050	★★★	★★★	★★☆	★★☆	★☆☆	★★☆

Assuming that TEB will be also autonomous in future it represents higher scoring than autonomous bus in conventional configuration. Mostly due to independency on traffic congestion and higher reliability and service quality. It will be preferred solution for highly congested routes. Regarding the need for dedicated lane(s) it can be claimed that full functionality and potential of TEB concept (including driver-less feature) will be available in 2035.

83 The Transit Elevated Bus (TEB) website, https://www.designingbuildings.co.uk/wiki/Transit_Elevated_Bus_(TEB)

4.3.1.3 Shared mobility

Rapidly developing ICT solutions creates new possibilities for dealing with challenge of joining the system efficiency with objective of meeting of individual and temporary needs of traveller. The concept of Mobility as a Service (MaaS) enabling sharing vehicles among different users is one of them. It covers both cars, electric bicycles, scooters and other on-demand means of transport).

4.3.1.3.1 Shared electric autonomous car

The goal is to achieve higher efficiency level (closer to that of public/collective means of transport) without compromising (significantly) on-demand character of car (mainly in terms of availability). It would allow for decreasing the fixed operating cost related to utilisation measure (e.g. driven km or pax-km) and share additionally these among many users. Beside challenges related to the fact of being electric and autonomous (see sections above) the shared mobility requires tailored ICT solutions (covering both tools and algorithms) gathering and/or assessing the needs from users and manage limited resources in a way which maximise the number of sufficiently satisfied users. As the efficiency of shared cars operational model increase with increased number of active users the highest potential for such solutions can be seen in populated, urban areas. Two main models of shared mobility can be distinguished: First is shared car enabling using it individually by many users but not at the same time. It can be considered as upgraded rental car model but paperless, officeless and fully automated with use of mobile application. Such solutions are available and getting popular in Europe. Second is shared travel enabling using the same car by two users sharing the same destination or direction of travel. Uber can be considered as some form of such model. Full potential of shared mobility is expected to be achieved when joining / mixing of those two models will be feasible. As the efficiency of both models of shared mobility increase with increased number of active users the highest potential for such solutions can be seen in populated, urban areas. It becomes being of utmost meaning when joining model is considered. The process of implementation of such solution in a scale which could be considered as having potential to reduce the number of cars and be remedy for congestion problems require advanced and dedicated solutions in the domain of ICT. Efficient management of available resources and needs of passengers will not be possible without high performance communication network, Internet of Things connecting cars, infrastructure and users. The following table shows an analysis of Shared, electric, autonomous cars performance with regard to the potential of integration with ATM services. The score should be interpreted as follows: one star is a weakness, two stars is an acceptable level, three stars is a strength.

Table 20 – Potential for integration with ATM services for Shared electric autonomous car

	Criteria and Score					
Horizon	Functionality	Efficiency	Flexibility	Integrability	Independency	**integration with ATM services**
2035	★★☆	★★☆	★★★	★★☆	★★☆	★★☆
2050	★★★	★★★	★★★	★★☆	★★☆	★★★

High functionality, flexibility and good independence allow for considering shared electric autonomous car as having a very good potential for efficient integration with ATM services, especially in longer perspective. But turning the vision into reality requires making a big effort in numerous areas. Further research is necessary in the fields of ICT. On base of scenarios defined in section 3 as well as current TRL it can be assumed that described functionality and availability of transport potential of shared electric autonomous cars will be achieved in 2050. Nevertheless sectoral implementation covering some specific separated routes or single models with increased efficiency as described above will be possible in 2035.

4.3.1.3.2 Shared (electric) micromobility

Micromobility refers to a range of small, lightweight vehicles operating at speeds typically below 25 km/h and driven by users personally. Micromobility devices include bicycles, E-bikes, electric scooters, electric skateboards, and electric pedal assisted bicycles. Here under the notion of micromobility only electric powered devices will be considered (e-bikes, scooters, etc.). Micromobility aims to tackle a "first mile" and "last mile" transportation, a situation where traveller have difficulty to get from a major transportation mode (a bus or train) to destination point. Often these first mile and last mile locations are in close enough proximity that makes using a car unjustified but are far enough away that walking is inconvenient or hazardous. Shared electric mobility with access points situated in accessible public locations provides a reasonable solution to this dilemma.

Electric bicycle, scooters sharing systems already exists and getting more and more popular in Europe. The technology is fully matured but with high potential for integration into the urban transport system at the same time. Especially with regard to virtual side. Exchange of information about availability, projected time of arriving at the destination point or real time travel management navigation as well as mobile access points are the functionalities which can significantly enrich this mode of transport. Especially if a dedicated infrastructure is developed at the same time (e.g. elevated paths [153]). The following table shows an analysis of Shared, electric, micromobility performance with regard to the potential of integration with ATM services. The score should be interpreted as follows: one star is a weakness, two stars is an acceptable level, three stars is a strength.

Table 21 – Potential for integration with ATM services for Electric micromobility

	Criteria and Score					
Horizon	Functionality	Efficiency	Flexibility	Integrability	Independency	**integration with ATM services**
2035	★☆☆	★☆☆	★★★	★★☆	★★★	★★☆
2050	★★☆	★☆☆	★★★	★★☆	★★★	★★☆

High flexibility and independency make shared micromobility a mode with sufficient potential to integration with ATM services, however with some serious limitations. It has to be noted that special dedicated infrastructure can be essential. Lack of paths and the fact that airport is usually located in remote areas far from the highly populated cities make airports rather hardly available by e-bikes or scooters. Therefore, consideration of direct changes from conventional air modes of transport to micromobility can be unreasonable. Other weakness is related to limited ability to transport a travel baggage. Full functionality enabling taking all advantages resulted from exchange of information between systems providing shared micromobility services require extended functionality in a range described above. On base of scenarios defined in section 3 as well as current TRL it can be assumed that described functionality and availability of transport potential of shared electric micromobility will be achieved in 2035.

4.3.2 Rail transport

Only mass/collective modes of transport can be considered with regard to rail transport. The area of passenger conventional rail, light rail and metro will be analysed. High Speed Train as well as disruptive Hyperloop transport technology[84] are considered as being of out of scope due to longer than regional operational range. Rail transport is considered as of most important means of transport today. Seen as safest, greenest and most efficient [154] will probably remain a *backbone of an intermodal "Mobility as a Service" within cities and beyond, for both passengers and goods - Rail 2050 Vision - Rail - The Backbone of Europe's Mobility* [155]. The same document indicates that in European metropolitan areas, 400 billion trips are made each year: 15% by public transport, 30% by non-motorised means and 55% by private car. Rail represents 45% of public transport. In absolute terms, commuter rail carries 8.9 billion people each year, metro 9.5 billion and tram/light rail 8.5 billion. Integration of rail with air transport can bring therefore the significant improvement in the field of multimodal transport integration.

Despite the many forms of rail transport applications (conventional rail, light rail, metro in underground or on suspended line) rail transport can be defined as complex network with numerous interconnected routes which main advantage is the fact that it is separated from other means of transport (no interaction between train and other vehicles types e.g. car is considered). As the feature of separation and independency on other means of transport can be applied to all rail forms of transport it was assumed that distinguishing on conventional rail, urban rail and metro was assumed as unnecessary from the transport integration point of view.

4.3.2.1 Autonomous rail wagons (rail AGV)

Similarly, as in the case of road transport the trend of elimination of human operator with its deficiencies is the main one in railroad transport. Introduction of connected wagons allowing for self-regulating in traffic, negotiating vehicle-to-vehicle and vehicle-to-X to determine movement priority and resolve potential conflicts at junctions in the network, and reacting to unexpected situations has potential to bring significant improvement in the field of safety, process efficiency or operational cost. In addition, the fact that trains would be also aware of and able to take account of the status of other transport modes creates real possibility for adaptive and accurate adjustments to transport demand patterns, dramatically increasing the capacity and flexibility of the rail transport system and enable implementation of total system approach with regard to multimodal transport integration or disruption management [155]. It can be applied to all types of operations: urban rail, high speed, freight, rural and mass transit system. Autonomous operations also enable new types of mobility on rail, such as self-operated light pods/shuttles providing seamless interconnection across infrastructures. All under the new generation of the traffic management systems such as *European Railway Traffic Management System*[85] *(ERTMS)* and mass transit *Communication Based Train Control (CBTC).*

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[84] The Virgin Hyperloop website, https://virginhyperloop.com/#our-story

[85] The European Rail Traffic Management System (ERTMS) website, https://www.era.europa.eu/activities/european-rail-traffic-management-system-ertms_en

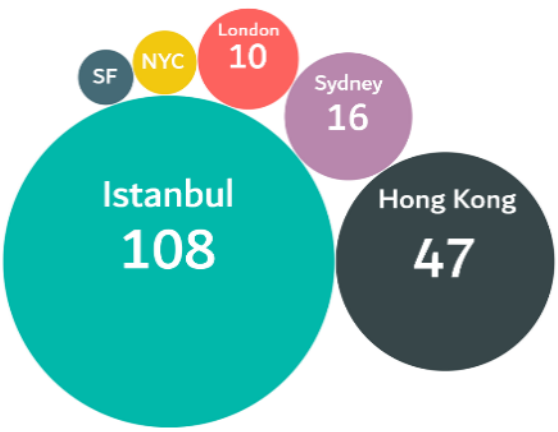
The challenge of introduction of *AGV* system is somehow comparable with that in road transport and concerning AV. Require deployment of Internet of Things and adequate communications systems allowing for continuous communication of every component of the system as well as a line of sensors eyes and ears of human operator. The following table shows an analysis of Autonomous Rail Wagon performance with regard to the potential of integration with ATM services. The score should be interpreted as follows: one star is a weakness, two stars is an acceptable level, three stars is a strength.

Table 22 – Potential for integration with ATM services for Autonomous rail wagon

	Criteria and Score					
Horizon	Functionality	Efficiency	Flexibility	Integrability	Independency	**integration with ATM services**
2035	★★★	★★★	★☆☆	★★☆	★☆☆	★★☆
2050	★★★	★★★	★☆☆	★★☆	★★☆	★★☆

High functionality and range levels in connection with good integrability as well improved flexibility and independency (resulted from digitaliisation and possibility of introduction shuttles better addressing independency aspects) allow for considering autonomous rails as potentially good mean for integration with ATM services. Very stable, predictable and reliable and flexible and allowing for personalised services at the same time. Full functionality enabling taking all advantages resulted from exchange of information between systems of rail and air transport require development and maturation of numerous solutions in the field of ITC (e.g. IoT, communication, etc.). On base of scenarios defined in section 3 as well as current TRL it can be assumed that described functionality and availability of transport potential for integration with ATM will be achieved in 2050. However sectoral implementation covering some specific, separated routes (e.g. connecting airport with city center) will be available in 2035.

4.3.3 Water transport



Typical maritime transport is out of the scope due to the condition of regional range. Common urban waterborne transport can be considered as interesting solution only in specific conditions like resulted from location of the city on islands or over big water reservoir and lack of land connections. In such situation waterborne transport become something more than touristic attraction – an important part of modern sustainable and integrated transport system. Among cities relying much on water transport the Istanbul, Hong-Kong or London can be listed [156].

Figure 15 – Annual ferry ridership 2017 (millions)

4.3.3.1 Autonomous ferry

The trend of automation and reducing of driver's/operator's effort is common for all modes of transport. In inland water transport as well. Moreover, in case of waterways can be considered as enabler for wider use of rivers or channels or other water reservoirs for transport people. An example of such solution is *Zeabuz* small autonomous electric ferry [157] developed by Norwegian University of Science and Technology (NTNU). The ferry is seen mainly as an alternative for expensive infrastructure like bridges, tunnels over/under the rivers but concept has potential to complement every urban transport system in locations where navigable water reservoirs disable direct and straightforward transportation. The technology readiness level of presented concept is in prototype phase [158]. Similar solutions but dedicated to cargo transport, like autonomous vessels also reached the TRL of 6 [72]. This allows for considering autonomous electric ferry as prospective solutions for future multimodal transport systems. The following table shows an analysis of Autonomous electric ferry performance with regard to the potential of integration with ATM services. The score should be interpreted as follows: one star is a weakness, two stars is an acceptable level, three stars is a strength.

Table 23 – Potential for integration with ATM services for Autonomous ferry

	Criteria and Score					
Horizon	Functionality	Efficiency	Flexibility	Integrability	Independency	**integration with ATM services**
2035	★☆☆	★☆☆	★☆☆	★☆☆	★★☆	★☆☆
2050	★★☆	★☆☆	★☆☆	★☆☆	★★★	★★☆

High independency (as autonomous electric ferry will be rather small-size in order to facilitate navigation) allows for on-demand flexible operations and integration with air modes of transport. On the other side low flexibility and integrability as relying on existing waterway network or requiring expensive investments. However, it is also worth of mentioning that autonomous ferry docking stations will be located in places which can be potentially attractive for UAM (in a safe distance from densely populated places). In summary, Autonomous electric ferry represents interesting potential for integration with ATM service but for very specific and advantageous locations. Full functionality enabling taking all advantages resulted from exchange of information between systems of autonomous electric ferry and air transport requires, beside dedicated infrastructure, development and maturation of numerous solutions in the field of ICT. On base of scenarios defined in section 3 as well as current TRL of autonomous electric ferry technologies it can be assumed that described functionality and availability of transport potential for integration with ATM will be achieved in 2050. However sectoral implementation covering some specific, separated routes (e.g. connecting airport with city center) will be available in 2035.

4.3.4 Multimodal transport technologies

Review of most interesting/promising technologies and solutions facilitating integration of transport. The section divided in to two parts: Devoted to new modes, vehicle types and infrastructure. Rapidly developing technologies creates new possibilities not only in aviation, road transport and rail but also in multimodal transport integration area.

4.3.4.1 Multifunctional vehicles

4.3.4.1.1 Flexible chassis systems

This can be considered as well as most probable form of roadable aircraft known as flying car. The idea as old as history of aviation. But the incoming era of passenger multirotors seems to really open the possibility of development of functional, safe and efficient solutions. One of the most interesting concepts is fully autonomous, compact-sized and electric common *Pop.Up Next, Airbus, Audi* and *Italdesign* project[86]:

https://evtol.news/pop-up-next/

Figure 16 – Two concept of autonomous, electric convertible aircraft

Besides questions described in previous sections (regarding in particular air and road autonomous, electric transport) like the need of completed digitalisation in road and air transport allowing for introduction of autonomous traffic at least on sectoral level. Such vehicle requires deep integration of air and road traffic management systems. Perhaps applications of some solutions developed for UAM in autotomized road transport could be considered as most adequate for multimodal vehicles. The following table shows an analysis of Autonomous electric ferry performance with regard to the potential of integration with ATM services. The score should be interpreted as follows: one star is a weakness, two stars is an acceptable level, three stars is a strength.

Table 24 – Potential for integration with ATM services for Autonomous, electric flexible chassis system

	Criteria and Score					
Horizon	Functionality	Efficiency	Flexibility	Integrability	Independency	**integration with ATM services**
2035	N/A	N/A	N/A	N/A	N/A	N/A
2050	★★★	★★☆	★★★	★★★	★★★	★★★

Very good scoring thanks to high functionality, flexibility, integrability and independency result with very big potential in terms of integration of ATM with other modes of transport. But only assuming shared mobility application. Full functionality enabling taking all advantages resulted from exchange of information between air and road systems in case of autonomous electric flexible chassis requires, development and maturation of numerous solutions in the field of ICT (e.g. IoT, communication, etc.). On base of scenarios defined in

[86] The Pop.Up Next website, https://evtol.news/pop-up-next/

section 3 as well as current TRL of given concept it can be assumed that described functionality and availability of transport potential for integration with ATM will be achieved in 2050.

4.3.4.2 Information and Communication Technologies (ICT)

This section is devoted to the analysis of Internet and Communication Technologies aiming at facilitating of multimodal passenger transport integration in future. Independently on particular solutions described in previous sections.

4.3.4.2.1 Traveller recognition on multimodal hubs

The goal is to enable (near) real-time demand evaluation and tailoring the transport supply to current real needs. It can be achieved by acquiring and real-time processing of data concerning movement (journey paths) of every transport user. Among possible ways to provide system with data about location and moving path of travellers is facial recognition system. China is pioneering this technology. Wuhan train station is an example where passengers can pay with "face swapping". They simply walk up, and if their face is scanned correctly, barriers are opened for boarding. Over 30 devices have been installed at Wuhan since 2017, leaving just 10 manned ticketing stations [159]. Regarding EU policy described in section 3 facial recognition system seems to be challenging from the point of security and private data protection view. Especially that the process of transport integration as driven mainly by digitalisation trend will reduce the need of people identification on favour of processing of large amount of anonymised data. As an alternative solution which could better answer the EU policy is portable personal device interacting with transport infrastructure and feeding transport management system with adequate and controlled by user data. Nevertheless it has to be added that one of Swedish train operator *SJ Railways*, has already started using microchips to quickly allow rail passengers to validate their tickets [160].

4.3.4.2.2 Navigation services with use of 5G communication

The idea of extensions of 5G services with localisation functionality is led by *LOCUS* project (*LOCUS – Localisation and analytics on-demand embedded in the 5G ecosystem for ubiquitous vertical applications*[87]). LOCUS will improve the functionality of 5G infrastructures to provide accurate and ubiquitous location information as a network-native service and to derive more complex features and behavioural patterns. Localization, together with analytics, and their combined provision "as a service", will greatly increase the overall value of the 5G ecosystem, allowing network operators to better manage their networks and to dramatically expand the range of offered applications and services. The project was funded within last, fourth wave of Phase 3 of *Europe's 5G Research Plan* which started in 2020. Together with eight other initiatives it will address the long term evolution of communication systems, investigating technologies which are not yet, or not fully, addressed under the 5G PPP, and paving the way towards smart connectivity systems beyond 5G. Independence from GNSS combined with possibility of providing localisation services inside building significantly increases potential reliability and robustness of future transport management systems allowing, among other for better transport demand forecasting (and nowcasting). It can be expected that GSM based

[87] The Localisation and analytics on-demand embedded in the 5G ecosystem for ubiquitous vertical applications (LOCUS) website , https://www.locus-project.eu/

navigation will be commonly available in urban, suburban areas as well as along all important transportation paths in 2035. Till 2050 also rural areas will be covered.

4.3.4.2.3 Terahertz technology

The idea of disruptive progress in communication systems developed by another project funded within last, fourth wave of Phase 3 *of Europe's 5G Research Plan* which started in 2020 - *TERAWAY - Terahertz technology for ultra-broadband and ultra-wideband operation of backhaul and fronthaul links in systems with SDN management of network and radio resources*[88]. Project aiming to develop a disruptive generation of photonics-enabled THz transceivers for high-capacity BH and FH links in 5G networks. TERAWAY will develop a common technology base for the generation, emission and detection of wireless signals with selectable symbol rate and bandwidth up to 25.92 GHz within an ultra-wide range of carrier frequencies covering the W-band (92-114.5 GHz), D-band (130-174.8 GHz) and THz band (252-322 GHz). In this way, TERAWAY steps into providing for the first time the possibility to organize the spectral resources of a network within these bands into a common pool of radio resources that can be flexibly coordinated and used. Regarding low TRL of terahertz technology it can be assumed that it will be available in 2050.

4.3.5 Conclusions

The table below presents summary of surface (and multimodal) modes of transport to the possibility and potential to be integrated with air transport via exchange of information between ATM and other modes management systems. Last column is simply rounded average of other criteria of evaluation. The weight distribution amongst them depends on numerous issues like city structure, distribution of transport workload among available modes, implemented policy priorities and many others. Simply on applied concept of operation. On base of analyses presented in previous section of this document the following assumption can be defined:

All transport technologies but Flexible Chassis system are expected to be available in 2035 at earliest. In addition, often in a limited range (see previous sections). Therefore, regarding lack of possibility to achieve full potential to be resulted from integration with air transport the criterion of possibility could be considered as being of higher weight. In results every surface mode represents possibility to be efficiently integrated with ATM service according to the key: high independency modes can be integrated with all other modes but mode with poor independency can be integrated only with modes assuring high independency. In 2050 in turn, as we assumed digitalisation process to be completed (see section 3.5.3) and all considered surface modes technologies (+multimodal one) to be commonly deployed we can switch to potential criterion as being of highest priority. In this situation the Efficiency aspect should be most weighted. The possibility of transport system management on the level of system of systems should enable implementation of sustainability and efficiency priority as being fully in line with goal of climate neutrality in 2050.

[88] The Terahertz technology for ultra-broadband and ultra-wideband operation of backhaul and fronthaul links in systems with SDN management of network and radio resources (TERAWAY) website, https://ict-teraway.eu/

Table 25 – Summary of surface & multimodal modes of transport with regard to integration with ATM services

Mode	Functionality	Efficiency	Flexibility	Integrability	Independency	Integration with ATM services average/weighted
Time Horizon 2035						
Electric car	★★☆	★☆☆	★★★	★★☆	★★★	★★☆/★★☆
Autonomous car	★★☆	★☆☆	★★☆	★★☆	★★★	★★☆/★★☆
Autonomous bus	★★☆	★☆☆	★★☆	★★☆	★☆☆	★★☆/★★☆
TEB - Transit Elevated Bus	★★★	★★☆	★★☆	★★☆	★☆☆	★★☆/★★☆
Shared car	★★☆	★★☆	★★★	★★☆	★★☆	★★☆/★★☆
Shared electric micromobility	★☆☆	★☆☆	★★★	★★☆	★★★	★★☆/★★☆
Autonomous rail wagon	★★★	★★★	★☆☆	★★☆	★☆☆	★★☆★★☆
Autonomous ferry	★☆☆	★☆☆	★☆☆	★☆☆	★★☆	★☆☆/★★☆
Flexible chassis systems	N/A					N/A
Time Horizon 2050						
Electric car	★★★	★☆☆	★★★	★★☆	★★★	★★☆/★☆☆
Autonomous car	★★★	★☆☆	★★★	★★☆	★★★	★★☆/★☆☆
Autonomous bus	★★☆	★★☆	★★☆	★★☆	★☆☆	★★☆/★★☆
TEB - Transit Elevated Bus	★★★	★★★	★★☆	★★☆	★☆☆	★★☆/★★★
Shared car	★★★	★★★	★★★	★★☆	★★☆	★★★/★★★
Shared electric micromobility	★★☆	★☆☆	★★★	★★☆	★★★	★★☆/★★☆
Autonomous rail wagons	★★★	★★★	★☆☆	★★☆	★★☆	★★☆/★★☆
Autonomous ferry	★★☆	★☆☆	★☆☆	★☆☆	★★★	★★☆/★★☆
Flexible chassis systems	★★★	★★☆	★★★	★★★	★★★	★★★/★★☆

5 Use Cases

5.1 Introduction

On base of scenarios defined in chapter 3 a set of most representative use cases will be defined. There will be processed in further parts of the X-TEAM D2D project.

General specifications of use cases:

- use cases are detailed scenarios describing multimodal door to door travel of passengers in three time horizons: 2025, 2035 and 2050. Use Cases should relate to urban, suburban, regional up to single small-size country distance trips;
- use Cases are “ATM-centred” (include role of ATM in multimodal transport). Therefore Use Cases should include air transport mode. This assumption in practice requires focussing on irregular multimodal travels (other than i.e. daily travel to work or school);
- use cases are based on results of chapter 2, 3 and 4. In details on: trends identified, strategies defined by EC (goals planned to be achieved in given time horizons), expected future passengers’ needs (identified within WP2.1) and identified technologies planned to be available in given time horizons (WP2.2).

Process of use case definition will consist of:

- identification of the most representative, key or specific passenger profiles for given time scenarios. The traveller profile results from economic, demographic and social changes expected to appear within considered time horizons (see section 5.2);
- identification of new modes of transport with providing its specifications with regard to transport capacity and possibility to use for multimodal journey but also respective priority resulting from applied or expected mobility strategy. Based mainly on result of chapter 3 and 4 (see section 5.3);
- transport integration and data exchange. Description of transport integration level with special focus placed on ICT related tools and solutions. It will cover travel planning, management as well as resilience for disruptions of various nature. Based mainly on results of chapter 3 and 4 (see section 5.4).

5.2 Passenger profiles definition

The passengers’ profiling for the Use Case definition is intended to provide the key information about the passengers expected behaviour that could determine the sequence of actions constituting the Door to Door travel to be executed by a given passenger in a specific time horizon. Therefore the passenger profiles contribute to the design of the actions’ flow describing the steps of the multimodal journey, also providing indication about the most plausible alternative actions flow in case a travel disturbance occurs, which request the passenger to switch to an alternative transport mean or timetable. The following tables provide an overview of the characteristics and consequent expected behaviour for each passenger profile.

Table 26 – Passenger profile key points for 2025

Passengers profile key points – 2025 scenario		
Passenger type	**Characteristics**	**Expected behaviour**
Business Traveller (BT)	- Travels alone (mainly) - Has time constraints/target times - Has budget limits but generally these are depending on the business goal of the trip and the role in the company - Have short stay and cabin luggage - Might need to work during the travel time - Is a frequent flyer/traveller - Is an adult (18-70 years), generally in normal health condition (no physical or sensorial impairments) - Can be allowed or not to arrange/rearrange his travel plan depending on internal procedures	- Can easily and quickly adapt to travel plan changes - Habitually uses on demand/personal transport means (taxi, car rental) - Spend few time in planning the trip, the trip is not arranged with large advance - Choose the fastest multimodal journey combination - Choose the most comfortable travel means (i.e. with reservation) - Might rely on travel assistance services (secretariat services, travellers club services)
Other travellers (OT)	- Travels in small or larger groups (mainly) - Unless specific travel reasons (a ceremony, family issues, etc.) has relatively low time constraints - Has budget limits - Can have larger/heavy luggage or other items such as sport equipment, walking aids, stroller, etc. - Might need assistance (children, elderly, disabled people) - Can be or not a frequent flyer/traveller - Can be of any age range, from baby/children to very elderly - Can have any kind of physical or sensorial impairment - Is free to arrange/rearrange the travel according to the preferences - Might have constraints in payment methods (i.e. unavailable credit card, unavailable cash etc.) - Might encounter language/communication barriers	- Plan the travel carefully and in advance (mostly) - Could be unable or unwilling to use some transport means (i.e. due to accessibility barriers, costs, etc.) - Could use sharing transport means with personal accounts (car/bike sharing, Uber, etc.) - Might prefer cheapest travel options (disregarding comfort or travel time)

Table 27 – Passenger profile key points for 2023

Passengers profile key points – 2035 scenario		
Passenger type	**Characteristics**	**Expected behaviour**
Business Traveller (BT)	- Travels alone (mainly) - Expect very high comfort standard - Expect very short travel time - Has few budget limits - Travels for short stay, with small luggage - Is a frequent flyer/traveller - Is an adult (18-70 years), generally in normal health condition (minor physical or sensorial impairments) - Relies on dedicated business services for travel arrangement (no reservation or payment methods constraints) - Has full flexibility for travel plans change	- Spend few time in planning the trip, the trip is not arranged with large advance - Uses personalized/on demand travel services, even if at higher costs - Choose the fastest multimodal journey combination - Choose the most comfortable travel means (i.e. with reservation), by selecting considering a priority the easiest connection - Might choose travel means to show a status, according to the position in the organization (will consider some mean more representative than others i.e. for urban air mobility) - Might choose travel means to reinforce sustainability policies of his/her company
Other travellers (OT)	- Travels in small or larger groups (mainly) - Unless specific travel reasons (a ceremony, family issues, etc.) has relatively low time constraints - Can have larger/heavy luggage or other items such as sport equipment, walking aids, stroller, etc. - Has budget limits - Has not constraints for reservation or payment methods - Might need assistance (children, elderly, disabled people) - Can be of any age range, from baby/children to very elderly - Can have any kind of physical or sensorial impairment	- Plan the travel carefully and in advance (mostly) - Could be unable or unwilling to use some transport means (i.e. due to accessibility barriers, costs, etc.) - Could be willing to pay environmental footprint compensation costs - Could use sharing transport means with personal accounts (car/bike sharing, Uber, etc.)

	- Is free to arrange/rearrange the travel according to the preferences - Is sensitive to environmental footprint of his/her journey - Has no communication limitations thanks to technology support	

Table 28 – Passenger profile key points for 2050

Passengers profile key points – 2050 scenario		
Passenger type	**Characteristics**	**Expected behaviour**
Business Traveller (BT)	- Travels alone (mainly) - Expect very high comfort standard - Expect very short travel time - Has few budget limits - Might travel for long stays (as short travels for face to face meetings will dramatically reduce) with large/heavy luggage - Is a frequent flyer/traveller - Is an adult (18-75 years), with possible physical or sensorial impairments - Relies on dedicated business services for travel arrangement (no reservation or payment methods constraints) - Has full flexibility for travel plans change - Must comply with environmental performance targets set by his/her company	- Uses personalized/on demand travel services - Can easily and quickly adapt to travel plans changes - Choose the fastest multimodal journey combination - Choose the most comfortable travel means /i.e. with reservation), by selecting considering a priority the easiest connection - If needed, will bear extra costs to pay carbon compensation or any environmental compensation amount to comply with sustainability targets of his company - Might rely on travel assistance services (secretariat services, travellers club services)
Other travellers (OT)	- Travels in small or larger groups (mainly) - Unless specific travel reasons (a ceremony, family issues, etc.) has relatively low time constraints - Has only personal items/small luggage as luggage will be picked up and delivered door to door (except for walking aids/stroller)	- The trip could be arranged with short advance - Choose the lowest environmental footprint travel option within the budget limits - Uses luggage transfer services for "free hand" travel

	- Has budget limits - Has not constraints for reservation or payment methods - Does frequent short stay/medium distance travels - Might need assistance (children, elderly, disabled people) - Can be of any age range, from baby/children to very elderly - Can have any kind of physical or sensorial impairment - Is free to arrange/rearrange the travel according to the preferences - Is sensitive to environmental footprint of his/her journey - Has no communication limitations (due to good education and/or technology support)	- Could use sharing transport means with personal accounts (car/bike sharing, Uber, etc.) - Will use any transport mean (as any mean will be fully accessible)

5.3 Transport modes specification

5.3.1 Baseline scenario 2025

Mobility strategy and policy. The trend of convincing people to use collective modes of transport instead of private cars by application of complex metropolitan-wide range solutions increasing their relative attractiveness. (i.e. closing city centers for non-electric cars, decreasing the travel speed in urban area, but also modernisation of mass transport) will be present. Despite the echo of Covid-19 pandemic commercial air transport connections will be available on considered regional range but only on the most crowded destinations. Mostly touristic traffic/charters oriented. In addition there will be also locally available connections executed by small aircraft in scheduled way (between islands or to remote sparsely populated destinations). New Mobility Services (NMS) i.e. car-sharing, ride-hailing, bike-sharing, e-scooters will be gaining users' interests earning significant share in transport work. Resulted assumptions for use cases:

- the only air mode of transport with potential to impact efficiency of transport system by data sharing is mentioned short range airlines connections. Connecting a hub airport with regional one or two regional airports (point-to point connections executed by LCC airlines);
- hub airport is connected with the city by numerous modes (trains, bus connections, taxi, etc.). From the hub airport there is no direct access to e-bikes, e-scooters sharing system. Also getting car-sharing services requires longer trips to walk (due to pressure on cost, contrary to the rental cars);
- regional airports provide access to one or maximum two public transport services (train, bus). It is easier than in hub airport to rent a car or use NMS services including e-bikes or e-scooters (depending on location of airport).

Further detailing of travel with regards to use of particular modes and its specification should be based on traveller profile and best answer his requirements/needs/priorities specified in previous section (5.2).

5.3.2 Intermediate scenario 2035

Further concentration of people in urban areas - Megacities will emerge. Together with progress in the process of circular economy paradigm implementation in EU will result with bigger, more complex transport system which will be more sustainable as well. More people will walk, use bicycles, (and other compact-size means of personal transportation like e-scooters), buses and trains. Traffic by cars will be inhibited by introduction of car-free zones in many cities. Due to technology development more users' focus will be on personal needs as well as impact on environment. Resulted assumptions for Use cases:

- several percentages of cars available on roads will be electric. Driving performances will by highly automated. In urban areas car sharing model will be dominating. In densely populated areas – city centres, where car traffic will be forbidden or limited, (electric) micromobility means of transport will have significant share (beside public mass means of transport);
- public means of transport network will be significantly extended to answer increased demand offering higher level of accessibility for citizens and reducing the length of first and last legs of multimodal travel;
- short range airlines connections will remain the air mode of transport with highest potential to impact efficiency of transport system by data sharing. Connecting a hub airport with regional one or two regional airports (point-to-point connections);
- Urban Air Mobility (UAM) for passenger transport in experimental sites will be available in Europe but without significant impact on mobility in metropolitan areas;
- hub airport is connected with the city by numerous modes (dominating is collective transport means - train, bus connections,). Electric Taxis is partially replaced by electric car-sharing, more popular than in 2025 and easier accessed from the airport terminal (replaced "traditional" rental cars). From the hub airport there is no direct access to e-bikes, e-scooters sharing system due to remote location of the hub airport with relation to the city;
- regional airports provide access to more than one public transport services (train, bus). Electric shared cars or NMS services including e-bikes or e-scooters are commonly used as airport cities develops (depending on location and size of the airport);
- further detailing of travel with regards to use of particular modes and its specification should be based on traveller profile and best answer his requirements/needs/priorities specified in previous section (5.2).

5.3.3 Final scenario 2050

Megacities enhanced by Artificial Intelligence & automation will become 'smart' and they will the core of global economy. They will deeply cooperate and coordinate using the algorithmic governance. As the dominating part of the energy consumed in the EU will originate from renewable sources and EU transport will reach net-zero emissions level. A policy of walkable cities will cause domination of soft modes, mass transit, NMS and, most likely, UAM. Intercity traffic will be supplied by high-speed rail transport, CCAM (connected, cooperative, automated mobility) and zero-emission large aircraft. This final scenario expects full satisfaction of the "extreme" travellers' needs. This will be achieved by the Inclusive Design paradigm addressing artificial or natural limits of human senses like touch, see, hear, and/or speak. Assumptions for use cases:

- all cars approved on roads will be electric and in most highly automated and autonomous. In urban areas car sharing model will be dominating. In densely populated areas – city centres, car traffic will be forbidden, (electric) micromobility (soft) means of transport will be the only personal means of transport having significant share (beside public mass means of transport);
- public means of transport network will reach maximum available density to answer increased demand offering highest possible level of accessibility for citizens and reducing the length of first and last legs of multimodal travel;
- short range airlines connections operated by zero emission aircraft will remain the air mode of transport with highest potential to impact efficiency of transport system by data sharing. Connecting a hub airport with regional one or two regional airports (point-to-point connections);
- Urban Air Mobility (UAM) dedicated to passenger transport will be available in Europe offering direct access to densely populated city areas. Regional range air travels will be also possible with use of both new concept aircraft, VTOL, multirotor and fixed wing aircraft depending on appropriate infrastructure availability. Due to relatively high cost of operation passenger UAM will be mainly in the area of interest of high-income and high value-of-time passengers and will be operating between airport and business centres and of course public services (like HEMS, police, etc.). UAM will not gain significant impact on mobility in metropolitan areas but will be considered as important and often necessary from social interest point of view;
- hub airport is connected with the city by numerous collective, autonomous transport modes. Complemented by electric (autonomous) car-sharing services. From the hub airport there is no direct access to e-bikes, e-scooters sharing system due to remote location of the hub airport with relation to the city;
- regional airports provide access to more than one collective autonomous transport services (train, bus). Electric shared cars or NMS services including e-bikes or e-scooters are commonly used as airport cities develops (depending on location and size of the airport);
- in case of favourable conditions – large water reservoir dividing metropolitan areas, multimodal journey can be supported by autonomous ferry services;
- further detailing of travel with regards to use of particular modes and its specification should be based on traveller profile and best answer his requirements/needs/priorities specified in previous section (5.2).

5.4 Transport system integration and resilience to disruptions

5.4.1 Baseline scenario 2025

As there is no dynamic interaction among transport modes, yet. Privately generated data is not available for public use modes are optimized mainly internally. There are available mobile applications collecting traffic information from various operators and providing users with optimal routes. Assumptions:

- multimodal journey if taken for the first time has to be planned in advance (it allows for significant travel time reduction). Especially if it starts or end in peri-urban locations or off the peak of traffic. It can be done with use of online services provided by i.e. Google;
- there is common access to services enabling reduction of time spent on change nodes (ability to buy ticket online in advance, proceed check-in at least the day before flight, remote ticket validation systems);
- time spent for waiting during multimodal journey is significant. In case of regional airport it is related mainly to waiting for connection from the airport to the city (usually several minutes). Assuming that passenger has to be on gate at least 30 minutes before take-of, time needed for reaching gate after leaving train or taxi in hub airport is about 25 minutes and 15 in case of regional airport;
- disruptions. Three types of occurrence can result with disruptions: Technical failures or bus/train driver or infrastructure operators' errors (internal reasons), accidents concerning mode interaction with other modes (i.e. in rail-road crossing, hitting a pedestrian) and third one: extreme causes (e.g. terrorist attacks). Despite the reason of disruption passenger has to manage it by yourself if it affects air-surface modes or different operators' interaction (wit use of the same tools as during travel planning). Information about disruption is available to the traveller shortly before start of journey at the earliest. Probability of internal reason and accident is comparable and much more likely than terrorist attack. Time necessary for full recovery after disruption other than terrorist attack can be assumed as equal to at least one hour depending on circumstances.

5.4.2 Intermediate scenarios 2035

The ATM will reach high level of automation. Unmanned Airborne Systems (UAS) will be certified for all classes of airspace, airports will be integrated with UAS. Multimodal cargo transport with use of unmanned aircraft will be present in urban environment paving the way for passenger transportation. As the digitalisation of transport modes will be progressing and privately generated data will be available for service providers daily demand forecasts will become possible making transport system more efficient and sustainable. Data generated and processed by ATM related to passenger air transport will be crucial component for demand forecast on routes containing air transport. Assumptions:

- exchange of information between ATM and surface modes together with access and communication with user's portable device allows for providing traveller with all data concerning his/her multimodal journey in advance (at least a day before the day of journey). Increased reliability of transport will allow for less care needed for alternative connections considerations (in case of disruption). Traveller will he offered with possibility to purchase one single ticket for entire journey with access rights to particular change nodes. Not completed digitalisation of transport systems in 2035 will prevents including all modes of transport in this solution;
- traveller will have possibility to modify his/her journey a day before travel (select other modes according to his preferences). Submission of preferences will include check-in before flight. Check-in will be also possible by activation of journey by its initialisation (check-in in first node). In addition smart pricing, due to regulatory pressure, will favour lower emission modes. Not completed digitalisation of transport systems in 2035 will prevents including all modes of transport in this solution;

- time spent on changing nodes will be slightly reduced especially off the traffic peak. Part of the potential efficiency increased in result of modes integration will be consumed by decreased resource utilisation (sustainability increase and savings on the side of operator turning into lower cost of transport);
- disruptions resulted with internal reason like failure or accidents originated outside the system will be less frequent and the time for recovery will be reduced thank to using of resources of other integrated modes not affected by disruption. For the modes integrated with ATM (often the preferred one – collective means of transport) information about disruption (e.g. delay) will be available for the traveller in very short time and if necessary, the traveller will be provided with available alternatives allowing traveller to react in time (in respect to his requirements e.g. related with disabilities). In case of lack of alternative (integrated) the traveller will have to manage disruption by his/herself with use of traditional mobile application providing data gathered from transport operators (more common on peri-urban locations). If disruption endanger timely aircraft departure, the traveller will be offered with use of taxi (perhaps co-funded by operator). Such interaction of passenger with the system will require having portable device with appropriate software installed.

5.4.3 Final scenario – 2050

Completed digitalisation of transport system enable to manage it on the level of systems of systems. ICT development will enable in turn full transport autonomation and will create possibility for much deeper integration connected with higher systems' flexibility.

- exchange of information between ATM and surface modes together with access and communication with user's portable device allows for providing traveller with all data concerning his/her multimodal journey in advance and update it even every hour till start of journey. Management on the level of system of system enabled by completed digitalisation will result with Increased reliability of transport and will allow for providing traveller with alternative connections in case of disruption. Traveller will be offered with possibility to purchase one single ticket for entire journey with access rights to particular change nodes. The offer will be designed on base of smart pricing favouring preferred/prioritised modes of transport (with regards to applied policy like carbon footprint or emissions, sustainability level). Solutions will cover all or almost all publicly available means of transport;
- traveller will have possibility to modify his/her journey even in a day of journey (select other modes according to his preferences). Submission of preferences will include check-in before flight. Check-in will be also possible by activation of journey by its initialisation (check-in in first transport node);
- time spent on changing nodes will be reduced thank to total system approach applied (System of Systems management). Some part of the potential efficiency increased resulted with integration will be consumed by decreased resource utilisation (sustainability increase and savings on the side of operator turning into lower cost of transport);
- completed digitalisation will allow traveller to make transport mode more fitted to his individual preferences/needs;

- disruptions resulted with internal reason like failure or accidents originated outside the system will be very rare and the time for recovery will extremely short due to using immediate activation of resources of other modes of transport. Completed autonomation will eliminate human drivers' limitations significantly inhibiting such actions. In case of disruption information about it (e.g. delay) will be available immediately and if it is necessary the traveller will be provided with required actions on his side. In case of lack of preferred alternative connection the traveller will be offered with use of taxi (perhaps co-funded by operator). Such interaction of passenger with the system will require having portable device with appropriate software installed.

5.5 Use case formulation

In the following, the use cases will be defined. They are based on two profiles of travellers that have distinctive characteristics and occurrences in travel. The business traveller and the visiting friends and relatives traveller (VFT).

For each traveller, a use case scenario is defined below, which is to be considered over the time horizons 2025, 2035 and 2050. In addition, disruptions and delays in the travel process are to be considered. The "disruptions" information should be available to the traveller at two different occasions: On the one hand side, the information is already available at least five hours before departure, and in the other hand, they occur during the journey. The use cases are described below only for the outward journey; the return journey is, so to speak, only the reverse image.

In the following, disruptions are considered to be: Technical failures or bus/train driver or infrastructure operators' errors (internal reasons), accidents concerning mode interaction with other modes (i.e., in rail-road crossing, hitting a pedestrian) and heavy weather conditions, blackouts and terrorist attacks. Probability of internal reason and accident is comparable and much more likely than heavy weather conditions, blackouts and terrorist attack. Time necessary for full recovery after disruption depending on circumstances. This leads to the following 18 use cases, which are shown in overview in Table 30 and are explained in detail in the following.

Table 29 – Overview of the use cases within the time horizons

Time horizon	2025		2035		2050	
	Traveller		Traveller		Traveller	
Disturbance	Profile B	Profile V	Profile B	Profile V	Profile B	Profile V
no disturbance	B025	V025	B035	V035	B050	V050
5h prior to departure	B525	V525	B535	V535	B550	V550
ad hoc disturbance	Bd25	Vd25	Bd35	Vd35	Bd50	Vd50

B: Business traveller   V: VFR - Visiting friends and relatives traveller

For the "Business Traveller", the following should apply to the use cases:

A business traveller making a one-day trip from an origin area with a regional airport to a destination area with a hub airport.

- Use Cases involve both, a hub airport and a regional airport
- importance to get to the meeting on time without delay
- value, but not always the lowest price: Usually spend more on their travels then others –Need space and privacy
- being busy, and often time poor means that business travellers appreciate convenience
- Business Traveller is advised by the company policy to use a public mode of transport (but then allowed to use first class)
- travellers start their journey around 7AM
- travellers will always try to use the most appropriate travel option

The following applies to the use cases "Visiting friends and relatives traveller":

A traveller categorized as a VFT is an immigrant, ethnically and racially distinct from the majority population of the country of residence (a higher-income country), who returns to his or her home country (lower-income country) to visit friends or relatives. Included in the VFT category are family members, such as the spouse or children, who were born in the country of residence.

Use cases for this group of VFTs include two adults (one of whom is a senior) and a minor child with baggage visiting friends and relatives for a long weekend on the occasion of a family event (e.g. wedding).

- Use Case involves a hub airport and a regional airport
- VFT are price sensitive, but need to be in time for a family event (e.g. wedding): very time inflexible.
- travellers know the area and transport system at destination very well
- travellers could start their journey even early and late at night (arrival should be more in the morning than in the middle of the night)
- travellers will always try to use the most appropriate travel option
- travellers are challenged in their choice of transport due to their possible impairments or the accompanied minor child
- it's a long-distance travel and the flight is minimum 4h
- the trip planning includes a buffer of 1h to 2h at beginning of the journey to reach the airport in time and at least 1 to 2 days before the event (e.g. wedding) for unexpected complications during the journey

5.5.1 Use Cases in 2025

First, the use cases for the scenario in the 2025-time horizon are defined. The following trends, needs and policies from the table below will be the basis for these.

Table 30 – Trends, needs and policies for the time horizon 2025

Scenario	Global and regional economic trends	Future Passenger needs (demography)	European Commission Policy		
			Sustainable Transport	UAM (ATM integration)	Smart city (IoT)
2025	global differences surge covid-19 tamed, slow recovery, China and USA (the West) cold war, separate global digital spaces, shortening of supply chains, low interest rates, high debt, low trust, risk aversion, low oil prices, **regional**: EU push decarbonization, end of fossil fuels subsidies, European Geostationary Navigation Overlay Service (EGNOS) 2nd generation	"classic needs" derived from travel time, travel cost, mode access time, commute distance and needs derived from travelers' social status (income, gender, age, household composition, car ownership and education level)	emerging of NMS (New Mobility Services), further development of TEN-T (mainly rail and maritime), shift to rail and maritime logistics, million public recharging and refueling stations, Euro vignette	initial U-Space services airspace reconfiguration, capacity on demand service, enabling framework for data service providers (ADSP), first ADSP certified, advance network operations and services, simulators, specification for ATM Validation Platforms, first harmonized standards for UAS, first certified UAS in controlled airspace	no dynamic interaction among modes hardly any privately generated data available for public use, modes optimized internally, tools applications collecting some information from operators

The figure below illustrates the selection of possible modes of transport in the "Use Cases" Business and VFT travellers in the time horizon 2025.

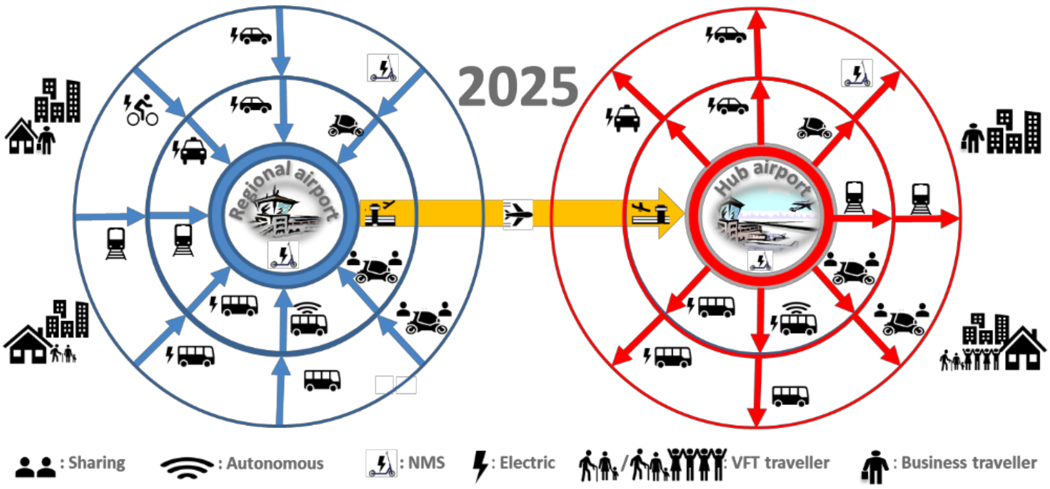


Figure 17 – Options for Business and VFT traveller for a journey include air transport in the time horizon 2025

5.5.1.1 Business traveller in 2025

A business traveller making a one-day trip from an origin area with a regional airport to a destination area with a hub airport.

Handicaps in 2025

- time spent for waiting during multimodal journey is significant;
- the more means of transport have to be changed, the more the waiting time increases and thus the travel time;
- despite the reason of disruption passenger has to manage it by them self if it affects air-surface modes or different operators' interaction (with use of the same tools as during travel planning). Information about disruption is available to the traveller shortly before start of journey at the earliest;
- in case of regional airport, it is related mainly to waiting for connection from the airport to the city (usually several minutes). Assuming that passenger has to be on gate at least 30 minutes before take-of, time needed for reaching gate after leaving train or taxi in hub airport is about 25 minutes and 15 in case of regional airport.

B025 no disturbance

- traveller starts at home: Multimodal journey - if taken for the first time - has to be planned in advance and to be managed by the traveller himself/herself. Planning can be done with use of online services provided. Online: Ability to buy tickets in advance, proceed check-in at least the day before flight, remote ticket validation systems. Flight is booked via Travel agency, app or internet in advance;
- using the combination bus and train to the regional airport, because change from one mode to the other is comfortable (ticket purchased online via mobile app/online);
- arrival at the airport (no registered luggage, passenger checked online the day before): He/ She need to walk to the gate. Time spent for waiting during multimodal journey is significant: e.g. passenger has to be on gate at least 30 minutes before take-of, time needed for reaching gate in hub airport is about 25 minutes and 15 in case of regional airport;
- flight (with an aircraft; digital ticket purchased online);
- arrival at hub airport: There is no direct access to e-bikes, e-scooters sharing system. Also getting car-sharing or rental cars services requires longer walk distance;
- traveller takes rental car from airport to business address;
- traveller arrives at business address.

B525 disturbance 5h prior to departure

A business traveller making a one-day trip from an origin area with a regional airport to a destination area with a hub airport. There is a disturbance **information** before the start of the planned trip.

- **traveller starts at home: He/she finds out about the delay** of his train via e-mail/app information service before leaving his/her home (Disruption: Technical failures on the train track). The traveller has to manage the new planning of his journey by himself/herself;
- the traveller can order via app an e-taxi or use car sharing to catch up his former plan to reach the airport and the flight in time (Assistance of the travel agency of his company could help to change the booking of his flight);

- **traveller is walking to a car-sharing depot** and using an autonomous car to airport (the single ticket purchased in advance is still valid);
- **business traveller arrives at the regional airport** and leave the car in the car-sharing parking slot;
- **he/she uses New Mobility Services** (e.g. e-scooters) at the airport parking to reach his/her terminal in time;
- **flight** (with an aircraft; digital ticket purchased online);
- arrival at hub airport: There is no direct access to e-bikes and e-scooters sharing system. Also getting car-sharing or rental cars services requires longer walk distance;
- **traveller takes rental car** from airport to business address;
- **traveller arrives at business address.**

Bd25 disturbance ad hoc

A business traveller making a one-day trip from an origin area with a regional airport to a destination area with a hub airport. During the trip, a disruption occurs in a mode of transport.

- **the business traveller starts at home** (digital ticket purchased via Travel agency, app or internet in advance);
- he/she is using **the bus to the train station** (digital group ticket purchased);
- **the traveller arrives at train station.** After a while the traveller receives the information of a **disruption**: technical failures on the track (Train is late/canceled). The traveller has to manage the new planning of his journey by himself/herself via portable devise (smartphone);
- **there are following options:**
  1. Calling a taxi via telephone or app to reach the regular flight and/or
  2. Change the flight: Getting assistance by the travel agency of travellers company via phone or change the booking directly via airline app or online; Using option one to stay still with is previous planning to reach the flight;
- **taking a taxi to the regional airport** (using app to call and pay the ride);
- **arrival at the airport** (no registered luggage, passenger checked in during the morning); Using a fast track through security) to catch up delay (if available and possible: Traveller need persuade the security staff to use the fast track): Miss the flight and need to use Option 2: Change the flight: Getting assistance by the travel agency of travellers company via phone or change the booking directly via airline app or online;
- **flight** (digital ticket purchased via Travel agency, app or internet);
- **arrival at hub airport**: The traveller takes an e-taxi (airport taxi stand) directly to the business address to make up time and saves the long walk at the HUB airport to the car sharing and rental car park (during the taxi trip the traveller cancels the car sharing/Rental car booking);
- **traveller arrives at business address.**

5.5.1.2 Visiting friends and relatives traveller in 2025

Use cases for this group of VFT s include two adults (one of whom is a senior) and a minor child with baggage visiting friends and relatives for a long weekend on the occasion of a family event (e.g. wedding).

Handicaps in 2025

- time spent for waiting during multimodal journey is significant;
- the trip is planed within a buffer of 1 to 2h at beginning of the journey to reach the airport in time and at least 1 to 2 days before the event (e.g. wedding) for unexpected complications;
- travellers could start their journey even early and late at night (arrival should be more in the morning than in the middle of the night);
- the more means of transport have to be changed, the more the waiting time increases and thus the travel time;
- in case of regional airport, it is related mainly to waiting for connection from the airport to the city (usually several minutes). Assuming that passenger has to be on gate at least 30 minutes before take-of, time needed for reaching gate after leaving train or taxi in hub airport is about 25 minutes and 15 in case of regional airport. For the group of VFTs include two adults and a minor child it will take longer;
- despite the reason of disruption passenger has to manage it by them self if it affects air-surface modes or different operators' interaction (with use of the same tools as during travel planning). Information about disruption is available to the traveller shortly before start of journey at the earliest;
- VFT need to be in time for a family event (e.g. wedding): very time inflexible;
- travellers will always try to use the most appropriate travel option;
- travellers are challenged in their choice of transport due to their possible impairments or the accompanied minor child;
- it's a long-distance travel and the flight is minimum 4 h;
- for disabled passengers and passengers with reduced mobility (PRM) the airport operator is responsible to provide assistance to these passengers to be able to get into and off the aircraft (Regulation (EC) No. 1107/2006 EU).

V025 no disturbance

Use cases for this group of VFTs include two adults (one of whom is a senior) and a minor child with baggage visiting friends and relatives for a long weekend on the occasion of a family event (e.g. wedding).

- **travellers start at home**: Multimodal journey has to be planned in advance and to be managed by the travellers themselves. The trip will to be planed within a buffer of 1 to 2h at beginning of the journey to reach the airport in time and at least 1 to 2 days before the event (e.g. wedding) for unexpected complications;
- planning can be done with use of online services provided. Ability to buy tickets in advance, proceed check-in at least the day before flight, remote ticket validation systems. Flight is booked via Travel agency, app or internet in advance;
- **using the combination of busses/trains to reach the regional airport**, because change from one mode to the other is comfortable (digital group ticket purchased);
- **arrival at the airport** (registered luggage, passenger checked online the day before): They have to go to check-in with their luggage and then through security and to the gate. Time spent for waiting during multimodal journey is significant: The group have to be on gate at least 30 minutes before take-of, time

needed for reaching gate in hub airport is about 25 minutes and 15 in case of regional airport and takes even longer with minors;
- **flight** (with an aircraft; digital group ticket purchased);
- **arrival at hub airport**: They need to walk through customs to the airport train or bus terminal;
- **using the combination busses/trains of the public service**, because change from one mode to the other is comfortable (ticket purchased online via mobile app/online);
- **travellers reach the accommodation.**

V525 disturbance 5h prior to departure

Use cases for this group of VFTs include two adults (one of whom is a senior) and a minor child with baggage visiting friends and relatives for a long weekend on the occasion of a family event (e.g. wedding). There is a disturbance information before the start of the planned trip.

- **travellers is at home**: Multimodal journey has to be planned in advance and to be managed by the travellers themselves. The trip will be planed within a buffer of 1 to 2h at beginning of the journey to reach the airport in time and at least 1 to 2 days before the event (e.g. wedding) for unexpected complications;
- planning can be done with use of online services provided. Online: Ability to buy tickets in advance, proceed check-in at least the day before flight, remote ticket validation systems. Flight is booked via Travel agency, app or internet in advance;
- **the travellers find out about the delay/cancellation** of planned train via e-mail/app information service before leaving his/her home (Disruption: Technical failures on the train track). The travellers have to manage the new planning of their journey by themselves;
- the travellers using a **different combination of busses and trains** to the regional airport (with longer travelling time), but they reach the airport and the flight in time, because they were 1-2 hours early. Eventually they need to purchase a new ticket for this routing, because it's not the direct way to the airport (digital group ticket purchased);
- **arrival at the airport** (registered luggage, passenger checked online the day before): They have to go to check-in with their luggage and then through security to the gate. Time spent for waiting during multimodal journey is significant: The group have to be on gate at least 30 minutes before take-of, time needed for reaching gate in hub airport is about 25 minutes and 15 in case of regional airport and takes even longer with minors;
- **flight** (with an aircraft; digital group ticket purchased);
- **arrival at hub airport**: They need to walk through customs to the airport train or bus terminal;
- **using combination of busses and trains** (group ticket purchased online via mobile app/online);
- **travellers reach the accommodation.**

Vd25 disturbance ad hoc

Use cases for this group of VFTs include two adults (one of whom is a senior) and a minor child with baggage visiting friends and relatives for a long weekend on the occasion of a family event (e.g. wedding). During the trip, a disruption occurs in a mode of transport.

- **travellers start at home**: Multimodal journey has to be planned in advance and to be managed by the travellers themselves. The trip will to be planed within a buffer of 1 to 2h at beginning of the journey to reach the airport in time and at least 1 to 2 days before the event (e.g. wedding) for unexpected complications;

- planning can be done with use of online services provided. Online: Ability to buy tickets in advance, proceed check-in at least the day before flight, remote ticket validation systems. Flight is booked via Travel agency, app or internet in advance: They want to use a combination of public busses/trains to reach the regional airport, because change from one mode to the other is comfortable (ticket purchased online via mobile app/online);
- **they use the bus to the train station** (digital group ticket purchased);
- **when they arrive the train statio**n there is a disturbance information for a train on the planned journey **(Disruption: Technical failures on the train track)**. The travellers have to manage re- planning of their journey by themselves;
- the travellers **using a different combination of busses and trains to the regional airport (with extended travelling time)**. Eventually they need to purchase a new ticket (or upgrade to the old ticket) for this routing, because it's not the direct way to the airport (online via mobile app/online);
- during this new routing the travellers **calling the airport in Advance: For disabled passengers and passengers with reduced mobility (PRM)** the airport operator is responsible to provide assistance to these passengers to be able to get into and off the aircraft (Regulation (EC) No. 1107/2006 EU);
- **arrival at the regional airport is much later** than expected (registered luggage, passenger checked online the day before): They walk to the check-in and got from there a with an electric cart with driver for PRM by the airport operator and got a quick and safe transfer through security to their gate;
- **flight** (with an aircraft; tickets purchased in advance online);
- **arrival at hub airport**: They are walk through customs to the airport train or bus terminal (or got another ride with an electric cart for PRM by the airport operator through customs, baggage claim to the airport train/bus station);
- **using the combination busses/trains of the public service** (ticket purchased online via mobile app/online);
- **travellers reach the accommodation.**

5.5.2 Use Cases in 2035

Next, the use cases for the scenario in the 2035-time horizon are described. The following use cases are based on the trends, needs and policies in the table below.

Table 31 – Trends, needs and policies for the time horizon 2035

Scenario	Global and regional economic trends	Future Passenger needs (demography)	European Commission Policy		
			Sustainable Transport	UAM (ATM integration)	Smart city (IoT)
2035	global tensions ease China, India and the West normalization, megacities, progress in healthcare and agriculture, reconversion of assembly lines, the 4th industrial revolution, "non-productive" citizens, slums, global fundamentalists, terrorism, **regional**: emerging of circular economy in EU	needs of elderly passengers population peak, longevity increase, more personal perceptions of value of time savings, data security and ethical (Orwellian) concerns, safety concerns, affinity to automation, to online services, to green awareness, to social media, to sharing, willingness to share	emerging of UAM (Urban Air Mobility), the Core TEN-T Network completed, smart pricing, shift to lower emission modes, intensifying intermodality among soft modes of travel, mass transit, NMS	high level of automation U-space testing, advance U-Space services, new ATM data service provision model, virtual centers, dynamic airspace configuration, certified UAS integrated in all classes of airspace, airport integrated with UAS and into ATM network	partial digitization of transport data and digitalization of business models, privately generated data becomes available, possibility to generate daily demand forecasts, tools – applications collecting more information from operators

Figure 19 illustrates the selection of possible modes of transport in the "Use Cases" business and VFT travellers in the time horizon 2035.

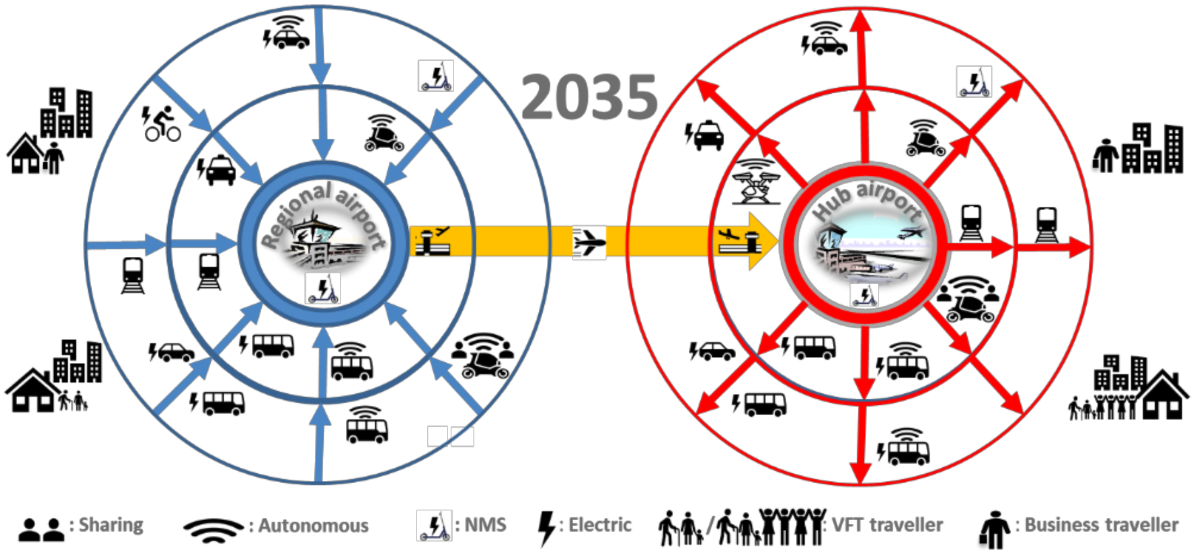


Figure 18 – Options for Business and VFT traveller for a journey include air transport in the time horizon 2035

5.5.2.1 Business traveller in 2035

A business traveller making a one-day trip from an origin area with a regional airport to a destination area with a hub airport.

B035 no disturbance

- **traveller starts at home:** Exchange of information between ATM and surface modes together with access and communication with user's portable device allows for providing traveller with all data concerning his/her multimodal journey in advance (at least a day before the day of journey). The traveller will be provided with available alternatives allowing traveller to react in time (in respect to his requirements e.g., related with disabilities). Privately generated data will be available for service providers daily demand forecasts will become possible making transport system more efficient and sustainable;
- Traveller got the possibility to modify his/her journey a day before travel (select other modes according to his preferences). Traveller will be offered to purchase one single ticket for entire journey with access rights to particular change nodes. Check-in is done automatically at the start of the journey (check-in at the first hub of the journey). Due to technology development more users' focus will be on personal needs as well as impact on environment;
- **walking to a e-scooter/e-bike sharing depot and using a e-scooter to e-VTOL platform** (covered by the single ticket (devices) for the journey: Not completed digitalization of transport systems will prevents including all modes of transport in this solution);
- **taking e-VTOL flight to the regional airport** (single ticket online using mobile app). Not completed digitalization of transport systems will prevents including all modes of transport in this solution;

- **arrival at the regional airport** (no registered luggage, passenger checked in automatically in the first node). **Using a e-scooter:** Time spent reach the gate will be slightly reduced;
- **flight by a short-range aircraft;**
- **arrival at hub airport**: There is no direct access to e-bikes, e-scooters sharing system. Electric Taxis is partially replaced by electric car-sharing and easier accessed from the airport terminal;
- **traveller takes electric car-sharing** from airport to business address (include in the single ticket book in advance);
- **traveller arrives at business address.**

B535 disturbance 5h prior to departure
A business traveller making a one-day trip from an origin area with a regional airport to a destination area with a hub airport. There is a disturbance before starting the planned trip.

- **traveller starts at home:** Traveller modified his/her journey a day before travel (select other modes according to his preferences). Traveller purchased one single ticket for entire journey with access rights to particular change nodes. Increased reliability of transport will allow for less care needed for alternative connections considerations (in case of **disruption**). Disruptions will be less frequent and the time for recovery will be reduced thank to using of resources of other integrated modes not affected by disruption. Privately generated data will be available for service providers daily demand forecasts will become possible making transport system more efficient and sustainable;
- ATM Information of disturbance (e.g. harsh weather conditions) of the planned e-VTOL flight is available for the traveller before his/her starts the journey. The traveller is provided with available alternatives modes (e.g. e-taxi, e-car-sharing and train) by an upcoming disruption allowing traveller to react in time (in respect to his requirements e.g., related with disabilities). In case of lack of alternative) the traveller will have to manage disruption completely by his/herself with use of a mobile application providing data gathered from transport operators (more common on peri-urban locations);
- the weather conditions interacting the other planned traffic modes, too: Rebooking the planned e-scooter/e-bike ride to autonomous e-car drive with a car-sharing;
- **traveller is walking to a car-sharing depot** and using a car to train station (the single ticket purchased in advance is still valid), Leaving car at the car sharing parking;
- **using train to airport;**
- **arrival at the airport** (no registered luggage, passenger checked in automatically in the first node). Time spent on changing nodes will be slightly reduced especially off the traffic peak;
- **flight by a short-range aircraft** (included in purchased single ticket in his/her device).
- **arrival at hub airport**: There is no direct access to e-bikes, e-scooters sharing system. Electric Taxis is partially replaced by electric car-sharing and easier accessed from the airport terminal (replaced “traditional” rental cars);
- **traveller takes electric car-sharing** from airport to business address (include in the single ticket book in advance);
- **traveller arrives at business address.**

Bd35 disturbance ad hoc
A business traveller making a one-day trip from an origin area with a regional airport to a destination area with a hub airport. During the journey, a disruption occurs in a mode of transport.

- traveller modified his/her journey a day before travel (select other modes according to his preferences). Traveller purchased one single ticket for entire journey with access rights to particular change nodes. The planned modes are integrated with ATM: Information about disruptions (e.g. delay) will be available for the traveller in very short time and if necessary, the traveller will be provided with available alternatives (in respect to his requirements e.g. related with disabilities). This allows the traveller to react in time. In case of lack of alternatives, the traveller will have to manage disruption by his/herself with use of traditional mobile application providing data gathered from transport operators (more common on peri-urban locations). Privately generated data will be available for service providers daily demand forecasts will become possible making transport system more efficient and sustainable. Due to technology development more users' focus will be on personal needs as well as impact on environment;
- **traveller starts at home:** Walking to a e-scooter/e-bike sharing depot and using a e-scooter to e-VTOL platform (buying the single ticket via devices in advance). There is an ATM Information of disturbance of the planned e-VTOL flight (e.g. delay because of harsh weather conditions). The disruption endangers the timely departure of the aircraft, the passenger is offered the use of a taxi (co-financed by the operator);
- **traveller is picked up by e-taxi** and brought to the airport;
- **arrival at the airport**; Check-in is done automatically at the start of the journey (check-in at the first hub of the journey). The traveller is guided to a fast track trough security to catch his/her regular flight in time (no registered luggage);
- **flight by a short-range aircraft** (included in purchased single ticket in his/her device);
- **arrival at hub hirport**: There is no direct access to e-bikes, e-scooters sharing system. Electric Taxis is partially replaced by electric car-sharing and easier accessed from the airport terminal (replaced "traditional" rental cars);
- **traveller takes electric car-sharing** from hub airport to business address (include in the single ticket book in advance);
- **traveller arrives at business address.**

5.5.2.2 Visiting friends and relatives traveller in 2035

Use cases for this group of VFTs include two adults (one of whom is a senior) and a minor child with baggage visiting friends and relatives for a long weekend on the occasion of a family event (e.g. wedding).

V035 no disturbance

- travellers got the possibility to modify their journey a day before travel (select other modes according to his preferences). Travellers will be offered to purchase a group ticket for entire journey with access rights to particular change nodes. Due to technology development more users' focus will be on personal needs as well as impact on environment. Check-in is done automatically at the start of the journey (check-in at the first hub of the journey);
- the exchange of information between ATM and surface modes together with access and communication with user's portable device allows for providing travellers with all data concerning their multimodal journey in advance. The travellers will be provided with available alternatives allowing traveller to react in time (in respect to his requirements e.g., related with disabilities). Privately generated data will be available for service providers daily demand forecasts will become possible making transport system more efficient and sustainable. This development means for planning that in case of unexpected complications, no buffer is needed at the beginning of the journey to reach the airport in time;
- **traveller starts at home:** VFT traveller group use **various combinations of public transport according to their preference to reach the regional airport** (digital group ticket purchased). Time spent on changing nodes will be slightly reduced because of exchange of information between ATM and surface modes;
- **arrival at the airport** (registered luggage, check-in at the first hub of the journey): VFT travel group with senior is automatically picked up at the train/bus terminal by the airport operator (PRM) with an **autonomous electric cart**. They will be taken to the check-in to check in their luggage. Then they will be brought trough security to their gate. Time spent for waiting will be slightly reduced. The time needed for reaching gate in regional airport will be less than 5 minutes;
- **flight** (with a short-range aircraft);
- **arrival at hub airport**: They got another ride with an autonomous electric cart for PRM by the airport operator through customs and baggage claims to the airport train/bus station);
- **using various combinations of public transport according to their preference** (group ticket purchased online via mobile app/online);
- **travellers reach the accommodation.**

V535 disturbance 5h prior to departure

Use cases for this group of VFTs include two adults (one of whom is a senior) and a minor child with baggage visiting friends and relatives for a long weekend on the occasion of a family event (e.g. wedding). There is a disturbance before starting the planned trip.

- travellers got the possibility to modify their journey a day before travel (select other modes according to their preferences). Travellers will purchase a group ticket for entire journey with access rights to particular change nodes. Due to technology development more users' focus will be on personal needs as well as impact on environment. Check-in is done automatically at the start of the journey (check-in at the first hub of the journey);
- the exchange of information between ATM and surface modes together with access and communication with user's portable device allows for providing travellers with all data concerning their multimodal journey in advance. The travellers will be provided with available alternatives allowing traveller to react

in time (in respect to his requirements e.g. related with disabilities). Privately generated data will be available for service providers daily demand forecasts will become possible making transport system more efficient and sustainable. This development means no buffer is needed at the beginning of the journey to reach the airport in time;

- **traveller is still at home:** ATM Information of disturbance **(e.g. harsh weather conditions)** of flights and train connections to airport is available for the travellers before their journey starts. Travellers is provided with available alternatives modes (e.g. e-taxi, e-car-sharing) by an upcoming disruption allowing traveller to react in time (in respect to his requirements e.g., related with disabilities). In case of lack of alternative travellers will have to manage disruptions completely by themselves with use of a mobile application providing data gathered from transport operators (more common on peri-urban locations);
- **travellers order an autonomous transport by car-sharing via internet** and using the car to regional airport (Group card purchased in advance for public service will be credited);
- **arrival at the airport** (registered luggage, check-in at the first hub of the journey): Leaving car at the car sharing parking. VFT travel group with senior is automatically picked up at the car sharing parking next to their car by the airport operator (PRM) with an **autonomous electric cart**. They will be taken to the check-in to check in their luggage. Then they will be brought trough security to their gate. Time spent for waiting will be slightly reduced. The time needed for reaching gate in regional airport will be less than 5 minutes;
- **flight** (with a short-range aircraft);
- **arrival at hub airport**: They got another ride with an autonomous electric cart for PRM by the airport operator through customs (and baggage claims) to the airport public transport station;
- **using various combinations of public transport according to their preference** (group ticket purchased online via mobile app/online);
- **travellers reach the accommodation.**

Vd35 disturbance ad hoc

Use cases for this group of VFTs include two adults (one of whom is a senior) and a minor child with baggage visiting friends and relatives for a long weekend on the occasion of a family event (e.g. wedding). During the trip, a disruption occurs in a mode of transport.

- travellers got the possibility to modify their journey a day before travel (select other modes according to his preferences). Travellers will purchase a group ticket for entire journey with access rights to particular change nodes. Due to technology development more users' focus will be on personal needs as well as impact on environment. Check-in is done automatically at the start of the journey (check-in at the first hub of the journey);
- the exchange of information between ATM and surface modes together with access and communication with user's portable device allows for providing travellers with all data concerning their multimodal journey in advance. The travellers will be provided with available alternatives allowing traveller to react in time (in respect to his requirements e.g. related with disabilities). Privately generated data will be available for service providers daily demand forecasts will become possible making transport system more efficient and sustainable. This development means no buffer is needed at the beginning of the journey to reach the airport in time;
- **traveller starts at home: VFT travellers using the bus to the train station** (digital group ticket purchased). During the lift the travellers receives information about **a disruption (e.g. Harsh weather conditions) which is affecting their upcoming train ride to the airport**. They are provided with

available alternatives modes. **Travellers order an autonomous transport by car-sharing via internet** and change their routing to a car-sharing depot: and using the autonomous car to regional airport (Group card purchased in advance for public service will be credited);

- **late arrival at the airport** (registered luggage, check-in at the first hub of the journey): Leaving car at the car sharing parking. VFT travel group with senior (PRM) is automatically picked up at the car sharing parking next to their car by the airport operator with an autonomous electric cart. They will be taken to the check-in to check in their luggage Then they are automatically taken in the fast lane through security to their gate (full information about their delay status). The time taken to reach the gate in the regional airport will be less than 2 minutes;
- **flight** (with a short-range aircraft);
- **arrival at hub airport**: They got another ride with an autonomous electric cart for PRM by the airport operator through customs (and baggage claims) to the airport public transport station;
- **using various combinations of public transport according to their preference** (group ticket purchased online via mobile app/online);
- **travellers reach the accommodation.**

5.5.3 Use Cases in 2050

Finally, the use cases for the scenarios in the 2050-time horizon are described. The trends, needs and policies in the table below are the basis for the use cases presented.

Table 32 – Trends, needs and policies for the time horizon 2050

Scenario	Global and regional economic trends	Future Passenger needs (demography)	European Commission Policy		
			Sustainable Transport	UAM (ATM integration)	Smart city (IoT)
2050	new world order domination of Asian capital, smart cities, universality of AI & automation, basic income, no more arable land, cultural uprooting, riots in Asia, Africa, **regional**: nuclear energy return in EU	"extreme" travelers need addressed by Inclusive Design derived from touch, see, hear, and/or speak limits, decline of ageing populations,	net-zero emissions the Comprehensive TEN-T Network completed, walkable cities, domination of soft modes, mass transit, NMS, UAM	Digital European Sky full U-space services and deployed with shorter lifecycles, scalable and highly automated ATM, service-oriented ATM, trajectory-based operations, passenger -centric, multimodality, zero inefficiencies due to ATM, Digital Voice communications	system of systems level optimization transport digitalization completed, possible dynamic interaction among modes and costless reaction on disruptions (flexibility)

The figure below illustrates the selection of possible modes of transport in the "Use Cases" business and VFT travellers in the time horizon 2050.

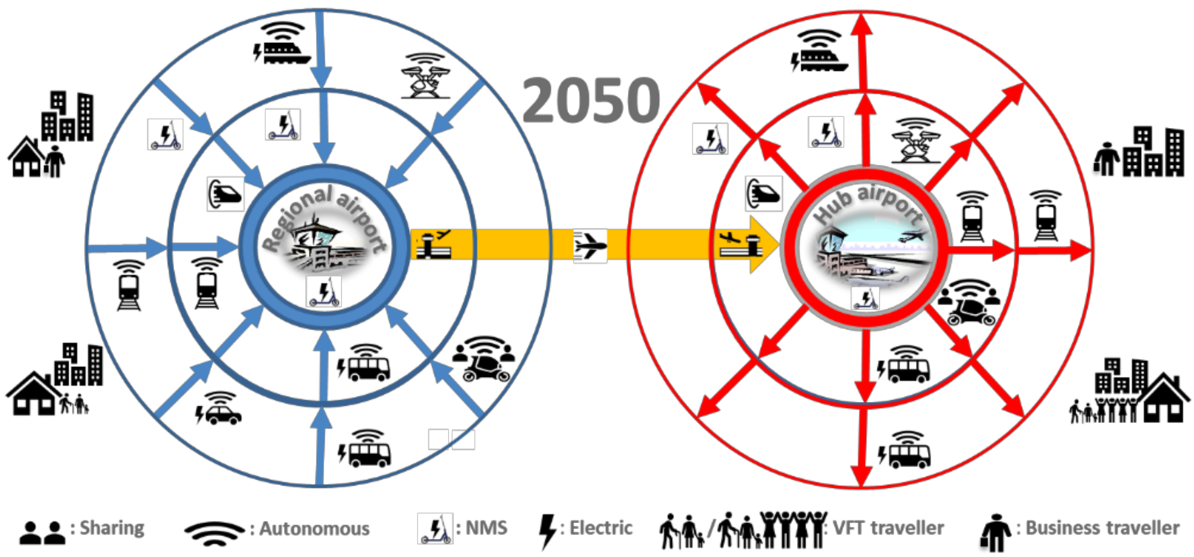


Figure 19 – Options for Business and VFT traveller for a journey include air transport in the time horizon 2050

5.5.3.1 Business traveller 2050

A business traveller planning a one-day trip from an origin area with a regional airport to a destination area with a hub airport.

B050 no disturbance

- **traveller starts at home:** Traveller is provided with all data concerning his/her multimodal journey at least every hour during the journey. He/she will have possibility to modify his/her journey even in a day of journey (select other modes according to his preferences). Traveller purchases one single ticket for entire journey with access rights to particular change nodes. The offer will be designed on base of smart pricing favouring preferred/prioritised modes of transport (with regards to applied policy like carbon footprint or emissions, sustainability level). Solutions will cover all or almost all publicly available means of transport. Time spent on changing nodes will be reduced thank to total system approach applied (System of Systems management). Completed digitalization will allow traveller to make transport mode more fitted to his individual preferences/needs: Next door is an NMS services including e-bikes/e-scooters and an electric autonomous car sharing depot;
- **traveller is using NMS to go to the next Urban Air Mobility (UAM) port;**
- **traveller is using an UAM**: For the Regional range air travels will be also possible with use of VTOL, multirotor and fixed wing aircraft;
- **arrival at the regional airport** (no registered luggage, passenger was checked in automatically): Use of an UAM gives the traveller a direct access to regional city airport. Security check and check-in is already done with/during the use of the UAM;
- **traveller is using NMS services** (e.g. e-bikes or e-scooters) at airport: Passenger is in nearly no time at gate;

- **flight** with zero-emission large aircraft;
- **arrival at hub airport**: NMS services (including e-bikes or e-scooters-versions) are commonly used in airport. There is (electric) micromobility (soft) means of transport to take the traveller to high-speed rail transport station;
- **high-speed rail transport ride**: Traveller modifies his/her journey to his preferences (he/she likes boat tours) and selects a ride with an autonomous ferry services instead of surface planned traffic modes: CCAM (connected, cooperative, automated mobility);
- **arrival at the high-speed rail transport station** with easy transfer to water mode system of the destination city. The destination city is divided by large water reservoirs. Traveller using an autonomous ferry services instead of surface planned traffic modes;
- **arrival at ferry pier:** He/she is using micromobility (soft) means of transport to the business address;
- **traveller arrives at business address.**

B550 disturbance 5h prior to departure and Bd50 disturbance ad hoc
A business traveller planning a one-day trip from an origin area with a regional airport to a destination area with a hub airport. There is an incident that leads to an interruption of the journey.

In 2050 there are between disruptions information from 5h prior and during the journey no difference for the traveller: In case of disruption information about it (e.g. delay) will be available immediately and if it is necessary the traveller will be provided with required actions on his/her side. The traveller will have possibility to modify his/her journey even in a day of journey and select other modes according to his preferences/needs.

Disturbances in 2050 resulted with internal reason like failure or accidents originated outside the system will be very rare. The time for recovery will be extremely short due to using immediate activation of resources of other modes of transport.

- **traveller starts at home:** Traveller is provided with all data concerning his/her multimodal journey at least every hour during the journey. He/she will have possibility to modify his/her journey even in a day of journey (select other modes according to his preferences). Traveller purchases one single ticket for entire journey with access rights to particular change nodes. The offer will be designed on base of smart pricing favoring preferred modes of transport (with regards to applied policy like carbon footprint or emissions, sustainability level). Solutions will cover all or almost all publicly available means of transport. Time spent on changing nodes will be reduced thank to total system approach applied (System of Systems management). Completed digitalization will allow traveller to make transport mode more fitted to his individual preferences/needs: Next door is an NMS services including e-bikes/e-scooters and an electric autonomous car sharing depot;
- **traveller is using NMS to go to the next Urban Air Mobility (UAM) port;**
- **traveller is using an UAM**: For the Regional range air travels will be also possible with use of VTOL, multirotor and fixed wing aircraft;
- **arrival at the regional airport** (no registered luggage, passenger was checked in automatically): Use of an UAM gives the traveller a direct access to regional city airport. Security check and check-in is already done with/during the use of the UAM;
- **traveller is using NMS services** (e.g. e-bikes or e-scooters) at airport: Passenger is in nearly no time at gate;

- **flight** with zero-emission large aircraft**;**
- shortly before landing at the hub airport the traveller reached a **disturbance** information about his/her high-speed train: Medical emergency on the booked high-speed train service. Heavy delay is possible. Traveller is given an alternative (UAM) to arrive safely on time for his appointment;
- **arrival at hub airport**: There is (electric) micromobility (soft) means of transport to take the traveller through customs to airport UAM port;
- **traveller using an UAM**: For the Regional range air travels it's a fixed wing aircraft (digital ticket needs an upgrade payment);
- **landing at UAM port next to the business center**. With soft mode he/she is transported to the business address;
- **traveller arrives at business address.**

5.5.3.2 Visiting friends and relatives traveller 2050 

Use cases for this group of VFTs include two adults (one of whom is a senior) and a minor child with baggage visiting friends and relatives for a long weekend on the occasion of a family event (e.g. wedding).

V050 no disturbance

- travellers are provided with all data concerning their multimodal journey at least every hour during the journey. They will have possibility to modify their journey even in a day of journey (select other modes according to his preferences). Travellers purchase a group ticket for entire journey with access rights to particular change nodes. The offer will be designed on base of smart pricing favoring preferred/prioritized modes of transport (with regards to applied policy like carbon footprint or emissions, sustainability level). Solutions will cover all or almost all publicly available means of transport. Time spent on changing nodes will be reduced thank to total system approach applied (System of Systems management). Completed digitalization will allow travellers to make transport mode more fitted to his individual preferences/needs. **Luggage is delivered door-to-door;**
- **luggage picked up in short notice before VFT traveller group starts at home;**
- **VFT traveller group starts at home: They are using NMS to go to the high-speed train station;**
- **traveller is using high-speed train** (digital group ticket purchased shorty before);
- **arrival at the regional airport** (passengers were checked in automatically);
- **traveller is using** micromobility means of transport at airport: Passenger is in nearly no time at gate;
- **flight** with zero-emission large aircraft;
- **arrival at hub airport**: There is (electric) micromobility means of transport to take the traveller group trough the customs to high-speed rail transport station;
- **high-speed rail transport ride**: Traveller group modifies their journey to their preferences (e.g. they like boat tours) and select a ride with an autonomous ferry services instead of surface planned traffic modes: CCAM (connected, cooperative, automated mobility);
- **arrival at the high-speed rail transport station** with easy transfer to water mode system of the destination city. The destination city is divided by large water reservoirs. Traveller using an autonomous ferry services instead of surface planned traffic modes;
- **arrival at ferry pier next to their accommodation:** They are using micromobility means of transport to the accommodation;
- **travellers reach the accommodation** (Baggage arrives promptly after them).

V550 disturbance 5h prior to departure and Vd50 disturbance ad hoc

Use cases for this group of VFTs include two adults (one of whom is a senior) and a minor child with baggage visiting friends and relatives for a long weekend on the occasion of a family event (e.g. wedding). There is an incident that leads to an interruption of the journey.

In 2050 there are between disruptions information from 5h prior and during the journey no difference for the traveller: In case of disruption information about it (e.g. delay) will be available immediately and if it is necessary the travellers will be provided with required actions on their side. The travellers will have possibility to modify their journey even in a day of journey and select other modes according to his preferences/needs. Disturbances in 2050 resulted with internal reason like failure or accidents originated outside the system will be very rare. The time for recovery will extremely short due to using immediate activation of resources of other modes of transport.

- VFT traveller group are provided with all data concerning their multimodal journey at least every hour during the journey. They will have possibility to modify their journey even in a day of journey (select other modes according to his preferences). Travellers purchase a group ticket for entire journey with access rights to particular change nodes. The offer will be designed on base of smart pricing favoring preferred/prioritized modes of transport (with regards to applied policy like carbon footprint or emissions, sustainability level). Solutions will cover all or almost all publicly available means of transport. Time spent on changing nodes will be reduced thank to total system approach applied (System of Systems management). Completed digitalization will allow travellers to make transport mode more fitted to his individual preferences/needs. Luggage is delivered door-to-door;
- **luggage picked up in short notice before VFT traveller group starts at home;**
- **VFT traveller group starts at home: They are using NMS to go to the high-speed train station;**
- **traveller is using high-speed train** (digital group ticket for the complete journey purchased shorty before);
- **arrival at the regional airport** (passengers were checked in automatically);
- **traveller is using** micromobility means of transport at regional airport: Passenger is in nearly no time at gate;
- **flight** with zero-emission large aircraft;
- **arrival at hub airport**: There is (electric) micromobility means of transport to take the traveller group trough the customs to high-speed rail transport station;
- **high-speed rail transport** (digital group ticket already purchased at the begin of the journey): Shortly before arriving at the High-speed rail station the VFT traveller group reached a **disturbance** information about their ferry boat booking (e.g. failure of ferry boat electric). Traveller Group is given an alternative (e.g. autonomous e-taxi ride) to arrive at their accommodation;
- **arrival at the high-speed rail station:** There is micromobility means of transport to take the traveller group to the autonomous e-taxi stand;
- **travellers reach the accommodation** (Baggage arrives promptly after them).

6 Barriers against 2D and air transport integration

6.1 Introduction

The EU 2020 mobility strategy details [161] makes clear its focus is not on personal ownership of transport modes, but on mobility per se, which is seen as service. As a seamless, cross-border, multimodal, automated to large extent service.

However, multimodal transport is hindered by administrative barriers and excessive complexity due to differences in sectoral and modal legislations at both the EU and national levels. There are many actors (local, regional and national operators, public, private, etc.) putting forward and reassigning available resources to make multimodal travel operable.

Before it goes universally multimodal, for example, railway sector still needs to overcome many legacy internal barriers, despite the reforms already have been pursued for many years. Rail has complex diverse infrastructure networks. The sector continues to have several different power systems, legacy signalling systems, unjustified differences in national safety and operating rules, absence of a well-functioning second hand rolling stock market, different approaches to charging and taxation, hybrid status of high-speed services (partly open access, partly subsidized) raising legal and financial challenges for competent authorities and infrastructure manager.

It is not only the EU railway system, that faces huge challenges in integrating. Lack of cooperation between services suppliers for payment system interoperability or lack of a conducive environment for multimodal information and ticketing and purchase services are EU-wide. Moreover, there is no EU tool for identification for all mobility-related services recognised in all Member States to avoid the burden to register each time travellers want to get access to parking, to city centres, to get access to and use mobility services, or to store (or even replace) all tickets/proofs of purchase (e.g. urban public transport, train, plane, taxi/PHV (private hire vehicles), shared mobility solutions, etc.).

Reconstruction of transport infrastructure has long-term investment cycles. Moreover, it may alter the quality and connectivity of habitats and can create physical barriers to the movement of plants and animals. The reach of the existing public transport system can be extended significantly simply by making walking to and from hubs and stops easier, less prone to barriers and more pleasant by creating attractive urban spaces that are well connected to public transport infrastructure.

Car industry approach in Europe is conservative compared to other developers of automated transport. There is no coordination mechanism at the EU level that would help ensure consistency of the deployment and management of ITS and CCAM across Europe. Rail sector is simpler than road transport to implement automation, but higher automation levels and autonomy on mainlines are not yet ready.

The EU's ATM still relies to a large extent on an outdated technology and lacks network oriented approach. There is no scalability, the service providers have fragmented and monopolistic nature. As a result congestion in the air causes sub-optimal flight paths in terms of CO2 emissions.

The engineers are racing to make previously science fiction personal air vehicles a reality – Urban Air Mobility. Unfortunately, there is not close enough alignment between R&I initiatives for specific modes and a systemic approach towards a multimodal integrated transport. The pathway between R&I projects, policy development and the market introduction are far too weak. Also, coordination among EU and national funding is sub-optimal.

Will UAM, similarly to high-speed train services, take form of contentious subsidized service under scope of Public Service Obligations (PSOs)? Public hand intervention should be carefully dosed. It can have a negative impact on the functioning of the internal market. Expected drones in cities will be limited by the boundaries of urban and public space, including urban infrastructure planning, levels of noise and safeguards to ensure citizens confidence, for instance in relation to privacy. Will all this find acceptance among stakeholders?

In subsequent chapters we consider barriers for ATM integration in intermodal transport network serving Urban and Extended Urban mobility in terms of regulations, certifications, information exchange and passenger expectations and needs. The identified barriers are allocated to three studied time horizons, according to defined scenarios.

The following main pillars regarding barriers are identified for achieving 2050 concept of flexible (near real-time optimised and managed on the level of system of systems), fully automated (in some areas autonomous), integrated urban and peri-urban multimodal transport. There are steps/prerequisites towards 2050 vision (barrier areas):

- policy and efficient and accurate planning
- digitalisation of urban and metropolitan transport system(s)
- achieving of potential of applicability by new transport technologies (covering TRL, but also social acceptance of new transport modes / types of vehicles and necessary infrastructure
- safe and secure use of personal data for transport integration and optimisation

6.2 Policy and efficient and accurate planning

Perspective of local governments, metropolitan regions and cities as main hosts and creators of integrated transport system on regional level. Strategy and in consequence definition of policy with regard to metropolitan transport network as well as transport integration implementation. Definition of goals and their meeting is complex process very individual in its nature. Knowledge necessary for it is usually broad and factors used for future estimation are uncertain. Especially if time horizon is long and changes expected disruptive. However partially addressed in this deliverable it still can be considered as a barrier. The example of challenging character of Urban Air Mobility (UAM) deployment process (addressed among others in ASSURED-UAM project) clearly shows how complex and difficult can be process of successful and efficient introduction to urban environment of new mode of transport. The variety and number of aspects which have to be addressed require dedicated multidisciplinary studies covering both technological as well as social topics. The process of transport integration cannot be realised without deployment of new solutions, also differential in terms of system components it addresses. Accurate prediction of impact caused by new technologies and proper identification of future transport specifications (shaped by new solutions) both in terms of needs/requirements and potential benefits for users, environment is of the highest importance. Especially if their deployment has to be preceded by expensive and resource demanding investments in e.g.: necessary infrastructure. Dynamic development of digital technologies and UAM make this barrier especially adequate in relation to urban and peri-urban surface and air transport integration. In detail it concerns:

- applicability/usability aspects. It can be related to all transport domains but clearly seen in case of UAM as part of integrated metropolitan transport system. Questions like public acceptance, privacy and security issues as well as ability to operate safely in urban environment during adverse weather conditions will lead to a set of operational constraints significantly limiting potential benefits coming from UAM introduction. These questions are of decisive character and have to be carefully evaluated before making decision about investment in UAM development;
- evaluation of cost of green technologies in transport. Covering manufacturing, life span operations and utilisation. Cost of sustainability assurance by introduction of green solutions as well as definition of adequate and relevant and weighted role in integrated transport system leading to minimisation of total transport carbon footprint and external cost;
- evaluation of direct cost of solution deployment. Necessary investments e.g. enabling digitalisation. In case of UAM it additionally covers definition of relevant business models and financing in relation to commercial and public service operations. Finally, definition of expected role in integrated metropolitan transport system (typical passenger profiles). Together with the previous issues allows for making conscious and robust decisions about UAM deployment;
- potential benefits for transport efficiency and integration resulted from access to personal data as well as data generated and processed by particular transport operators. Expected cost of access to data versus long lasting benefits in terms of operational cost reduction or service extension;
- resilience on disruptions caused by natural disasters, extreme weather conditions, security deficiencies as well as questions of reliability and cost of recovery after disruptions of different nature;
- integration of transport in 2050 means limitation of operators' responsibility to providing (deployment and maintaining) resources necessary for service provision. There is a need for definition of legal conditions enabling taking control over movement of all modes of transport in a way which will be attractive for operators. Metropolitan transport ecosystem should assure equal entry conditions for all and be open for all interested parties willing to integrate their resources (e.g. car-sharing companies, or other private operators). Appropriate law defining the rules of public transport service provision has to be implemented. It should cover adequate incentives for transport providers as well as be a tool for transport policy implementation.

The table below present particular barriers relevant to the planning area for given modes and time horizons. Due to the fact that planning, especially on strategic level is adequate only if longer perspective is considered for 2025 reference scenarios planning related barriers are not addressed.

Table 33 – Policy and planning barriers in specific time horizons

Policy and planning barriers in specific time horizons	
2035	**2050**
Air Transport (SATS, STOL, PATS, VTOL)	
(Manned) - Operability in dynamic urban environment - Cost of system deployment and operation including financing model - Roles in sustainable integrated metropolitan transport system (ConOps) - Definition of strategy for energy policy assuring necessary level of electric energy supply on base of renewable sources. - Identification of UAM-free zones, definition of space constraints related to city structure (e.g. Bird strike risk reduction by introduction of UAM free-zones over bird habitat areas, or security related – military zones)	As in 2035 and (Unmanned) - Operability in dynamic urban environment - Cost of system deployment and operation including financing model - Roles in sustainable integrated metropolitan transport system (ConOps)
Road Transport – Personal Transport – Electric car	
- Cost of operation by user and resulted popularity (vs fossil fuel powered cars) - Demand for charging stations, its distribution and fares - Electric car sustainability and definition of adequate policy (e.g. access to city centres) - Definition of strategy for energy policy assuring necessary level of electric energy supply on base of renewable sources. - Definition of incentive policy.	- As in 2035. - Expected degree of autonomation of personal travelling by car - Electric car sustainability in relation with public collective modes of transport and definition of adequate policy
Road Transport – Personal Transport – Electric autonomous car	
- Identification of requirements on infrastructure enabling efficient and safe operation of AV - Cost of infrastructure deployment vs benefits for users - Definition of incentive policy.	- As in 2035 and - Expected degree of autonomous cars on roads (vs manned) City cost of enabling manned cars operations - Popularity of MaaS model in relation to having own AVs - Integrability and sustainability vs collective means of transport - policy
Road Transport – Public/mass Transport – Electric autonomous bus	
- As for Autonomous car	- As in 2035.

	- Integrability and sustainability vs other collective means of transport – policy - Introduction of dynamic resource management on base of real-time demand data provided by other operators and users.
Road Transport – Public/mass Transport – Transit Elevated Bus	
- As for Autonomous car	- As for autonomous bus
Road Transport – Shared mobility – electric autonomous car	
- Popularity and shares in total transport - Identification of requirements on infrastructure enabling efficient and safe operation of electric cars and AV - Cost of infrastructure deployment vs benefits for users - Definition of strategy for energy policy assuring necessary level of electric energy supply on base of renewable sources. - Definition of incentive policy.	- As in 2035 - Popularity of MaaS model in relation to having own vehicle, - Integrability and sustainability vs other means of transport - policy
Road Transport – Shared mobility – electric autonomous car	
- As for electric autonomous car	- As in 2035 - Popularity of shared car model in relation to having own vehicle, - Integrability and sustainability vs other means of transport – policy - Incentive policy definition – promoting of healthy lifestyle.
Rail transport - Autonomous rail wagon (AGV)	
- Cost of system modernization and upgrading of infrastructure vs operational cost reduction and benefits for users	- As in 2035 and - Introduction of dynamic resource management on base of real-time demand data provided by other operators and users.
Water transport - Autonomous ferry	
- Evaluation of demand for such mode highly dependent on city location and topography - Operability in dynamic urban environment (various weather conditions) - Cost of system deployment and operation - Roles in sustainable integrated metropolitan transport system (ConOps)	- As in 2035 - Introduction of dynamic resource management on base of real-time demand data provided by other operators and users. - Integrability and sustainability vs other means of transport - policy

- Definition of strategy for energy policy assuring necessary level of electric energy supply on base of renewable sources.	
Multimodal - Flexible chassis systems	
N/A	- Operability in dynamic urban environment - Cost of system deployment and operation including financing model - Roles in sustainable integrated metropolitan transport system (ConOps)
Multimodal - Use of public data	
- Cost of digitalization highly dependent on mode and type of data needed as well as potential benefits for all stakeholders - Digitalisation financing - Definition of rules of data exchange, distribution	- As in 2035 and - Definition of model of integrated transport management (system of systems) - Definition of legal conditions enabling taking control over movement of all modes of transport. Appropriate law defining the rules of public transport service provision has to be implemented. It should cover adequate incentives for transport providers. - Cost Benefits Analysis of dynamic supply management on base of real-time data provided by public bodies and transport operators.
Multimodal - Use of private data	
- Definition of rules of private data exchange, distribution and use, - Cost of data acquisition vs benefits for stakeholders	- As in 2035
Multimodal - Resilience on external conditions like weather, security issues	
- Evaluation of probable disruption reasons and its severity in terms cost of recovery. Definition of mitigation means. Both in the area of hardware and software components of the system	- As in 2035

Accurate planning should be addressed in order to enable 2035 and further 2050 scenarios for multimodal transport concept as well as it can be considered as enabler for dealing with next barrier area.

6.3 Digitalisation and communication

6.3.1 Digital transport infrastructure and management

Digitalisation in the meaning of gaining ability by the system to generate and process real-time data covering numerous aspects of system functioning. It is a crucial step in the process of transport integration as it:

- enables initially provision of some types of data to the users allowing them for efficient self-management of their multimodal journey (Phase 1) and in further perspective multisystem cooperation on base of exchange of data (Phase 2) finalised by shifting of system management function to the level of system of systems and near real-time optimisation (Phase 3).
- Improve the system resilience and reliability. Access to real-time data covering parameters of functioning of various system components allows for implementation of proactive approach with regard to safety and reliability issues. In effect probability of disruptions resulted from technical failure, human error or external factor decreases significantly.

Digitalisation of transport process already exists. From many years in almost all its domains. However the path is various and dependent on many social and economic factors. In relation to defined scenarios and expected progress in the field of ICT three main phases of digitalisation can be distinguished:

Phase 1 reflexed in assumptions for reference scenario 2025 covering ability of collecting and processing real-time data concerning traffic and making them available for users, especially passengers. It is already commonly available and used by Google maps or dedicated travel planner software. However the quality of data still represents potential for improvement or extension with regard to type of information provided to the users. Further progress in Phase 1 as well as moving to the Phase 2 (communication between modes and users) planned on 2035 requires among other:

- Communication infrastructure/system development enabling common access to higher data transfer for large number of users (5G and beyond) in considered urban and peri-urban areas.
- Development of technologies enabling (better) integration of vehicles into the transport mode. Especially for road transport where it is considered as enabler for autonomous road traffic and exchange data with other modes.
- Investment for transport system modernisation, upgrading enabling better, faster and more data gathering, processing and transmission including internal and external interfaces (Internet of Things, Big Data topics). Especially with regard to collective, public modes often underinvested but also personal modes of transport relaying on performances of portable internet devices (e.g. smartphones).

As it is depicted in scenario for 2035 the process of digitalisation of transport system(s) is expected to be completed and ready for reaching another step which is introduction of dynamic resource management including transport service supply relying on forecasted demand determined on base of data provided by other operators and private users (Phase 2). The topic as involving many other challenges is addressed in dedicated sub-section (see below). Similarly as Phase 3 enabling shifting systems managerial functions to the one body supervising and optimising integrated transport consisting of numerous modes on given (e.g.

metropolitan, regional) area. UAM understood as unmanned goods transport is expected to start in 2025 and be fully implemented by 2035 paving the way for passenger unmanned operations forecasted to be available since 2035 reaching full operability potential till in 2050. Bearing in mind that the D2D travelling will take place at different airspace levels depending on the aircraft type, cruise selection and operational conditions, it is crucial to develop automation processes and systems that will allow for an interoperability of all users of the airspace by providing the coordinated mission planning and geo-awareness. Additional regulatory actions are required to manage this barrier. To meet these requirements, following systems components must be developed: UTM systems, Communication systems (datalink, Command-and-Control link,), Geo-awareness and Detection and avoidance.

UTM systems

With the aim to achieve effective and safe multimodal transport systems, it is crucial to deliver such solutions that would enable the interoperability of all transport modes in the same volume of space at the same time. Bringing on the concepts of U-Space that defines the one common airspace for both unmanned and manned vehicles, there must appear sets of standardized solutions, providing for the smooth and uninterrupted flight operations. Air traffic management encompassed the management of all airborne operations conducted mainly by manned aircrafts. Thereby the existing procedures, standards and regulations have been established to serve the purposes of the manned operations. Thus, with regard to the integration of ATM services with the UTM, it is essential to indicate their linking points and domains that need to be identified and analysed. The superior and most important factor that defines the domains of interoperability of ATM and UTM is the common airspace.

Communication systems (datalink, Command-and-Control link, etc.)

Cellular and satellite communication are two of the data links used in modern aircrafts. Depending on the mission type, either piloted or automated, the specific datalink is required. Most of the ground-piloted UAS employ cellular communication with frequency ranging from 27MHz to 5,8GHz. On the other hand, UAS conducting automated missions rely rather on the satellite based datalinks which pose better performance during long, high altitude and distant flights. This is due to the fact that the cellular data links require denser coverage of transceivers for maintaining safe and reliable communication with the UAS. What is more, 4G and LTE technologies, despite their advantages over previous generations, present insufficient latency levels and problems with space in allocated bandwidths. This leads to the unreliability of the cellular communication for a vast number of unmanned operations over distant areas. Adding the fact that cellular communication works best at lower altitude (<125m), the use of this data link presents major drawbacks in use in the ATM and UTM services. Satellite communication data link provides much greater coverage area than cellular. The most developed standard utilizing satellite-based communication is ADS-B (Automatic Dependent Surveillance-Broadcast). This system works on the 978/1090 MHz spectrum and is globally deemed as obligatory equipment of all aircrafts. Undoubtedly, it poses great advantages, such as providing the information to other aircrafts and ATC about its identification, current position, altitude and velocity, weather conditions. This ensures the situational awareness of the aircrafts that can move in a safe distance (separation). This standard seems more reliable for acquisition of the aircraft key parameters rather than by use of SSR or PSR.

So far, many agencies developed standards for manned aviation purposes. However, in the face of the emergence of increased unmanned operations that must exhibit high level of reliability and safety, new standards are being or are to be developed in order to meet the required levels of safety.

Geo-awareness

Geo-awareness is one of the most important aspects of both piloting and managing the group of aircrafts in a safe and planned manner. It comprises the geo-fencing and geo-caging. The first one relates to assisting the operator with the conformance to the rules and actions made by authorities to prevent entering the prohibited or restricted areas. Whereas the geo-caging is assisting the operator with maintaining the flight path as determined during the mission planning. These systems alert the operator with visual and audible notifications if notified deviations from the plan.

Both geo-fencing and geo-caging may be static or dynamic. Static indicates the areas or flight paths that are fixed and cannot be changed. On the other hand, dynamic allows for modifications to restricted or prohibited areas and flight path in real-time.

Detection and avoidance

This system also known as ACAS (Airborne collision avoidance system) secures the aircraft from unexpected and undesirable contact with foreign objects. As mentioned in Unmanned Aircraft Systems (UAS), Cir 328 AN/190 (ICAO), ACAS serves the following purposes:

- Recognition and understanding of aerodrome signs, markings, lighting
- Recognition visual signals (e.g. interception).
- Identification and avoidance of terrain;
- Identification and avoidance of severe weather;
- Maintaining applicable distance from cloud;
- Provision of "visual" separation from other aircraft or vehicles; and
- Collision avoidance

It may be said that detection and avoidance is part of the geo-awareness but in comparison to geo-fencing or geo-caging based on the datalink communications, detect and avoid systems rely on systems utilizing LIDARs, RADARs and Optical imagery processing. What is more, ADS-B systems also provide great situational awareness, contributing to avoid and detect mechanisms.

With regard to established time horizons as well as scenarios specified in previous chapter it is assumed that unmanned passenger flights will be possible after till 2050 but after the 2035. Therefore time horizon 2025 is considered as current situation – reference. Effort concerning development of UTM environment dedicated to managing unmanned non-passenger operations will cover questions of integration of UTM and ATM in order to assure possibility of manned passenger operations within a city (together with UAS), also with use of new configuration air vehicles. It is as well a prerequisite for enabling passenger unmanned flight till 2050.

6.3.2 Horizon 2025 up to 2035

Currently there is three fundamental bottlenecks during clear weather operations: gates, runways, and ATC workload. Digitalisation process is expected to directly address these barriers.

At the moment there are many examples of such systems being developed (e.g. NASA UTM or SESAR SES). There are also examples of UTM systems developed at smaller, national scale like PANSA UTM in Poland. For now, the UTM systems exhibit management of unmanned drones in terms of route planning, flight monitoring, implementation of prohibited, restricted, reserved and temporarily segregated areas. Further development of common airspace enabling denser UAM operations over urban areas with use of larger aircraft as well as possibility to introduce manned operations into one airspace requires:

- Interoperability with manned aviation what in turn requires progressed automation in manned aviation and reducing the role of human, to supervising purposes. Especially in common airspace;
- Increased airspace capacity. Achieved by introduction of automatic route path determination and optimisation, taking into account questions like traffic congestion including manned aviation, weather conditions, type of aircraft, energy consumption and risk assessment, as well as purpose of the flight (mission profile – e.g. goods drop-offs and pick-ups, stops for recharging, etc.);
- Integration with necessary infrastructure (e.g. vertiports) in terms of traffic management.

EUROCAE WG-105 SG-21 / RPAS C2 Datalink develops the standards for the C2 communications. What is more, WG-51 Automatic Dependent Surveillance-Broadcast (ADS-B) works on the detailed standards for this datalink. As for now, the capacity of both the cellular and satellite datalinks for unmanned applications poses some limitations at the current technology level. To obtain reliable datalinks for unmanned missions it is required to exploit and improve the cellular and satellite technologies. One of them is the 5G technology that exhibits many advantages: Ultra-Low Latency, Extreme Capacity, High Reliability, High Availability, High Density, Strong Security. These factors will enable the effective, fast, safe and uncongested use of cellular bands for the UTM purposes. On the second hand, developing the sat technologies like ADS-B Next will contribute to more accurate and automated air traffic management. Despite the hardware advancements, the issues with safety and high level of security will pose some threats concerning mass human travelling in common airspace.

Taking into account the existing technology, employing many sensors on-board the UAS to provide sufficient level of redundancy, lead to the increase of the UAS weight, diminishing its flight parameters. Thus, many of UAS built nowadays utilize minimal number of such systems. Furthermore, working alone, they cannot provide comprehensive data concerning the area around, as each individual system presents limitations in capabilities and speed of data processing.

As stated in RTCA DO-365, required level of safety is crucial for allowing for unmanned operations. Adding that operations with people involved contribute to more severe rules of safety, regulations encompassing combination and redundancy of DAA systems must emerge. Those should also cover the issues related to interoperability of manned and unmanned aircrafts in the context of DAA systems, as it is required to specify rules for integrating big passenger airplanes with SATS/PATS/VTOL/STOLs in the common airspace.

6.3.3 Horizon 2050

Further progress in the field of UTM. Gained experiences during freight operations. Introduction of unmanned automatic passenger operations overpopulated areas will require availability of matured and validated solutions. Further limiting the human factor in aviation is expected.

Unmanned passenger operations beside introducing an additional risk to the equation (risk for passengers aboard) significantly increase the risk related to ground impact as flights over (densely) populated areas will be unavoidable, especially during take-off and approach and landing phases. It will be considered as disruptive change in the way UAM operates. Solutions assuring highest possible level of safety will be required, also in the area of UTM addressing questions of separation from other airspace users as well as terrain obstacles. Integration with other (surface) passenger modes of transport will lead to traffic concentration over vertiports additionally highlighting the need for higher level of automation (seen also as one of means to achieve safety and increased capacity).

Possibility to transport passenger within the UAM will increase complexity of the process of traffic management by introduction of additional types of operations linked with specific priorities and rights. In additions the progressing integration of transport will lead the need of a dedicated structure of traffic, airspace, able to be optimised and adapted to passenger travel preferences and changing conditions in other modes of transport. Both in terms of forecasted/nowcasted demand for transport (based on data from other operators as well as private users) as well as process of disruption management expected to be carried on higher level than UTM/ATM (level of system of systems).

Increased density of unmanned automatic/autonomous operations together with increased risk off satellite signal interfering will entail the need for assuring an alternative, navigational system independent on GNSS especially in dense urban environment. It will be of critical importance for providing separations, geo-fencing and geo-awareness services.

2050 time horizon is considered as time for achieving all milestones necessary for completing the process of transport integration (on metropolitan, up to regional level). Transport system managed from the level of System of Systems fed by near real-time demand data, dynamically managing available resource will have to rely on automation and autonomous systems in all modes. This in turn will require implementation of digitalisation in the area of regulation allowing for efficient management form the regulatory and decision makers level. In details governance and regulatory language turning it into form which is understandable for transport management systems and their components.

6.3.4 Algorithmic governance

As the current law has been created to be readable and interpreted by the human, there exists an increasing gap between the human and digital world that prevents the flawless and coordinated functioning of the algorithm-driven systems. As a consequence, the incidents involving semi- or fully autonomous vehicles might be of great hurdle to decide whether the systems on-board incorrectly reacted to the conditions around or the implemented algorithms worked well according to the input data but the errors might have resulted from the misinterpretation of the law and regulations governing the behaviour of the vehicles in specific conditions by the software engineer [162]. Barriers for development of regulations that will cover the full scope and cope with the algorithmic nature of transport modes to emerge in not too distant future may be collected in following segments.

Machine-readable regulatory code

As already mentioned above, a significant gap between the current regulations and technology that they relate to, inhibits the innovations in the field of multimodal transport. It happens so by not allowing the technologies in specific modes of transport to be implemented or to cooperate with each other as there is a lack of clear and simple set of laws and regulations. A growing number of ground, water and air vehicles packed with ICT technology, must be then regulated prudently. To do so, efficient and automated process of adaptation of such vehicles to conform with the new law may be introduced by establishing the machine-readable regulatory code. Simply speaking, machine-readable regulations are the documents that contain the specific guidelines as in conventional regulations but are presented in the programming language (as a code) that can be implemented into software of the systems. This kind of regulations significantly reduce the mistakes made by the wrong interpretation of the law and thus leads to improved performance of the systems during their operation in the area regulated by the law.

So far, little effort has been put into creating the machine-readable law. This problem may be decomposed into two factors. First is the huge amount of data (laws, acts, regulations, standards, decrees) that is already in use. To transform these all documents into machine-readable units, software processing natural language (NLP) into the programming code must be employed. Until now, only few of such software have been developed. A lot of effort has been made by Microsoft, Apple, Google in the research of artificial intelligence (deep learning) for the NLP purposes. Unfortunately, much has yet to be made that NLP software be available for a larger scale, especially in the field of regulation. The second factor preventing the establishment of machine-readable law is necessity of the uniformity and clarity of the law and programming language. Regulations governing specific area of interest must be established in conformity with both the intention of the regulators and also with the scope and limitations of the programming language. There must be a conjunction between the law makers and computer science so that the machine-readable law be as precise as possible [163].

Taking into account the huge amount of data to be processed during the establishment, development and utilisation of law and regulations for multimodal transport services to come in future, safe and secure DLT (Distributed Ledger Technology) may be employed. This technology may serve as data storage and distribution both for the regulators and the services' operators. To sum up, utilizing artificial intelligence and DLT employed for the purposes of machine-readable regulations is a great opportunity for the ATM and UAM services to be governed in a well-organized, auditable and safe manner. It may be achieved by taking advantage of the following conveniences:

- real-time data management and analysis
- advanced risk assessment and change management
- dangerous patterns and incidents detection
- need for regulatory change and update identification

6.3.5 Summary

The table below presents particular barriers identified within the area of transport digitalisation with regard to given time horizons and transport modes.

Table 34 – Digitalisation barriers in specific time horizons

Digitalisation barriers in specific time horizons	
Up to 2035	**2050**
Air Transport (SATS, STOL, PATS, VTOL)	
- Regulations and standards for UTM systems integration with ATM with regard to flights management and sharing a common airspace. - Implementation of geo-awareness and geo-fencing technologies in integrated UTM/ATM airspace (e.g. assuring separation from prohibited areas like CAT airport). As well as avoiding of adverse weather conditions. - Regulations and operational standards for aircraft intended to operate in UTM system (with regard to performance and equipment, both for manned and UAM). - Regulations and operational standards for vertiports, airports, heliports enabling safe and efficient automatic approach, landing and take-offs within integrated ATM/UTM system (including capabilities and limitations. - C2 and data link communication standards for aircraft operating in integrated UTM/ATM airspace enabling real-time traffic data for big number of aircraft (employing 5G cellular and sat technologies). - Development of independent on-board technologies for assuring other aircraft and ground obstacles separation. - Standards and requirements and procedures for manned aircraft flight control systems operating within UTM airspace covering manned aircraft flight automation and HMI.	- The same as in 2035. Implementation of regulations and operational standards for flexible UTM airspace enabling near real-time airspace and traffic management (covering sustainability issues, nowcasted demand for flights, as well as emergency, military or other public service operations prioritizing). - Standards and regulations concerning AI procedures in case of appearing unintended, unexpected situation (covering risk mitigation and occurrence severity minimization/ optimisation) - Availability of communication technologies providing ability to efficiently communicate all airspace users. Regulations and standards for 5G and beyond. - Technical criteria and requirements for IoT devices distributed both on the ground (vertiports, airports) and in the air (UAS). - Implementation of algorithmic governance in order to assure efficient high-level management of air transportation as well as integration with other modes of transport.
Road Transport - Personal transport - Electric car	
- Communication technologies assuring high speed access to large number of users in considered area enabling creation of accurate	- The same as in 2035. Regulations and standards covering safe operation in mixed environment (manned and autonomous vehicles) covering

traffic patterns forecast in a day-scale. Realized by portable or car-integrated devices. - Deployment and integration with necessary infrastructure like charging stations, traffic lights, parking sites, etc.	aspects of risk mitigation and procedures for occurrence severity minimization/optimization, - Driving support technologies (e.g. advanced automation or full automation in some situations) as two-way V2V, V2I, V2X communication enabling safe and sustainable operations in mixed environment (5G and beyond). - Deployment of necessary infrastructure enabling V2V, V2I, V2X communication. - Implementation of algorithmic governance in order to assure efficient high-level management of air transportation as well as integration with other modes of transport.
Road Transport - Personal transport – Electric autonomous car	
- Communication technologies assuring high speed access to large number of users in considered area enabling creation of accurate traffic patterns forecast in a day-scale. Realized by portable or car-integrated devices. - Regulations and standards covering safe operation in non-mixed environment (separated autonomous traffic) covering aspects of risk mitigation and procedures for occurrence severity minimization /optimization, - Development of technologies concerning two-way V2V, V2I, V2X communication enabling safe and sustainable operations in non-mixed environment (autonomous traffic only). - Deployment/adapting of necessary infrastructure enabling V2V, V2I, V2X communication in areas (roads, lanes, etc.) dedicated to autonomous traffic.	- The same as in 2035. Regulations and standards covering safe operation in mixed environment (manned and autonomous vehicles) covering aspects of risk mitigation and procedures for occurrence severity minimization/optimization, - communication technologies enabling safe and sustainable operations in mixed environment (5G and beyond). - Deployment of necessary infrastructure enabling V2V, V2I, V2X communication. - Implementation of algorithmic governance in order to assure efficient high-level management of air transportation as well as integration with other modes of transport.
Road Transport - Public transport - Autonomous bus, TEB, Shared mobility – electric autonomous car	
- Communication technologies assuring high speed access to large number of users in considered area enabling creation of accurate demand patterns forecast in a day-scale as well as resulted transport resources allocation and timetable. Realized by portable passenger devices and bus installed sensors.	- The same as in 2035. Regulations and standards covering safe operation in mixed environment (manned and autonomous vehicles) covering aspects of risk mitigation and procedures for occurrence severity minimization/optimization, - communication enabling safe and sustainable operations in mixed environment (5G and beyond).

- Regulations and standards covering safe operation in non-mixed environment (separated autonomous traffic) covering aspects of risk mitigation and procedures for occurrence severity minimization/optimization, - Development of technologies concerning two-way V2V, V2I, V2X communication enabling safe and sustainable operations in non-mixed environment (autonomous traffic only). - Deployment/adapting of necessary infrastructure enabling V2V, V2I, V2X communication in areas (roads, lanes, etc.) dedicated to autonomous traffic.	- Deployment of necessary infrastructure enabling V2V, V2I, V2X communication. - Implementation of automation in the area of e.g., fleet and resource management enabling high flexibility and delay-free answering on nowcasted demand for bus transport. - Implementation of algorithmic governance in order to assure efficient high-level management of air transportation as well as integration with other modes of transport.
Road transport - Shared mobility – shared micromobility	
- Communication technologies assuring high speed access to large number of users in considered area enabling creation of accurate traffic patterns forecast in a day-scale. Realized by portable or car-integrated devices. - Deployment and integration with necessary infrastructure like charging stations, traffic lights, parking sites, etc.	- The same as in 2035. Regulations and standards covering safe operation in mixed environment (manned and autonomous vehicles) covering aspects of risk mitigation and procedures for occurrence severity minimization/optimization, - Driving support technologies (e.g. advanced automation or full automation in some situations) as two-way V2V, V2I, V2X communication enabling safe and sustainable operations in mixed environment (5G and beyond). - Deployment of necessary infrastructure enabling V2V, V2I, V2X communication. - Implementation of algorithmic governance in order to assure efficient high-level management of air transportation as well as integration with other modes of transport.
Rail transport - Autonomous rail wagon (AGV)	
- Communication technologies assuring high speed access to large number of users in considered area enabling creation of accurate demand patterns forecast in a day-scale as well as resulted transport resources allocation and timetable. Realized by portable passenger devices and railroad vehicles installed sensors. - Regulations and standards covering safe operation in non-mixed environment (separated autonomous traffic) covering aspects of risk	- The same as 2035. Regulations and standards covering safe operation in mixed environment (manned and autonomous vehicles) covering aspects of risk mitigation and procedures for occurrence severity minimization/optimization, communication enabling safe and sustainable operations in mixed environment (5G and beyond). - Implementation of automation in the area of e.g., available resource management enabling high

mitigation and procedures for occurrence severity minimization /optimization. - Deployment/adapting of necessary infrastructure enabling V2V, V2I, V2X communication in areas (rails, terminals, etc.) dedicated to autonomous railroad traffic.	flexibility and nearly delay-free answering on nowcasted demand for train transport. - Implementation of algorithmic governance in order to assure efficient high-level management of air transportation as well as integration with other modes of transport.
Water transport - Autonomous ferry	
- Regulations and standards for autonomous water transport systems integration with manned water transport with regard to traffic management and sharing a common area. - Implementation of geo-awareness and geo-fencing technologies in integrated water transport (e.g. assuring separation from prohibited zones). - Regulations and operational standards for autonomous ferries intended to operate (with regard to performance and equipment). - Regulations and operational standards for ports, piers or marinas enabling safe and efficient automatic approach, and mooring (including capabilities and limitations) - C2 and data link communication standards for water vehicles enabling real-time traffic data for big number water vehicles (employing 5G cellular and sat technologies). - Development of independent on-board technologies for assuring other boats, ships etc. and ground obstacles separation. - Standards, requirements and procedures for manned water vehicles operating in nearing of autonomous ferry area and HMI.	- The same as in 2035. - Implementation of regulations and operational standards for near real-time water traffic management (covering sustainability issues, nowcasted demand for cruises, as well as emergency, military or other public service operations prioritizing). - Standards and regulations concerning AI procedures in case of appearing unintended, unexpected situation (covering risk mitigation and occurrence severity minimization/ optimisation) - Availability of communication technologies providing ability to efficiently communicate all users. Regulations and standards for 5G and beyond. - Implementation of algorithmic governance in order to assure efficient high-level management of air transportation as well as integration with other modes of transport.
Multimodal - Flexible chassis systems	
N/A	- Regulations and operational standards for integration of airports, vertiports or airfield enabling safe and efficient automatic approach, and landing, take-off as well as reconfiguration (including capabilities and limitations).T - he same as for air and surface modes of transport.

6.4 Availability of new modes/types of vehicles

The topic of availability and adequacy (in terms of specifications) of (flying) vehicles and dedicated infrastructure can be considered as another barrier area beside questions of optimal strategy definition and accurate planning connected with application of appropriate approach to the process of surface transport digitalization as well as preparation of Urban Air Mobility (in terms of organisation – UTM/ATM). It covers two areas:

- development of vehicle and infrastructure related technologies enabling safe, efficient and sustainable deployment and operation of the systems
- definition of appropriate regulatory framework (certification, initial and continuing airworthiness) ensuring safe, efficient, sustainable and affordable operation of system (crucial in terms of UAM)

Due to the fact that Horizon perspective of 2025 is close to the current it can be identified as equivalent. Therefore, the barriers are identified for two longer time perspectives - horizons: 2035 and 2050.

6.4.1 Horizon 2025 up to 2035

6.4.1.1 Air transport

As it defined in scenarios up 2035. The years about 2035 are expected to be earliest time for introducing of test unmanned passenger operations of UAM for all types of air vehicles except VTOL in convertible configuration as most complex. Convertible configuration VTOLs are expected to enter the market in considered timeframe. For all available air modes of transport flights overpopulated areas however highly automated will require a pilot aboard. Main areas of technological barriers will be:

- providing a safe electrification of small aviation
- introducing new vertical take-off and landing aircraft
- development and maturation of technologies enabling safe and weather resilient operations in urban environment. Covering all phases of flight

Preparation for passenger UAM started in 2015 by initiating of process of definition of common European law for light drone operations. In order to provide UAM transportation into consumer use there should be considered variety and complex regulatory issues and certification challenges. One of the most crucial issues is certification mostly focused on design, initial airworthiness and continuing airworthiness.

Under the 2015 EU Aviation Strategy [53], the Commission, working closely with EASA has proposed a risk-based framework for all types of drone operations by developing the regulatory framework for Unmanned Aircraft Systems (UAS): Basic Regulation [164] introducing a completely new law requiring changes in the economic sphere, as well as challenges in the administrative sphere - the so-called base regulation as well as UAS – Unmanned Aircraft Regulations [165] and EASA ED Decision 2019-021-R [166] and Commission Implementing Regulation (EU) 2019/947 of 24 May 2019 on unmanned aircraft systems and on third-country operators of unmanned aircraft systems introduces the division of operations into 3 categories: open, specific

and certified, depending on the risk involves an operation carried out with the use of UAVs. Open and specific categories are only devoted to the drones for different services except for transportation of people. Only certified category takes into account the possibility of passenger transportation.
There have been recent promising developments in Europe in the area of certification that will enable a regulatory framework for the safe operation and certification of air taxi and electric VTOL (eVTOL) in Europe. In July 2019, EASA has issued the special condition SC-VTOL-1 [167] pioneering technical specifications and airworthiness standards which enable the type certification process of small vertical take-off and landing (VTOL) aircraft. Those certification requirements apply to "small VTOLs" with the Special Condition including aircraft with a passenger seating configuration of 9 or less and a maximum certified take-off mass up to 3175 kg. EASA issued in January 2020 the Special Condition SC-E 19 developed to provide certification requirements for Electric and/or Hybrid Propulsion System (EHPS) [168] and support applications received by the Agency.

The barriers will be referenced to the new types of air transport vehicles identified in chapter 4. However, it has to be noted that the concept of using light 4-19-seat aircraft to complement commercial air transport system and enable door2door traveling within 4 hours was deeply and thoroughly analyzed in multi-aspect context in set of SAT dedicated projects[89] [90] [91] [92]. Most of them is still adequate and can be extended to all types of air vehicles in relation to UAM (SATS, STOL, VTOL and PATS) and its integration within transport systems. As it is indicated in D3.1. The ROADMAP for technology development for future Small Air Transport system and its elements [136] The Small Aircraft Transport responds to serious challenges for the transport system i.e., spending less time in travel and creating better conditions for traveling, while meeting the following conditions compared to road transport:

- **use less energy:** less energy used means lower operational as well as external cost e.g., emissions). Mostly related to the questions of competitiveness to surface transport and economic justification of SATS system deployment - reduced energy consumption during operation would allow for consideration of SAT as rational alternative for other modes of transport not only for business traveler;
- **increase safety and reliability during flight:** the statistics data undoubtedly indicate on large gap in safety between commercial air transport and light aircraft [169]. Increased number of operations of small aircraft without significant progress in safety and reliability will result with big and outstanding number of occurrences which will negatively impact safety perception and acceptance of UAM. Safety is partially addressed by the digitalization and automation domains by requirements on autopilots (e.g. in case of flying in IMC) but it is also connected with aircraft component reliability (engine failure is the most frequent technical reason for accidents). It should cover also safety and security of infrastructure

[89] The EPATS at Cordis website, https://cordis.europa.eu/project/id/44549

[90] The SAT-Roadmap at Cordis website, https://cordis.europa.eu/project/id/265603

[91] The ESPOSA at Cordis website, https://cordis.europa.eu/project/id/284859

[92] The DART at ESA website, https://business.esa.int/projects/dart

(airports): Following are the main domains that need to be analyzed, assessed and regulated to assure safety of UAM infrastructure [170];

- **weather resilience:** all flight operations even those performed nowadays in scheduled civil and cargo air transport are strictly dependent on atmospheric conditions. Most delays, accidents and inconvenience during flight are caused by bad weather conditions. Some weather conditions like high winds, gusts and icing are much more crucial especially when it comes to small aircrafts. Especially in the context of climate change and weather phenomena intensification. City environment is even more demanding as obstacles like skyscrapers or even smaller buildings can lead to generate local dangerous and hard to recognize wind vortices. Aerial traffic and obstacles avoidance systems are being developed but there is no typical standard or regulation for those solutions. In addition to that weather resilience can be assured by providing and integrating of short time weather forecasts – addressed in the domain of digitalization;

- **noise:** besides sustainability questions and forecasted competitive position of future passenger vertical air mobility the noise generated by rotating parts of air vehicles will be a subject of public acceptance. Especially in the area of landing pads/verti-ports. These challenges can be a barrier constraining the freedom of airport location and potentially significantly limiting passenger UAM operability;

- **reduce cost:** it is one of the biggest obstacles preventing deployment of affordable SAT systems today. Current operational cost of light aircraft is too high to enable development of economically attractive offer. It resulted from high cost of product development especially certification, manufacturing mostly due to usually low series production as well as high cost of operation both related to flying and maintenance. In this set of costs, the burden of certification process is seen as most critical. Definition of more adequate regulatory requirements and development of technologies decreasing the cost in various life cycle phases are highly demanded for light aircraft transport systems;

- **reduce pollution:** very important from the sustainability point of view. In aviation the topic is mainly addressed by electrification but also decrease the noise generated by aircraft – very important overpopulated areas. According to defined scenarios UAM will be fully electric. So, technologies addressing these barriers should cover following aspects: Reliability of electric propulsions, level of noise generated by moving parts, safe, reliable and resilient to temperature fuel cells allowing for flights duration meeting the requirement of market till 2035;

- **exploit more efficiently the existing infrastructure:** the challenge is connected with possibility to use existing usually underutilized airports, airfields and airstrips. Cost of adapting of already available or nearly available infrastructure will be much lower that building a new one providing benefits to all stakeholders. In addition, such airports are often located inside or in proximity of city allowing for fast connection with destination point (by available surface modes of transport). The airport needs to be upgraded in order to enable integration within UTM/ATM. However, in case of landing sites located within highly populated areas (e. g. for VTOLs) a set of dedicated, suitable requirements/standards have to be defined (covering the issues for ground-based operations, infrastructure, vehicle servicing and maintenance infrastructure as in case of fixed wing aircrafts and helicopters in the time of writing of this document.);

- **increase seamless intermodal connectivity:** addressed by sections dedicated to policy and planning (6.2), Digitalisation (6.3) and exchange of data (6.5). Deploy intelligent transport system to achieve efficiency and easy way of reservation service and possibilities for sharing travel (per seat on demand). Addressed in previous section (Digitalisation).

Additionally, the following challenges can be added regarding UAM especially VTOL and other unconventional configurations like multirotors often considered as key element of UAM.

- **certification of new configurations and disruptive innovations:** financial burden related to the process of classic configuration aircraft certification is seen as one of main inhibitor of light aviation development. Introduction of unconventional configuration multiply the cost, in practice, preventing from progress today. Therefore, not technology (however needed to be matured) but definition of dedicated standards assuring its safety is seen as enabler for future common passenger UAM in Europe (manned to 2035 and unmanned till 2050);
- **birds activity:** Low attitude (several hundreds of meters) is occupied by birds, especially in urban environment. It leads to the increased risk of bird strike. Development of dedicated is bird's deterrents or other means of assuring separation from birds is critical for enabling UAM operations. No solutions for birds' activity over metropolitan area is yet developed.

In terms of PATS, it can be assumed that the scale of operations will directly results from the level of affordability of technologies. Similarly, to the other air modes of transport it requires dedicated standards. Beside standards the only barrier preventing its use in future is allocated in the area of integration with existing traffic. This topic is addressed by section entitled digitalization.

6.4.1.2 Road transport

In terms of road transport main barriers determining availability of identified road technologies are mainly located outside the domain of vehicles hardware. The only car or generally saying road vehicle component demanding urgent progress is electric propulsion, especially fuel cells which are commonly considered as not sufficiently efficient in order to enable reaching a fossil fuel car level (from the user point of view). Electric cars are more expensive to purchase than traditional, they offer lower range, often dependent on external conditions and savings resulted from using electrical energy instead of fossil fuel or simpler maintenance are consumed by high cost and limited battery life. Similarly, in case of public transport buses, however easier to adapt (e.g. by deployment on shorter routes) the room for technology progress is still significant, especially in terms of economic rationale. Therefore, the main barriers related to electric road mobility are:

- **new propulsion:** electric propulsion efficiency especially capacity and life duration of available fuel cells covering also the issues of dependence of external temperature
- **new technologies:** allowing for fast charging
- **new standards and requirements:** for charging stations. Standards and regulations covering requirements to be imposed on electric car other than addressed by digitalization domain

The second main technology expected to be deployed till 2035 is autonomous cars and buses. It is expected that fully automated driving will be possible only on dedicated infrastructure without or with limited interaction with non-automated traffic. Similarly, as in case of electrification, the available vehicles technology level seems to be ready for "restricted" automation. The only/main barrier addressing development of safe and reliable autopilot which digitalization of road traffic is a prerequisite. The barriers which can be identified in relation to the above are:

- **availability of reliable onboard technologies assuring separation from obstacles, pedestrians or other vehicles enabling autonomous drive in non-mixed environment (on dedicated infrastructure):** the barrier partially addressed by digitalization and autopilots. Standards and regulations covering requirements to be imposed on autonomous car and buses in non-mixed traffic other than addressed by digitalization domain. Standards and recommendations for dedicated infrastructure assuring safe operation of autonomous cars and buses (covering road signs, road specification, necessary equipment);

- **security aspects:** driver free autonomous buses seems to be more vulnerable to terrorist attack or vandalism act.

Transit Elevated Bus (TEB) – the concept developed and finally abandoned. However as considered as interesting by numerous cities should be taken into account in terms of barriers identified to be overcome in order to enable final implementation. They are:

- **maturation of technologies:** necessary for deployment concerning dedicated electric propulsion, fuel cells as well as inclusive design and structure and requirements enabling admission to road traffic;
- **new requirements:** assuring safety and efficiency of TEB services covering necessary changes in terms of traffic as well as linked regulations on routes occupied by TEB;
- **new standards and recommendations:** concerning dedicated infrastructure especially elevated bus stops;
- **security aspects:** driver free autonomous buses seems to be more vulnerable to terrorist attack or vandalism act.

In case of shared mobility identified barriers are the same as technically vehicles (cars) are the same. The possibility of introduction of such services is highly determined by elimination of barriers connected with other domains like digitalization or ability to efficiently exchange data.

Shared micromobility in turn relies highly on organization of traffic. Efficient travelling by (electric) bicycle, scooter as well as by foot require dedicated and safe infrastructure, separated from motorized traffic. In details main barriers for development of micromobility and its further integration with other (including air) modes of transport are:

- **new standards and recommendations:** for dedicated infrastructure. Safe, efficient and separated from motorised traffic;
- **new infrastructure:** development of as well as maintenance (e.g. bicycle path network), connection with change nodes including airports;
- **weather conditions:** climate related limitations. Poor weather conditions, precipitations, low temperature often limits use of soft mobility;
- **lack of ability to transport baggage:** this barrier can be addressed by introduction of cargo e-bicycle or ability to send a baggage with use of e.g., parcel locker services.

6.4.1.3 Rail transport

Completed digitalization of rail transport covering integration of rail vehicles with infrastructure is a necessary condition for autonomous rail wagon implementation. Onboard rail wagon technology seems to be matured and implemented among other in HST (e.g. ERTMS system). Application of this technology to regional railways, metro or light city rail (tramway) seems to be determined by availability of adequate and safe infrastructure. Therefore, the main barriers for city autonomous rails are located outside the wagon and concern mainly city rails:

- **new standards and recommendations:** covering traffic organization minimizing risk of interaction of autonomous tramway with road users, pedestrians, standards and recommendations covering inclusive design of tramway stops or metro stations minimizing the risk of unintended passenger behavior and occurring of dangerous situations undetectable by the system;
- **new technologies:** related to sensing of potentially dangerous situation (e.g. image analysis, behavior analysis);
- **security aspects:** human free transport trains seem to be more vulnerable to terrorist attack.

6.4.1.4 Water transport

Ability to deploy water transport is highly determined by presence and specifications of available water reservoir. Assuming advantageous natural conditions the following barriers related to the availability of electric autonomous ferry and necessary infrastructure can be identified:

- **new standards and recommendations:** for inclusive design and specification of dedicated safe infrastructure like piers, mooring systems. Standards and recommendations for inclusive design and specification of ferries enabling safe and efficient travel. Standards and recommendations for operating of autonomous vehicles concerning ethics, definition of safest solution, minimisation of risk or accident severity;
- **new propulsion systems:** development of safe, efficient and fast electrical propulsions including safe and environmentally friendly fuel cells. Analogically to road transport;
- **new technologies:** assuring separation from other ships, ferries, boats as well as water obstacles like shallows etc. with regard to onboard systems;
- **safety:** definition of operational conditions assuring safe operation (concerning required water level, shallows, water current as well as weather conditions e.g., wind speed);
- **natural conditions:** both related to weather/climate issues like (freezing of water reservoir) and changing water levels;
- **security aspects:** human free transport trains seem to be more vulnerable to terrorist attack.

6.4.2 Horizon 2050

Regarding defined scenarios 2050 will bring passenger unmanned UAM as well as multimodal vehicles (roadable aircraft). In addition, finalized digitalization will allow for management of all modes by one system.

6.4.2.1 Air transport

As it was noted the main progress in the area of air vehicles in 2050 when compared to 2035 is initiation of passenger unmanned operations overpopulated areas. Therefore, overcoming of all barriers identified for 2035 is critical for enabling of such operations till 2050. On base of the assumptions and scenario definition the time period between 2035 and 2050 will be focusing on multi-criteria optimization of passenger UAM transport covering also air vehicles and related infrastructure components. UAM being a part of integrated metropolitan/regional transport system operated and managed from the level of System of Systems. Airspace overpopulated areas as available since more than decade is expected to be saturated and close to the applied limits. In addition, passenger air vehicles will be probably the heaviest aircraft operating overpopulated areas. I will lead to the set of safety and public acceptance related challenges:

- **higher risk:** people aboard and significantly bigger mass leads to the higher risk to be addressed by dedicated standards and recommendations. It will be of major significance especially in case of eVTOLs of convertible configuration as innovative and more complex than multirotors;
- **ethics:** The fact of people (passengers) aboard of unmanned aircraft critically complicates the question of risk mitigation and especially severity minimization in case of emergency. The topic of balance between the risk/hazard for people on ground and in aircraft during recovery from dangerous situation and definition of "optimal in terms of ethics" algorithm for flight control system is a big challenge. Definition of solutions which will not affect the system's perception by citizens can be also considered as barrier;
- **demanding entry conditions:** expected to be imposed on passenger unmanned UAM vehicles and in result high cost of design, certification, manufacturing as well as maintenance and operation will generate strong need for solutions/technologies decreasing these costs. Nevertheless, high cost of operation resulted from certification and regulatory related burden can be a strong barrier for passenger operation deployment;
- **new propulsions systems:** common switching from fossil fuels to electric energy require development of energy efficient electric propulsions, safe, reliable and of big energy density cells as well as energy recovering systems;
- **arranging small aerodromes within a city (connected, integrated, safe and small in terms of land use):** passenger transport entails a need for integration with other existing mainly surface modes of transport. In order to exploit full potential resulting from VTOLs there is necessary to integrate it with metropolitan transport system. It can be achieved by location vertiports in close proximity to important passenger transfer hubs. There are usually located in densely populated urban areas with no or very limited space to be used for UAM terminal arrangement. Elaboration of standards and regulatory requirements for vertiports (and elevated vertiports located on rooftops, specifically designed drone towers for vertical take-off and landings, etc.) covering the same areas as anagogic document for big aerodromes is necessary;
- **climate change:** the global warming effect will ultimately result in significant weather change. Although advanced weather forecasting/nowcasting tools will be available allowing for efficient route and type of vehicle planning, still many operations will be disrupted by weather phenomena.

The number of flights being delayed or cancelled will have an impact on social perception of this kind of transportation – wheeled transport will maintain more desirable and reliable;

- **bird population:** however, DAA systems will work fully integrated with ATM avoiding potential mid-air collisions, it is expected that birds' population will decrease rapidly over the years due to advanced bird's deterrent systems and huge number of bird strike collisions in the past few years.

6.4.2.2 Road transport

The main changes expected to appear with regard to road transport till 2050 when compared to 2035 are significant increased share of electric vehicles on roads and autonomous vehicles able to safely participate in mixed road traffic.

As it is expected that progress in number of electric vehicles will be driven mainly utilisation economy. It can be improved by better electric propulsion efficiency and electric energy cost. New technologies enabling achieving of fuel cells energy density comparable to that of fossil fuel is necessary to make electric propulsion more attractive for users. However, in parallel to the process of transport electrification the increase of energy supply should be also ensured to avoid blackout. In addition to that positive impact on environment of introduction of electric will be possible only if renewable sources of energy will play dominating role.

It is expected that fully automated driving will be possible everywhere and it will include interaction with non-automated traffic. The barriers which can be identified in relation to this are:

- **availability of reliable onboard technologies:** assuring separation from obstacles, pedestrians or other vehicles enabling autonomous drive in mixed environment. The barrier is partially addressed by digitalization and autopilots;

- **standards and regulations:** covering requirements to be imposed on autonomous car and buses in mixed traffic other than addressed by digitalization domain. Standards and recommendations for dedicated infrastructure assuring safe operation of autonomous cars and buses (covering road signs, road specification, necessary equipment). Standards and recommendations for operating of autonomous vehicles in mixed environment concerning ethics, definition of safest solution, minimisation of risk or accident severity;

- **security aspects:** driver free autonomous buses seems to be more vulnerable to terrorist attack or vandalism act.

In case of other road modes of transport like autonomous bus, TEB or shared mobility the identified barriers are the same as technically vehicles (cars) are the same. The possibility of introduction of such services is highly determined by elimination of barriers related to electrification and autonomation.

6.4.2.3 Rail transport

Completing of the process of railway autonomation or automation is crucial for enabling integration with other modes planned for 2050 time horizon. As according to scenarios, the technology of autonomous rail wagon will be deployed till 2035 on some routes. The period till 2050 will be devoted to extension of the technology to at least all main routes. In order to achieve it, it is necessary to modernize and upgrade existing infrastructure. Gathering benefits from implementation of autonomous railways entails the need for changing of railroad design philosophy. High-efficiency autonomous railway management needs are:

- **new standards and recommendations:** for wagons, cars, locomotives, multiple units in freight and passenger transport
- **new standards and recommendations:** for railroad infrastructure, both in terms of railroad track geometry, traffic management system components as well as passenger dedicated like terminals (train station, platforms arrangement, etc.)

In addition to that also autonomous rail wagon dedicated standards will have to cover standards and recommendations for operating in mixed environment concerning ethics, definition of safest solution, minimisation of risk or accident severity (adequate mostly to tramways in case hard separation is not possible).

6.4.2.4 Water transport

Barriers identified as determining development of water transport are analogical as for other means of transport and concerns:

- **new electric propulsion:** efficiency, safety and reliability of fuel cells and the goal of chasing fossil fuel energy density.

- **new standards and recommendations:** for autonomous boating operations in changing mixed traffic conditions (e.g. risk mitigation, emergency situation management, recovery)

6.4.2.5 Multimodal

Flexible chassis systems as joining the functionalities of car and VTOL it requires overcoming of the barriers for both of them as well. In addition to that it requires development of dedicated propulsion systems as well as a set of numerous other dedicated technologies like rotors platform detachment systems. What is of crucial significance, the introduction of such solution into the market has to be preceded by development of adequate technical standards and regulations.

6.4.3 Summary

The Table 36 presents summary of all barriers identified for considered modes of transport (here: vehicles types) in given time horizons.

Table 35 – Vehicle availability technological barriers in specific time horizons

Vehicle availability technological barriers in specific time horizons	
Up to 2035	**2050**
Air Transport - SATS, STOL	
- Operational cost and energy consumption in comparison to surface transport. - Pollution/emission free operations - Electric propulsion technology assuring economic justification for it (fuel cell energy density). - Technical reliability of UAM vehicle components – strong need for cost efficient improvement. - Weather resilience. Providing possibility to safety operate during adverse weather conditions (turbulent, icing, conditions, IMC) - Exposition to noise. Development of silent propulsion technologies, especially for heavier aircraft over populated areas. - On-board bird-deterrence technologies to mitigate bird strike risk.	- The same as in 2035. - Development of affordable technologies enabling reduced operational cost without compromising safety. - Affordable safety technologies compensating risk increase resulting from higher weight of unmanned UAM aircraft and people aboard (concerning bird deterrence, aircraft components reliability, wind gust avoidance). - Limitations due to unpredictable atmospheric conditions due to climate change and weather phenomena intensification. - Technologies reducing the noise. - Adequate security solutions preventing from vandalism, terrorist attack, etc.).
Air Transport – PATS, VTOL	
- The same as for SATS and STOL an - Development of efficient, reliable and affordable propulsion systems for VTOLs (e.g. rotors, conversion systems) as well as PATS.	- The same as in 2035 for PATS and VTOL. - The same as for SAT and STOL in 2050.
Air Transport – Certification – SATS, STOL, PATS, VTOL	
- Certification burden and in result cost, especially for disruptive solutions (e.g. limited suitable regulations and standards referring strictly to new types of aerial vehicles. - Certification requirements for Electric and/or Hybrid Propulsion System (EHPS) in aircraft - Lack of development of standards for larger units - Regulations for certification bodies and research infrastructure/ development certification able to cope with bug number of applications. - Regulations and standards for design, operations of larger VTOLs (more than 9 passenger seats). Initial and continuing airworthiness. - Limited regulations to Special condition SC-VTOL-1 with technical specifications and airworthiness standards for type certification process of small vertical take-off and landing (VTOL) aircraft including aircraft with a passenger seating	- The same as in 2035. - Certification standards for passenger unmanned air vehicles operating over densely populated areas.

configuration of 9 or less and a maximum certified take-off mass up to 3175 kg.	
Air Transport – Infrastructure – SATS, STOL, PATS, VTOL	
- Regulations for the dedicated infrastructure of vertiports covering guides for airport winter safety, operations, plowing, deicing and anti-icing issues., guidelines for all-weather VTOL facilities (i.e., heliports with precision instrument approach capability), limitations due to unpredictable atmospheric conditions due to climate change and weather phenomena intensification or fire protection requirements. - Definition of regulations regarding location of landing sites in urban areas (covering approach safety – ground obstacles, birds' habitats, turbulences around buildings).	- The same as in 2035. - Standards and certification covering all regulatory and technical aspect of location of small aerodromes within a densely populated city structure (connected, integrated, safe and small in terms of land use). Including regulations for rooftops and designed drone towers for vertical take-off and landings and covering storage of dangerous materials like fuel cells. - Security assurance for small intra-city aerodromes (vertiports as part of transfer infrastructure).
Road Transport - Personal transport - Electric car	
- Electric propulsion efficiency capacity and life duration of available fuel cells. - Technologies allowing for fast charging. - Standards for charging stations. - Standards and regulations covering safety requirements to be imposed on electric car. - Technology progress decreasing cost of purchasing and operation of electric car.	- The same as in 2035. - Limitation of supply of electric energy resulted from increased demand. - Technologies for low-cost electric energy production.
Road Transport - Personal transport - Electric autonomous car, Public transport - Autonomous bus	
- Security aspects. Driver free autonomous buses seems to be more vulnerable to terrorist attack or vandalism act. - Availability of reliable onboard technologies assuring separation from obstacles, pedestrians or other vehicles enabling autonomous drive in non-mixed environment (on dedicated infrastructure). - Standards and regulations covering requirements to be imposed on autonomous car and buses in non-mixed traffic (concerning onboard equipment). - Standards and recommendations for dedicated infrastructure assuring safe operation of autonomous cars and buses (covering road signs, road specification, necessary equipment)	- The same as in 2035. - Availability of reliable onboard technologies assuring separation from obstacles, pedestrians or other vehicles enabling autonomous drive in mixed environment. - Standards and regulations covering requirements to be imposed on autonomous car and buses in mixed traffic other than addressed by digitalization domain (concerning onboard equipment). - Standards and recommendations for dedicated infrastructure assuring safe operation of autonomous cars and buses (covering road signs, road specification, necessary equipment, bus stops)

	- Standards and recommendations for operating of autonomous vehicles in mixed environment concerning ethics, definition of safest solution, minimisation of risk or accident severity.
Road Transport - Public transport - Transit Elevated bus	
- Maturation of technologies necessary for deployment (dedicated electric propulsion, inclusive design and requirements enabling admission to road traffic. - Definition of traffic arrangement requirements assuring safety and efficiency of TEB services. - Development of standards and recommendations concerning dedicated infrastructure e. g. elevated bus stops. - Development of technologies related to sensing of potentially dangerous situation (e.g. image analysis, behavior analysis) - Security aspects.	- The same as in 2035. - The same as for electric, autonomous cars and buses in 2050.
Road transport - Shared mobility – electric autonomous car	
- The same as for electric, autonomous cars.	- The same as for electric, autonomous cars.
Road Transport - Shared mobility – shared micromobility	
- Development of standards and recommendations for dedicated infrastructure. Safe, efficient and separated from motorised traffic. - Integrating of dedicated infrastructure (e.g. bicycle path network) with change nodes including airports. - Weather conditions – climate related limitations. - Lack of ability to transport baggage.	- The same as for 2035. - Weather and climate phenomena intensification.
Rail transport - Autonomous rail wagon (AGV)	
- Standards and recommendations covering traffic organization minimizing risk of interaction of autonomous tramway with road users, pedestrians. - Standards and recommendations covering inclusive design of tramway stops or metro stations minimizing the risk of unintended passenger behavior and occurring of dangerous situations undetectable by the system.	- The same as in 2035. - New standards and recommendations have to be defined and cover all components of railroad transport: high-efficiency autonomous railway management for wagons, cars, locomotives, multiple units, in parallel for both freight and passenger transport, autonomous railway management for railroad infrastructure, for high-efficiency autonomous railway management passenger dedicated infrastructure.

- Development of technologies related to sensing of potentially dangerous situation (e.g. image analysis, behavior analysis) - Security aspects.	
Water transport - Autonomous ferry	
- Standards and recommendations for inclusive design and specification of dedicated safe infrastructure like piers, mooring systems. - Standards and recommendations for inclusive design and specification of ferries enabling safe and efficient travel. - Development of safe, efficient and fast electrical propulsions including safe and environmentally friendly fuel cells. - On board technologies assuring separation from other ships, ferries, boats as well as water obstacles like shallows etc. with regard to onboard systems. - Definition of operational conditions assuring safe operation (concerning required water level, shallows, water current as well as weather conditions e.g. wind speed) - Natural conditions. Both related to weather/climate issues like (freezing of water reservoir) and changing water levels. - Security aspects. - Standards and recommendations for operating of autonomous vehicles concerning ethics, definition of safest solution, minimisation of risk or accident severity.	- The same as in 2035. - Efficiency, safety and reliability of fuel cells and the goal of chasing fossil fuel energy density. - Standards and recommendations concerning safe operation in changing mixed traffic conditions (e.g. risk mitigation, emergency situation management, recovery).
Multimodal - Flexible chassis systems	
N/A	- The same as for electric autonomous cars. - The same as for air transport (VTOL). - Development of propulsion systems as well as a set of numerous dedicated technologies (e.g. rotors platform detachment systems). - Development of adequate technical standards and regulations concerning unique components of the flexible chassis system.

6.5 Information exchange in multimodal transport

Ability to share data in order to process them and develop mobility models turning into real-time mobility management is another barrier area on the way to fully integrated transport system. It can be divided into two main groups.

A first group: possibility to collect and process data generated by transport operators. This data shared to other operators allows better identify expected demand for transport and allocate available resources in form of supply. Aggregated data value highly depends on digitalisation level enabling higher detailing level, currency level and the domain it concerns (e.g. passenger traffic specification, infrastructure or fleet operational data). Digitalisation and automation of some processes leads to creation of new data resources and allows for more efficient management, building foundations for establishment of interfaces between operators (modes) and future integrated management. In case of existing modes it is often require long term upgrading and modernisation process. In 2017 the EU has passed a delegated act requiring members to put in place open data frameworks for multimodal trip data [134]. According to ITF Report [71] Finland and France have both recently enacted ambitious data-sharing requirements in their national transport legislation. In terms of UAM and unmanned aviation developed solutions are aimed at enabling future digital integration. According to assumed scenarios digitalisation is expected to be finalised till 2035. Among data which can be collected and potentially shared by operators are:

- route-based data are collected by sensors at fixed locations of a path such as a highway or a train. One of the most used sensors is a loop detector. Numerous loop detectors are harnessed for monitoring intersection traffic, as well as detecting incidents, classifying vehicle and re-identifying vehicle;
- vehicle-based data are collected by mobile devices or in-vehicle GPSs. Whereas the route-based data are collected at a specific location, vehicle-based data are dynamic such as data of route choice, travel time estimation and more. In particular, connected vehicle technologies enable vehicles to share data in real-time with other vehicles and the transport system.

A second group: possibility to collect, process and share the data generated by private users. The sample of opportunities can be seen in Google Map service providing drivers with real time data about road traffic collected from devices used for navigation. Possibility of getting access to anonymised and aggregated data concerning users plans (e.g. work schedules, shopping habits), patterns, habits by transport operators would enable better planning, preparation of more attractive offer for passengers and be more efficient in terms of management of available resources. The area of private data use has to be regulated to assure necessary level of privacy and security. According to defined scenarios it assumed that private data will be available for operators till 2035 enabling introduction of dynamic timetable based on forecasted traffic (on a day-scale). An example of private data are traveller-based data collected by people like traffic jams which are inferred from one's location and accidents are voluntarily reported by mobile device users. In this group are also data not directly concerning travelling but indicating the need for making travel (e.g. buying a ticket, check-in for flight or even setting an alarm for wake-up to go work on data about planned holidays). Availability of such data are critical for enabling day-scale timetable planning in 2025 and dynamic transport supply management in 2050. Further part of this sections indicates on particular barriers for unconstrained transport data sharing in given time horizons for passenger centric services.

6.5.1 Horizon 2025

In 2025 transport data are assumed to be available for the users in dedicated applications providing users with necessary data and allowing them for planning of multimodal journey. Privately generated data will not be available for public bodies in a scale enabling relying on it. Similarly in case of exchange data between operators, however possible will not allow for disruptive change in operation flexibility.

Inter-platform providing service offers involving different modes by unified and simplified access to a number of different mobility services (e.g. public transport, ride-sourcing, car-haring or shared micro mobility, taxi or car rental/lease, or any combination of these). Operators offer their services to people via an app-enabled platform that may be operated either by one of the operators themselves, by a public authority or by a dedicated third-party. Nevertheless further development and gaining market share of such platforms requires:

- definition of clear and transparent platform access rules and trustable auditability of platform operation in order to avoid anti-competitive activity or being compatible with applied transport policy;
- common data syntaxes in order to make future exchange of digital data possible or at least easier. The settled syntaxes will also allow for reduction of regulatory burdens to be imposed on regulators related to interface building effort as well as will enable easy exchange of data between different modes. The data can be shared with neutral third parties that mediate access to the data or its analytic outputs according to rules agreed by all or with support of solution like The Mobility Data Specification (*MDS*), a data standard and application programming interface (*API*) specified and dedicated for mobility as a service (*MaaS*) providers, (such as ride-source companies) and developed to facilitate two-way communication in a regulatory environment between regulated entities a regulator (covering data sharing, monitoring, and communication). Public authorities recognise MDS as a tool to manage regulated entities and require that it be used and complied with in the licensing process[340]. However the despite the objective of data exchange, the further development of usability of such applications is currently constrained by issues concerning detail and granularity of data collected and associated risks for individual privacy and commercial. Solving it requires design of regulatory frameworks for smart mobility systems.

Extension of services provided by platform gathering data with e.g. enabling buying a single ticket for travel require a legal framework to be established between different operators. Such agreements have to rely on robust data concerning passenger distribution among modes/operators to enable just and clear income distribution. However available single ticket solutions are often limited to public bodies. It is expected that more concrete and more detailed traffic data (coming from private users as well) will create solid base for development of this solution.

6.5.2 Horizon 2035

According to defined scenarios it is expected that till 2035 private data collected by various operators will be available for using by transport providers to more accurately model demand and optimize transport supply in a day-scale at least on some routes. The tools available for passengers to plan their travel will provide them with more, more accurate information. Meeting of these assumptions require overcoming of the following barriers:

- identification of valuable data, especially data coming from sources other than transport operators. It is connected with the fact that the various traffic data is collected by various organizations, ranging from private organizations like operators to public and government organizations. Therefore, full exploitation of available data would require all these different organizations to provide access to their data and share it;

- technologies for Big Data processing. Especially those related to data infrastructure. For the purpose of transport ecosystem a dedicated solution aiming at collection, processing and sharing of data for transport demand modelling have to be developed. Current diversity of data in terms of source, format, value prevents from efficient using it for day-scale operation demand prediction. Another barrier to be overcome by technologies is quality of data collected covering lack of errors, faults as well as undefined biases resulted from extraordinary events (being of special meaning when small samples are analysed);

- regulatory framework concerning standards and recommendations assuring ethical, with equitable access as well as safe and secure collecting, processing and sharing of private data. In a human centered way covering the aspects of security, liability, privacy and data protection. The transport related data both private as well as sourcing from operators should be exchanged in dedicated platforms. The rules concerning data collecting by the platform as well as data processing and providing access to data should be subject of appropriate standards and regulations;

- regulatory framework covering standards and recommendations enabling unconstrained sharing data between operators and involved stakeholders. Mentioned platform dedicated to transport use for exchange of data between operators is necessary. It has to be supported by adequate regulations assuring, as in case of private data, appropriate level of equity, transparency, safety, security as well as be a tool for transport policy implementation. One of the critical aspects to be addressed by regulations is data ownership. Data owners are transportation operators or the various agencies which may hesitate to share data as it might be used by their competitors. Also, when data is owned by a private data collector, data is not publicly available due it's monetary value;

- standards and recommendations concerning security of automated systems. Communication links creates the cybersecurity risks to be addressed. It should cover the following areas:
  - designer vulnerability (source code, architecture, component specification, and product whole life design and support);
  - manufacturer vulnerability (component selection and manufacture, threat identification and mitigation, software/ firmware update creation, and version control;
  - vendor vulnerability: Inventory management, inventory protection, version management. A special consideration is the extent to which sensing and other critical sub-components are designed manufactured and programmed with attention to security;
  - maintainer vulnerability: Version management, design integrity management, platform protection, 3rd Party Engineering/Customisation/Enhancement Compatibility and Vulnerability Management;
  - infrastructure Provider Vulnerability: direct network attack, jamming of communications and location services, spoofing, impersonation, and interfaces to/ from other public systems.

- law enforcement and traffic management vulnerability: direct network attack, jamming of communications and location services, spoofing, and impersonation;
- end point vulnerability: on-board interface (external or internal attack), individual system control (e.g. a car), access, disruption of operation, selective/ non-selective, and ransom, kidnapping, or theft of data.

6.5.3 Horizon 2050

In 2050 reference scenario it was assumed fully, digitally integrated transport ecosystem (Level of System of systems). High degree of driving automation with regard to all modes of transport (rail, road, air both public and personal) allows for disruptive progress in terms of operational flexibility. Together with the fact that all main system components (vehicles, infrastructure, users) will be connected it creates possibility for nearly real time management. Implementation of the concept requires overcoming of the following barriers when compared to the 2035 scenario:

- new operational model of metropolitan/regional transport system requires dedicated ITC solutions. Technologies enabling IT integration of all city transport systems will be necessary. Large number of devices connected in the process of transport management require:
  - platforms for safe, transparent data management
  - dedicated software technologies to manage it (Big Data, IoT)
  - appropriate data transfer technologies (beyond 6G)
  - IT hardware systems with necessary computing power (quantum processors);

- as operators' activity will be reduced to the provision and maintaining of resources necessary for making of transport operations in considered area (e.g. metropolitan area) an appropriate standards and regulations concerning rules of public transport service provision within integrated context has to be defined and implemented;
- progress in terms of efficiency of the process of (private) data acquiring, processing and sharing is necessary to enable shortening of time between appearing of usable information and making decision by transport system. Appropriate regulations enabling easier access to new types of data as well as term so use of it have to be defined. It has to be supported by development of necessary algorithm technologies (e.g. forecasting passenger flow on base of number of tickets bought for an event or share of remote working and resulted decrease of demand for transport – Covid-19 related).

In addition to the above, all the necessary solutions will be vulnerable for security related threats. Level of connected systems significantly complicates the issue. Comprehensive cybersecurity frameworks will have to be defined.

6.5.4 Summary

The Table 37 present particular barriers relevant to the exchange of data within transport system for given time horizons. All barriers are identified on the level of complex transport system and are considered as equally adequate to all particular modes of transport.

Table 36 – Exchange of data

Exchange of data		
2025	**2035**	**2050**
Definition of clear and transparent travel planners platform access rules. Regulation concerning establishment of common data syntaxes in order to make future exchange of digital data.	The same as in 2025. Identification of ways of acquiring as well as sources of data necessary for transport demand forecasting Technologies for Big Data processing, related to data infrastructure as well as transport related data collection, processing and sharing. Regulatory framework covering standards and recommendations enabling unconstrained sharing data between operators and involved stakeholders. Regulatory framework concerning standards and recommendations assuring ethical, with equitable access as well as safe and secure collecting, processing and sharing of private data. Standards and recommendations concerning security of automated systems.	The same as in 2035. IT technologies able to manage metropolitan ecosystem (Platforms for safe, transparent data management, Dedicated software technologies to manage it (Big Data, IoT), appropriate data transfer technologies (beyond 6G), IT hardware systems with necessary computing power (quantum processors) . Standards and regulations concerning rules of public transport service provision within integrated context has to be defined and implemented. Appropriate regulations enabling easier access to new types of data as well as term so use of it have to be defined. Development of algorithm technologies enabling better transport demand forecasting/modelling.

6.6 Passenger needs and expectations

Barriers related to needs and expectations of future multimodal passengers are mainly linked to possible inequalities and gaps that might arise or increase as consequence of future scenarios realization. In principle, any new product or service resulting from technological or business innovation aim to match users' needs and satisfy, even possibly overcome, user expectations. Socio-cultural trends show an increasing consideration of the relevance of diversity and inclusion management; this let us foresee that in the near future (starting from 2025, in the purpose of X-TEAM D2D project) passengers belonging to vulnerable categories will expect full and equal access to any transport service. As consequence, digital (i.e. travel management mobile applications) and physical (i.e. buildings, urban areas, transport means, etc.) travel infrastructures will adapt to a variety of needs and expectations, also in the view of trends in recommendations and directives at EU level.

On the other hand, social divide is expected to increase, with the possible consequence of more people in Europe at risk of being excluded from accessible Door to Door private travels, especially leisure ones; this will be possibly linked to unaffordable travel costs or to a less common habit to travels (i.e. for time shortage or more general cultural reasons).

Currently, one of the major obstacles found by passengers is the lack of real time communications when a disruptive event occurs. Despite real time data is expected to progressively integrate and autonomously manage travel disruptions at a wide systemic level, according to IPCC (Intergovernmental Panel on Climate Change) it is very likely that extreme weather events will increase in the 21st century over many areas of the globe. Critical infrastructures, such as railway, tube stations, and airports are important assets to society and if they are hit by some hazards such as climate-related events (e.g., flash floods and so on), their functionality could be compromised preventing passengers to complete their journey in reasonable way and time. In fact, despite critical infrastructures are expected to become more resilient to climate change, extreme events overcoming transport system resilience could occur, impacting any normal activity in a given area for a given time; in that case, passengers will be probably informed about the expected disruption, but travels could be discouraged or hindered for safety reasons.

The table below depicts future possible obstacles that could undermine the full satisfaction of passengers' expectations and their probability in the X-TEAM D2D scenarios in 2025, 2035 and 2050.

Table 37 – Future possible obstacles in the X-TEAM D2D

Expectation	Future possible obstacles in the X-TEAM D2D scenarios
Real time communication on disruptions	**Trend:** disruption will be duly communicated but the reason of disruption might make the travel discouraged or hindered **2025:** poor communication, high probability of limited disruptions, the passenger can complete the journey with alternative solutions found by him/herself **2035:** more prompt communication, medium probability of partial disruptions, the passenger can follow automatically suggested alternatives to complete the journey **2050:** real time and autonomous management of limited disruptions, higher probability of extreme events producing total disruption of travel services in a given area/period
Integrated ticket	**Scenarios trend:** Ticket and means integration will increasingly rely on wide smart city system management so that seamless travel will be the normality but in case of highly rare smart city system failure, it could be more difficult rearranging the journey. **2025:** poor integration of systems, low probability of failure propagation. **2035:** partial integration of systems, possibility to solve "manually" booking and ticketing services, medium probability of failure propagation. **2050:** full integration of systems, low probability of system failure but high propagation of failure in case of occurrence.
Comfortability and inclusion	**Scenarios trend:** full comfort and inclusion achieved, no specific impact expected from external conditions.
Clarity of fares by considering policy of cancellation,	**Scenarios trend:** The full integration of ticket and transport means could request a significant increase of the integrated ticket cost. **2025:** ticketing is not integrated, low fares available, medium probability of hidden costs and surcharges in case of travel plan changes

costs for change.	**2035:** fares linked to comfort and additional service level, low probability of hidden costs, high probability of more expensive basic fares **2050:** top level comfort services available, high probability of expensive basic fares (not largely accessible).
Low Environmental impact	**Scenarios trend:** Some social groups could prefer paying carbon compensation costs to ensure the highest comfort levels, disregarding reasonable more sustainable multimodal travel alternatives. **2025:** awareness of environmental footprint at personal level, carbon compensation voluntary surcharge available for few means (air transport mainly), low probability of carbon compensation surcharge payment (rather alternative transport means are chosen) **2035:** awareness of environmental footprint of the journey mainly linked to company social responsibility policies, medium probability of carbon compensation payment/donation linked to type of travel **2050:** environmental footprint awareness disregarded for top class travels, medium probability of carbon compensation payment/donation linked to type of travel.

Real time communication disruptions are likely to persist in the future scenarios, given the likely increase of climate change related extreme weather events, which technological developments may not be able to avoid.

The need of integrated tickets and transport modes integration in a multi-connected transport system is likely to increase, driven by new technologies and type of vehicles, e.g. automated vehicles, in the long-term horizon.

The willingness to pay for more comfortable, but unsustainable, transportation options depend on the consolidation of the social trend towards more sustainability in lifestyle behaviour. Nowadays, this social habit is strong, but it is difficult to say whether it will last in the long-term horizon.

6.7 Summary

Presented barrier areas cover all domains which should be addressed if we consider implementation of the idea of integrated transport. Besides development of technologies enabling safe and affordable passenger transport over urban areas, one of critical conditions to be met both in 2035 and 2050 is access to knowledge being hidden behind transport data, especially those generated by private users - common passengers of transport systems. Accurately planned, fully digitally integrated automated/autonomous and flexible transport system complemented with robust (near) real-time information about demand will allow for disruptive improvement in overall efficiency. In addition managed on the level of System of systems, supported by algorithmic governance will enable revolutionary progress (by total system approach) in achieving of climate neutrality goal in relation to transport.

7 Summary and conclusions

Summary and conclusions provided according to main chapters of deliverable and corresponding tasks:

Scenarios definition: The World will change much after COVID-19. Coherence among the priorities, forces Western financial capitalism, stalled globally since the 2008 financial crisis, to give way to a new system, less individualistic, preserving public goods, economic security, and inclusion. Public hand, like in the EU, will lead climate action and reconstruction to more efficient industrial systems, buildings, and vehicles to reach net-zero emissions. To achieve this goal, experts suggest, a return of next generation nuclear as a low-carbon energy source alternative to fossil fuels. Even now the nuclear represents a critical component in the energy mix of 13 of the 27 EU Member States. In the transport sector, the EC policy follows its circular economy paradigm aiming to complete the networks, further the sustainability, redefine airspace management (Digital European Sky), and make use to the fullest of the emerging technologies (Internet of Things, smart city) while protecting freedoms and leaving no one behind. A set of EU rules already addresses protection of passengers' needs traveling by road, air, rail or water including urban public transportation. One of newer regulations provides a framework conditions enabling the co-operation in the EU-wide multimodal travel information exchange to support the interoperability, compatibility, and continuity of services.

No matter how sophisticated the system can get, it will hardly reach the desired effect if not serving the passengers' needs: convenience, easiness, frequency & speed of service, exhaustiveness and reliability. Moreover, for the active elderly, an expected large share of future passengers, some extra features will have to be added to the system: affordable, barrier free, comprehensible, friendly, safe, secure, transparent and complementary.

In this general context, our three scenarios (years 2025, 2035 and 2050) and conclusions of the current passenger experiences set external conditions for Urban Air Mobility ConOps for ATM intermodal integration in Europe which are input for the project's Use Cases described in next sections.

Technologies: **In air transport.** Naturally, regional or even metropolitan range air operations should be reserved for light aircraft. This domain can be divided into two main domains:

- **classic configuration:** aircraft represented by SATS and STOL categories. For both of them technology is almost already available but other advances will still have to be achieved in an environment in which safety assurance and affordability are key and often conflicting constraints. However its usability for UAM is constrained by landing side availability - short runways are still not very widespread in urban areas;
- **new configurations:** taking advantage from technology progress in the area of drones, electric propulsion but also miniaturisation of jet engines (Jetpack) represented by VTOL and PATS categories. The technology seen as, perhaps the most important element for Urban Air Mobility, is even less available, since there are few ready-made vehicles and the biggest challenge will be building and managing the dedicated infrastructure.

In surface transport. In the area of surface transport no new vehicles types is predicted to appear in given time horizons. Despite the aviation road, rail, water modes will be a subject of evolutionary change rather that disruptive. For all means of transport two main trends can be identified:

- **electrification:** zero emission goal for 2050 require elimination of fossil fuels. Electric propulsions are seen as solution for urban mobility of future. It will be applied to cars, buses as well as ferries and (air modes of transport as well);
- **automation and autonomation (Toyota) of transport:** Especially important for public, mass means of transport as enabler for disruptive increase of efficiency and flexibility. However challenging the trend of limiting driver/operator effort related to moving by surface vehicles is seen in road, rail as well as water transport (and air modes as well).

In multimodal context. Autonomous transport requires communication. Communication is enabler for integration and coordination. Exchange of data between modes is considered as main driver for achieving progress in the field of transport efficiency, sustainability. Together with digitalisation it will allow for optimisation on the level of entire transport ecosystem and will open the door for future inter-domain optimisations (e.g. analysing of metropolitan transport carbon footprint in connection with energy, industry efficiency and impact on other branch of economy).

Use cases: Definition of examples of travels with their specification in given time horizons under the conditions defined for particular scenarios. A form of validation and verification of scenarios consistency in numerous dimensions. Hypothetical passenger – typical for given perspective (representing dominating group) starts his multimodal journey taking advantage from technology progress both in terms of new modes availability but as well as information exchange and progress in the field transport integration. The use cases will be used for simulation to verify agreed assumptions.

Barriers: Implementation of all assumptions and turning defined use cases into real situations in future require overcoming of numerous barriers of various nature. The four groups of barriers were identified:

- **policy and strategy planning**: related barriers dealing with question marks commonly attached to the numerous aspects related to the process of implementation of defined solutions. They all have to be solved before initiation of complex and effortful investment like deployment of necessary infrastructure for electric cars or Urban Air Mobility;
- **digitalisation:** it is enabler for exchange of information. The data has to be available. It leads to the requirement of cost investment and upgrading of current management systems (like in case of local railroad transport network). In addition a dedicated standards and recommendation as well as regulation covering future data collecting, processing and sharing have to be defined. The digitalisation should cover not only transport but also regulations enabling future high level management of complex transport ecosystem (algorithmic governance);
- **hardware technology availability:** Development of solution enabling safe, reliable and efficient operation of autonomous vehicles, passenger unmanned drones (eVTOLs) and necessary ground infrastructure in changing and more and more demanding natural conditions. It considered as determined by development of dedicated, adequate standards for new mobilities;
- **unconstrained data collecting, processing and sharing:** the data as seen as main determinant of future transport integration process. Addressing the standards and recommendations for exchange of real-time data between operators and all interested parties is very important. Definition of rules of using private data is critical for the success as enabling demand forecasting.

Annex 1 - Appendix to Section 3.2

Scenarios developing methodology

What is a scenario[93] [171]? Depending on tradition, scenarios could be descriptions of possible future states or descriptions of developments. They can take descriptive forms of future visions, desirable futures or target-fulfilling scenarios. Scenarios are used to understand the risks and opportunities, likely impacts of different strategic policy directions, impacts of future external circumstances. For scenario development, appropriate scenario building techniques are used such as quantitative modelling, qualitative analysis based on expert judgement or both. Scenarios may be distributed along axes of dimensions or around theories, discourses and strategies. Typical social sciences bases are:

- welfarism [172] that develops society goals around rationality, scarce resources and sum of well-being of its members while ignoring well-being distribution;
- governing the commons [173], that in contrast to the prevailing rational-economic predictions and the tragedy of the commons, humans are not trapped and helpless amid diminishing supplies, but can increase or at least maintain their well-being;
- capabilities approach [174] [173], that stresses the intrinsic importance of rights, freedoms and diversity of human beings when evaluating well-being.

Given theoretical base, objectives, goals or targets of scenarios are identified. They refer to particular measures like Gross Domestic Product (GDP), Human Development Index (HDI), Gender-related development index, United Nations Development Programme's Human Poverty Index or sets of goals like the 17 Sustainable Development Goals (SDGs) of the United Nations 2030 Agenda [175].

In terms of their uncertainty, scenarios, can be ”most probable”, i.e., central, average or baseline – or – “less probable” – i.e. downside or upside, negative or positive, pessimist or optimist depending on chosen criteria extremes. For example, the 2020 World Bank Group's (WBG) short-term economy prospect [176] includes baseline, upside and downside scenarios, and the criterion is evaluation if the 3-month COVID-19 mitigation in 2020 is enough. Similarly, the 2017 Emerging Markets Forum's (EMF) long-term vision [5] consists of average, optimist, pessimist and very optimist scenarios depending on global productivity.

Scenarios example

A concise example of future scenarios formulation in general sense is a Swedish set [177] developed in 2019. Their assumptions for Sweden in 2050 are very precise: no fossil fuels, maximum of 0.82 ton CO_2eq per capita,

[93] The SUMP guidelines provide the following 'scenario' definition for urban mobility planners: "A scenario is a description of a specific set of developments in the future which are relevant to urban mobility, including the likely effects of external factors (such as demographic and economic circumstances), as well as those of strategic policy priorities (such as a strong active mobility or electromobility focus)."

average of 1.24 ha per capita of land use, all residents' participation in social life, sufficient access to resources and services, and a governing fairness principle. Through a complex procedure involving multi-stakeholder participation they obtained 4 possible future states:

- **Collaborative economy.** Citizens governance and prosumer networks prevail and the main provider of welfare are networks and cooperatives. Total import and export of goods is lower than present. Digitalization, civil society and informal economic activities play major role. Hours spent on work are similar as today, but hours spent in work are much lower;
- **Local self-sufficiency.** Household production is in locally governed communities, that also provide welfare. Total import and export and hours spent in employment are much lower than present. Digitalization and hours spent on work are lower than today;
- **Automation for quality of life.** Robots produce while citizens enjoy leisure time, the main provider of welfare are regional authorities. Total import and export of goods is slightly lower than present. Digitalization is vast and power of business is stronger than power of government;
- **Circular economy in the welfare state.** The government is strong and rules supported by industry, the main provider of welfare are central authorities. Total import and export of goods is lower than present. Digitalization is slightly higher than today. Hours spent on work and in work are similar as today.

Annex 2 - Appendix to Section 3.3

In this section we explain short and long-term trends in global and European economy reported by several key global institutional[94], business[95] and non-profit organizations[96].

Short-term trends

In June 2020, both, the WBG prospects [176] and the OECD outlook [9] reported devastating effects to economy caused by the COVID-19 epidemic and by the World reactions to its outbreak. Growth forecasts having been repeatedly revised down. The main headlines were pessimistic: economic distractions, output contractions, uncertainties, costly reconfigurations, shifts in consumer behaviour, precautionary saving, decline in confidence, the erosion of the rule based procedures to settle trade disputes.

Together with cancelled six months of debt payments due from 25 countries, expectations of weak growth and disinterest of investors could become a self-fulfilling mantra leading to a risk of a super-hysteresis: permanent loss of output levels, slowdown, damage to global supply chains and long-term loses of human capital.

According to a September issue of the OECD report [178] a 2020-decline in some advanced and emerging-market economies might be of more than 20% and the World's Gross Domestic Product (GDP) would fall by 4.5% in 2020 and grow by 5% in 2021. This forecast is a little better for 2020 and slightly worse for 2021 than in the June issue of the report.

USA

In the United States, unemployment claims rate grew faster than during Global Financial Crisis (GFC) of 2007-2008, oil prices collapsed, the Federal Reserve (Fed) cut rates to near zero and began, unlimited purchase of the US government debt. The government prepared a USD 3.0-trillion fiscal support including USD1.0 trillion in loans to firms and initiated a programme of direct transfers to households. In the WBG baseline scenario [176], the US economy is expected to shrink by -6.1% in 2020 and recover by +6.9% in 2021. The September OECD's expectations [178] are minus 4.8% in 2020 and plus 4.0% in 2021.

[94] institutional organisations: World Bank Group (WBG), Organisation for Economic Co-operation and Development (OECD) and European Union (EU)

[95] business organisations: The Economist Group, Mitsubishi Corporation

[96] non-profit organisations: The Emerging Markets Forum (EMF), EUROCITIES

Advanced economies

In other advanced economies, along with lockdowns introduction and moderate unemployment, governments reached deeply into current and future taxpayer pockets and legislated corporate bonds purchases and fiscal support, 40% of GDP in Japan, or expensive stimulae in Europe, 4.5% of GDP in Germany and 4% of GDP in Italy.

The EU Summer 2020 Economic Forecast [179] projected that the Euro area economy will contract by 8.7% (comparing to OECD's minus 7.9% [178]) in 2020 and rebound by 6.1% (5.1% [178]) in 2021, while the EU economy is expected to contract by 8.3% in 2020 and grow by 5.8% in 2021. Employment also declined more than ever in the second quarter of 2020, though much less than the fall in GDP in light of the support[97] [180] and flexibility in the use of cohesion policy funds[98] [181] [182]. For further implications, see Chapter 3.6 EC Policy.

China

Even in China [176], due to global trade fall, exports plunged and its government started emergency health and welfare spending (2.8% of GDP) and bond issuance (2.6% of GDP). Chinese economy is expected to grow at the rate of only +1% (+1.8% [178]) in 2020 and +6.9%(+8.0% [178]) in 2021.

Industry sectors

The most severely hit industries are tourism, live entertainment, automotive and electronics [176]. Companies with outsourced production and long and complex global value chains (GVC) are especially at risk caused by steep rise in air freight costs. Many services sector companies are likely to have to operate well below full capacity for an extended period, with foregone consumption of the services during shutdowns unlikely to be regained.

Financial markets

Financial markets, in many countries, experienced equity plunge at the fastest daily pace since 1987 (by 30-50%) [176]. Volatility soared above the levels recorded during the GFC. Long-term government bonds yields have declined substantially in many advanced economies reflecting monetary policy easing and a flight to safety. Demand for US dollar rose sharply. Most emerging markets bonds spreads rose and currencies depreciated. Foreign direct investments fell dramatically.

Corporate bank spreads also rose along with risks of downgrade due to the high level of indebtedness and deteriorated credit quality. As companies drawn upon credit lines, the deteriorating creditworthiness and capacity to extend loans put bonds of these companies at risk of downgrading to non-investment grades. The

[97] EUR 100 billion of financial assistance in the form of loans to be provided to the Member States requesting it.

[98] Coronavirus Response Investment Initiative (CRII and CRII+)

regulations will prompt forced sales by some institutional investors, increasing demand for cash and weighing negatively on the prices.

Risk aversion in financial markets rose substantially at the beginning of the COVID-19 outbreak but eased in summer 2020 along with pick-up in demand in China [178].

Commodities markets

On commodity markets, oil prices fell by 70% from late January to mid-April 2020, global oil production started to fall and many countries imposed temporary restrictive policy in exports [176].

The emerging markets and developing economies introduced economy-wide lockdowns, which caused unemployment. Since remittances were an important source of income, a consumption declined in detail sales. This caused subsequent decline in investments, manufacturing and raw materials export orders.

The commodity exporting countries applied a pro-cyclical fiscal tightening, fiscal stimulae and central banks' monetary support.

The commodity importers experienced a serious decline in demand for their manufactured goods. To maintain their capital India, Pakistan, Poland, Thailand or Turkey also introduced stimulus packages. Tourism dependant countries like Croatia, Maldives, Seychelles or Thailand report downgraded economy forecasts, the same happened in the deeply embedded in value chains countries like Bulgaria, Mexico or Poland and in the commodity exporting countries like Chile, Nigeria, Russia or South Africa.

COVID-19 lasting effects

Even the optimist, upside scenario of the WBG assumed a decline of 4% if sputter back to life happens in Q3 of 2020, but with monetary and fiscal stimulae remaining. The downside is a horrible decrease of global economy by 7%. Unfortunately, the sputter back to life in Q3, after initial bounce-back in many activities, lost momentum since June [178]. Situation is uncertain until an effective treatment or vaccine is deployed and all citizens understand importance of masks wearing in public places. Then, consumer confidence will, gradually, recover in 2022.

Mitigation schemes like active labour market programmes and enhanced vocational education and training may create opportunity for all, facilitate possible job reallocations and prevent erosion of human capital. The measures put in place at the height of the pandemic to support companies need to be refocused to limit the risk of non-productive "zombie" firms and jobs.

The lasting effects will be local lockdowns, firm closures, travel restrictions, eroding confidence, reduced consumption, lower productivity, threat to viability of transportation companies, reshoring production, inability to service debt, not enough mitigation measures, renewed trade restrictions, prices below the fiscal break-even point level for many producers.

Low real interest rates may make further monetary policy easing difficult. Countries with weaker macroeconomic fundamentals should seek extra borrowing payment moratoria or restructuring.

On the other hand, the potential robust recovery may bring sustainable gains in living standards and innovations: in healthcare, in education, in addressing infrastructure shortages, in digitalisation, in reconversion of assembly lines, in access to international markets, in human capital and knowledge, in transport facilitation, in reducing policy uncertainty about the longer-term challenges from climate change, and finally, in better globalisation.

Current global leaders in research are China and USA, where the EU's agreed 3% of GDP on research is far from reality [183].

Long-term trends up to 2050

The Emerging Markets Forum report [5] presents a long-term vision of global economic trends. They expect emerging and developing countries to have an average annual GDP growth of 4%. This rate may reach 5% in Sub-Saharan Africa, 4% in emerging Asia, 3.1% in Latin America and 3.4% in the Middle East. The growth in emerging European countries, in the South and East, will not exceed 1.7%, while the developed countries of Europe and America will reach an average of 1.8%. In 2050, 79 countries will have GDP per capita higher than the current average income in southern Europe.

The Economist forecast of 2015 [4] expected Chinese economy to overtake USA in 2026, with India taking 3rd place. The Mitsubishi's Future Society [8] prediction goes alike, just postponing the shift – by 2030. This hierarchy will be maintained until 2050 with Asia accounting for 53% of global GDP. The emerging economies and developing countries, however, will have to anticipate many threats that may cause a slowdown in their sustainable development (credit crisis, COVID-19 lasting effects, technological progress, 3D printers, robotics) [5].

A unipolar world ruled by the USA supported by its allies will gradually disappear. International institutions will have to adapt to allow China and India to exert greater influence and let the world become multipolar. After a new era of freezing international relations, a new order should emerge. The question whether it will be universally based on fundamental values like human rights, rule of law, privacy and sustainability remains open [8].

Urbanisation

In 2010, 73% of European citizens lived in urban areas, this percentage is expected to increase to over 80% by 2050 [6]. The picture will be similar globally. Current economic advantages of high urbanization as improvement in the ratio of the number of economically active people to the number of children and the elderly will be damped by ageing of the population [5]. See Chapter 3.4.1 Demography. 20-30% of food production will come from urban areas along with disappearance of arable land outside cities.

Risks for deterioration of public services, living conditions, cultural uprooting or even riots will grow, especially in Asian or African agglomerations, where beyond the borders of privileged districts swollen with wealth, 2 billion inhabitants – or even more if including unregistered children – will be living in slums.

Globalisation

The strong trend towards economic and financial globalization will continue and emerging economies will remain on this path. Despite many positive initiatives like investment and trade partnership between the USA and Europe, an agreement between Japan and the USA, far-reaching discussions under the aegis of the ASEAN+6, the US President Donald Trump's protectionist agenda will cast a shadow on the prospect of continuing expansive trade. Opening up exchanges respecting the same rules for all would benefit the growth and well-being of citizens.

Financial markets

Financial assets in emerging economies will exceed USD 700 billion, which will be over 1.5 times the sum of corresponding assets in advanced economies, USD 420 billion. Asia's emerging markets will account for 76% of the financial assets of emerging economies. There will be, however, a risk of excessive dependence on debt and the inability of the international monetary system, especially if finances would not recognize their legitimacy solely in the service of the economy.

Middle class domination

World will experience a mass rise of the middle class [184] which together with the upper class should exceed 82% of population. The total number of middle-income and upper-income people could approach 2.3 billion in East Asia and 700 million in Latin America, as well as 700 million in the Middle East, Central Asia and India.

Fourth Industrial Revolution

A progress will be visible in many areas: information technology, internet and communication, work automation, Artificial Intelligence (AI) [5]. A computer will be as powerful as all the computers currently installed in Silicon Valley. Digitalisation and mobile communications will grant universal access to services (for example banking) and will be a main component of ubiquitous AI. AI, combined with automation, will significantly shift labour force structure, as fast as it becomes more competitive than humans in solving problems that require complex analysis, creativity or subtle evaluation. This could lead to introduction of special measures to ensure material existence on a jobless market and opportunity to participate in society [185]. Mitsubishi [8], however, predicts humans cannot be easily substituted by AI in more creative areas. AI will benefit humans and their endeavours with immediate access to information, significant improvements in quality, speed of decision-making and profitability.

The fourth industrial revolution [5] [8] [4] will reveal its full potential in high efficiency production, energy consumption, transport, new materials, genetics, medicine, internet or robotics. More solidarity, full automation in agriculture, reuse of food waste, efficient maintenance of infrastructure, the borderless market, new type of economic zone in digital space, digital currencies, digital immigration, will lead to decline in living costs, value-driven consumption and demographic shift to regional cities or metropoles. The fourth industrial revolution will bring opportunities to cities as it can help [186]:

- predict level of pollution
- adapt cultural policies and investments (e.g. predicting tourists' behaviour)
- improve urban mobility (e.g. redirecting drivers to free areas)
- increase sense of participation (e.g. government AI chatbots)

On the other hand, central banks influence will diminish and crime in digital space may often occur [8]. Due to no optimal resource allocation, the balance between the global supply of natural resources and the demand for them may be broken. Without safety-nets and dynamic approach to education, huge economic disparities could emerge. Without growth-friendly policies growing number of potential workers unable to find employment may cause political instability. The misuse of AI and robotics could create unforgiving environment and infringe on basic human rights, manipulate decision-making mechanism and lead to decline in overall human ability and motivation.

World stability

Further polarization and conflicts over hegemony [8] may turn violent, especially locally in a hybrid manner. The risk of total annihilation, similarly as during 20th century Cold War, will keep major conflict at bay. As an effect, a divided digital world is very likely.

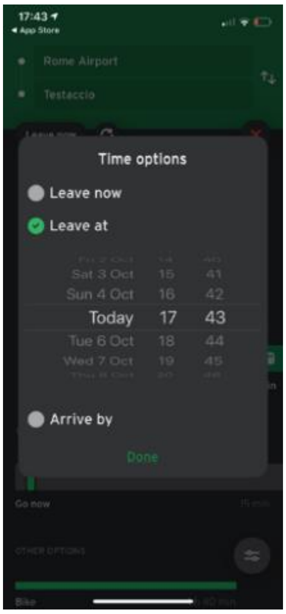
There will be high risk of terrorism and fundamentalism as an effect of unsolved societal issues and inability of human brain, developed in a longer-term of Neolithic Period, to adapt to a very fast pace of changes. It will have destructive effect on economic growth, especially in less stable countries [5].

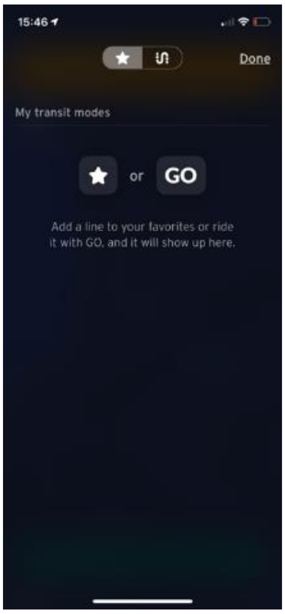
Annex 2 - Appendix to Section 3.6.3

Applications Analysed in Section 3.6.3

TRANSIT

The app was birth with the aim to give commuters how to move inside cities. It is very simple in usage and let people know about upcoming departure times for nearby lines without even tapping mobile screen. It gives the opportunity to plan the trip selecting the best options with real-time data for improved accuracy (left figure below). To start a trip, you should tap the bottom part of the screen "where to?" and it gives also the possibility to select "favourite places" like home and work. The right-side figure shows also the possibility to select favourite lines (star button) or favourite rides (Go button)

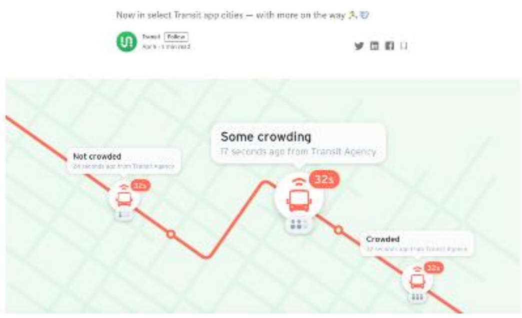




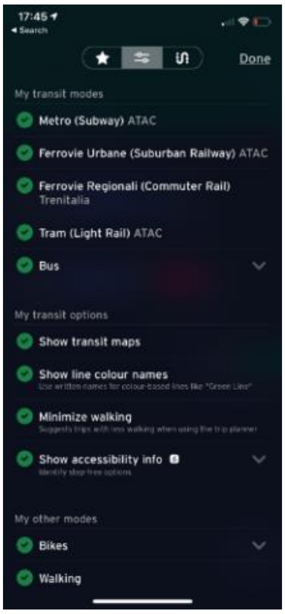
The GO button permits also to start the trip (the commuter selects the best route for him) and let people know when to get on and off trains and buses.

Some functionalities are available just in few cities, while some others have been initiated in the beginning of September 2020, like the possibility to buy bus fares (that are touch free) and bikes passes. These options are at the moment possible just in Montreal.

It is very interesting also the possibility to know how each transport mean is crowded: this responds to specific requests of users, due to the Covid-19 emergency. At the moment, the to the Every Transit-supported city with the data is live: Sydney; Auckland; Springfield, MA; Modesto, CA Akron, OH; Erie, PA; MBTA in Boston; MTA buses in New York; and others. At the moment, this specific function is not ready for Europe, but could be important.



How the app works



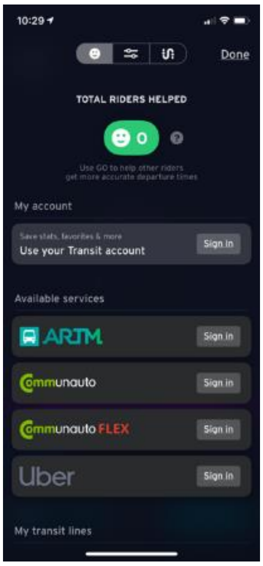
In this section we simulate a trip from Rome Fiumicino airport to the Testaccio district (Rome). The user selects the options for the trip, by flagging his preference. There is also the possibility to flag the accessibility option, to minimize walks and so on.

Once trip preferences have been flagged, the user can choose the itinerary: the app shows all preferences, with the indication of estimated time of arrival, together with the combination bus/walk/train.

As it can be easily noticed, the app shows all the stops of the combined means of transport to be caught by the user. Furthermore, there is also the indication on accessibility: when the bus or train is not accessible, the accessibility symbol has a (?).

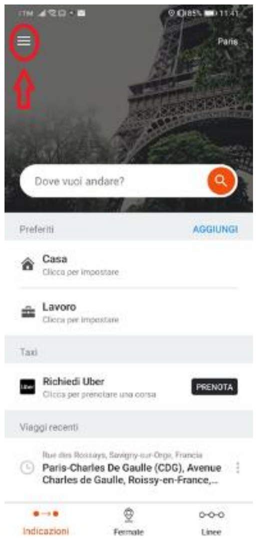
The app could also include information about delays and possible disruptions along the route. As the app shows more functionalities in the Northern America, a simulation from Montreal airport to the Baie-D'Urfè was undertaken.

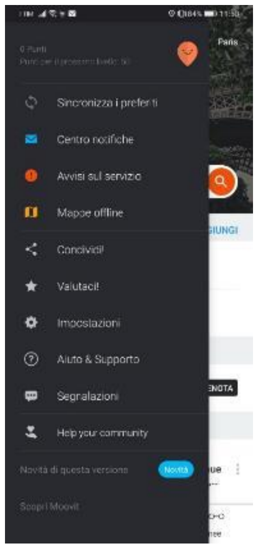
In this specific case, you can buy tickets by using the Transit account (left side figure), for the identified companies (on the bottom part of the figure). On the right side the user founds the information about the trip, with specific information on delays (figure on the right). It is important that the information about disruption is given by other commuters, though the button "GO". This function can used just to registered people and to people who are undertaking the trip.



MOOVIT

Moovit is an APP for urban mobility. The App guides the user step-by-step with the optimal route using bus, train, metro, bike, scooter or a combination of them.





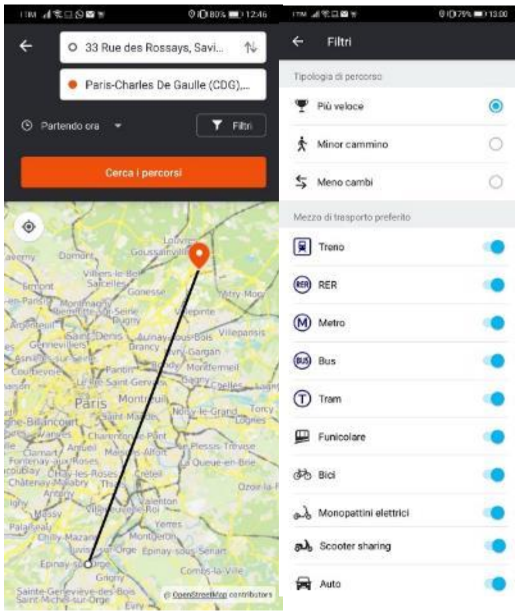
The above figure shows the Moovit home screen, where the user can schedule his/her travel:

- top left (three bars): open drop-down menu (shown in figures below)
- top right: the City's name (Paris in this case)
- middle screen: the user destination
- favorites: the usual location such as home, work and others
- taxi: the user can decide to call an Uber (no other companies can be chosen)
- recent trips: the user can quickly select the last trip if needed

Figures shows the drop-down menu opening:

- synchronize the favourite: allow the user to synchronize the favourites destination;
- notification: allow the user to receive all the data about the transport used;
- service alert: allow the user to know all the interruption occurred in the selected region;
- offline maps: allow the user to download the maps needed when the phone mobile data are not available;
- others voice such as: Share us, Evaluate us, Settings, Help & Support, Reports and help your community.

Paris case study



Departure: 33 Rue de Rossays, Savigny-Sur-Orge;

Destination: Paris-Charles De Gaulle (CDG) Airport;

Departure Time and date: 14:41:00 – 05/10/20.

The Figure shows the scheduled trip from the departure point to destination in a straight view. The user can decide to schedule his/her trip in different ways; based on the time of departure, based on desired time of destination and based on the last run of the day. In fact, the user can select from a drop-down menu:

- Starting now
- Departure time
- Time of Arrival
- Last run today

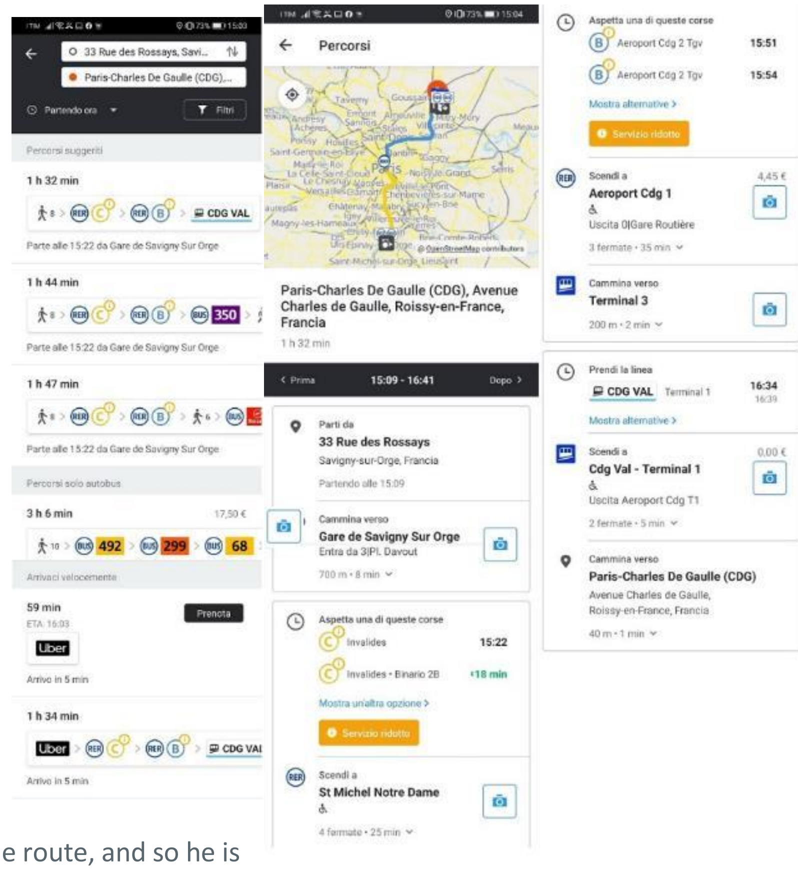
Furthermore, the user can decide to select/unselect filters, as shown in the figure below.

User can decide the type of path:

- Quickest;
- Minor distance;
- Minor number of changes;

In this case, all the possible transports are selected.

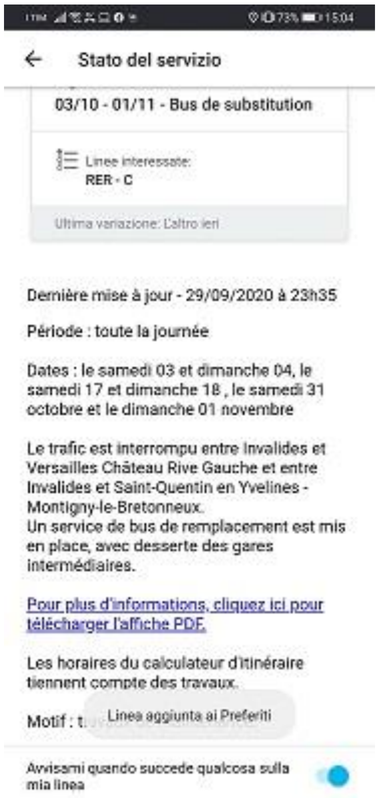
The figure on the right side shows all the possible paths that the user can use from the fastest (selected by filter) to the slowest. The price of the entire course is shown close to the path, and the user can decide which path he/she wants to execute.



The quickest path is selected, and all the steps of the trip are shown. The user can decide to "navigate" the route, and so he is notified by the app when his/her stop is coming.

However, the name and number of stops are shown as well as real time user position in order to make him/her aware of his stops. Furthermore, the orange bar represents an alert due to an interruption occurred or maintenance service on the line. However, alternative courses are proposed. The figure below shown an example of type of alert occurred. Although the app shows the detailed course and the price for each of the provided alternatives making an interpolation of all transportation data, it doesn't allow to buy any kind of ticket.

According to the figure on the right, the first alert is due to maintenance on the line. Anyway, a detailed schedule of maintenance and a substitution bus is provided.



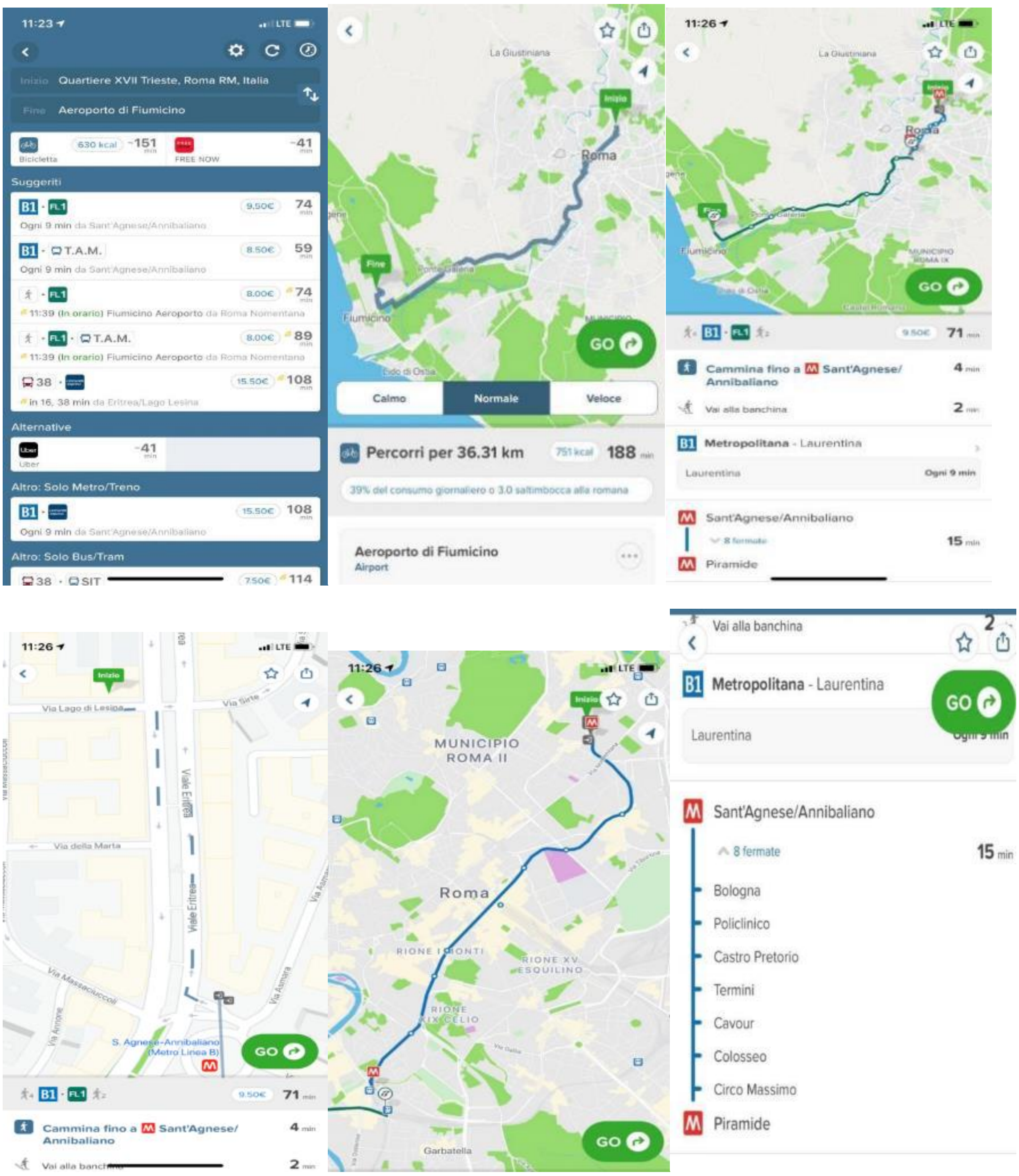
CITYMAPPER

Citymapper is a public transport app. It integrates data from various public transport services, from walking to cycling to driving. Some of the main functions are:

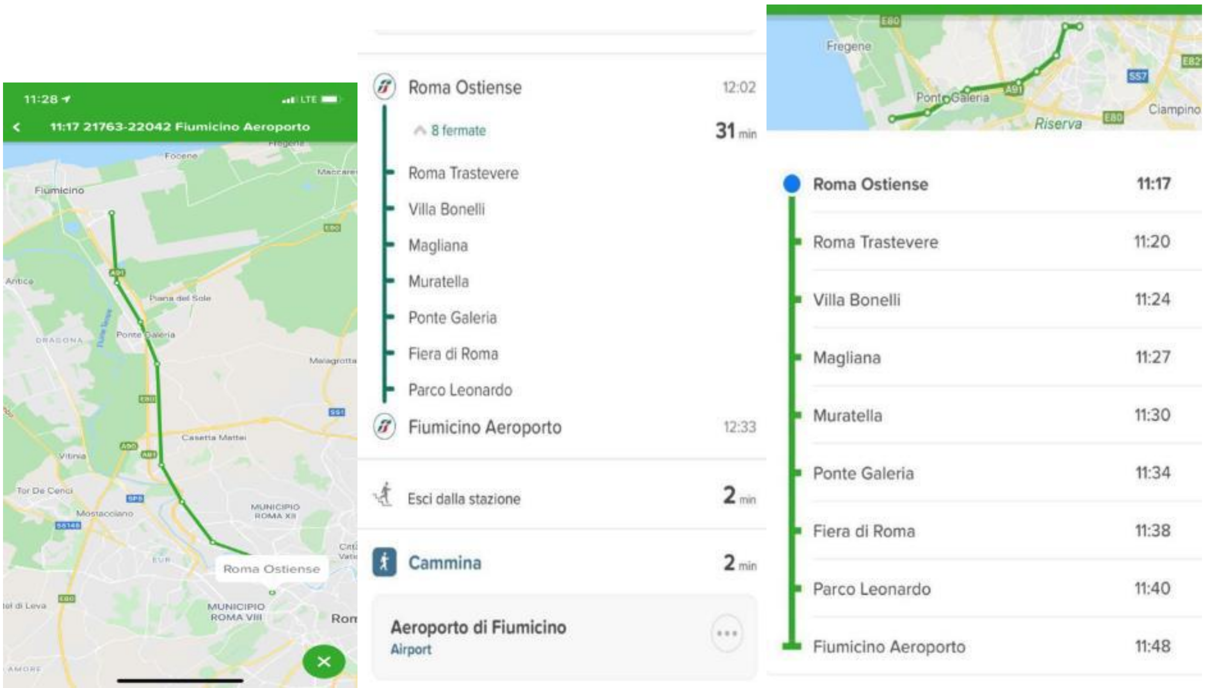
- usual travel planning
- real time waiting times
- metro/tram maps in offline mode
- notifications to help the user to get the destination

The following section presents a simulation trip from the XVII Trieste Rome district to the Fiumicino Airport.

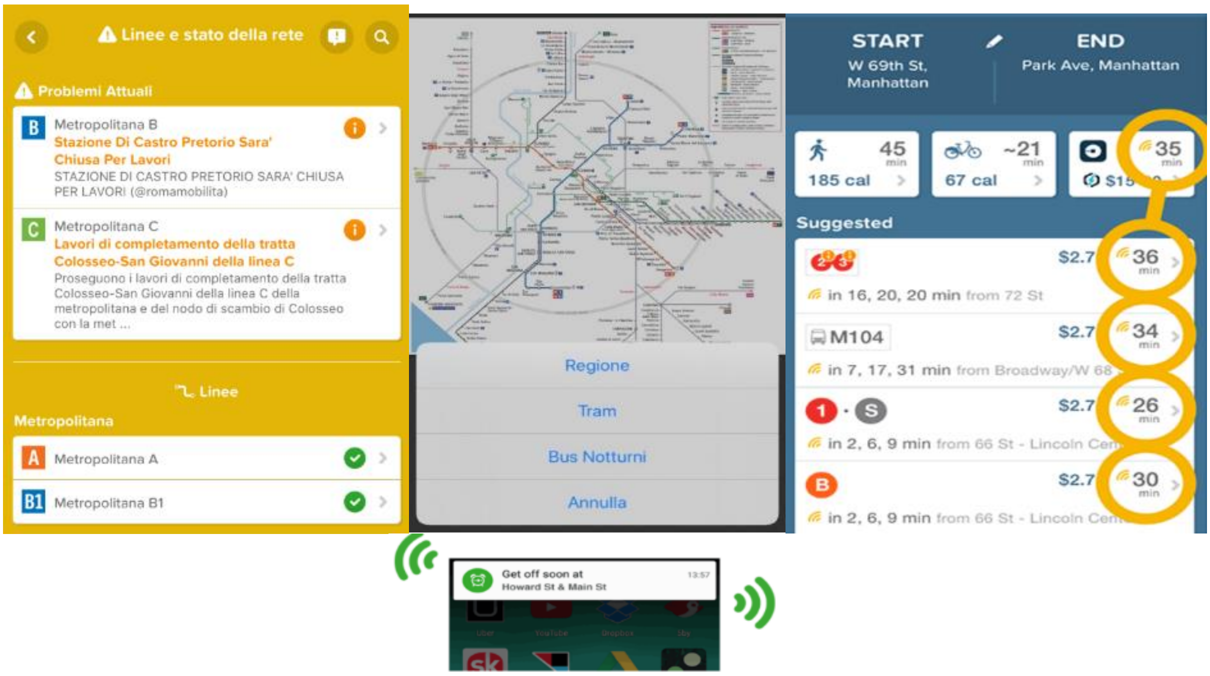
By launching the route, the user can see different travel possibilities. Analysing them in order, the user finds the bicycle section and the ''FreeNow'' section.
In the bicycle section the user can choose between 3 route options: quiet, regular and fast. Quiet routes show the most of dedicated cycle lanes, parks and paths.
Fast routes are the most direct. Regular routes give the best selection from fast and quiet routes. In addition, the km to be done and the % of calories burned are also reported.
Below, an example of suggested routes.



The user is informed about the duration of the trip and the average cost. By clicking on walking, the user is directed to the metro station. Next steps are clearly communicated, and displayed on the map, including distance and street names. If the user gets lost or changes the plan, the route will adjust accordingly. Once the user arrives at the station, the metro stops and the duration of the journey is shown.



When changing the metro with the train, the user finds the complete route, the name of the various stops, the timetable for each stop and the duration of the complete journey.
The citymapper application also has other features, such as the **Problems section**:



This section indicates all the problems related to the state of the network and lines. The user has also the possibility to look at metro, tram and night bus **Maps in Offline Mode.**

The application sends also an alert when the user has to get off the bus or the train during.

Travel times are updated real-time. The figure shows the actual state of the city and its transport network. The wavy yellow symbol (right figure) represents the real travel time and it is based on users' current location and possibility to catch the train or bus.

The "GO" mode permits the user to have the best position to get on the train. Unfortunately, this feature is not yet supported in all cities.

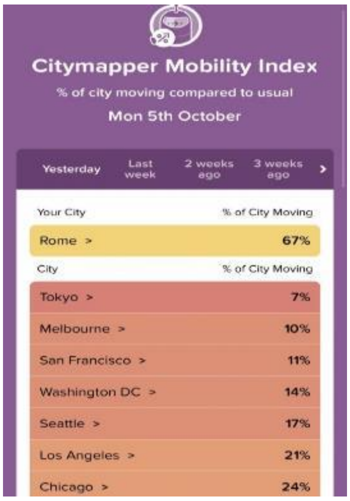
In the citymapper app the user has also **carsharing, scooter sharing and Dott** (electric scooters) tools.

The map shows us the location of the vehicle and the % of battery/petrol available.

In addition to all the services described, the user finds also the "citymapper mobility index" which indicates the% of use of the app in the various cities available.

The app givens also the possibility of purchasing "premium" subscriptions (monthly or annual) in order to obtain additional functions such as:

- voice instructions for those traveling by bike / scooter / electric scooter
- weather reports
- telescope that allows to see the destination



Multimodal travel variable /indicators	Need (Service/function provided)	Analysed applications					
		City Mapper	Moovit	Transit	Gatwick Airport	Munich Airport	Flytoget (Oslo Airport)
T ravel time	Sorting travel options per journey duration	Yes	Yes	Yes	Yes	Yes	Yes
	Confronting travel options per departure time	Yes	Yes	Yes	Yes	Yes	Yes
	Confronting travel options per arrival time	Yes	Yes	Yes	Yes	Yes	Yes
	Confronting travel options per service reliability/punctuality	Yes	Yes	Yes	Yes	Yes	Yes

	Getting advanced information (at proper time) on expected waiting time (i.e. taxi queuing, security check, luggage delivery, check-in/luggage drop, health check, visa check, gate/terminal etc)	Yes	No	No	Yes	No	No
Connections/modes	Sorting travel options for number of connections	Yes	Yes	yes	Yes	Yes	yes
	Selecting travel options for type of mode (i.e. no road journey, use car, bike, kick scooter sharing services etc.)	Yes	Yes	Yes	Yes	Yes	Yes
	Sorting travel options per length and walking time of pedestrian paths	Yes	Yes	Yes	Yes	Yes	Yes
	Sorting travel options per length of outside walks	Yes	Yes	Yes	Yes	Yes	Yes
	Sorting travel options per number of floor changes	No	No	No	No	No	No
	Sorting travel options per availability and position of elevators	No	No	No	No	No	No
	Sorting travel options per inclusive wayfinding infrastructures (audio and	No	No	No	No	No	No

	tactile for visually impaired, written/graphics for auditory impaired etc)						
	Provision of detailed directions in case of multiple entrance/exit point	Possibly	Yes	Yes	Possibly	Yes	Yes
	Pre-view of waiting/entrance/exit points (i.e. google street view)	Possibly	Yes	Yes	Possibly	Yes	Yes
Accessibility and comfort of each travel segment	Availability of boarding/getting off aids (handrails, slides or elevating platforms, assisting personnel etc)	No	No, but provides a figure if the station is for wheelchair	No, but provides a figure if the station is for wheelchair	No	No, but provides a figure if the station is for wheelchair	No, but provides a figure if the station is for wheelchair
	Seat reservation allowed/avoidable	Possibly	No	No	Possibly	No	No
	Clearance for large luggage	No	No	No	No	No	No
	Slides/facilities for heavy luggage/strollers	No	No	No	No	No	No
	Overcrowding alert	No	No	Yes, in some cities	No	No	Yes, in some cities

	Wi-Fi/mobile connection available	No	No	No	No	No	No
	Power recharge points	No	No	No	No	No	No
Cost and level and services provided	Sorting travel options per price	Yes	Yes	Yes	Yes	Yes	Yes
	Clarity of fares: what is included and dot for luggage (limitations in number, size and weight, drop on/off rules, boarding or)	No	No	No	No	No	No
	Clarity of fares: additional services included or selectable (extra-space, priority, assistance for children/elderly/impaired persons, luggage insurance, porter, etc)	No	No	No	No	No	No
	Clarity of fares: cancellation and change policy (timing for free change/cancellation, costs for change/cancellation, number of allowed changes,)	No	No	No	No	No	No
	Fares comparison tool	Yes	No	No	Yes	No	No

	Passengers help desk available by multiple means (phone, chat, email, physical assistant) and languages	No	No	No	No	No	No
Personal security	Operating surveillance /security service	No	No	No	No	No	No
	Possible under-crowding	No	No	No	No	No	No
	Controlled access area vs free access area	No	No	No	No	No	No
	Available shops (opening hours) & lights	No	No	No	No	No	No
Luggage security	Luggage storage (availability, opening hours, cost)	No	No	No	No	No	No
	Luggage boarding constraints (i.e. shuttle bus to airport allowing or not luggage in the cabin)	No	No	No	No	No	No
Environ mental impact	Sorting travel options for CO2 emissions	No	No	No	No	No	No
	Sorting travel options for % of renewable energy source used	No	No	No	No	No	No
Ticket ing	Advanced ticket buying	No	No	yes	No	No	Yes
	Just in time ticket buying (physical)	No	No	yes	No	No	Yes

	Ticket reservation with later payment	No	No	Yes	No	No	Yes
	Alternative paying means (credit cards, PayPal, apple pay, google pay,	No	No	Possibly	No	No	Possibly
	Fully digital ticketing system	No	No	Possibly	No	No	Possibly
	Integrated ticketing	No	No	No	No	No	No
Early and real time information provision	Prompt alert and display of alternative travel paths in case of delay and/or service disruption	Yes	Yes	Yes	Yes	Yes	Yes
	Mean of on-board information provision (audio and tactile for visually impaired, written/graphics for auditory impaired etc)	No	No	No	No	No	No
	Mean of information provision at hub/connection (audio and tactile for visually impaired, written/graphics for auditory impaired etc)	No	No	No	No	No	No
	Number of languages of information provision	Possibly	No	No	Possibly	No	No
	Automatic ticket conversion to alternative travel paths in case	No	No	No	No	No	No

	of delays and/or service disruption						
	Real time update of expected travel time in case of delays and/or service disruption n	Yes	Yes	Yes	Yes	Yes	Yes
	Contextual notification alerting for next travel step (at proper time and proper geographical position, including boarding time, ETOT etc)	Yes	No	Yes	Yes	No	Yes
	Getting real-time information on expected waiting time (i.e. taxi queuing, security check, luggage delivery, check-in/luggage drop, health check, visa check, gate, etc)	No	No	No	No	No	No

eXTEnded AtM for Door2Door travel
X-TEAM D2D

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Institute for Sustainable Society and Innovation

DLR

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