Automated Vehicles to Evolve to a New Urban Experience

DELIVERABLE

D9.3 Roadmap for cost-attractiveness

Co-funded by the Horizon 2020 programme
of the European Union

This project has received funding from the European Union's Horizon 2020 research and innovation program under grant agreement No 769033

Disclaimer

This document reflects only the author's view and the European Commission is not responsible for any use that may be made of the information it contains.

Document Information

Grant Agreement Number	769033
Full Title	Automated Vehicles to Evolve to a New Urban Experience
Acronym	AVENUE
Deliverable	D9.3 Roadmap for cost-attractiveness
Due Date	31.08.2022
Work Package	WP9
Lead Partner	Hochschule Pforzheim University
Leading Author	Guy Fournier
Dissemination Level	Confidential

Document History

Version	Date	Author	Description of change
1.0	01.08.2021	Eliane Nemoto	First drafts Eliane Nemoto based on slides from Guy Fournier
2.0	14.08.2021	Michael Thalhofer	Check and restructuring
2.0	14.08.2021	Guy Fournier	Check and restructuring
2.1	27.08.2021	Dorien Korbee	Rephrasing and restricting sections 3 and 4
2.2	28.08.2021	Guy Fournier	Check and restructuring
2.3	31.08.2021	Markus Dubielzig	Check and PRM
2.4	01.09.2021	Dorien Korbee, Guy Fournier	Check and restructuring
2.5	08.09.2021	Christian Zinckernagel	Check and restructuring
2.6	01.11.2021	Christian Zinckernagel	Technical barriers and success factors
2.7	04.11.2021	Ines Jaroudi, Eliane Nemoto, Adrian Boos	Check in particular externalities
2.8	10.11.2021	Dorien Korbee, Adrian Boos	Check chapter 5 and 6
2.9	20.11.2021	Guy Fournier	Check all the document and adding parts in chapter 5
2.10	04.12.2021	Gabrielle Naderer	Check all the document and adding parts in chapter 5

2.11	27.01.2022	Guy Fournier	Check all the document and adding parts in chapter 5
3.0	10.02.2022	Adrian Boos, Eliane Nemoto, Nicole van den Boom	Check all the document and restructured some of it
3.1	15.02.2022	Guy Fournier	Check all the document and restructured some of it
3.2	01.03.2022	Michael Thalhofer	Check all the document
3.3	15.03.2022	Eliane Nemoto	Updates and changes along the document
3.4	30.03.2022	Adrian Boos	Updates and changes along the document
3.5	10.04.2022	Lionel Binz	Updates and changes along the document
3.6	01.05.2022	Guy Fournier	Updates and changes along the document
3.7	10.05.2022	Adrian Boos	Updates and changes along the document
3.8	15.05.2022	Michael Thalhofer	Updates and changes along the document
4.0	01.06.2022	Adrian Boos	Check all the document and restructured some of it
4.1	10.06.2022	Guy Fournier	Revision and formatting of the entire document
4.2	15.06.2022	Adrian Boos	Revision and formatting of the entire document
4.3	20.06.2022	Nicole van den Boom	Revision and formatting of the entire document
4.4	20.08.2022	Guy Fournier	Review and approval of Vision
4.5	21.08.2022	Adrian Boos	Review of the whole document
5.0	26.10.2022	Adrian Boos and Guy Fournier	Review of the whole document
5.1	05.11.2022	Guy Fournier Adrian Boos	Incorporation of the internal review and preparation of the final document
5.2	13.12.2022	Dimitri Konstantas	Review of the whole document
5.3	15.12.2022	Guy Fournier Michael Thalhofer Adrian Boos	Incorporation of the review
6	18.12.2022	Guy Fournier	Release of the final document
6.1	15.01.2023	Vedran Vlajki, Dimitri Konstantas	Presentation adaptations
6.2	20.2.2033	Adrian Boos, Michael Thalhofer, Guy Fournier	Finalising the document
6.4	7.03.2023	Dimitri Konstantas, Vedran Vlajki	Finalising the document, Comments for corrections
6.5	21.03.2023	Adrian Boos, Michael Thalhofer, Guy Fournier	Cleaning and Finalising the document

Table of Contents

List of Figures

List of Tables

Acronyms

AI	Artificial Intelligence
AM	Automated Minibus
AMPT	Automated Minibuses for Public Transport
API	Application Programming Interface
AV	Automated Vehicle
AVENUE	Autonomous Vehicles to Evolve to a New Urban Experience
BMVI	Bundesministerium für Verkehr und Digitales
CPT	Conventional Public Transport
DESI	Digital Economy and Social Index
DLT	Distributed Ledger Technology
DMA	Digital Market Act
DNN	Deep Neural Networks
EU	European Union
GAFAM	Google, Apple, Facebook, Amazon
GDPR	General Data Protection Regulation
GNSS	Global Navigation Satellite System
GPS	Global Positioning System
IMU	Inertial Measurement Unit
ITS	Intelligent Transport System
LCA	Life Cycle Assessment
LiDAR	Laser Detection and Ranging
MAAMA	Meta, Alphabet, Amazon, Microsoft, Apple
MaaS	Mobility as a Service
NGO	Non-Governmental Organization
ÖBB	Österreichische Bundesbahnen
PRM	People with Reduced Mobility
PTA	Public Transport Authorities
PTO	Public Transport Operator
RTK	Real-Time Kinematic Positioning
SUMP	Sustainable Urban Mobility Plans
TÜV	Technischer Überwachungsverein

Executive Summary

Roadmap of recommendations for cost-attractiveness

In the following we provide a summary of main recommendations within a roadmap (from status quo to a Vision for 2030) to achieve cost attractiveness (efficiency), which is then found in more detail in the rest of the document. First of all, it must be pointed out that in the earlier work package WP8 of the AVENUE project, all possible future scenarios were presented as business models and discussed in detail. The result was that the most sensible business model for the future of connected, cooperative and automated mobility (CCAM) is to integrate AM (automated minibuses) in a MaaS/ITS, which we present in detail in the AVENUE vision below.

In the deliverable at hand, this vision is analysed in detail with all the tools of a business model such as the Business Canvas and the SWOT analysis. However, the costs for this cannot be calculated and presented yet in detail because it is currently a vision that follows the European CCAM vision and will not become reality soon. We anticipate that the large-scale deployment of automated vehicles (AVs) will not become reality in the next 5 years, due in particular to barriers and shortcomings in the technology, high depreciations and legal framework. Too many prerequisites have to be fulfilled. It is for example common sense that the cost attractiveness is only possible if security drivers can be reduced soon in the course of time and replaced by supervisor, but this is currently neither technically nor legally possible at every location in Europe. However, both technology and legal framework are evolving very fast and we expect that in the next 2-3 years (and at the latest in the time horizon of our Vision 2030) the majority of the issues can be resolved when following the recommendations.

Accordingly, we will present first in summary (table 1), then in overview points, a roadmap for achieving this cost-attractive vision. We do not interpret the topic of cost attractiveness in the narrow sense of balance-sheetable costs, as these are currently not yet presentable, but rather in a broader sense including all cost-related factors - we understand our objective beyond the TCO (Total cost of ownership) approach not only as a contribution to the consolidation of the Total Cost of Mobility (TCM), but also as a contribution to economic efficiency - cost coverage – and profitability:

The roadmap for cost-attractiveness targets all the related actors in the public transportation. Specifically, at the lowest level we have the vehicle manufacturers, who should be able to develop and market at competitive prices large numbers of vehicles, creating profit for their companies. We then have the service provision companies, developing fleet management solutions, who should be able to provide their services to the public transport operators (PTOs) and public transport agencies as commercial for-profit companies. Next, we have the PTOs/PTAs that are in general funded by public funding, and have as target to provide high quality public transportation services, with as low costs as possible for the financing government or municipal authorities, taking into account social and environmental targets defined by the public authorities. Finally, we have the citizens who as users require an affordable public transportation service with a high level of service quality. Our roadmap covers each of the above actors, with different time horizons. However, as we cannot give recommendations to citizens, a few for the EU itself are included below, in addition to the others.

AVENUE ROADMAP – MAIN RECOMMENDATIONS ... for COST ATTRACTIVENESS

TODAY 2022 → VISION 2030

2022 – M0: no AM → STEP 1	2024 – M1: AM → STEP 2	2026 – M2: AM System → STEP 3	2028 – M3: AM in MaaS → STEP 4 (2030 – M4: AM in MaaS /ITS)

Legend:
R_202x-202y.z = Recommendation for the years 202x-202y, no. z

Timeline Categorization of Recommendations

STEP 1	STEP 2	STEP 3	STEP 4
R_2022-24.1: Freeze the Vehicle design to a standardized model **R_2022-24.2:** Intensify the use of Data and AI to reach SAE level 4 and enable profitable business models for OEMs, PTOs and related service providers **R_2022-24.3:** Clarify the business model: choose between selling vehicles or providing services **R_2022-24.4:** Create alliances and/or partnerships with AM-"competitors" in Europe (coopetition) in order to set common targets to win the European market **R_2022-24.5:** Redefine and integrate AMs (shared vehicles and services providing ecological, social and cost benefits) into the Sustainable Urban Mobility Planning of cities (SUMP), defining target areas for initial large scale deployments. **R_2022-24.6:** Strengthen the positive attitude towards a high acceptance and initiate information campaigns and nudges toward citizens and decision makers to present advantages, issues and changes to achieve the citizens' intended use of public transport-tation, on-demand services and in particular AM in MaaS. **R_2022-24.7:** Propose an EU-wide standardized and common certification methodology for AMs, reducing costs and promoting cross-country markets. **R_2022-24.8:** Ensuring symmetry in competition between public and private PTOs through avoiding closed eco-systems and respecting European laws like GDPR, DSA and DMA.	**R_2024-26.1:** Define a roadmap for the design and implementation of an adequate technical urban infrastructure, integrating AM (traffic lights, charging station etc.) in it to increase the safety and the ability to get the safety driver out and the related costs **R_2024-26.2:** Value added in-vehicle services (for passenger comfort, safety and security, navigation, etc.) to increase the acceptance by the citizen and the attractiveness of services **R_2024-26.3:** Plan the transition from driver-based operation to driverless operation of vehicles, from the point of view of today's bus drivers. **R_2024-26.4**: Establishment of an open legislative database to make the different European regulations more transparent and to ease the diffusion of CCAM in MaaS in the European Union	**R_2026-28.1:** Present a plan for an integrated citizen-centric mobility ecosystem, taking into account all available/possible transport modes, in order to offer a unique integrated solution for passenger mobility needs **R_2026-28.2:** Develop and promote mobile Apps for seamless on-demand door-to-door transport and accessible to all types of citizens (inclusion) **R_2026-28.3:** Create a plan, identifying which and how data can be provided as open data for value added services **R_2026-28.4:** Management concept for coopetitive public/private PTO-collaborations to increase the complementarities of the means of transports and the efficient use of the fleets and of the transport system as a whole **R_2026-28.5:** Create and align PTO and other stakeholder (e.g. service providers, OEMs etc.) business models for the transport system **R_2026-28.6:** Define an attractive tariff system and incentives for citizens to favor seamless driverless transport **R_2026-28.7:** Adopt and develop ecosystems based on standardised open APIs, open protocols **R_2026-28.8:** Design and establish a novel governance concept for citizen centric AMs in a MaaS to serve general interest and the creation of the required eco-system to support economically viable deployments	**R_2028-30.1:** Integration of automated minibuses in low and medium scale areas, in MaaS/ITS to satisfy citizen needs **R_2028-30.2:** Increasing trust and reliability of the mobility system for the citizen by AI based value adding user experience **R_2028-30.3:** Use the AM in ITS to improve the flexibility, the resilience and the efficiency of the transport system as a whole

Ownership Assignment of Recommendations

STEP 1	STEP 2	STEP 3	STEP 4
Rec. for Vehicle Manufact. (OEM): 1, 2, 3, 4 **Rec. for PTOs/PTAs:** 2, 4, 5, 6, 8 **Rec. for the European Union:** 7, 8	**Rec. for PTOs/PTAs:** 1, 3 **Rec. for Service Providers** 2 **Rec. for the European Union:** 3, 4	**Rec. for PTOs/PTAs:** 1, 2, 3, 4, 5, 6 **Rec. for Vehicle Manufact. (OEM), Service Providers & PTOs/PTAs:** 7, 8 **Rec. for National & Local Authorities:** 8	**Rec. for PTOs/PTAs:** 1, 2, 3 **Rec. for the European Union:** 1, 2, 3

Table 1: Roadmap of Main Recommendations for Cost Attractiveness

Detailed description of the recommendations from the roadmap

Roadmap – STEP 1 – 2022-2024:

R_2022-24.1 (Recommendation for OEM):

Freeze the Vehicle design to a standardised model

Today vehicle manufacturers are producing permanent Beta-versions of the AMs, with continuous changes and medications. As result each vehicle unit is a prototype almost individually constructed, which results in very high unit costs. The manufacturer should freeze the design and implantation to a standard model and proceed so that they can next advance to chain production, bring the production cost per vehicle to a fraction of today's price and opening the way for large number orders by the PTOs/PTAs. Currently, there are whether economies of scale nor economies of scope on the market, which are urgently needed for cost attractiveness.

R_2022-24.2 (Recommendation for OEM / PTOs / PTAs):

Intensify the use of Data and AI to reach SAE level 4 and enable profitable business models for OEMs, PTOs and related service providers

The improvement of road behaviour requires solid automated recognition of different events and situations. This can only be done with the use of AI technologies. However, AI technologies require relevant data, coming from the deployment environments. Today, the vehicles produced in the European Union do not have enough data coming from European streets, thereby hindering the substitution of the safety driver by a back-office supervisor. The collection and analysis of the massively required relevant data is also hindered by the misunderstanding of the GDPR rules and restrictions by the PTOs and PTAs, who simply prohibit the mass collection and analysis of the data collected (or being able to be collected) by the deployed vehicles. In addition, the effort required by the manufactures to analyse the data, is beyond their capacity and the pavement towards profitable business models for PTOs are not realistic. Thus, from one side the Public and EU authorities should provide clarifications on the GDPR overreach, reassuring the European OEMs to develop GDPR compliant AI and enable a GDPR performant AI-based ecosystem for EU CCAM mobility. GDPR compliance for AI should become mandatory for non-European competitors to ensure a symmetry in competition with home competitors.

R_2022-24.3 (Recommendation for OEM):

Clarify the business model: choose between selling vehicles or providing services

Today vehicle manufacturers have an unclear business model that is neither this of a car seller, nor of a service provider. The manufacturers try to make their profit from both selling vehicles (hardware) and providing required services (from commissioning to maintenance and supervision). As a result, the overall costs to the PTO/PTA is both high as CAPEX and as OPEX making any large scale acquisition plan extremely costly. Past experience (in the 70 to 90s) has shown that equivalent companies (like IBM in the 70; s and 80's) were able to dominate the market by proving a services model (software rental) and providing the hardware at cost price or even free of cost (but with long term service and software leasing contract), whereas car companies were making their business by selling hardware only. This means, vehicle manufacturers have to identify, analyse and design Business Strategies/Opportunities and Models for profitable AM applications for example the use of existing infrastructure data to improve the behaviour of the vehicle in the street and its attractiveness.

R_2022-24.4 (Recommendation for OEM / PTOs / PTAs):

Create alliances and/or partnerships with AM-"competitors" in Europe (coopetition) in order to set common targets to win the European market

AMs are manufactured today in many countries around the world, from China to USA, where the state (China) and private companies (USA) are investing billions per year. In Europe the relevant companies do not have the possibility to raise even a fraction of the USA and Chinese investments. It is more than urgent for the different manufacturer to align their efforts to provide solutions adapted to the European market, before the international players take over the European market offering lower prices. The fragmentation of the European market of vehicle manufacturers and the lack of communication and collaboration, does further not allow the creation of a dynamic and sustainable business ecosystem in order to be competitive with non-European manufacturers by offering competitive prices. In order to assure supply chains for vehicle components and to avoid a market consolidation via bankruptcies, vehicle manufacturers should identify, analyze and design Partnering Strategies/Opportunities with service providers and create new partner oriented business models for a profitable AM system. This could be interesting in particular for open API, open Data and open Protocols. The recommendations in this deliverable can be implemented independently but it would be best to be considered together to optimise cost effectiveness, where each manufacturer can specialise in the areas of its best expertise, reducing thus costs.

R_2022-24.5 (Recommendation for PTOs / PTAs):

Redefine and integrate AMs (shared vehicles and services providing ecological, social and cost benefits) into the Sustainable Urban Mobility Planning of cities (SUMP), defining target areas for initial large-scale deployments

With a laissez-faire strategy, the development from status quo to a mobility system with AVs could end in more individual private transport and weakening of public transport. Considering that the urban public transport mobility strategy implementation can take 10 years from the moment of its definition, PTOs and PTAs must integrate in their under development/adaptation urban mobility strategic planning, the use and deployment of AVs, even if the technology is not yet to the expected level. With a 10 years lead time to implementation, PTOs/PTAs need to anticipate as early as possible the future deployments and initiate the required studies to evaluate costs, define possible deployment areas and define targeted service levels.

The AVENUE environmental impact assessment shows, that if the AMs are well utilized in terms of mileage and regularly used by passengers, they will present great advantages over individual vehicles. Therefore, it is strongly recommended to integrate AMs in the strategic planning of a MaaS/ITS ecosystem to enable positive externalities (through increased citizen choice and inclusiveness, improved fleet efficiency, saving natural resources and energy etc.) and lower external costs (ecological advantage). The governance will decide if the use of AMs is environmentally friendly and sustainable or not. Therefore, a system should be created in which it is standard that vehicles and services are shared, which would also improve the ratio of costs to paying customers.

R_2022-24.6 (Recommendation for PTOs / PTAs):

Strengthen the positive attitude towards a high acceptance and initiate information campaigns and nudges toward citizens and decision makers to present advantages, issues and changes to achieve the citizens' intended use of public transportation, on-demand services and in particular AM in MaaS

The transition from fixed line, fixed time-table public transportation to on-demand, door-to-door, is a major paradigm change for the passengers, which can create a negative/rejection attitude, is not well explained. An important finding of the AVENUE social impact assessment is that (potential) users present a positive and receptive attitude towards the AM. Therefore, there is potential to convince others through well-targeted communication campaigns, especially in social media. It is a recognised principle of economics that increasing demand, e.g. through more customers due to a higher acceptance of shared mobility with AMs, could reduce the cost per customer. However, erroneous use of AM based mobility, can drastically increase operational and external costs (for example, using the AMs for very short distances or as substitute to public mass transport (tramway, trains, etc.), as it is the case when AMs are used like robotaxis) and lower service quality. An information campaign should be started as soon as possible to inform the citizens of the benefits of the new models of transport and the related issues. Create positive incentives towards the use of AMs (nudges).

R_2022-24.7 (Recommendation for the European Union):

Propose an EU-wide standardised and common certification methodology for AMs, reducing costs and promoting cross-country markets

Throughout Europe each country is setting up its own certification process and rules for automated vehicles. As a result, the same vehicle needs to be homologated under different rules in each deployment country. Although steps have been already made to simplify the process, a European wide regulation (as is the case with traditional vehicles) will strongly promote the market, reduce the acquisition costs and allow cross-country commerce of AVs and of their components like batteries.

R_2022-24.8 (Recommendation for the European Union / PTOs / PTAs):

Ensuring symmetry in competition between public and private PTOs through avoiding closed ecosystems and respecting European laws like GDPR, DSA and DMA

We recommend open platforms, open APIs and open Data which respects GDPR, DSA and DMA to avoid closed private ecosystems and enable fair competition in the mobility market. To this end, the EU has to create the regulatory and governance conditions for the PTAs to orchestrate a fair and balanced competition on the local, national and EU-level (seamless interoperability) and thus create a European mobility ecosystem which serves the general interest and promotes a European mobility industry ecosystem. The EU has to make laws which anticipate AM in MaaS/ITS and anticipates the speed of legislative processes. Once closed ecosystems are created with gatekeepers like it is the case in several other European industries, it will be too late to regulate the mobility market ex post due to already created facts and dominant positions.

Roadmap – STEP 2 – 2024-2026:

R_2024-26.1 (Recommendation for PTOs / PTAs):

Define a roadmap for the design and implementation of an adequate technical urban infrastructure, integrating AM (traffic lights, charging station etc.) in it to increase the safety and the ability to get the safety driver out and the related costs

A roadmap for the design and implementation of an adequate technical infrastructure regarding battery charging, communication infrastructure/data exchange, vehicle related services and maintenance needs to be defined and included in the sustainable urban development planning (SUMP), with an at least 10 years' horizon. The PTAs must be coordinated with urban planning authorities to identify how the city will develop and how the required infrastructure will be installed. This planning will be required in order to secure the required funding and authorisations. The urban planning should take into account the needs of AMs for accurate geolocalisation (centimetric) and identify shadow areas where additional equipment will need to be installed (e.g. RTK (Real-Time Kinematic) positioning, road side sensorics on traffic lights (Vehicle to Infrastructure, V2I, Vehicle to vehicle, V2V or vehicle to passenger, V2P)). Furthermore, cybersecurity as well as physical security of the installations should be integrated in the planning and backup solutions as well as disaster recovery solutions should be anticipated. AM in MaaS or better later AM in ITS should thus integrate the infrastructure as a long-term strategy to create inherent resilience of all the transport system.

R_2024-26.2 (Recommendation for Service Providers):

Value added in-vehicle services (for passenger comfort, safety and security, navigation, etc.) to increase the acceptance by the citizen and the attractiveness of services

Based on the local needs, regulations and target service quality, a series of passenger in-vehicle services, replacing the driver offered services, must be planned before the deployment of a full scale, driverless public transportation service. The in-vehicle services should be able to provide easily accessible alternatives to the services offered by the bus driver, preserving the passenger privacy, and enhancing the security of the passengers in the vehicle. A way for the passenger to interact with a human assistant should be available in the vehicle. The services will need to be supported by target information campaign and clearly indicated in the vehicle.

R_2024-26.3 (Recommendation for PTOs / PTAs / European Union):

Plan the transition from driver-based operation to driverless operation of vehicles, from the point of view of today's bus drivers

The suppression of the bus drivers will be seen a threat of job losses of the current drivers. A medium to long-term transition plan should be developed for the gradual reduction of the number of drivers and their conversion to back-office operators and intervention team operators. This plan should consider the natural departure of personnel (retirement for example), the lack of bus drivers and the lack of attractivity of the bus driver profession and organise the medium to long-term re-education of the drivers to the new functions.

R_2024-26.4 (Recommendation for the European Union):

Establishment of an open legislative database to make the different European regulations more transparent and to ease the diffusion of CCAM in MaaS in the European Union

The fragmentation of European legislation in terms of deployment of CCAM vehicles is an administrative obstacle for pan-European deployment of innovative mobility services, especially for SMEs, who do not have the means to study the differences between EU countries' legislation. A legislative database at European level (similar to the existing platforms in the US) which brings up-to-date and real-time information about the fast-growing AV legislation on local, state, and regional level is missing should be in place and operational by 2026. This could simplify the planning of all stakeholders like vehicle manufacturers, deployers of AM, transport operators, states, municipalities, etc., and encourage the diffusion of AM technologies and the improvement of the transport system.

Roadmap – STEP 3 – 2026-2028:

R_2026-28.1 (Recommendation for PTOs / PTAs):

Present a plan for an integrated citizen-centric mobility ecosystem, taking into account all available/possible transport modes, in order to offer a unique integrated solution for passenger mobility needs

Different mobility modes are becoming available in cities, each with its own targets and different passenger needs. At the same time many mobile phone applications are appearing giving access to the different mobility modes. However, today these mobility solution modes represent competing mobility solutions, instead of complementary mobility solutions.

A plan should thus be created for seamless multimodal forms of transport, were AMs play a central role as mobility gap filler enabling spatial (e.g. area instead of line in particular in time of low demand), temporal (e.g. on-demand) and functional flexibility (door-to-public transportation network, part of the public transport network, door-to-door) similar attractive to a private car.

R_2026-28.2 (Recommendation for PTOs / PTAs):

Develop and promote mobile Apps for seamless on-demand door-to-door transport and accessible to all types of citizens (inclusion)

Before the deployment of AMs, aggregator-apps for seamless and efficient on-demand door-to-door journeys for citizens, should be developed and extensively tested, especially for passengers with special needs. All mobility modalities need to be integrated in a single app increasing thus the mobility offer. The offer could in particular be adapted to all the passenger depending on the persona (mobility for work or for leisure), weather (a passenger would probably prefer the AM in case of rain instead of bicycle) etc. and of the PRM needs and capabilities. In order to provide an integrated citizen-centric mobility ecosystem the passenger capabilities should be integrated in the app service (e.g. we cannot propose to an 85-year-old person to complete his trip using a bicycle!) which will suggest and reserve the most adapted mobility solution.

R_2026-28.3 (Recommendation for PTOs / PTAs):

Create a plan, identifying which and how data can be provided as open data for value added services

The operation of AMs in public transportation will generate large quantities of data which until now were very difficult to collect. From exact passenger trips, to road conditions (congestion, speed etc.), to passenger incidents and vehicle status. These data, if exploited correctly, will allow e.g. service quality improvement, trip optimisation, energy consumption reduction but also optimisation of AM fleets, infrastructure, city planning etc.. However, in order to promote the creation of new services for and new mobility models, the data should become available to third parties. A plan must be ready defining which data can be available (preserving any possible sensible passenger privacy information) and how third parties will be able to access and use them. Detailed specifications and formats should be easily available and published, so as the interested parties can start development of analytical tools and services. This has to be regulated by the ecosystem provided by the PTA in the privacy and security concept.

R_2026-28.4 (Recommendation for PTOs / PTAs):

Management concept for coopetitive public/ private PTO-collaborations to increase the complementarities of the means of transports and the efficient use of the fleets and of the transport system as a whole

In the long run, innovations and new mobility services will be developed from different private companies. These innovations will need to be integrated to the overall mobility offer to enable increase in efficiencies and allow a citizen-centric approach. PTAs will thus need to design a management concept for a balanced ecosystem for public/private PTO-collaborations to increase the complementarities of the means of transports and the efficient use of the fleets through the use of data and of the transport system as a whole.

R_2026-28.5 (Recommendation for PTOs / PTAs):

Create and align PTO and other stakeholder (e.g. service providers, OEMs etc.) business models for the transport system

Providing high quality, low cost, on-demand, door-to-door public transportation services, will eventually have a major impact on the mobility business in the urban environment. Taxis services, private transport services and even delivery services will be highly impacted. The PTAs should clarify the perimeter of the services that will be provided by the AMs, so that they would impact the existing business models of other mobility stakeholders. For example, in order to avoid competition with taxi services (including robotaxis), door-to-door services can be limited to a certain distance or time, while imposing no limits to door-to-hub AM based transport.

R_2026-28.6 (Recommendation for PTOs / PTAs):

Define an attractive tariff system and incentives for citizens to favor seamless driverless transport

One of the key goals of the deployment of AMs in door-to-door, on-demand urban mobility, is to provide to citizens an efficient mobility service and ”pull” them to abandon the use of a private car without coercive “push” policy but with an attractive mobility offer (the so-called pull strategy). However, one of the key elements to this transition is the tariffing model. PTAs and PTOs should therefore create an attractive tariff system together and provide incentives for citizens to utilize the multimodal MaaS-system instead of utilizing private owned cars or robotaxis. The proposed tariffs could e.g. be compatible with the overall cost for using a private car, including parking fees, infrastructure costs, energy consumption, urban toll etc..

R_2026-28.7 (Recommendation for OEM / Service Provider / PTOs / PTAs):

Adopt and develop ecosystems based on standardised open APIs, open protocols

A key element in the development of interoperability of all the means of transport, their platforms and apps, but also of a competitive market, is the use of standardised interfaces and protocols, that open the doors to innovation, marked competition, increased quality and price reductions. In order to avoid a winner-takes-it-all situation, where a major non-European company dominates the market, European manufacturers (OEM) should propose, national authorities should adopt, and PTOs, App providers etc. should use open standards for APIs and protocols.

R_2026-28.8 (Recommendation for National and Local Authorities):

Design and establish a novel governance concept for citizen centric AMs in a MaaS to serve general interest and the creation of the required ecosystem to support economically viable deployments

The deployment of CCAM will require the creation of a local, regional or national ecosystem, where key expertise can be found. This will require a dual action from the authorities, in both the legislative and educational domains.

On the level of city or national/regional governments, it will be necessary to design, implement and supervise individual technical certification and licensing concepts for AMs and their integration into MaaS according to respective regulations and selected standards. However, the required expertise, be it technical or regulatory, must be available in the local ecosystem. For this, relevant authorities will need to create technical trainings and integrate at different levels of education the required courses and programs to create the locally needed expertise.

This implementation will enable economic efficiency and, above all, social and ecological benefits that are only possible through sensitive mobility governance. To do so, a balance between individual and general interest must be found for the stakeholders on the city level.

Roadmap – STEP 3 – 2028-2030:

R_2028-30.1 (Recommendation for PTOs / PTAs / European Union):

Integration of automated minibuses in low and medium scale areas, in MaaS/ITS to satisfy citizen needs

By 2030, and based on the strategy that was developed earlier, the first medium scale deployments of AVs should become available in selected targeted areas with low and medium mobility demand, fully integrated to the MaaS services. The deployment should address the needs in rural and suburban areas where public transport is weak and enable a flexibility which is nearly as convenient but much cheaper than a private car. The target being that an integration of AMs to other means of transport within a MaaS (through an App also adapted for persons with special needs), would increase the attractivity for passengers in terms of time, space, function and usability. Beyond this inclusive approach, starting in rural and suburban areas would further have the advantage to raise the level of education with a lower technical complexity.

R_2028-30.2 (Recommendation for PTOs / PTAs / European Union):

Increasing trust and reliability of the mobility system for the citizen by AI based value adding user experience

As most of the offered mobility services will be eventually based and/or make use of a AI-based real-time self-optimisation, leading to a better information situation and permanently optimised journey for citizens, it is of major importance for the PTA/PTOs to have established a strategy to reply, first to the questions of the citizens regarding data usage and how decisions are taken, and second a “disaster recovery” strategy to reply to incidents and failures of the services, that will eventually increase the positive user experience and trust into the mobility in ITS ecosystems.

R_2028-30.3 (Recommendation for PTOs / PTAs / European Union):

Use the AM in ITS to improve the flexibility, the resilience and the efficiency of the transport system as a whole

By the application of AI-based real-time self-optimisation of the entire AM in MaaS ecosystem in all facets the risk of technical failures and down-times can be significantly reduced, which increases the cost-efficiency at the same time. This increases the attractivity for EU towards a faster market penetration of the AM in MaaS/ITS concept.

1 Introduction

AVENUE aims to design and carry out full-scale demonstrations of urban transport automation by deploying, for the first time worldwide, fleets of Automated minibuses in low to medium demand areas of 4 European demonstrator cities (Geneva, Lyon, Copenhagen, and Luxembourg) and 2 to 3 replicator cities. The AVENUE vision for future public transport in urban and suburban areas, is that Automated vehicles will ensure safe, rapid, economic, sustainable, and personalised transport of passengers. AVENUE introduces disruptive public transportation paradigms based on demand, door-to-door services, aiming to set up a new model of public transportation, by revisiting the offered public transportation services, and aiming to suppress prescheduled fixed bus itineraries.

Vehicle services that substantially enhance the passenger experience as well as the overall quality and value of the service will be introduced, also targeting elderly people, people with disabilities and vulnerable users. Road behaviour, security of the Automated vehicles and passengers' safety are central points of the AVENUE project.

At the end of the AVENUE project four-year period the mission is to have demonstrated that Automated vehicles will become the future solution for public transport. The AVENUE project will demonstrate the economic, environmental, and social potential of Automated vehicles for both companies and public commuters while assessing the vehicle road behaviour safety.

1.1 On-demand Mobility

Public transportation is a key element of a region's economic development and the quality of life of its citizens.

Governments around the world are defining strategies for the development of efficient public transport based on different criteria of importance to their regions, such as topography, citizens' needs, social and economic barriers, environmental concerns, and historical development. However, new technologies, modes of transport and services are appearing, which seem very promising to the support of regional strategies for the development of public transport.

On-demand transport is a public transport service that only works when a reservation has been recorded and will be a relevant solution where the demand for transport is diffuse and regular transport is inefficient.

On-demand transport differs from other public transport services in that vehicles do not follow a fixed route and do not use a predefined timetable. Unlike taxis, on-demand public transport is usually also not individual. An operator or an automated system takes care of the booking, planning and organization.

It is recognized that the use and integration of on-demand Automated vehicles has the potential to significantly improve services and provide solutions to many of the problems encountered today in the development of sustainable and efficient public transport.

1.2 Fully Automated Vehicles

A self-driving car, referred in the AVENUE project as a **Fully Automated Vehicle** (**AV**), or as Autonomous Vehicle, is a vehicle that can sense its environment and moving safely with no human input.

The terms *automated vehicles* and *autonomous vehicles* are often used together. The Regulation 2019/2144 of the European Parliament and of the Council of 27 November 2019 on type-approval requirements for motor vehicles defines "automated vehicle" and "fully automated vehicle" based on their autonomous capacity:

An "automated vehicle" means a motor vehicle designed and constructed to move autonomously for certain periods of time without continuous driver supervision but in respect of which driver intervention is still expected or required

"Fully automated vehicle" means a motor vehicle that has been designed and constructed to move autonomously without any driver supervision

In AVENUE we operate ***Fully Automated minibuses for public transport***, (previously referred as Autonomous shuttles, or Autonomous buses), and we refer to them as simply *Automated minibuses* or *the AVENUE minibuses.*

In relation to the SAE levels, the AVENUE project will operate SAE Level 4 vehicles.

SAE INTERNATIONAL

SAE J3016™ LEVELS OF DRIVING AUTOMATION

	SAE LEVEL 0	SAE LEVEL 1	SAE LEVEL 2	SAE LEVEL 3	SAE LEVEL 4	SAE LEVEL 5
What does the human in the driver's seat have to do?	You are driving whenever these driver support features are engaged – even if your feet are off the pedals and you are not steering			You are not driving when these automated driving features are engaged – even if you are seated in "the driver's seat"		
	You must constantly supervise these support features; you must steer, brake or accelerate as needed to maintain safety			When the feature requests, you must drive	These automated driving features will not require you to take over driving	
	These are driver support features			These are automated driving features		
What do these features do?	These features are limited to providing warnings and momentary assistance	These features provide steering OR brake/ acceleration support to the driver	These features provide steering AND brake/ acceleration support to the driver	These features can drive the vehicle under limited conditions and will not operate unless all required conditions are met		This feature can drive the vehicle under all conditions
Example Features	• automatic emergency braking • blind spot warning • lane departure warning	• lane centering OR • adaptive cruise control	• lane centering AND • adaptive cruise control at the same time	• traffic jam chauffeur	• local driverless taxi • pedals/ steering wheel may or may not be installed	• same as level 4, but feature can drive everywhere in all conditions

Table 2: SAE Driving Automation levels *(©2020 SAE International)*

1.2.1 Automated vehicle operation overview

We distinguish in AVENUE two levels of control of the AV: micro-navigation and macro-navigation. Micro navigation is fully integrated in the vehicle and implements the road behaviour of the vehicle, while macro-navigation is controlled by the operator running the vehicle and defines the destination and path of the vehicle, as defined the higher view of the overall fleet management.

For micro-navigation Automated Vehicles combine a variety of sensors to perceive their surroundings, such as 3D video, LIDAR, sonar, GNSS, odometry and other types of sensors. Control software and systems, integrated in the vehicle, fusion and interpret the sensor information to identify the current position of the vehicle, detecting obstacles in the surround environment, and choosing the most appropriate reaction of the vehicle, ranging from stopping to bypassing the obstacle, reducing its speed, making a turn etc.

For the Macro-navigation, that is the destination to reach, the Automated Vehicle receives the information from either the in-vehicle operator (in the current configuration with a fixed path route), or from the remote-control service via a dedicated 4/5G communication channel, for a fleet-managed operation. The fleet management system considers all available vehicles in the services area, the passenger request, the operator policies, the street conditions (closed streets) and send route and stop information to the vehicle (route to follow and destination to reach).

1.2.2 Automated vehicle capabilities in AVENUE

The Automated vehicles employed in AVENUE fully and automatically manage the above defined, micro-navigation and road behaviour, in an open street environment. The vehicles are automatically capable to recognise obstacles (and identify some of them), identify moving and stationary objects, and automatically decide to bypass or wait behind them, based on the defined policies. For example, with small changes in its route the AVENUE minibus is able to bypass a parked car, while it will slow down and follow behind a slowly moving car. The AVENUE mini-buses are able to handle different complex road situations, like entering and exiting round-about in the presence of other fast running cars, stop in zebra crossings, communicate with infrastructure via V2I interfaces (ex. red light control).

The minibuses used in the AVENUE project technically can achieve speeds of more than 60Km/h. However, this speed cannot be used in the project demonstrators for several reasons, ranging from regulatory to safety. Under current regulations the maximum authorised speed is 25 or 30 Km/h (depending on the site). In the current demonstrators the speed does not exceed 23 Km/h, with an operational speed of 14 to 18 Km/h. Another, more important reason for limiting the vehicle speed is safety for passengers and pedestrians. Due to the fact that the current LIDAR has a range of 100m and the obstacle identification is done for objects no further than 40 meters, and considering that the vehicle must safely stop in case of an obstacle on the road (which will be “seen” at less than 40 meters distance) we cannot guarantee a safe braking if the speed is more than 25 Km/h. Note that technically the vehicle can make harsh break and stop with 40 meters in high speeds (40 -50 Km/h) but then the break would too harsh putting in risk the vehicle passengers. The project is working in finding an optimal point between passenger and pedestrian safety.

Due to legal requirements a **Safety Operator** must always be present in the vehicle, able to take control any moment. Additionally, at the control room, a **Supervisor** is present controlling the fleet operations. An **Intervention Team** is present in the deployment area ready to intervene in case of incident to any of the minibuses. Table 3 provides an overview of the AVENEU sites and ODDs.

	Summary of AVENUE operating sites demonstrators							
	TPG		Holo		Keolis	Sales-Lentz		
	Geneva		Copenhagen	Oslo	Lyon	Luxembourg		
Site	Meyrin	Belle-Idée	Nordhavn	Ormøya	ParcOL	Pfaffental	Contern	Esch sur Alzette
Funding	TPG	EU + TPG	EU + Holo	EU + Holo	EU + Keolis	EU + SLA	EU + SLA	EU + SLA
Start date of project	August 2017	May 2018	May 2017	August 2019	May 2017	June 2018	June 2018	February 2022
Start date of trial	July 2018	June 2020	September 2020	December 2019	November 2019	September 2018	September 2018	April 2022
Type of route	Fixed circular line	Area	Fixed circular line	Fixed circular line	Fixed circular line	Fixed circular line	Fixed circular line	Fixed circular line
Level of on-demand service*	Fixed route / Fixed stops	Flexible route / On-demand stops	Fixed route / Fixed stops	Fixed route / Fixed stops	Fixed route/Fixed stops	Fixed route / Fixed stops	Fixed route / Fixed stops	Fixed route / Fixed stops
Route length	2,1 km	38 hectares	1,3 km	1,6 km	1,3 km	1,2 km	2,3 km	1 km
Road environment	Open road	Semi-private	Open road	Open road	Open road	Public road	Public road	Main pedestrian road
Type of traffic	Mixed	Mixed	Mixed	Mixed	Mixed	Mixed	Mixed	Pedestrians, bicycles, delivery cars
Speed limit	30 km/h	30 km/h	30 km/h	30 km/h	8 to 10 km/h	30 km/h	50 km/h	20 km/h
Roundabouts	Yes	Yes	No	No	Yes	No	No	No
Traffic lights	No	No	No	No	Yes	Yes	Yes	No
Type of service	Fixed line	On demand	Fixed line	Fixed line	Fixed line	Fixed line	Fixed line	On Demand
Concession	Line (circular)	Area	Line (circular)	Line (circular)	Line (circular)	Line (circular)	Line (circular)	Line (circular)
Number of stops	4	> 35	6	6	2	4	2	3
Type of bus stop	Fixed	Fixed	Fixed	Fixed	Fixed	Fixed	Fixed	Fixed
Bus stop infrastructure	Yes	Sometimes, mostly not	Yes	Yes	Yes	Yes	Yes	Yes
Number of vehicles	1	3-4	1	2	2	2	1	1
Timetable	Fixed	On demand	Fixed	Fixed	Fixed	Fixed	Fixed	On-demand
Operation hours	Monday-Friday (5 days)	Sunday-Saturday (7 days)	Monday-Friday (5 days)	Monday-Sunday (7 days)	Monday-Saturday (6 days)	Tuesday & Thursday Saturday, Sunday & every public holiday	Monday - Friday	Monday – Saturday
Timeframe weekdays	06:30 – 08:30 / 16:00 – 18:15	07:00 – 19:00	10:00 – 18:00	7:30 – 21:30	08:30 – 19:30	12:00 – 20h00	7:00 – 9:00 16:00 – 19:00	11:00 – 18:00 11:00 – 18:00
Timeframe weekends	No service	07:00 – 19:00	No service	9:00 – 18:00	08:30 – 19:30	10:00 – 21:00	No Service	On Suterday only
Depot	400 meters distance	On site	800 meters distance	200 meters distance	On site	On site	On site	500 m distance
Driverless service	No	2021	No	No	No	No	No	No
Drive area type/ODD	B-Roads	Minor roads/parking	B-Roads/minor roads	B-Roads	B-Roads	B-Roads	B-Roads/parking	
Drive area geo/ODD	Straight lines/plane	Straight lines/ plane	Straight lines/ plane	Curves/slopes	Straight Lines/ plane	Straight lines/ plane	Straight lines/ plane	Straight lines / plane
Lane specification/ODD	Traffic lane	Traffic lane	Traffic lane	Traffic lane	Traffic lane	Traffic lane	Traffic lane	Open area
Drive area signs/ODD	Regulatory	Regulatory	Regulatory, Warning	Regulatory	Regulatory	Regulatory	Regulatory	Regulatory
Drive area surface/ODD	Standard surface, Speedbumps	Standard surface, Speedbumps	Standard surface Speedbumps, Roadworks	Frequent Ice, Snow	Standard surface, Potholes	Standard surface	Standard surface	Standard Surrface

Table 3: Summary of AVENUE operating site (+ODD components)

1.3 Preamble – the AVENUE Vision for a Future Mobility

In the following deliverable we present the path and the implementation of a vision for a future mobility that is purpose driven. We summarise and compare the scenarios considered in the other deliverables of the project and build the case for why a scenario of automated vehicles (AVs) in a Mobility-as-a-Service (MaaS) / Intelligent Transport Service (ITS) environment is preferable to a pure laissez-faire strategy resulting in the development of robotaxis for individual transport.

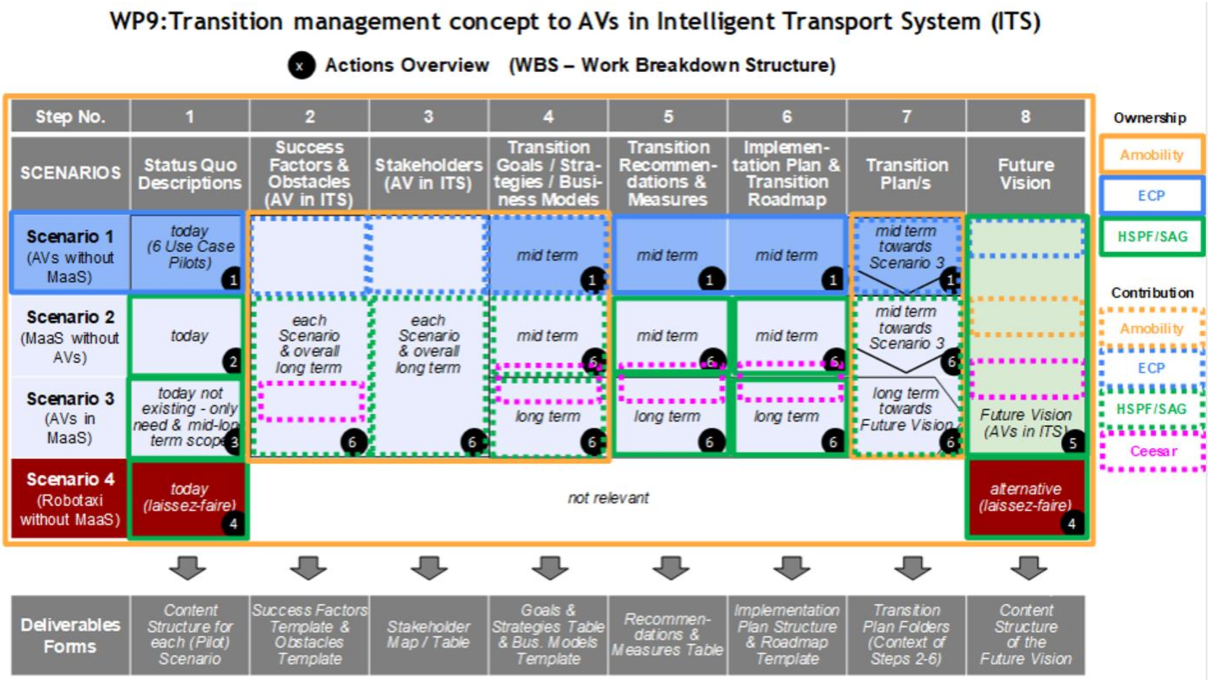

Figure 1: WP9 – Transition to AVs in ITS

We will discuss and present the vision of AVENUE for a medium-term horizon (2030) of future public transportation. Our aim is to integrate automated minibuses into all citizen transportation systems available in a city. A central issue in this vision is the mobility needs of citizens which have to be satisfied in an optimal way: an abundant service offer portfolio with a high variety of private and public mobility modalities should be provided and combined to one individualized intermodal trip. Automated Minibuses (AM) play a central and critical role in this model 1) as a feeder for the other means of transport and 2) as a mobility gap filler for the entire transport system. Public as well as private transport operators (PTOs) are forming an enhanced public-private partnership (PPP) to utilize and synergize their multifaceted complementarity in this MaaS vision. The application of advanced self-learning systems (e.g., based on human and/or Artificial Intelligence) could in a further stage let this visionary MaaS concept become a self-learning ITS. This disruptive transport system innovation could create best human centric transportation, optimized and balanced private and public value and raised acceptance by citizens.

This is a slightly different approach from what was envisaged in the project planning at the beginning and was therefore also presented somewhat differently by us in the project proposal. In the course of the project, however, it became clear that there is nothing more or more detailed to be said about the direct costs of the microsystem of automated minibuses that is described in detail in Deliverable D8.6 (Economic Impact Assessment), and that a more strategic approach from a bird's eye view is needed, which is why a vision was developed in the project. We are convinced that a cost-efficient system can only be achieved through an overarching vision within an interdisciplinary approach.

One of the most important results on the study of the direct costs of the microsystem was that it will be very difficult to integrate the automated minibuses into the mobility system in a profitable or even cost-covering way as long as a safety driver and thus his or her salary are needed. The details of this and all other major direct cost items can be found in the three Economic Deliverables D8.3, D8.4 and D8.6, as well as several other deliverables describing the test routes and operation of the buses. This brought us to the level of thinking about a vision that includes more than just the direct costs of a single regulation. In our view, a reasonable business model cannot depend on a single point, but is influenced by many criteria, mainly the economic environment, of course, but also technical, social, ecological and governance criteria. We look at this in detail in this deliverable.

In the following, after the derivation of the scenario mentioned above (AVs in MaaS), an introduction to the vision is given with concrete steps for action. After that, however, it will also be considered as a business model and, in more detail than was already done in D8.6 (Economic Impact Assessment), we will go into why the scenario makes the most sense and what its detailed transition and implementation strategies are, using business methods such as the SWOT analysis. We also present these in comparison for the scenario with robotaxis in order to develop a feeling why AVs in MaaS / ITS also represent the best alternative from a business point of view, but we have also prepared the analyses for all other scenarios. For reasons of space, these are not all reproduced in this deliverable, but can be requested from the authors at any time.

In the end, this deliverable gives a detailed overview of the success factors and obstacles and resulting recommendations in the technical, economic, environmental, social and governance fields for a cost-efficient but also purpose driven future mobility.

1.4 Preamble – Procedure within the document

This deliverable presents a roadmap for a vision of future mobility based on the status quo of the mobility system and on the AVENUE project with its demonstration sites. The aim of this roadmap is to show a possible transition from the status quo to a cost-attractive and purpose-oriented vision of automated vehicles in a Mobility-as-a-Service (MaaS) and Intelligent Transport System (ITS) environment.

The deliverable is structured in seven main chapters:

Chapter 1 introduces the aims and context of the AVENUE project, as well as the current operation and capabilities of automated vehicles.

Chapter 2 provides a brief introductory insight into the AVENUE Vision for future mobility to explain the aim of the entire report to the reader.

Chapter 3 gives an overview of the following four scenarios (which also correspond to the business scenarios developed in WP8):

- Scenario 1: Status Quo of AVs without MaaS
- Scenario 2: Status Quo of MaaS without AVs
- Scenario 3: AV in MaaS/ITS scenario (AVENUE vision 2030 and later)
- Scenario 4: Status Quo of robotaxis in competition with public transport (laissez-faire strategy)

Chapter 4 explains in detail a citizen centric future vision of automated vehicles within MaaS and ITS (scenario 3) that aims to add value to society (purpose economy). It investigates in detail how cost-attractiveness can be designed in the future by providing society with an efficient and purpose-driven mobility system.

Chapter 5 presents a transition concept from the current status quo towards the vision of a future integrated mobility system (scenario 3). For this task, tools of business administration such as the Business Model Canvas or the SWOT analysis are used and a detailed transition roadmap with strategies and an implementation plan is built up.

Chapter 6 is the most important part of the deliverable and builds comprehensive recommendations. For this purpose, an overview of the success factors and obstacles of this vision of AVs in a MaaS is provided. A structure is then presented on how to approach the implementation of this vision based on five criteria. Recommendations are made in detail for these criteria, which are:

- Technical factors
- Economic factors
- Environmental factors
- Social factors
- Governance factors

2 Status Quo Mobility Scenarios

By 2050, almost 70% of the world's population is expected to live in cities, indicating that urban areas will continue to experience rapid growth (Zhao 2010). Therefore, it is essential for metropolitan areas in particular, but also for connecting these areas with rural regions, to develop and use new forms of mobility as a complement to existing transport systems. One recent example for this are the rentable e-scooters that can now be used in most cities.

Conventional transport systems are made up of a mix of public and private transport. Local public transport is a vital economic and location factor, particularly in conurbations, but also in numerous medium-sized and small towns. From an environmental perspective, there is a strong interest in expanding and enhancing local public transport by decreasing the traffic volume from private vehicles, while at the same time lowering environmental pollution through improved journey timing and further expansion of local public transport. It also offers a wide range of transportation options in the urban environment. Except for some local special forms such as cable cars, the commonly used forms of public transport throughout the world are buses, trams, metros, and trains.

However, with a share of up to 70%, private cars are used far more frequently. In Germany, for instance, the share of total mobility in 2017 amounted to 43% as a driver and 14% as a passenger, which shows that 57% of approximately 3.2 billion total passenger kilometres per day were travelled by car (Federal Ministry for Digital and Transport 2019). Additionally, there exist private-sector mobility systems, like taxi & ride-hailing, regional and suburban rail, car, and bicycle sharing, or the previously mentioned e-scooters.

Within the AVENUE project, the boundaries of automated driving are divided as shown in the diagram below:

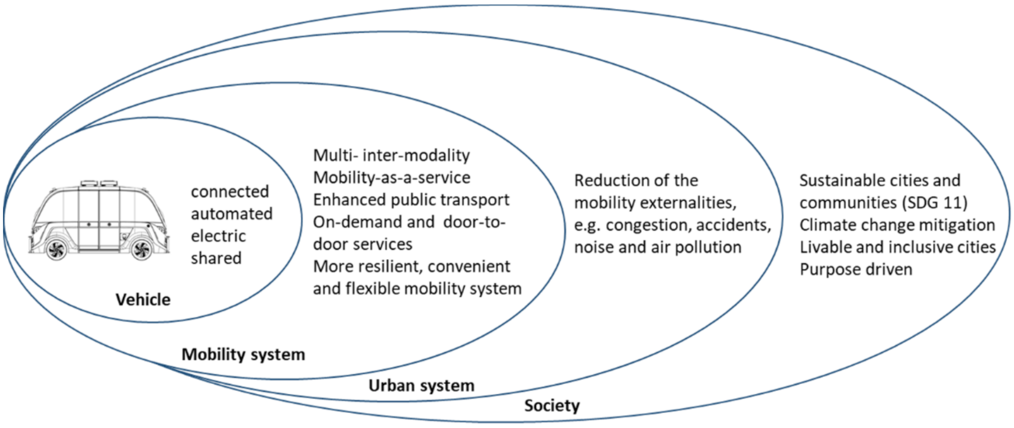

Figure 2: System boundaries (Nemoto 2022)

2.1 Scenario 1: Status Quo of AVs without MaaS

The status quo of AVs, especially AMs within the project, is explained in detail in almost all deliverables of the project. In WP2, the trials use cases are described in detail, in WP3 international pilots, in WP4 in- and out-of-vehicle services, integration in public transport and much more. The main objective of the whole AVENUE project was to test and present this status quo and to identify what can be possible in future mobility scenarios. That´s why the description of different topics and details continues naturally throughout all deliverables of the project, e.g., in D5.5 “vehicle-to-platform interfaces” or the reports from the pilot sites in work package 7. The main part, however, can be found in the assessments of WP8, especially in D8.9 (social impact), D8.5 (environmental impact), but especially in the three deliverables on economic impact. D8.3, D8.4 and D8.6 describe how the direct and indirect costs of the status quo are distributed. However, a meaningful summary is not feasible in a short form that makes sense to this deliverable, which is why the reader is referred to these deliverables, especially the three on economic impact.

2.2 Scenario 2: Status Quo of MaaS without AVs

Considering the current state of transport options, it can be observed that mobility in cities has been transformed by mobility services such as car-sharing, ridesharing, and on-demand services. These provide flexibility, convenience, and customisation while helping to reduce the number of private vehicles and increase the use of mobility service providers. Hence, a multimodal transport infrastructure, which refers to the parallel use of different means of transport, is in place already. The emphasis is on making the serial use of different modes of transport on one route efficient and attractive. It is already a possibility right now to use different means of transport in every city, but it is in many cases not very intuitive to change and switch between them. Because of changes in travel behaviour and customer demand, new players are entering the market besides the traditional transport providers. This presents new challenges for public infrastructure and public transport services regarding planning, design, operation, regulation, and financing. To enable citizens to use these different modes of transport and mobility offers in combination, and thus providing them with optimised route planning tailored to their needs, the MaaS concept is being adopted in a growing number of cities. This concept provides users with access to various means of transport with different mobility offers, which can be chosen, booked, and paid for using an app. MaaS marks a shift away from a transport model where individuals travel by private vehicle to a model where individuals can choose between different travel service providers to create the optimal itinerary.

In consequence, mobility is no longer viewed as a "commodity", since owning a vehicle is no longer required to move around, but as a service where the journey is purchased. It is believed that the travel behaviour of citizens is shifting and as a result the use of private vehicles is decreasing. MaaS is made up of two components:

1. The mobility modes and mobility service providers, like bike sharing, scooter-sharing, ride-hailing, micro-transit, and carsharing in addition to the existing transport modes.
2. A mobility platform where all mobility forms and mobility service providers are integrated, and the user can map out his routes and obtain the travel costs to then book the route and pay the mobility providers. This mobility platform will be provided to the user as an app.

Given the global trend of urbanisation, MaaS is projected to grow at a gigantic rate (Araghi et al. 2020). In certain cities, the first MaaS are already in operation, including companies and start-ups with promising concepts, such as the “Whim” app (Whim online) or “Trafi” platform (Trafi online), both with millions of users worldwide. In addition to examples like these, there are now also normal public transport providers such as Ruter AS in Norway, who already offer a functioning MaaS in Oslo and beyond, although without AVs so far (Ruter 2019).

2.3 Scenario 3: Status Quo of AVs in MaaS

To our knowledge, there is currently no MaaS that includes Avs. Even in AVENUE, this is only a vision for the year 2030, but it is far from being a reality. As mentioned above, a variety of MaaS environments exist worldwide in which AVs can be included. For this to happen, they must first be recognised and accepted as one of the reasonable building blocks of modern mobility. Therefore, the AVENUE vision for a future mobility of a MaaS with AVs is presented in detail below.

2.4 Scenario 4: Status Quo of the development of robotaxis

This section details the status quo of development and testing phases of existing robotaxi players. A robotaxi is an autonomous taxi that can be hired by up to two passengers for individual trips.

As the population will continue to move to urban areas in the future, mobility in these areas will also undergo changes. The development and use of autonomous vehicles through robotaxis appears to be a realistic future scenario. A study on "Urban mobility and autonomous driving in 2035" by Deloitte identifies five possible developments resulting from the use of autonomous driving services. Firstly, autonomous driving services could become the primary mode of transportation, with one in three journeys made by citizens in urban regions being made by autonomous driving services. In addition, the use of autonomous vehicles could result in a price war since they could be up to 25 % cheaper compared to current public transport and private vehicles (Deloitte 2019). Furthermore, the market potential of autonomous vehicles is very considerable. The Deloitte study estimates a sales volume of up to 16.7 billion euros per year. Nonetheless, this is also dependent on the business model of the providers and on future regulations. Still, it is expected that the use of autonomous vehicles will decrease the number of private vehicles in cities, but that the use of driving services will increase traffic volumes in total. In consequence, up to 40 % more vehicles can be on the road simultaneously during peak times. With higher traffic volume, the risk of congestion rises and the average speed in cities declines (Deloitte 2019).

The forecasts of this and other studies reveal a large market potential for established mobility companies as well as for newly created start-ups globally. The most important, or at least most recognised, companies with respect to the development of autonomous vehicles are Cruise, Waymo, EasyMile and Mobileye, which are summarised in the following:

Cruise

This company constructs the self-driving vehicle "Poppy" which is used for food deliveries, and for ride-hail service in San Francisco (USA). So far, the Cruise company has driven over two million kilometres with its AVs. Every kilometre travelled helps the AVs to learn and improve. To ensure safe driving, the AVs have over 40 sensors, allowing them to locate objects and the surroundings with centimetre precision (Cruise online (1)). Cruise is developing a new AV, the “Cruise Origin”. This AV concentrates on the needs of the driver through a spacious cabin for relaxing or working. To accomplish this, all pedals, mirrors, steering wheel and more will be eliminated from the vehicle (Cruise online). Meanwhile, many well-known partners such as GM, Honda, Softbank, Microsoft, and Walmart were part of the Cruise company (Cruise online (1)).

Waymo

Waymo was founded in 2009 as the Google self-driving car project. Their mission is to transport people and things safely to their destination. To do this, the driver can be used in a variety of vehicles: from minivans to trucks, in applications such as ride-hailing and deliveries. Waymo One denotes the driverless ride-hailing service. This service is currently operational in Phoenix, Arizona (USA). If a customer is in the Phoenix metro, a ride can be ordered using the Waymo One app. To identify the booked ride, two letters are submitted by the user in the Waymo One app, which are displayed on the front of the vehicle. In contrast, in San Francisco, the app allows users to participate in the "Trusted Tester" programme, since the vehicles there are only in the testing phase. When booking a trip, users can stop up to five times for different errands (Waymo online (1)).

EasyMile

EasyMile's autonomous vehicles are equipped with a variety of sensors. These capture data and process it to create a 360-degree image of the surroundings in real time. This real-time processing allows the vehicle to make situation-specific decisions on the road. Due to the unique algorithms the software is able to adjust to every sensor system of autonomous vehicles. Moreover, with the available data from the different sensors, such as LiDARs (Laser Detection and Ranging), Differential GPS (Global Positioning System) and RTK (Real-Time Kinematic Positioning), inertial measurement unit (IMU) and odometry, the AV's position can be identified at any time. Additionally, the AV is in permanent communication with the EasyMile monitoring centre. It also enables sophisticated navigation functions, like obstacle avoidance and predictive steering, as well as decisions at intersections and pedestrian crossings. The vehicle accomplishes this because of its 4G data link network and through ongoing communication with the environment and the monitoring centre. The EasyMile EZ10 passenger shuttles are currently in operation in hundreds of locations worldwide. TractEasy tugs are also already utilized for supply chain optimization (EasyMile online).

Mobileye and SIXT

SIXT is best known as a car rental company and has plans to provide autonomous ride-hailing services in Munich (Germany) in 2022 through its collaboration with Mobileye. The autonomous robot taxi ride can be booked using the Moovit or the SIXT app. In the project, Mobileye will equip the AVs with the self-driving system, the Mobileye Drive. The vehicle also features eleven cameras, long- and short-range LiDAR sensors and a full range of radar sensors. The cameras and radar & LiDAR sensors function in two independent subsystems to provide True Redundancy in perception capabilities. The sensors supply the decision-making algorithms into the EyeQ system-on-a-chip. In addition, the Mobileye roadmap adds another layer of perception of the driving environment (Mobileye 2021). In the cooperation between Mobileye and SIXT, Mobileye will own the fleet of robotaxis and SIXT will be in charge for providing, maintaining, and operating the fleet (Sixt 2021).

2.5 Transition to the vision

All results from the whole project, but especially the relevant deliverables from work package 8, especially deliverables D8.6 and D8.12, indicate that the environment of a MaaS with included AMs is far better suited for the implementation of a new kind of mobility than the laissez-faire-strategy of sending robotaxis from private companies on the streets. In the following, we detail in our vision why this would make sense not only from a societal but also from a business perspective.

3 Future Vision of automated vehicles within MaaS and ITS (extension of scenario 3)

The vision of AVENUE is that automated vehicles will provide safe, fast, economical, sustainable, and personalised transport for passengers in urban and suburban areas. In this manner, AVENUE seeks to provide an on-demand, door-to-door public transport service through automated vehicles, thereby eliminating pre-planned and fixed bus routes. With the help of automated minibuses, the mobility needs of all citizens should be optimally satisfied by providing a service offer that unites public and private mobility providers and merges them into an individual intermodal journey (Fournier et al. 2022).

3.1 Introduction: The integration of AVs into future transport – (Dis)Advantages

There are three possibilities for integrating automated vehicles into a transport system.

Through the advancement of vehicle technologies, ranging from the continued development of driver assistance systems to automated driving, private vehicles can be employed as private automated vehicles (Fournier et al. 2022).

AVs could also be deployed as robotaxis and therefore also as private means of transport. The function of robotaxis is akin to that of traditional taxis; they can be used as a private means of transport without the need to own a vehicle. Subject to the governance chosen, they can participate in competition with public transport.

In a MaaS system, automated minibuses (AM) are integrated into the public transport system. In this MaaS system, different public and private mobility providers are incorporated to offer the most efficient journey to the customer from various combinations. The MaaS users are viewed as self-determined citizens. The user sets up an individual user profile and on the basis of this data, all selected means of transport can be included into individual trips. The AMs provide a door-to-door service to users (Fournier et al. 2022).

In the development and deployment of automated private vehicles in the transport system, the costs for the vehicles are high, as are the externalities of driving. This is due to the fact that widespread deployment is limited (Fournier et al. 2022).

In the case of robotaxis, it is probable that they will have affordable costs for the user and will also be widely accepted. Yet, the additional introduction of robotaxis will result in the transport system becoming less efficient and sustainable. One of the negative outcomes could be the crowding out of public transport, which could cause an asymmetry in competition between private and public transport providers (Fournier et al. 2022).

On the contrary, the implementation of AM in a MaaS system could turn into a "game changer". In this system, the users are at the centre of the offer, providing them a better mobility service, higher efficiency, and a more flexible transport system. As part of the MaaS concept, AMs are anticipated to cover first and last mile travel, thus serving as a mobility gap filler for seamless journeys. In this way, AM could diminish congestion and negative externalities while boosting the acceptance of public transport by increasing reliability and availability at the same time. To successfully implement MaaS and establish an ITS, open data and open APIs are key requirements. Through artificial intelligence (AI), the intelligent transport system could become a self-learning system, thereby enhancing the positive externalities (Fournier et al. 2022).

3.2 The AVENUE Vision of future mobility: a citizen centric approach

The vision of the AVENUE project for future public transportation in an urban environment integrates both personal transportation and public transportation in mass transit. This vision of future mobility is outlined using the citizen-centred approach. In this vision, citizens' mobility needs are depicted with the possibility of using an automated minibus combined with other modes of transport, depending on citizens' preferences. This includes automated vehicles in addition to the established means of transportation like bus, train, cab, car sharing, bicycle, and others. Furthermore, travel planning and ticketing services are incorporated. This necessitates factors such as the interoperability of hardware and software devices providing standardized interfaces (APIs), coordination and management software, as well as management services provided by service aggregators and other intermediaries (Fournier et al. 2022).

3.3 From product innovation to citizen and purpose centric transport system innovation

The integration of (road bound) automated vehicles into intelligent urban mobility systems can be envisioned in three different pathways (based on Grisoni and Madelenat 2021; Heineke et al. 2019):

- **Automated private vehicles**: AVs are deployed as privately owned, automated cars. The developments in this pathway focus on improvements of individual automobile technologies, from driver assistance systems to fully automated driving. This path is the continuum of the current individual cars-based mobility which remain yet the dominant choice across the mobility market (Fraedrich et al. 2015).
- **Robotaxis:** AVs are deployed as robotaxis that are owned and run by private companies. Robotaxis are used as individual transport means, that, depending on the chosen governance, are either competing with or supporting the public transport system (UITP 2017; Niles 2019). This has significant influence on potential environmental and social impacts. Robotaxis function similarly to conventional taxis and will be able to satisfy individual mobility needs of users. Hence, users can use it as a private means of transport, without having to own a vehicle (Nagel et al. 2019). Robotaxis can provide ride pooling similar to Uber Pool or Moia (Merlin 2017) which also could reduce their external costs (Fagnant and Kockelman 2015; Fournier et al. 2020)
- **Automated minibuses in a MaaS system**: AVs are deployed as AMs integrated in the public transport system. The AM offer an on-demand, door-to-door service, in which trips are pooled (i.e., multiple trips of users are combined) and connected to other means of transport. This strategy is poised to support the public transport network by filling mobility gaps (Sochor et al. 2016) (see below). For that purpose, different combinations of private and public transport operators are bundled to one trip to offer users the most efficient trip. In this way, the AM are integrated as one option in a broader MaaS system, as is visualised in Figure 3. MaaS entails the integration of public and private mobility options through the definition and commitment to a single standardized interface for offering passengers a multimodal and intermodal trip (Sochor et al. 2018; Kamargianni et al. 2015). MaaS users are regarded as self-determined citizens facing a broad unimodal transportation offering portfolio (Figure 4). The selection of transport modes depends on the individual user profile, persona or even weather, etc. Based on this all selected means of transport, including AM, can be combined to one integrated seamless trip (Vleugel and Bal 2017).

Figure 3: The integration of the automated e-minibus (AM) into a MaaS-System

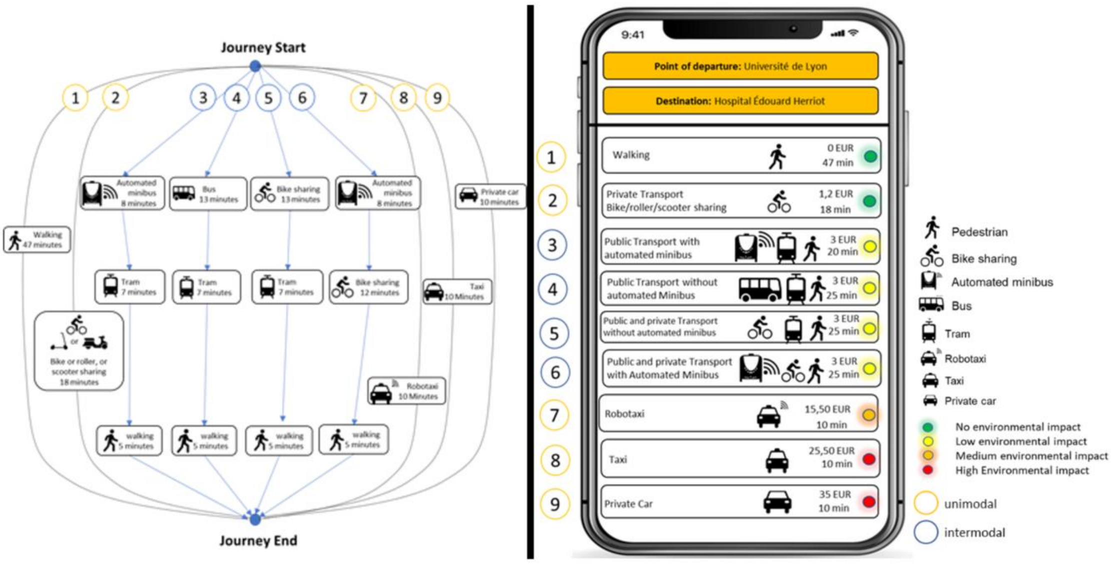

Figure 4: Illustration of various citizen journeys as combinations of all means of transport offered to a citizen by the MaaS concept

All three pathways each have advantages and disadvantages. In the development of privately-owned AVs (1), the prices or cost of automated vehicles and driving externalities are high and the diffusion in the next decade is likely limited due to regulatory limitations, citizen behavioral change and others reasons (Fournier et al. 2020; Milakis et al. 2017).

It is believed (2) that robotaxis will be met with high user acceptance and affordable prices for private users (especially when used as shared robotaxis, see Uber offering apps) but avoid a synergetic complementarity to all other means of transport (Korbee et al. 2022). As a result, robotaxis compete with and replace other means of transport like private cars but also walking or public transports. Thus, mobility would become more convenient for individuals. At the same time the transport system as a whole will be less efficient and sustainable as it causes an increase in external costs due to additional traffic and displaced public transport (Meyer et al. 2017; Niles 2019; May et al. 2020; Clewlow and Mishra 2017; Rayle et al. 2016; Merlin 2017; Childress et al. 2015; WEforum 2020). The raise of a dominant robotaxi provider could further lead to fragmented markets and asymmetry in competition between public and other private mobility providers (Hassani 2018; Niles 2019). For instance, if private transport platforms do not provide open mobility data as public transport operators, it causes a data asymmetry and unequal competition (Hassani 2018). This leads to lock-in effects and the hereby related winner-takes-it-all phenomenon, a dominant position of private PTOs and the associated market power such as monopolies or the currently existing oligopoly for online services, which can be referred to as GAFAM (Google (Alphabet), Apple, Facebook (Meta), Amazon) or now MAAMA (Meta, Alphabet, Amazon, Microsoft and Apple) (The Economist 2022; Cabral et al. 2021; Toledano 2020).

The integration of AM in a MaaS system (3) could be a real "game-changer" making public and private transports individual and providing a real alternative to individual privately-owned vehicles. In this system, the citizens are at the heart of the concept to providing better transport services, improved efficiency and flexibility in the transport system and positive externalities (Coyle et al. 2020). AM in MaaS creates multisided values for the involved stakeholders which makes a win-win situation possible for everyone involved

The third pathway 'AM in MaaS' can provide the best a public value and thus represents the long-term vision of AVENUE. It is the main enabler of a holistic system innovation and is not only regarded as a classic product (e.g., AM) innovation. However, this does not underrate the high importance of AM as a product innovation: the combination of AM and the MaaS concept forms a disruptive game changer to raise the transport system to a higher level of mobility evolution.

Within the AVENUE vision of AM in MaaS, the mode of implementation of AVs (e.g., if shared, electric or not, ride-matching capacity, etc.) is initially of subordinated relevance. Rather, it is the technology and concept design of AM integrated into MaaS which is the central 'game changer' in public transport by offering on-demand and door-to-door first and last mile trips, as well as being a success-critical mobility gap-filler for seamless trips. As an important feeder of the entire transport system, AM could enlarge the accessibility and the acceptance of mass transit modalities significantly and lower congestions and other negative externalities at the same time (Becker et al. 2018). As a primary mobility gap-filler the AM could avoid or improve transport system weaknesses or prevent risks in providing e.g., night services, an improved offer in suburban or rural areas or compensating technical or organizational failures (Mahmoodi Nesheli et al. 2021; Lazarus et al.). In addition, the AM could serve as a catalyst for citizens to trust into MaaS to strengthen the reliability and availability of transport systems (also: safety, security, efficiency etc.) and thus also the acceptance by total system excellence and performance. Through AM in MaaS, the transport system can provide a solution which is, in many ways, as simple, individual, and attractive as the use of a private car, reducing many disadvantages (e.g., negative externalities, such as air pollution, climate change and traffic congestion) (Crozet 2020) and increasing many advantages (e.g., accessible and available for anybody and any trip demand). The results of a representative survey among 1,816 citizens (of which 1,526 have privately-owned vehicles) in Lyon, Copenhagen, Luxembourg, and Geneva confirm that 45% of car drivers are 'willing' (22%) or even 'very willing' (23%) to give-up using their own car to use AM to bridge the first and the last mile if this were available. If the service is on-demand and door-to-door, the acceptance could be even higher (Korbee et al. 2022). Following such a policy would thus better satisfy the needs of the citizens and their acceptance of automated transport but at the same time make transport in the cities more sustainable. Unpopular regulative or restrictive policies and measures (e.g., prohibition of vehicles) by transportation authorities could be avoided (Litman 2021; Becker et al. 2020; Zha et al. 2016).

By taking this perspective, all offered means or modalities of transport are potentially available for an individual trip design. The mobility choice and subsequently the modality choice of the citizen (the end user/customer as central 'king/queen of the system') is considered as right and definitive, and not limited by the transportation portfolio of a single (private or public) transport provider (Figure 4). With shared lesson learned, the AM integration into the urban mobility system avoids thereby the "winner-takes-it-all phenomenon". The rise of platforms in recent decades has increasingly resulted in this winner-takes-it-all-phenomenon in specific markets. These are characterized by one or a few companies holding large market shares (Clement et al. 2019). The 'winner-takes-it-all' aims to prevent competitors from having access to the market through, e.g. proprietary API's, copying or taking over competitors or potential competitors, locking-in customers and manipulating or restricting the choice of the customers by suggesting preferred partners, or tying transactions, among others. Digital platforms with a sufficient installed base – so-called platform leaders – can use their dominant position to further increase their market share and penetrate new business areas (Hein et al. 2020). Platform owners can exclude complementors from their platforms or restrict collaboration with hardware partners, as Google did with device manufacturer Huawei in 2019 (Hein et al. 2020).

Finally, Open Data, Open Data and Interaction Platforms and Open APIs are a prerequisite to enable access to all the means of transport, their interoperability and intermodality (positive externalities), to ensure balanced win-win situations among all stakeholders and thus a kind of democratization of the AM in a MaaS ecosystem (ERTICO – ITS Europe 2019; Coyle et al. 2020). This concept, mechanisms and tools are important to avoid "the winner takes it all" phenomenon and increases the attractivity and ensures the holistic sustainability of the AM in a MaaS ecosystem. Open Data and open APIs are further a condition to enable innovation and evolution of mobility concepts and develop the MaaS towards an ITS. Using Data makes it easier to generate information and knowledge and provide this way the basis for decisions to improve the transport system. The transport system could become a self-learning system with the support of AI and humans (see details in chapter below). A "circulus virtuosis" (virtuous cycle/loop) and positive externalities could be created, to guarantee safety and to promote global improvement. To achieve this ITS vision, several improving loops have been identified which could be implemented and make the transport system more resilient and future oriented (see chapter 4).

Automated minibuses in a MaaS seem thus to provide more advantages for the stakeholders (travelers, TPOs, Cities) and for the general interest (Becker et al. 2020). The integration of the AM into the public transport of urban, suburban, and rural areas and into a MaaS system (our vision) is highly beneficial and advantageous for its stakeholders, in particular for citizens, private and public mobility providers, as well as cities and regions (administrations/government) in general. This integration is understood in the following way:

i) A customer/citizen centric approach is an individual combination and compilation of all means of transport to one seamless and reliable trip which could better meet the needs / requirements and preferences of all customer/citizen groups. This way the AM in MaaS can be seen as a game changer in urban mobility, capable to offer individualized public transport with more choice, better accessibility (including people with reduced mobility), inclusive and affordable. This could be an attractive and advantageous alternative to transportation with private cars.

ii) For the transport operators, the AM into a MaaS concept provides a better exploitation of existing capacities and resources and a positive experience of fair competition. AM is especially a significant lever for the attractivity and exploitation and thus profitability of large mass transport modalities like trains, metros, buses etc.

iii) For the cities (governments), the designed concept could provide a significant increase of excellence in mobility (efficiency, effectivity, safety, transportation quality, usability, etc.) which serves public interest as well as economic, environmentally, and socially sustainable mobility. The complementarity of public and private means of transport together with AM could thus:

a. make transport cheaper, fair in coopetition (cooperate to compete) (Schmück et al. 2021), better manageable, support a more resilient mobility system,
b. alleviate mobility externalities (Alazzawi et al. 2018; Vleugel and Bal 2017) and
c. increase the acceptance of the citizens, contributing to Sustainable Urban Mobility Plans (SUMP).

Beside the increased satisfaction of the transport needs of citizens, this vision could accordingly enable a win-win-situation for all the stakeholders towards value creation, fair value sharing, sustainable mobility, and long-term purpose, as stands the Purpose Economy (Hurst 2016; Business Roundtable 2019). Furthermore, SUMP approach is a cornerstone for the AVENUE sustainability assessment (AVENUE WP8). Likewise, the SUMP approach is the strategic target for the AVENUE transition studies and recommendations (AVENUE WP9). Together with the analysis of the current status quo, the identification of the general success factors and obstacles, the transition goals and strategies, the derivation of recommendations and measures, they are the main building blocks for the implementation plan and the transition roadmap. In combination they represent the comprehensive transition concept for realising future (public) transportation services for AM in MaaS and ITS.

3.4 Integration of AM in a MaaS system: a citizen and purpose centric approach

The concept of a purpose economy refers to a new way in which people and organisations create value and define the principles for innovation and growth (Hurst 2016). The value lies in establishing purpose and creating meaning value for employees and customers beyond their own benefits, but aiming personal and community development (Hurst 2016). In Hurst words (2016):

"The Purpose Economy creates purpose for people. It serves the critical need for people to develop themselves, be part of a community, and affect something greater than themselves"

Additionally, the concept of 'Citizen Centric MaaS' is in line with the purpose economy and targets a mobility system built by all and for all. The concept of 'Citizen centric MaaS' is focusing the compilation of various transportation service modalities to one single seamless trip on demand and according to the preferences of the citizen including related services like trip planning, ticketing, and others (European Commission 2016).[1]

This requires factors like interoperability of hardware (physical) and software (virtual) devices provided by e.g., standardized interfaces (APIs) as well as management and coordination software and services provided by service aggregators and other intermediaries. Digitalization combined with this citizen centric approach will dilute the difference between the private and public transport operators[2] introducing coopetition. Coopetition refers to a new form of perspective where both competition and cooperation coexist together. Cooperative elements can nourish joint payoff creation through using complementary resources cooperatively (Liu et al. 2015).

Figure 5 depicts the citizen centric MaaS. At the core are the citizens as it follows a citizen-centric approach. A variety of transport means is available for the citizens to choose from; these are depicted in the middle circle in Figure 5. The transport options are provided by various stakeholders (the actors named in the yellow blocks, at the outer circle of Figure 5). Other governance scenarios to coordinate the different stakeholders are of course possible depending on market (private, public and coopetition) and data schemes (private or open data, open interfaces, and protocols). These scenarios have been developed by UITP (UITP 2017; ERTICO – ITS Europe 2019; Capgemini 2020). The scenario which fulfils the best the needs of the customer, enables fair competition through avoiding the "winner-takes-it-all" phenomenon, enables positive externalities and fulfils sustainable and societal goals is the citizen centric MaaS approach chosen by AVENUE.

[1] The citizen centric approach naturally also includes older people and people with disabilities, as these groups are dependent on accessible public transport and expected to change fast future mobility demand. This is also required by law (European accessibility act). The ageing society and 80 million people with disabilities in the EU create a new demand for products and services and will have a major impact on mobility in the future. Especially since public transport can influence how and where people live and whether they can maintain their independence. Future mobility services must take this into account. For example, booking services need to include special needs in their service portfolio. Aspects such as additional space (e.g., for guide dogs or walkers), booking assistance for entering/changing means of transport, as well as barrier-free design of the apps used to book these services need to be considered.

[2] Private Transport Operators are the owners of a private transport operation platforms providing and managing private transportation services from various modalities by subcontracting private suppliers.

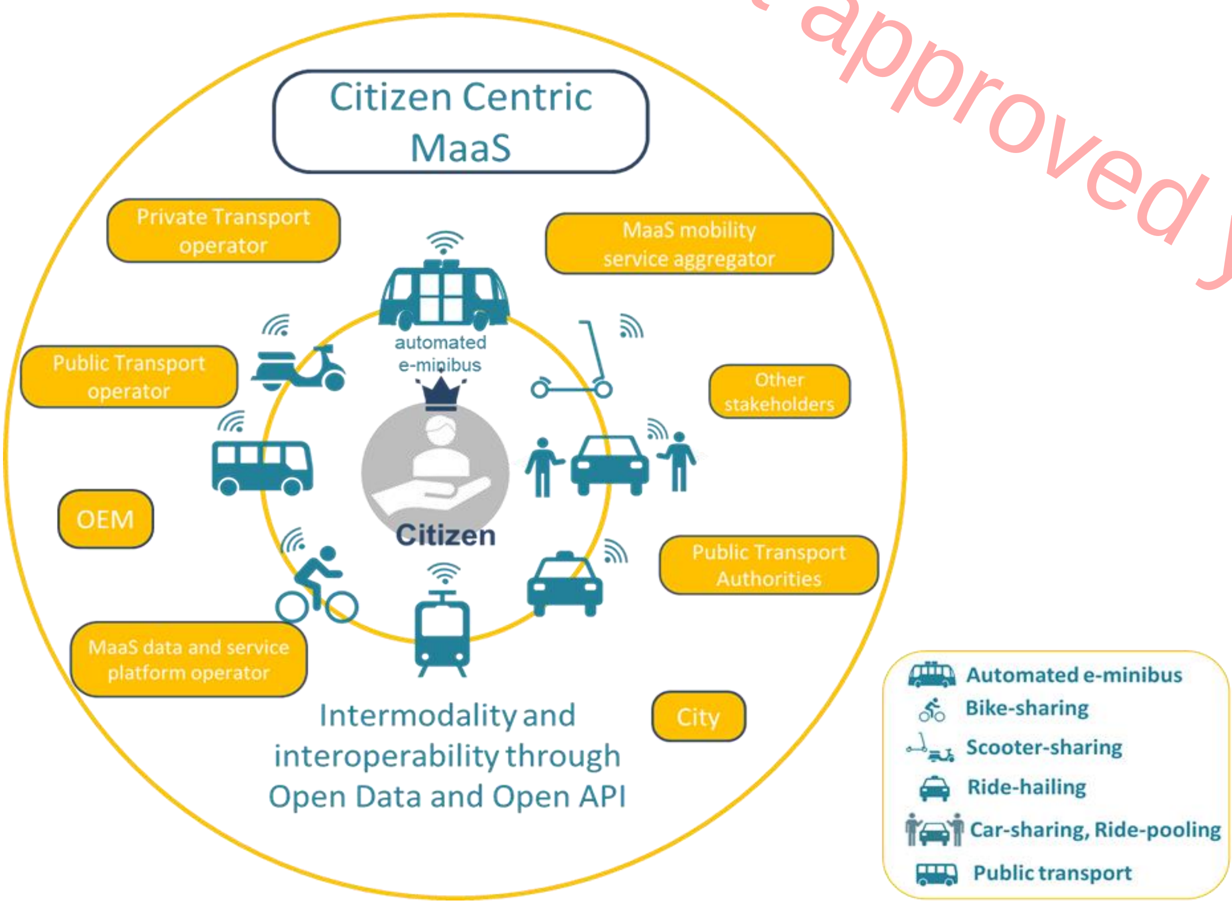

Figure 5: (New) Citizen centric MaaS

Important for the AVENUE vision, is that the automated minibuses are integrated in this citizen centric MaaS system. To understand how AM could be integrated in MaaS system, a typical booking process which integrates automated minibuses is set-up with the following 5 steps:

1. Citizen can choose several means of transport from public or private operators. AM services are provided as an integral part of the transport system. (See Figure 6)
2. The position and availability of an AM is documented together with other public and private means of transport in the MaaS platform. (See Figure 7)
3. The availability of other means of transport of other MaaS in the country or other countries of the EU are documented in the MaaS platform. The MaaS platform provides information to stakeholder to improve the transport system. (See **Error! Reference source not found.**)
4. A MaaS mobility service aggregators as intermediary organizations between Public and Private PTOs and the citizen provides the existing choice for the requested passenger journey. (See Figure 9)
5. Individual citizens have the choice to select between different transportation options for his trip and provide a booking and order. The AM is planned and reserved for the citizen. The mission is provided to the vehicle. (See Figure 10)

These steps are detailed and explained below; each of the steps is visualised by a figure (Figure 6 - Figure 10). The step-by-step description starts with a current, conventional outline of the system, in which the citizen must enquire about options and must make the decisions themselves, building up to a fully integrated system. With each of the steps, more complexity (through the integration of stakeholders and additional platforms) is added to the MaaS system.

Step 1: The first step in a MaaS booking process consists of the citizen choosing the destination of its trip. All combinations of several means of transport, offered by both public and private operators can be chosen. Public transport operators provide demand responsive transport (DRT), which aims to optimize the match of transportation supply with transportation demand efficiently and uses automated minibuses for the first and last mile and as mobility gap filler, and conventional public transport (CPT) services, like bus, metro, and train. Private transport operators provide transportation modes like taxi, ride-hailing like Uber, car sharing, bike sharing and other micro mobility devices like e-scooter.

Traditionally the citizen is forced to select and schedule separately every modality from private or public transport operators or a combination of it on his own and singularly according to his trip planning from A to B and related modality compilation, as is visualised in Figure 6. This also includes a multi-factor optimization of the modality-portfolio sample regarding time, cost, travel requirements (e.g., luggage, wheelchairs), personal preferences and others, including inherent error-proneness.

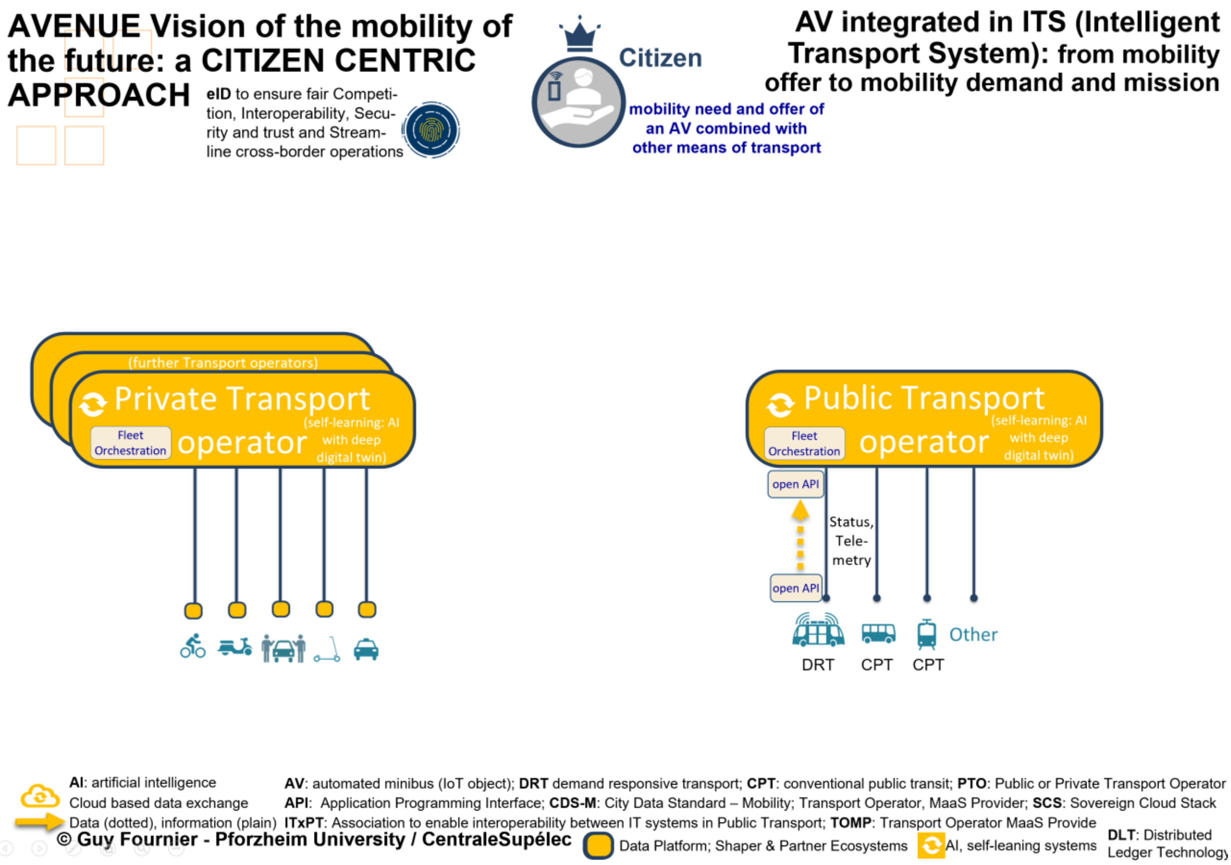

Figure 6: Vision of the mobility of the future: Step 1

Step 2: In the next step, the position and availability of an AM is documented together with other public and private means of transport in the MaaS platform. This connective platform is visualized as the yellow bar in Figure 7. To optimize the decision and selection process, these tasks are transferred from citizens to specialized intermediaries: a MaaS data service platform is installed. This data service platform is designed, managed, and controlled by a MaaS data and service platform operator and governed by Public Transport Authorities (PTA) as regulation bodies, for instance by extending the existing National Access Points (Art. 3 Delegated Regulation 2017/1926 of 31 May 2017). In this platform all necessary data about modality and transportation provider offerings and related metadata from private and public transport operators are integrated, managed and exchanged. Private transport operators should provide all their journey-relevant data which are necessary to offer a seamless intermodal trip to the customer. Providing data avoids an information asymmetry with public transport operators which are per law (Art. 4 and 5 Delegated Regulation 2017/1926 of 31 May 2017) obliged to share static and eventually dynamic travel data. This information asymmetry could lead to the aforementioned "winner takes it all phenomenon" and to a private MaaS and a market dominant position. Private transport operators are already obliged to provide the data foreseen under Annex I of Delegated Regulation 2017/1926 (Debussche et al., 2018). In addition, the private transport operators might receive a reasonable and cost-based compensation for providing this data: "Any financial compensation shall be reasonable and proportionate to the legitimate costs incurred of providing and disseminating the relevant travel and traffic data" (Art. 8 (4) Delegated Regulation 2017/1926 in fine).

In the case of an integration of AMs services in this MaaS platform information about current location of the AM and the status of occupation by passengers should be made accessible. Where personal data is or may be involved at any stage, in transit or in rest, obviously the appropriate regulations need to be complied to, more notably the General Data Protection Regulation (GDPR) and ePrivacy Directive. The latter is in the process of being aligned with the GDPR, into the ePrivacy Regulation. Where personal data is defined in article 4 GDPR, Preamble 26 provides for anonymized data mechanisms and use. If data cannot be established a such anonymized data, the GDPR is directly applicable and data processing will need a legal ground as mentioned therein, and appropriate data protection measures need to be in place. In any case, personal data not being anonymized data as per Preamble 26 GDPR is to certain, legitimate, proportionate and otherwise reasonable and accountable extent possible but need careful handling and governance, before, during and after being provided to the private or public transport operators[3]. To make the data available to all users in a standardized and quality assured form[4], an open API is required, as well as commonly agreed standards. These so-called APIs[5] enable authorized applications to communicate, use one another's functions, and exploit data sets provided by other applications or databases (Matthes and Bondel). These APIs make it in fact possible for the stakeholder to communicate with other stakeholders to

[3] This has of course to be deepen in further research: according to some studies, "Merely technically collected data could, due to the transformational impact of big data analytics, become personal data or even sensitive data and thus trigger the application of privacy and data protection laws." (LeMO D4.1 p. 16 and quoted references link).

[4] This should be documented as required by the GDPR. The data users as considered as data controllers who have obligations regarding the processing of data. This obligation could be placed in in another (existing or upcoming transport dedicated) legal basis than in the "generic" GDPR.

[5] For applications to communicate with each other they need policies. In the digitized world, access to systems through open interfaces is called an Open API (Termer 2017). APIs are blocks of code that allow developers to access smartphone functionality, such as using GPS data or turning the phone camera light on and off (Bonatti, et al. 2021)

provide a uniformed offer to the MaaS user (citizen). APIs are the 'connective tissue of the cloud', they are essential to integrate the transport system. However, the urban mobility ecosystem is still very fragmented (Bestmile 2020). To overcome this barrier, initiatives envision setting standards of open APIs to enable mobility providers to integrate services. Examples of such an initiative are the projects MyCorridor, MaaS4EU and IMOVE. These projects foresee the use of a 'common language' to designing a transport service API, comprehending 'the use of communication protocol and data format to security standards, basic methods and service calls, responses, and general behavior of an API (MaaS Aliance 2019). Another initiative, the Information Technology for Public Transport (ITxPT), focuses on open standards and procedures for integrated Information and Technology Systems for public transport (Rogg 2021). Therefore, open interfaces, protocols and standards are key factors for MaaS ecosystems[6].

Consequently, the open API[7] is initially required for a functioning MaaS platform. It must connect the vehicle modality and its providers, the transport operators, and the exchange platform and its platform operator. Additionally, they are utilized by further relevant parties of the ecosystem, like other MaaS systems (e.g., when trips are overreaching MaaS systems of other cities), or regulatory tasks of PTAs and City infrastructure management. For the AM, its MaaS relevant information is transferred to the open data MaaS platform to be exchanged between the PTO on the one side and the 'MaaS data and service platform operator' on the other side. In addition to the exchange of data, open API ease the management of AM from different OEMs. This allows a flexible use of the individual vehicles as well as the entire fleet. A functioning system results in lower costs of operation as less vehicles are needed.

An important reason for an open API for the 'MaaS data and service platform operator' is that in case a PTA desires to redesign the 'MaaS data and service platform' itself, there is no barrier due to dependencies with the data model of the OEM.

[6] A study conducted in nine cities divided data formats into the following three categories and found that all of these cities already have developer-friendly data formats (Yadav, et al. 2017). This can facilitate both application development and the handling of this data in the future (Yadav, et al. 2017). Therefore, a standard for data sharing should be created so that both small and large transit agencies can connect to the MaaS solution (UITP 2019).

[7] An open API allows universal access and allows application programs to interact with each other and share data, those elements are crucial for the mobility system interoperability and intermodality. Data interoperability is essential in this case, as the quality and consistency of shared open data and the data format are crucial for MaaS (UITP 2019). For data mobility, the free flow of information must be enabled, interoperability must be ensured, and the values and interests of the broader society must be safeguarded, as private actors will play a central role in exploiting the value chain of data (Passau Declaration 2020).

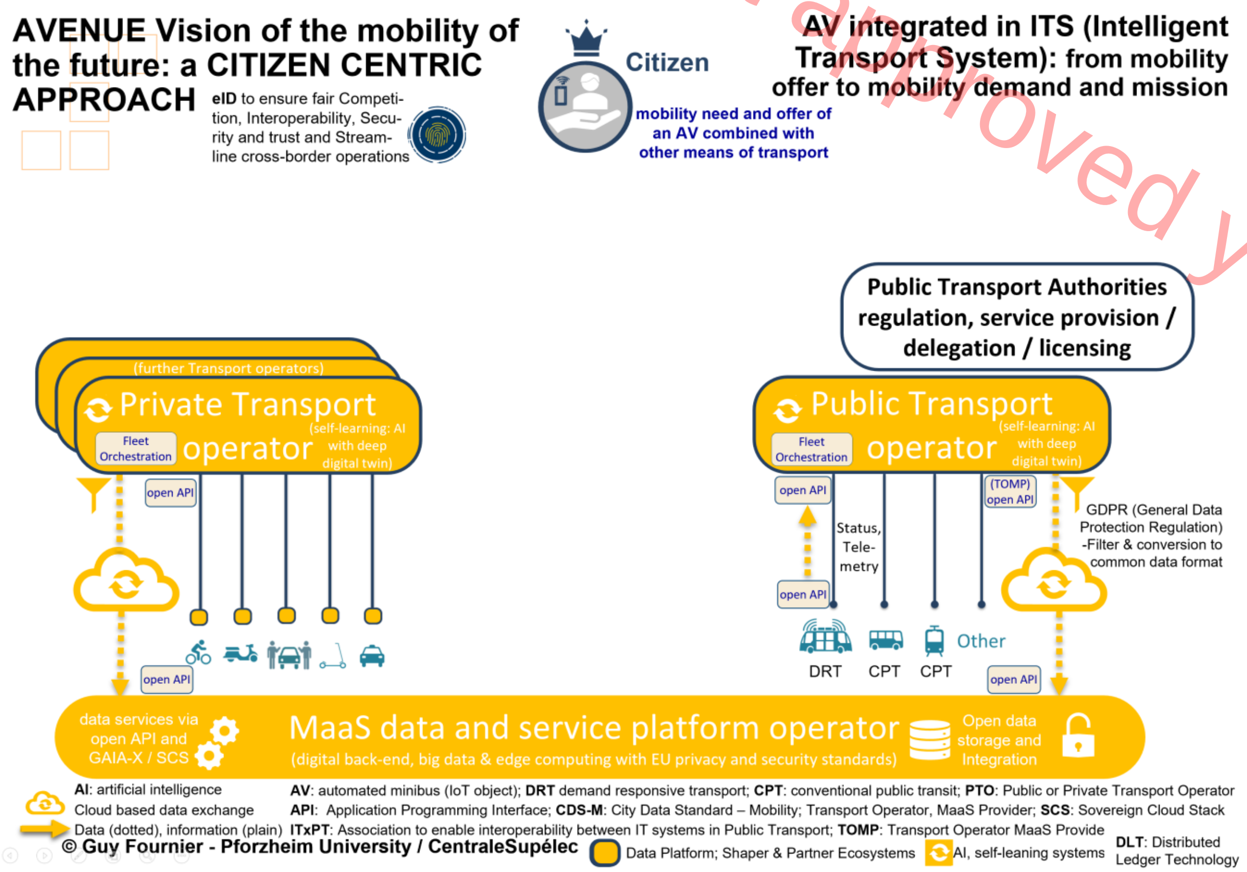

Figure 7: Vision of the mobility of the future: Step 2

In **step 3**, the availability of other means of transport of other MaaS in the country or other countries of the EU are documented in the MaaS platform. The MaaS platform provides further information to stakeholders to improve the transport system. This is visualized in Figure 8 by adding yellow arrows connecting the MaaS platform to the private operators, other MaaS systems and other stakeholders.

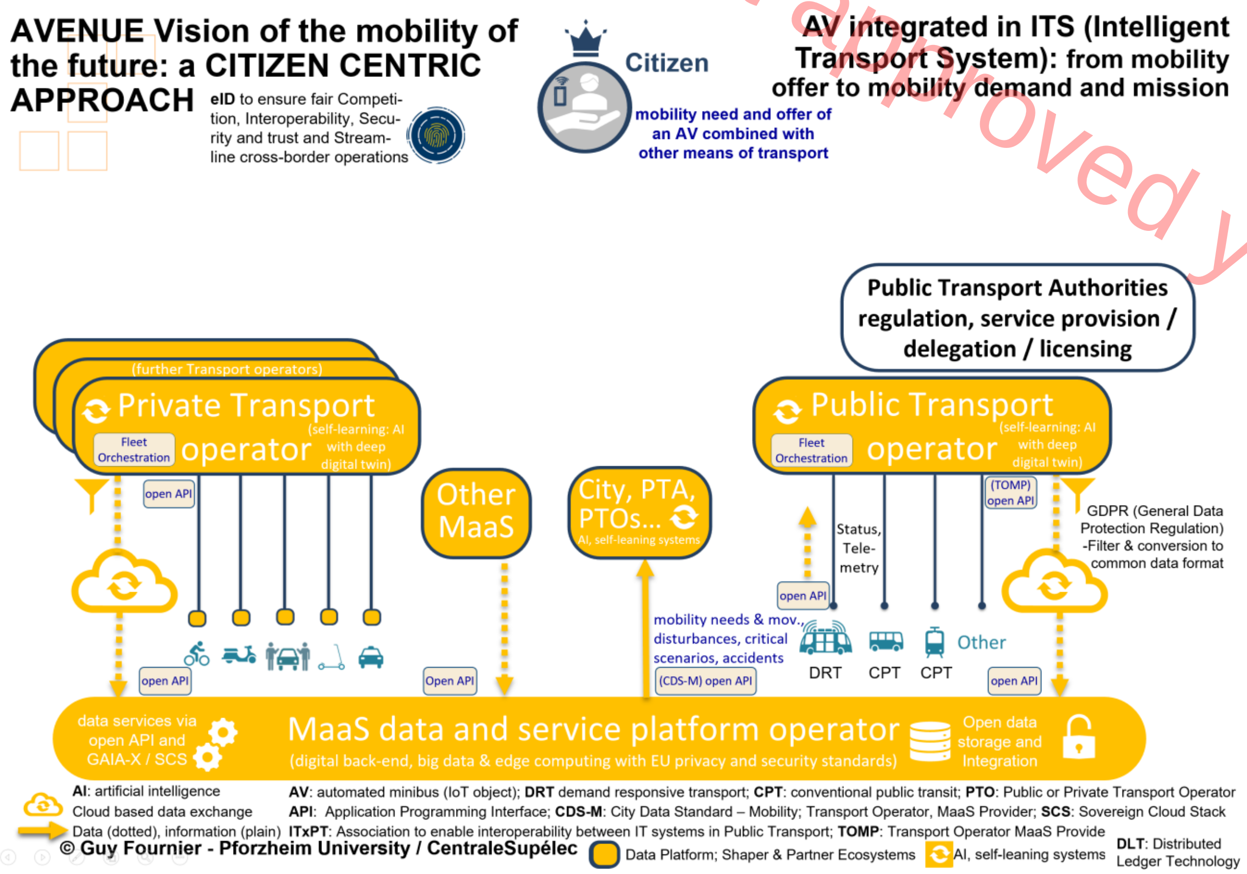

Figure 8: Vision of the mobility of the future: Step 3

Step 4 integrates MaaS mobility service aggregators, as intermediary organizations between public and private transport operators and the citizen to provide the existing choice for the requested passenger journey. This new layer is introduced by local, national, or supra-national private or public mobility aggregators and even by PTAs themselves. PTAs regulate, delegate, and supervise this market. The mobility service aggregators are designed to analyse and process citizen profiles (in an anonymous manner, under Art. 4 (4) GDPR) and trip requests as well as general data about transport providers, vehicles, services, and specific data about current positions and status of vehicle usage from public and private transport operators. Hence, this additional layer integrates information from both sides: trip request or transportation demand, and transportation offering services or vehicles, in combination with further information from other MaaS ecosystems and city infrastructure.

All relevant data are utilized for compilation of alternative trip options, as displayed in Figure 4 and Figure 9. Alternative trip options are selected based on the trip request, including individual preferences, but must be protected by adequate privacy and security concepts and measures. These concepts must be completed / developed and deployed. Especially in case of an incident disruptions, critical scenarios, and accidents will be analyzed and evaluated using concepts and tools of self-learning systems and AI.

By applying algorithms of AI to a MaaS ecosystem, the infrastructure and the value chain of transport companies can be significantly improved according to the needs of the citizens. Furthermore, with the support of AI all kinds of incidents, risks, or problems within the MaaS ecosystem can be identified, tracked, traced, and analyzed to define and conduct strategies and measures for detecting, preventing, and solving them. AI applications comprise multiple functionalities for supporting success critical tasks, such as finding patterns and new insights, making predictions, interpreting unstructured data, and interacting with the physical environment, their machines, and humans (Scherk et al. 2017). One of the central topics of AI are self-learning algorithms of systems (e.g., based on neuronal networks) with the goal of finding independent solutions to new and unknown problems (Scherk et al. 2017).

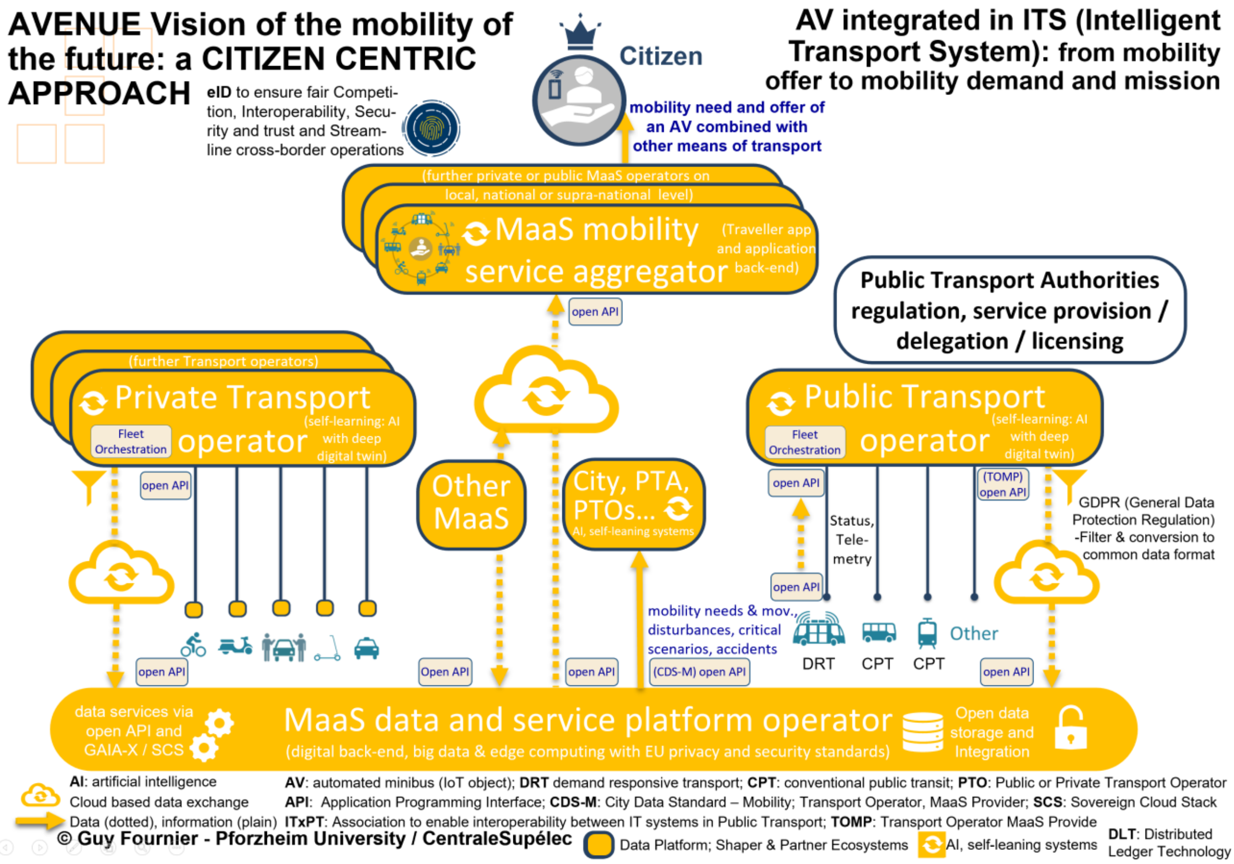

Figure 9: Vision of the mobility of the future: Step 4

To summarise: all potential trip-relevant information from the MaaS stakeholders must be available and quality of related data must be assured (i.e., static, and dynamic real-time data, data validity, data privacy and security). This information should be provided to the MaaS mobility service aggregators, who are able to aggregate all transportation needs or requests from citizens on the one hand, all transportation modality offerings (including automated minibuses) on the other hand, match them in an intelligent way (supported by AI algorithms) according to citizen preferences (1st priority: e.g. time efficiency, cost efficiency, carbon footprint) and offering goals (2nd priority: e.g. route efficiency, vehicle utilization) in order to subsequently provide the information of alternative transportation options to each citizen.

In step 5, individual citizens can select their preferred transportation option for his trip and can place a booking and ordering with payment. The AM is planned and reserved for the citizen. The mission is provided to the vehicle, which requires a return flow of the data (indicated by the blue arrows in Figure 10). The citizen has the choice to select between different transportation options for his trip from A to B in or outside of the city of even of the country. Hereby various valuable functionalities (like simulations about time or distance or cost or CO_2 footprint, together with option comparisons) are provided to the citizen. After making this decision the citizen is requested by the ticketing app to make the booking and place the binding order. After ordering, the data from the selected trip option is sent back to the MaaS data and service platform and hereafter to the private and / or public transport platform and transportation provider, or possibly to other MaaS system platforms .

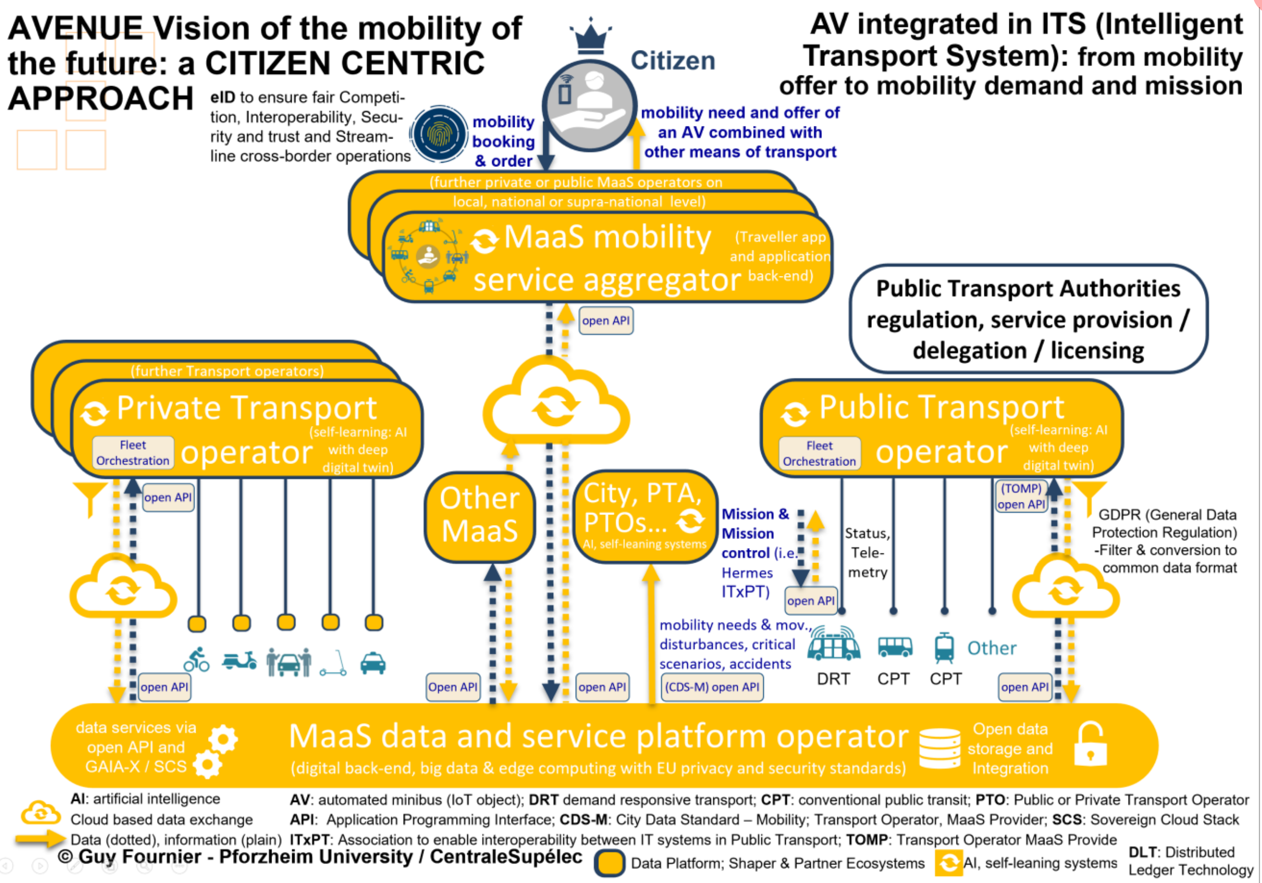

Figure 10: Vision of the mobility of the future: Step 5

As mentioned above, AM in MaaS could be used to generate information and knowledge and provide this way the basis for human or AI based decisions to enable a self-learning resilient transport system. This will be the endeavor of the next chapter **Error! Reference source not found.**.

3.5 AM integrated in intelligent transport systems: a system innovation approach for a resilient self-learning citizen and purpose centric city transport

The concept of 'Citizen centric Intelligent Transport system' combines the intelligent transportation system with the citizen centric approach. An ITS aims to provide services relating to different modes of transport and traffic management, enable users to be better informed and make safer, more coordinated, and 'smarter' use of transport networks. They include advanced telematics and hybrid communications including IP based communications as well as Ad-Hoc direct communication between vehicles and between vehicles and infrastructure (ETSI 2021). Another keystone refers to a self-learning system with data-driven approach and AI for the development of Intelligent Transport System for smart cities and sustainable mobility (Iyer 2021; UNESCO 2021). AI and digital transformation could support to identify common patterns of mobility and quantify the crucial factors affecting the efficiency of the whole system (Lucca 2022).

Figure 11 depicts the citizen centric Intelligent Transport System. At the core are the citizens as it follows a citizen-centric approach. A variety of transport means is available for the citizens to choose from; these are depicted in the middle circle in Figure 11 in a similar way to Figure 5. The transport options are provided by various stakeholders (the actors named in the yellow blocks, at the middle circle of Figure 11). In addition to Figure 5, data are used to generate information and knowledge about and within the transport system. An intelligent transport system can learn and improve through experience gained by data, this is visualized by the loops in the outer circle. Important is to notice that these positive externalities can only be enabled in closed loops. This means that collected data is not enough and that decisions to close the loop e.g., to improve the transport system must be taken. This is the case when automated vehicles have "learned" from data how to avoid an obstacle or a critical scenario in the city and the improved drive algorithm and eventual related hardware have been uploaded (fast closed loop). This can happen as well when a city chooses to change the traffic rules on places with a high level of safety problems (slow closed loop).

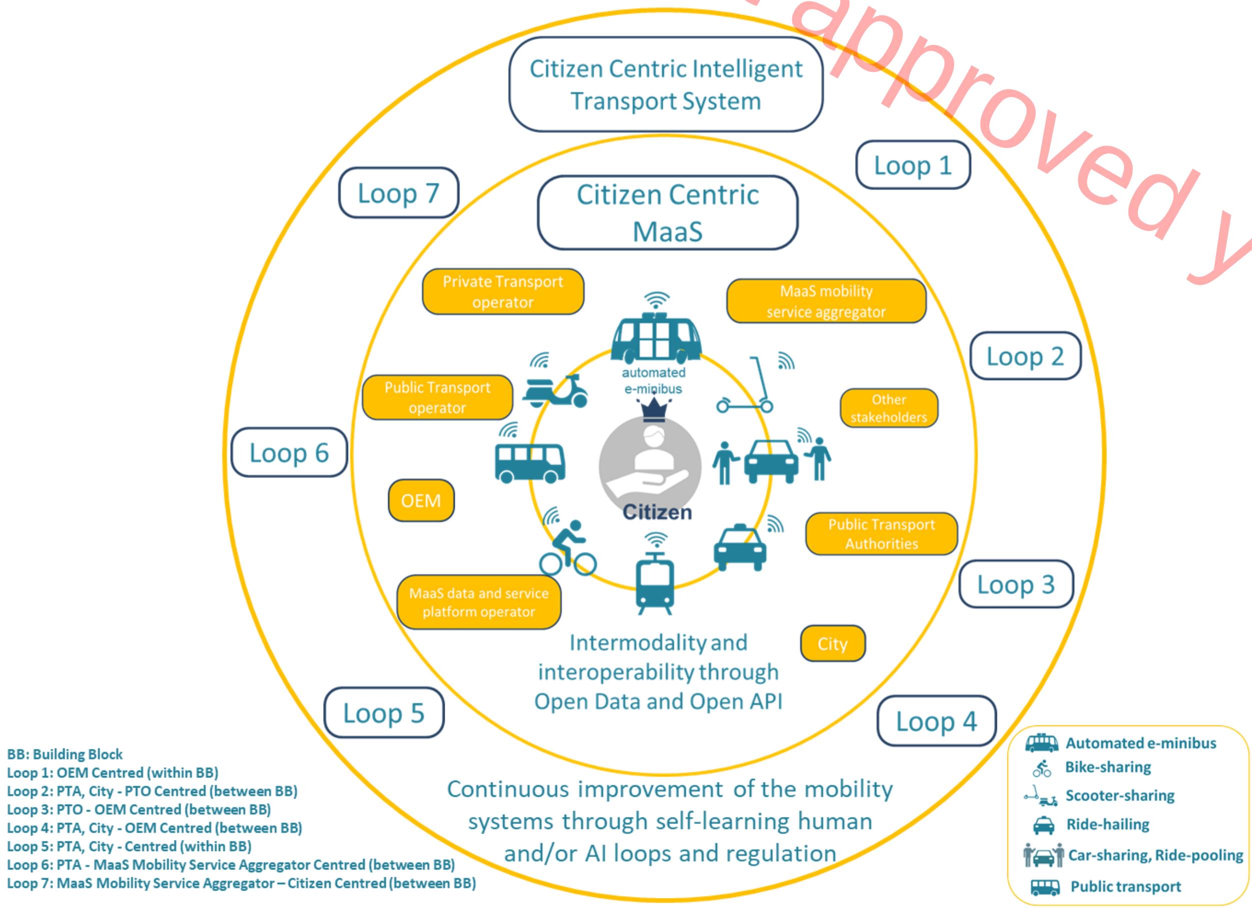

Figure 11: Citizen Centric Intelligent Transport System (ITS)

On-demand and door-to-door data which respects GDPR could be provided with a precision in quality and quantity never reached before. These data could indeed be used to generate information, including decisions and knowledge about the transport system thus enabling continuous improvement of the mobility system of the urban area through edge-of-technology based self-learning human and/or AI loops and regulation. The loops (Figure 11) have been designed around the stakeholders and can only be useful when closing the loop to implement the lessons learned, for local and global improvement. The AM, infrastructure, platform, application etc. and the stakeholders (in particular the user) generate data and information which can be used by stakeholders to close the loop to get to know, understand and improve the transport system (ERTICO – ITS Europe 2019).

Under adequate compliance of data privacy and security, these data can be used locally or crypted and transmitted to trustworthy partners for analysis in case of an incident. For example, this can be assured with support of distributed-ledger technologies such as blockchain. To identify and understand the mobility needs of the citizens and related possible risky situations, the implementation of an intelligent transport system with an integrated self-learning concept must be individually adapted and continuously improved.

The functional context of an intelligent transport system is systematically described by the following step by step illustrations.

Depicting the 7 relevant loops (as indicated in Figure 11):

- Loop 1: OEM centred (within building blocks (BB)
- Loop 2: PTA, city – PTO centred (between BB)
- Loop 3: PTO – OEM centred (between BB)
- Loop 4: PTA, City OEM centred (between BB)
- Loop 5: PTA, City centred (within BB)
- Loop 6: PTA – MaaS Mobility Service Aggregator Centred (between BB)
- Loop 7: MaaS Mobility Service Aggregator – Citizen Centred (between BB)

Each of the loops will be described and explained below. The descriptions are accompanied by visualizations (Figure 12 - Figure 17) of the 7 self-learning loops to achieve a complete self-learning ITS ecosystem. Each loop builds upon the previous system. The coding within the graphical representations is defined in the following way:

Arrows have different meanings: Dotted arrows indicate the data flow; plain arrows indicate the information flow and the related decisions. Yellow arrows indicate the outward flow of data or information, blue arrows indicate the return flow and the clothing of the loop; a data exchange loop is represented by the combination of outward and return flow. The determined loops can be fast (because e.g., just one Stakeholder or one building block like an OEM is involved), medium or slow (when a consent between stakeholder (building blocks) or laws/vehicle specification/vehicle certification must be developed and published.

Loop 1 as depicted in Figure 12, is an OEM centred fast loop. An automated minibus emits three data flows and one information flow to the surrounding systems. The first data flow concerns the circular interaction between vehicle and roadside or traffic environment generating sensor data from onboard or roadside sensors and represents a closed loop. The automated minibus is also sending sensor data to the OEM's. As with the PTA, the OEM could also be supported by AI technology, but rather in an almost closed loop, which means that improvements and optimisations occur very regularly and most quickly. With support of AI algorithms, software, maps, automated minibuses can be updated with upgrades of new software releases, updated map, deep neural networks (DNN) and next gen hardware upgrades from the OEM of the AM.

The second data flow is characterized as a targeted transmission of data via IT infrastructure to a virtual black box (like planes) where they are permanently recorded and stored in real time (like a continuous tracker). These data are e.g., electronic trip records of incidents and accidents caused by both the automated minibuses and the infrastructure and is further on transmitted from the virtual black box to the PTA through a trusted AV third party. The transmitted data from the black box provide information to the PTA about causes, location and time of accidents or incidents. Based on this information, AI algorithms can provide significant qualitative and quantitative improvements for the service quality and safety, the requirements for AM and AV and for infrastructure (see loop 2, 4 and 5 below).

A further link originating from the automated minibus is the flow of information to the PTO. Here, information about the location of the automated minibuses, possible malfunctions, incidents, and accidents are transmitted and possible recommendations for infrastructure, traffic rules, change of means of transport are provided. The PTO could also be supported with AI algorithms for a medium closed loop (see loop 3 and 4 below).

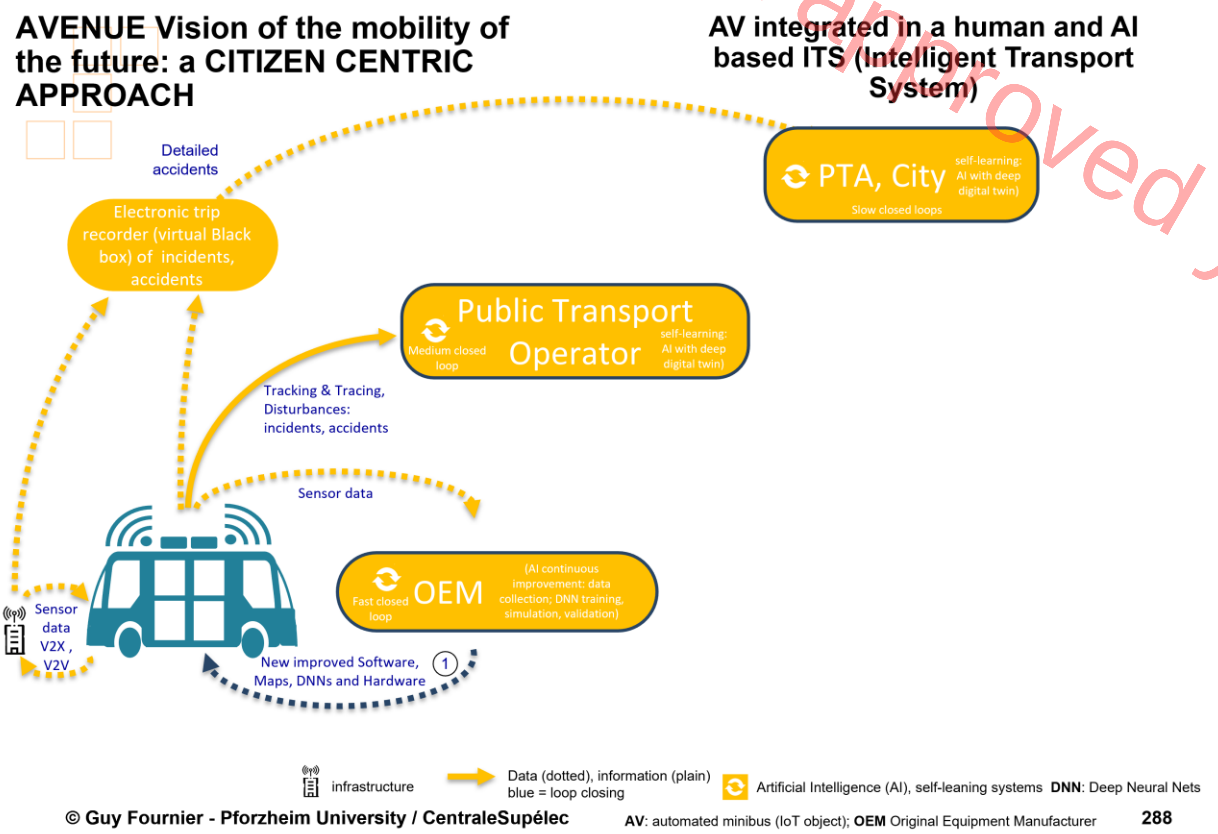

Figure 12: Automated minibus integrated in ITS: Loop 1

The second loop, as depicted in Figure 13 is PTA, city – PTO centred. It shows that trusted third parties – as intermediary scientific service providers – could analyse such data to build anonymised lesson learned, processing data including personal data from the electronic trip recorder and provide it to the PTA for improvement. These trusted third parties are certified and working on behalf of the PTA and as such a 'neutral' and objective institution. They could process all incidents and accidents to satisfy improvement needs, but also supply for juridical treatment when necessary. They could also proof the AI used by the OEM for their vehicles and forwards this information to the PTA in form of recommendations for preventive or improvement measures for regulation.

Information flow occurs between the PTO and the PTA. With the data and information transmitted to the PTO, AI algorithms could suggest improvements for infrastructure or optimization of traffic regulations and forward these to the PTA. At the PTA, a separate loop takes place in parallel, in which the traffic regulations and infrastructure are permanently optimized and improved. Subsequently, the regulations regarding service quality and safety are forwarded to the PTO (see closing loop 2 in Figure 11).

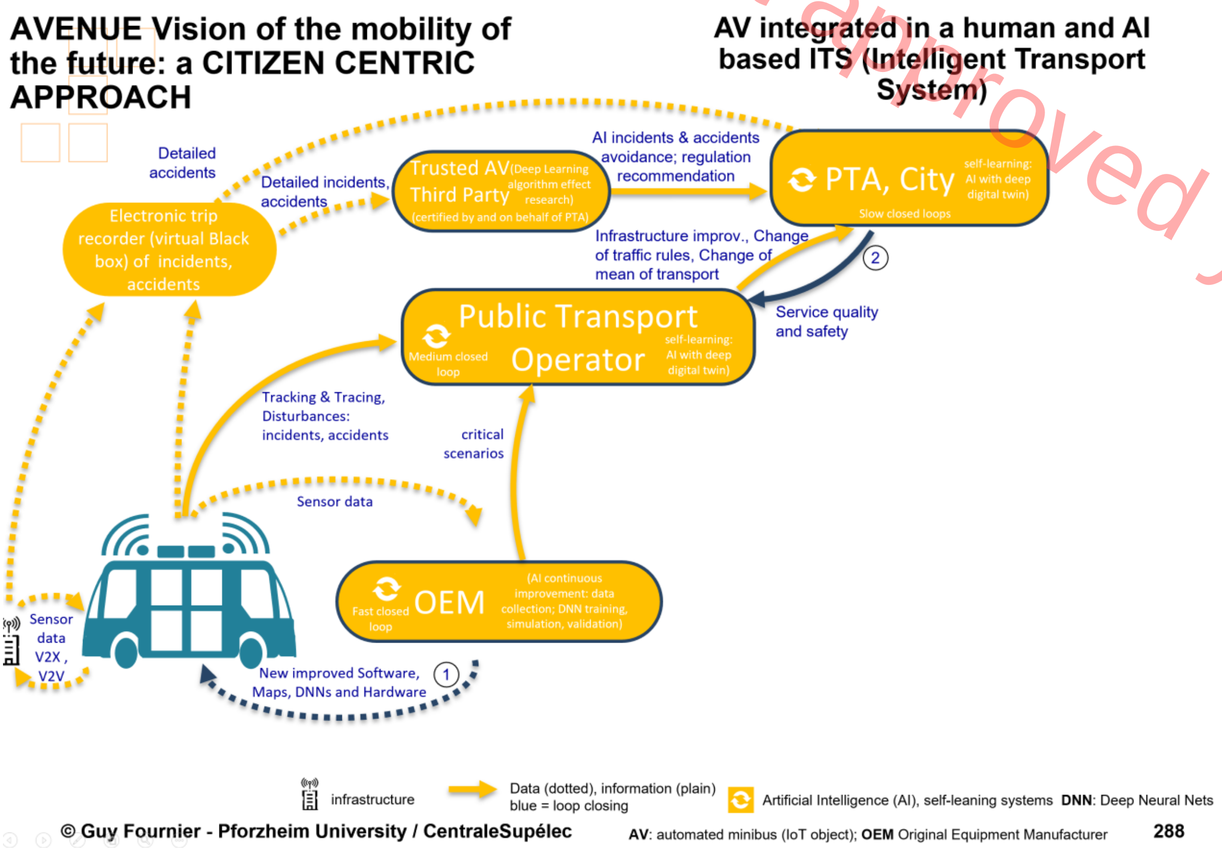

Figure 13: Automated minibus integrated in ITS: Loop 2

The third loop, depicted in Figure 14 is PTO – OEM centred, and further completes the Intelligent Transport System. This third loop depicts an information flow between the public transport operator and the OEM, as well as between the public transport operator and the PTA.

From the OEM, the data of the critical scenarios of AM are transmitted to the public transport operator, supported by AI algorithms. Subsequently, a backflow of information takes place between the PTO and the OEM where the OEM receives information on adjustments to the transport specification in the form of shuttle capacity, range, availability, and persona profiles as well as adjustments to the vehicle specification. Based on this, the OEM can process this information, send the corresponding data to the minibuses to determine the optimal utilization and considering the new safety requirements in road transport.

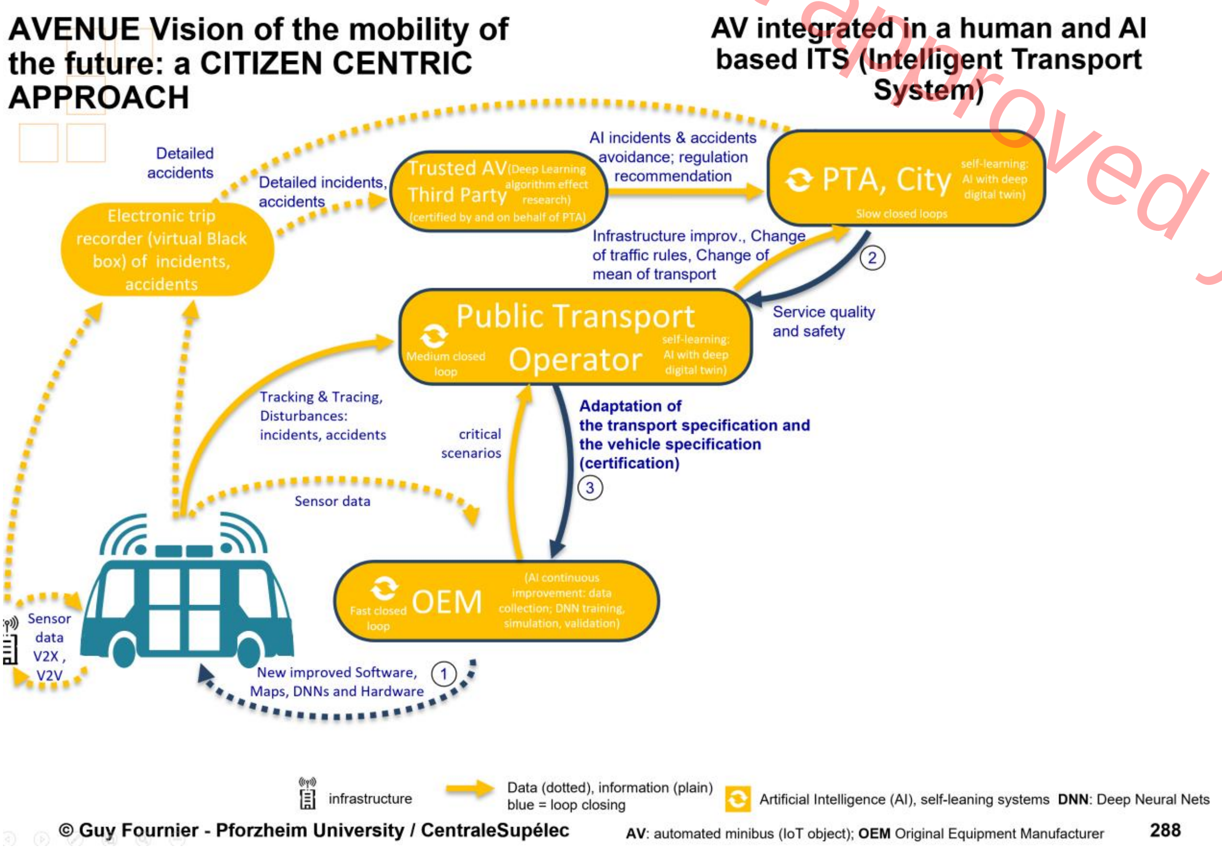

Figure 14: Automated minibus integrated in ITS: Loop 3

The fourth loop, depicted in Figure 15, is PTO – OEM centred. The PTAs, based on the mobility database flow from all the stakeholders create and improve the requirements and regulations for OEM certification and approval requirements and regulations for automated driving (vehicle architecture, AI algorithms, etc.). For example, new active and passive safety requirements can be introduced from accident analysis and lesson learned coming from the third party.

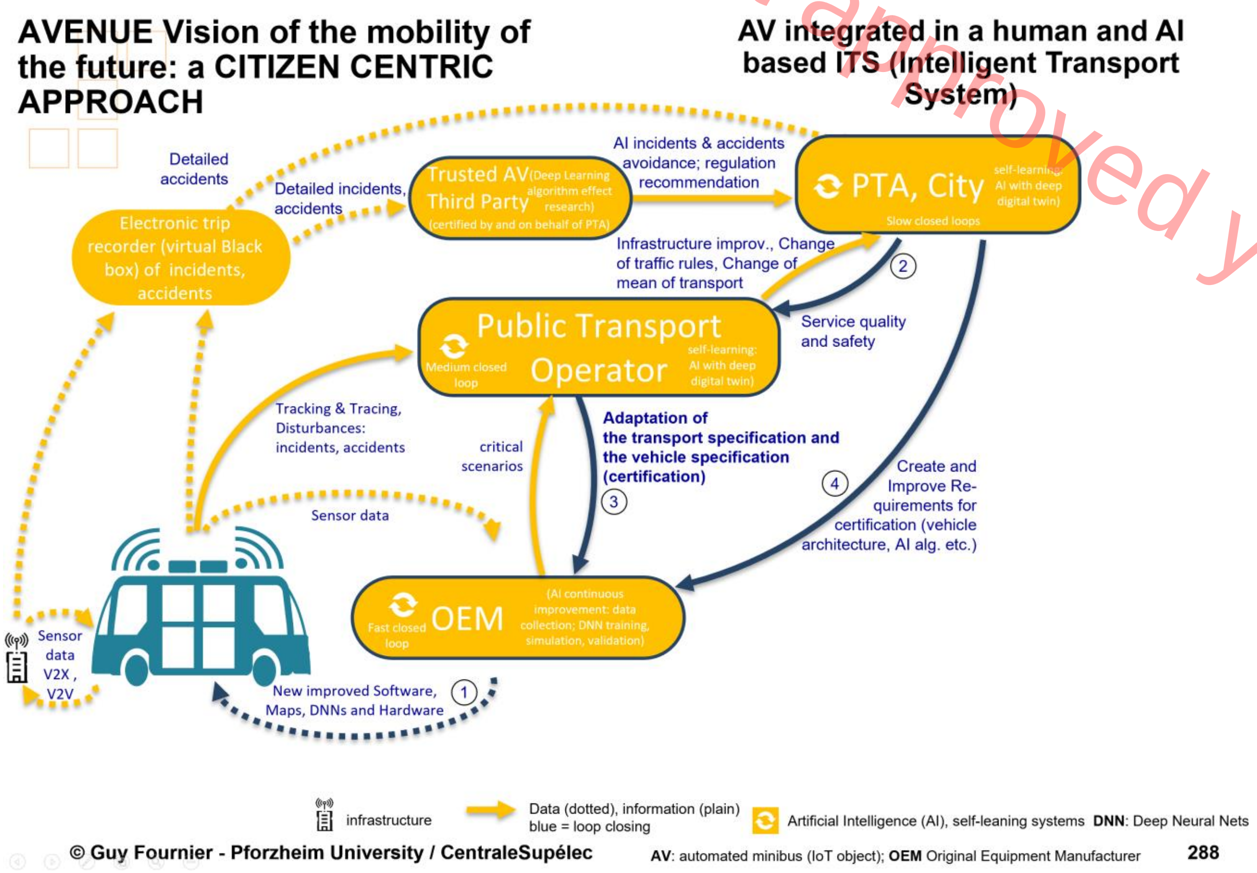

Figure 15: Automated minibus integrated in ITS: Loop 4

The fifth loop, depicted in Figure 16, PTA, City centred. This slow loop highlights the closed loop of PTAs receiving data from all the stakeholders and using them to improve the urban infrastructure and traffic regulation for updates, monitoring and mobility (re)planning

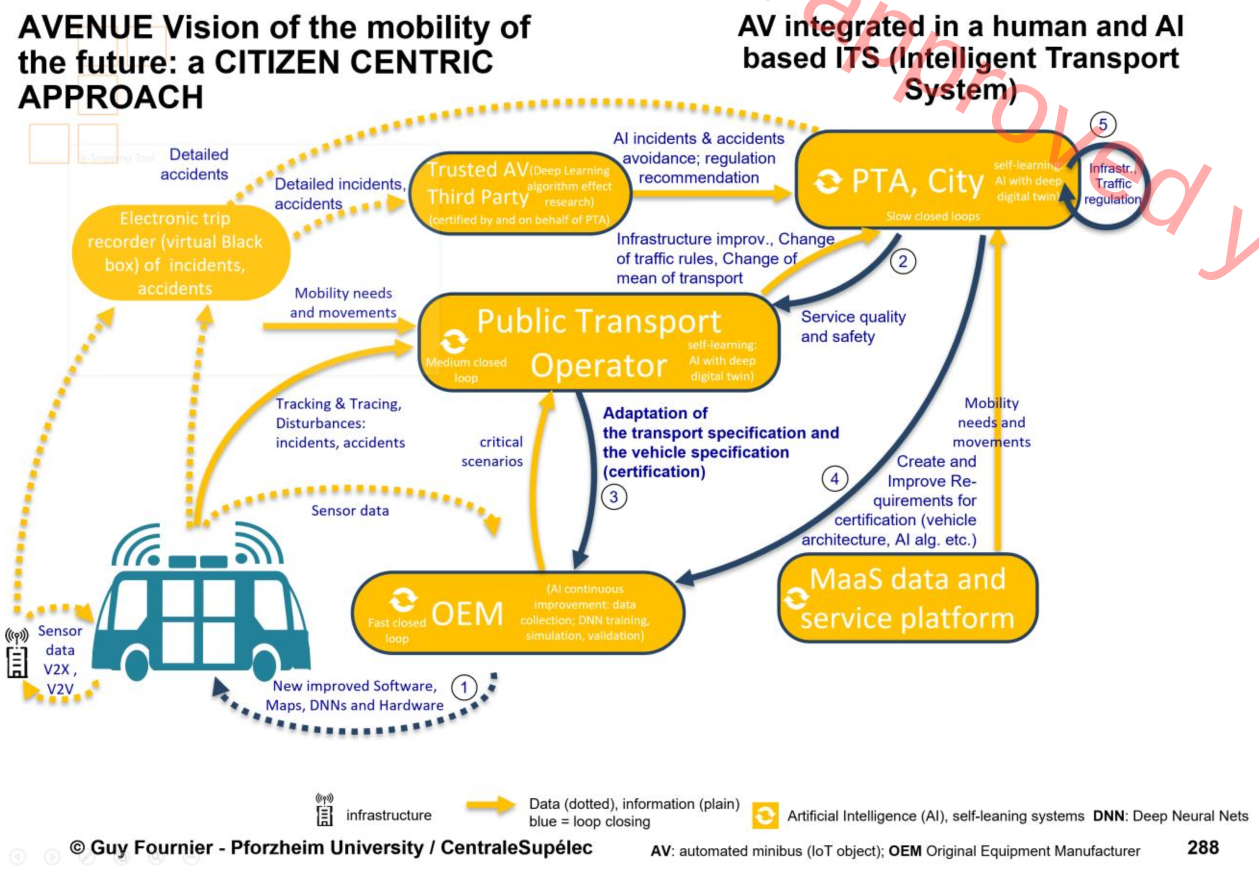

Figure 16: Automated minibus integrated in ITS: Loop 5

To finalize the vision of the intelligent transportation system, both the citizens as well as the MaaS data and service platform are added (loops 6 and 7), as shown in Figure 17. As mentioned above, the AI supported PTA will optimize and improve the infrastructure and traffic rules (loop 5). Thus, corresponding information required for the certification of the automated minibuses, (e.g., in form of improved vehicle architecture) can also be determined and transmitted to the OEM (loop 4).

To create the connection between ITS and the AVENUE Vision of a ‘Mobility of the Future’, an information flow takes place finally between the MaaS data and service platform, the PTA, and the Citizen. The MaaS data and service platform and the MaaS mobility service aggregator transmits the mobility needs to the PTA. The PTA as the ‘general supervisor’ of the entire ITS must ensure that all mobility needs of the citizens are also AI supported to offer adequate and optimal transport options in an efficient and quality assured way to the citizens.

In loops 6 and 7, completes the ITS by adding both the citizens as well as the MaaS data and service platform. The exchange of information between the PTAs and the MaaS mobility service aggregator is crucial: i) on one side data from the mobility aggregator and from the MaaS data and service platform provider anonymously informs the PTAs about the citizen mobility needs and behaviour ii) in return, the PTAs are better able to improve the mobility system and infrastructure (loop 5), aiming to trigger positive externalities and reduce negative mobility externalities. This last loop is also crucial to guarantee positive mobility experience, trust, and satisfaction, as well as safer trips.

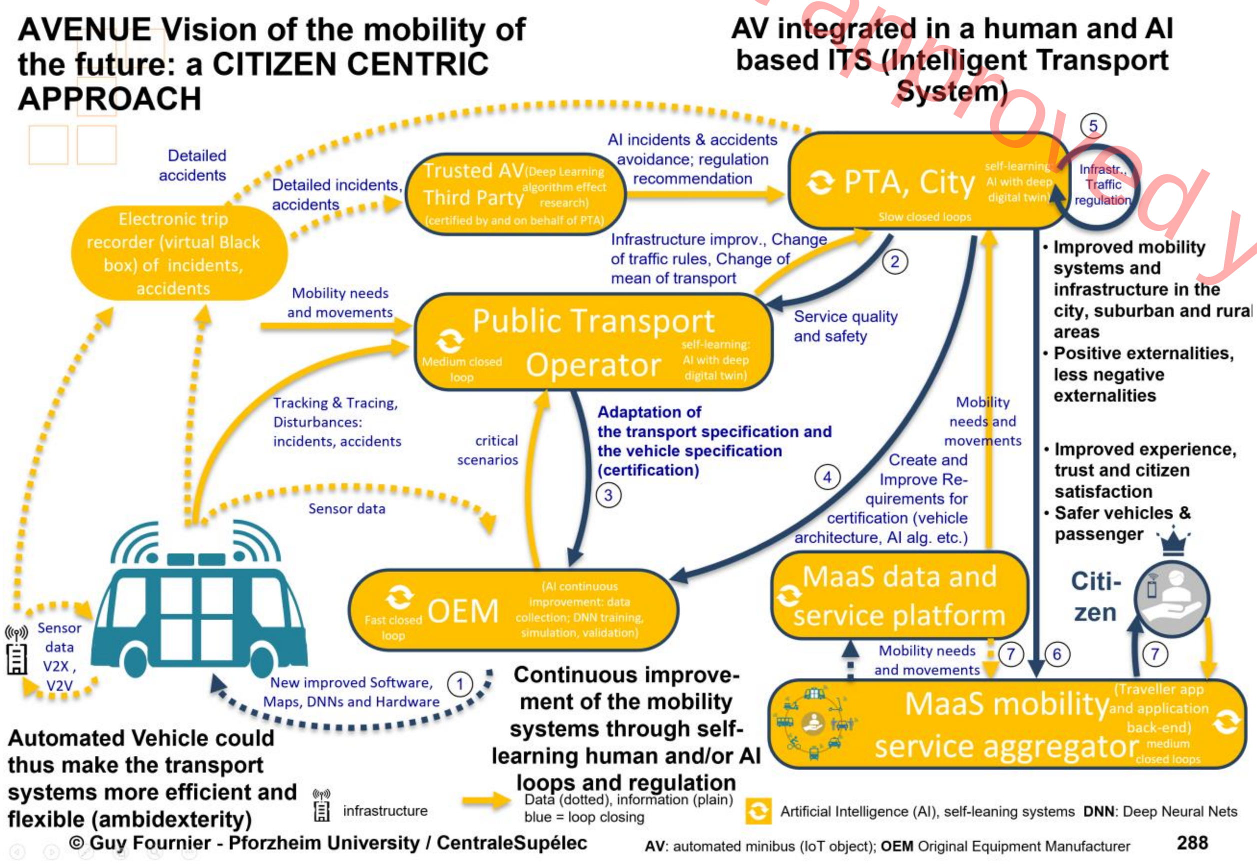

Figure 17: Automated minibus integrated in ITS: Loops 6 and 7

The integration of automated minibuses in the future transport system could thus be beneficial for all the stakeholders, lower negative externalities, provide positive externalities and satisfy better the citizen needs and their acceptance. All the means of transport can be offered and combined to a seamless offer which is as individual, safe, and attractive as an individual car. With the integration of automated minibuses into an intelligent transport system, the whole transportation system could further be improved continuously through the described self-learning loops.

Finally, the data gathered by the mobility aggregator permit the provision of customised unimodal or intermodal mobility alternatives to optimise the choice of the customer depending on own profile, persona or even weather. Travel time, costs and environmental impact can be used as a basis for decision making. These last loops are crucial to ensure positive mobility experiences, trust and satisfaction, safer journeys, and acceptance.

The entire transport system could thus be continuously improved with the integration of automated minibuses into an intelligent transport system, through AI-based self-learning loops described to fulfil the requirements and purpose of the focused application area in urban, suburban, and rural environments.

Various upcoming digitalization technologies like digital twins of automated (smart) vehicles as transportation objects, digital twins of (smart) citizens, digital twins of (smart) infrastructures, and even digital twins of all kinds of stakeholders (PTOs, Intermediaries, PTA's, etc.) and mobility subsystems are enabling the governance, simulation, monitoring, tracking / tracing, analysis, and optimization of the entire mobility ITS/MaaS ecosystem. Together with photorealistic visualizations and avatar technologies the AI-based self-learning loops of the mobility ecosystem could be ready-for-design and -implementation into a future citizen-centric 'Mobility Metaverse' aiming to optimize the physical / real 'Mobility Universe' as a Digital Twin.

Finally, it is worth noting that this approach has also limitations as it is a complex and technologically risky innovation project combining two disruptive innovations: AM as a product (or even vehicle system) innovation and MaaS / ITS as a mobility system innovation which could be called also a holistic (technical, social, ecological, business, and governance-related) "ecosystem" innovation. Further, even if huge progress can technically be achieved with AI, deep learning is not enough to enable computers (of an AM or an AV or a transportation system) to truly think like humans. Deep understanding and common-sense reasoning will probably be necessary and of course the intervention of humans (Levesque 2018; Brachman and Levesque 2022; Liang et al. 2022).

The main risks and limitations of the AM in MaaS concept are addressed in the following section.

4 Transition Concept to the AVENUE Vision (Scenario 3)

4.1 Introduction

As briefly explained before, the AVENUE vision involves a mobility concept combining MaaS with the use of AVs. This implies that the transport service providers of the public and private transportation providers deliver citizens a combined and individual mobility option via an app in which the journey can be planned, booked, and paid for. The AVs, which comprise for instance the AMs, are regarded as the key "game changer" in local public transport. In this regard, the AVs enable first and last mile travel serving as mobility gap fillers for seamless transport. Furthermore, AVs are intended to compensate in the event of private and public transport failures (disruptions, accidents, etc.). This is expected to reduce the negative externalities and thereby make public transport more attractive for citizens (Fournier et al. 2022).

4.2 Stakeholder

The stakeholder group of manufacturers and software developers is focused on developing and advancing the required technologies for the automated minibuses following the detailed work from work package 2 (Nemoto et al. 2021).

This is due to the fact that **software providers** are directly involved in both the MaaS system and AVs, providing platforms that permit the operation and optimisation of automated mobility services, overseeing both scheduled and on-demand services. These cloud-based platforms act as an intermediary between the mobility providers and customers; therefore, they have a major influence on the overall project. In addition, it is very important to develop a trustworthy system where users take advantage of the rides in automated vehicles to pursue other activities without having to focus on the road. This generates added value for the user, which is what the project seeks to accomplish. Nevertheless, a close collaboration with other stakeholders, the public transport operators (**PTOs**), is also needed. Since the PTOs have to operate these new services already during the transitional phase, a high level of involvement is required from them, particularly at the beginning. The PTOs are commissioned by the municipality, making them one of the stakeholders with a great amount of influence on the project. This is the case because the municipality is not only responsible for commissioning the PTOs, but also for the requirements for the public transport system and for the requirements for the registration of the automated minibuses. They are equally charged with urban planning. Urban planners concentrate on decreasing urban space for private transport and preparing infrastructure for transformation by assisting the PTOs. In this way, these stakeholders define the rules of the game for the project launch (Nemoto et al. 2021). However, since the **city administration** is also subject to the **national government** and the **European Commission**, it is mainly the European Commission and the national government that shape the scope of action for the city government and consequently also for the PTOs (Nemoto et al. 2021). The European Commission can impose regulations and thereby support or obstruct the development of the technology. National governments can step in and impact the project through regulations, incentives, and rules (Nemoto et al. 2021).

Besides the actors of software development, the government, and the city administration, the **manufacturers** of the automated minibuses are crucial stakeholders which have a great effect on the implementation of the project. As they are in charge of developing and offering mobility solutions, they have to build trust and acceptance for their vehicles among consumers, and they must secure a good market position to establish their own company in the market. To achieve these three key issues, they put their focus on the quick introduction of products into the public system, where well-designed standards can reduce the total cost per vehicle while increasing the speed of development (Nemoto et al. 2021). The **drivers' union** will be involved in the implementation of the project by engaging in driver retraining and education, optimised road conditions, safety and arrangements with governments and employers' organisations (Nemoto et al. 2021). However, drivers' unions and environmental **Non-Governmental Organizations** (NGOs) have up to now taken a negative position towards automated minibuses, and to lessen negative impacts on the environment and society, these stakeholders should be implicated in decision-making and discussions in a more purposeful way (Nemoto et al. 2021). The final critical stakeholders are the **end users** of the system. The project will only succeed if it is accepted by the users. To ensure that users alter their mobility behaviour in the future, the automated vehicles must afford the flexibility and convenience of customised mobility solutions (Nemoto et al. 2021).

This was a summary of the main stakeholders in Scenario 3. Given that there are several more stakeholders, they are enumerated in Table 4 for completeness.

- Insurance companies
- Electricity charging infrastructure providers
- Energy providers
- Research institutes
- Financial services
- Recycling industry
- Emergency aids
- Industry lobbies
- Consultancy companies

Table 4: Stakeholder Scenario 3

4.3 Transition Goals

Software and hardware implementation

The software-technical and hardware-technical point of view comprises a fully automatic order processing of the booking, considering the personal preference for one of the Transition Goals. A further goal is to inform the user about the next mobility alternative entirely automatically in the case of a change in scheduling. The data should be exchanged between the mobility providers and the means of transport as well as the administration between different AV manufacturers without any problems.

Technological implementation of vehicles and infrastructure

The possibilities for the means of transport and the AVs as well as for the AVs and the infrastructure to interact should be adjusted and increased.

Customer-oriented needs

This should ensure a customer-optimised provision of seamless transport options without any waiting times. Furthermore, attention should be paid to take into account the transport needs of customers and to automatically offer a satisfactory solution in case of unforeseen events, like accidents or breakdown of transport means. The optimised transport system should reduce negative externalities.

4.4 Recommendations and Measures

To implement Scenario 3: AVs in MaaS, several recommendations and measures support the introduction and implementation.

Software and hardware implementation

By integrating AI in the MaaS system, vehicle and user data can be analysed and evaluated. This allows for the recognition of mobility patterns and as a result to the optimisation of vehicle utilisation and trip adaptation. It can even be used to modify and optimise the infrastructure to the users' mobility needs. This translates to a reduction in journeys without passengers. With the assistance of AI in the MaaS system, route information, such as accidents, disruptions, and route closures, can be communicated to the MaaS platform in real time and processed.

Technological implementation of vehicles and infrastructure

By using AI, the insights derived from the journeys can help to optimise the infrastructure. Furthermore, AI can be employed to monitor vehicle utilisation and subsequently contribute to the timing of the means of transport, which in turn can result in fewer empty journeys. To guarantee optimal communication between the actors in the transport system, it is vital to expand the data network of the infrastructure, the vehicles, and other actors, with 4G and 5G. This data network is equally required to enable comprehensive function, communication, and interaction of the sensors in the vehicles and the infrastructure with the AVs.

Regulatory and Legal Conditions

To implement the project successfully and set uniform targets, contractual coordination between all public and private mobility providers and the municipalities is needed. In addition, the adopted laws must be extendable to be applied to new technologies and developments.

Client-oriented needs

Using AI, the various transport options can be coordinated with each other, leading to schedule optimisation and thus to a reduction in waiting times enabling seamless transport for the user. On top of that, the additional development of individual mobility in the form of AV on-demand buses promotes the decrease of private vehicle ownership.

4.5 Measure roadmap

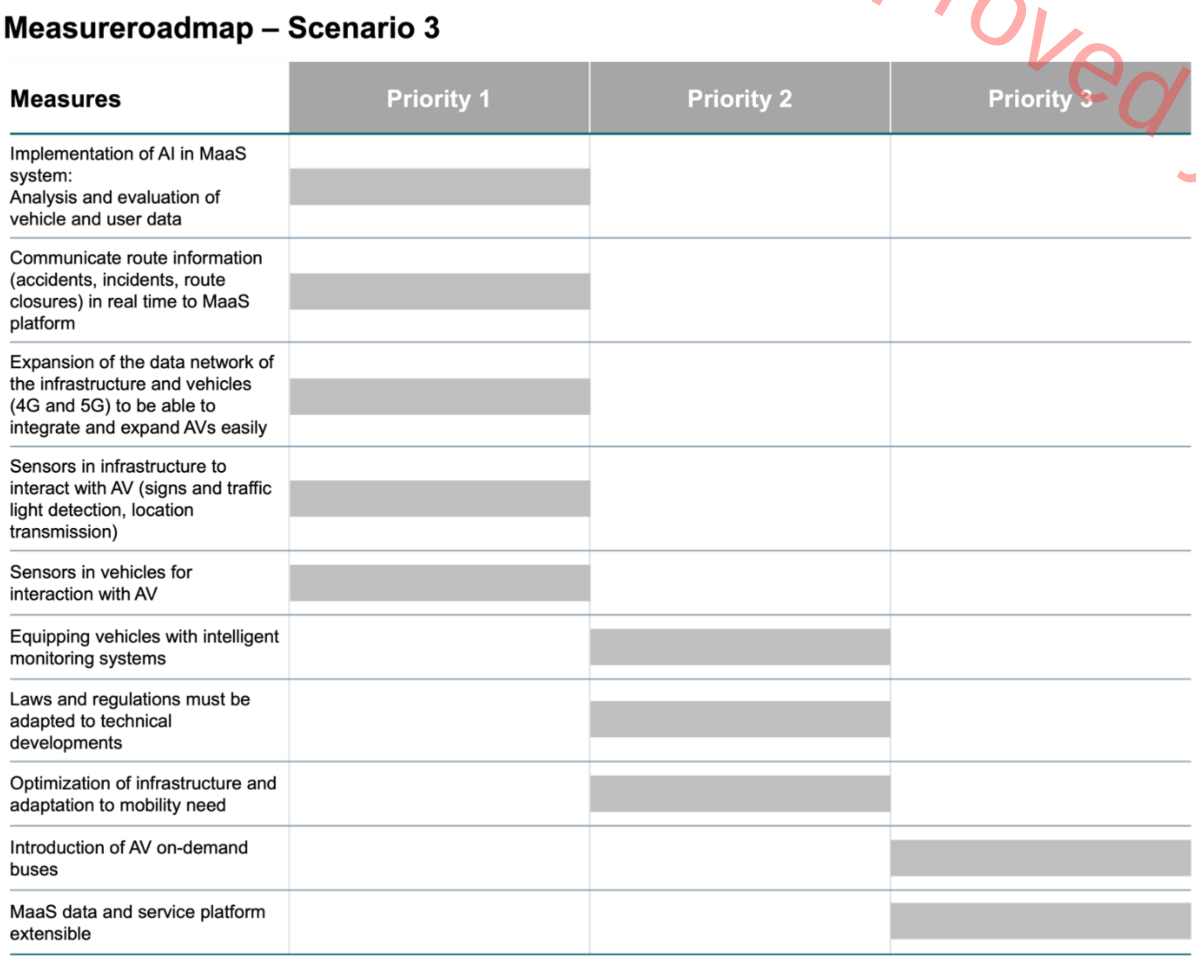

Figure 18: Measure roadmap Scenario 3

4.6 Transition Strategies

For the implementation of Scenario 3 in urban areas, Transition Strategies are required. In the subsequent section, the potential strategies for this scenario are described. The required information was drawn from the deliverable "D8.4 Second Iteration Economic Impact".

In the first possible transition strategy, **"Collaboration with Public MaaS Sub-BES"**, the hypothesis is that the technology, solution, and transition strategies of Automated Minibuses for Public Transport (AMPT) must be consistently aligned and integrated with the technology, solution and transition strategies of the Public MaaS provider in all aspects of the service portfolio and business model modules. Therefore, the solution strategies must be consequently specified and adapted with the Public MaaS Providers to ensure that this is a long-term perspective. In conclusion, an alignment with the strategy of the Public MaaS Sub-BES orchestrator can be very beneficial in the event of success but can also entail a high risk in case of failure (Antonialli et al. 2021).

The second transition strategy describes the **"Collaboration with Private MaaS Sub-BES"**. For this strategy, the hypothesis is that the technology, solution, and transition strategies of AMPT must be systematically aligned and integrated with the technology, solution, and transition strategies of the private MaaS provider in all aspects of the service portfolio and the business model modules. This illustrates that the solution strategies are consequently specified and adapted to those of the Private MaaS Provider, in order for it to be a long-term perspective. In summary, aligning the strategy of the private MaaS sub-BES orchestrator can be very beneficial in case of success, but can also pose a high risk in case of failure (Antonialli et al. 2021).

The third transition strategy that is possible is **"Competition within Public or Private MaaS Sub-BES"**. The hypothesis here asserts, *"…that AMPT MaaS are one among other AMPT solution partners within a Public or Private MaaS Sub-BES and thus enhanced AMPT strategies for USP and technical / business innovations as well as dedicated adaption to the strategies Public or Private MaaS Integrator in every facet of the offering portfolio and business model modules are necessary." (Antonialli et al. 2021)*

This strategy concentrates primarily on the USPs in the domains of social and accessibility or in the fields of safety and security as well as on flexible and collaboration-based innovation strategies. Therefore, a strong focus on USP over the relevant competitors within the private and public MaaS sub-BES as well as a focus on integrators' success factors and an emphasis on the innovation strategy are feasible (Antonialli et al. 2021).

Finally, the fourth transition strategy is **"Competition / Own (Private) MaaS BES with other (Private & Public) MaaS Sub-BES"**. In general, the hypothesis for this strategy is that AMPT MaaS is part of one of the other AMPT solution partners within the public or private MaaS sub-BES but is keen on and seeks to build its own MaaS sub-BES. This strategy demonstrates that AMPT strategies are needed to develop a MaaS BES as an integrator for AMPT solutions and other modalities and offerings, like infrastructure, along with innovation strategies to attain USPs. Therefore, this strategy puts emphasis on technology and business innovation to build a designated MaaS BES and simultaneously a competitive USP strategy (Antonialli et al. 2021).

4.7 Business Model Canvas

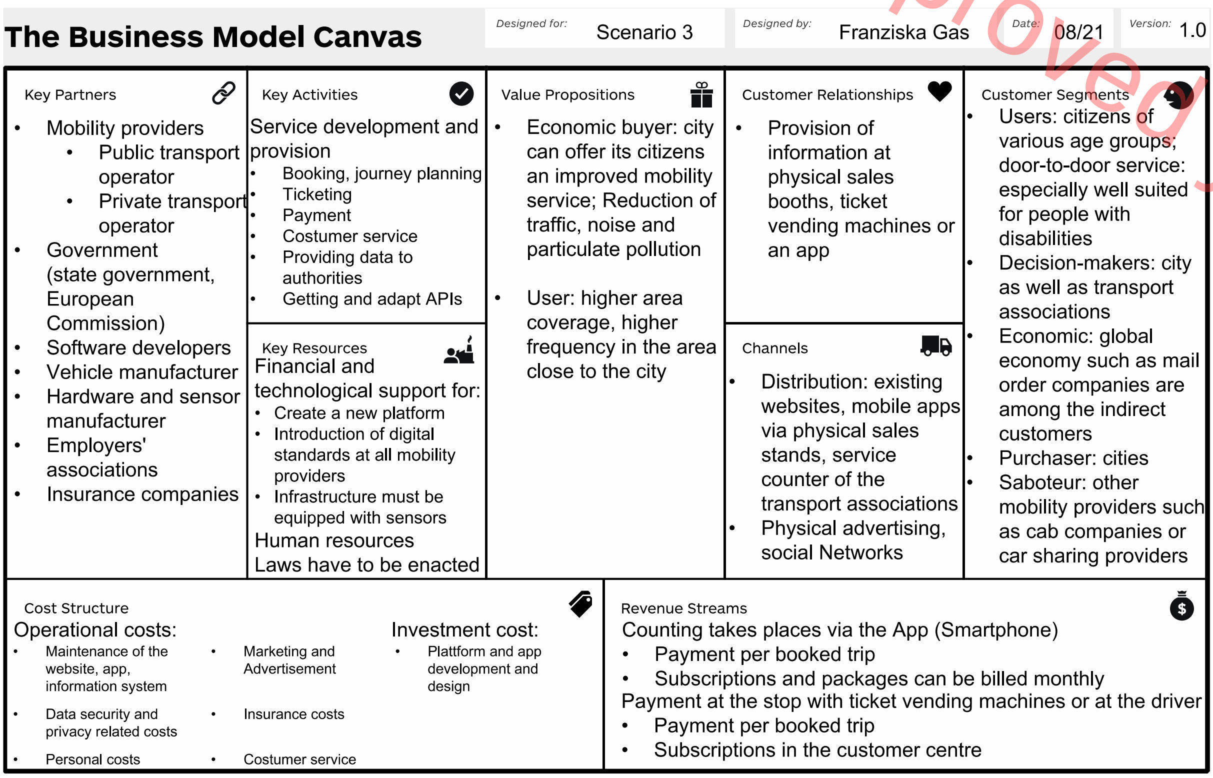

Figure 19: Business Model Canvas: Scenario 3 (Strategyzer AG online)

Beginning with the value position, two key categories were defined: the economic buyer and the user. In their role as an economic buyer, the city can provide better mobility to its citizens. Urban traffic can be decreased, which in turn results in a reduction in noise and particulate matter. With the area coverage achieved, the mobility concept can offer a higher frequency, and the use of autonomous minibuses can make individual and door-to-door mobility available and thus increase comfort for customers.

The field "customer segment" is divided into five categories: user, decision-maker, economic, purchaser and saboteur. Users are assumed to be citizens of different age groups; door-to-door service is especially suited to people with disabilities and elderly people. In this scenario, the decision-makers are the transport associations and the city. Together they are responsible for the legislation and infrastructure redesign. Indirect customers are global enterprises like mail order companies since autonomous minibuses can also be used for delivering parcels and letters. The city also assumes the role of purchaser because other cities may also realize the benefits of this project and subsequently show interested in it in case the project is successfully implemented in the first city. Lastly, the saboteurs must not be disregarded. These include primarily the private mobility providers, who perceive the new mobility services as competitors and fear being forced out of the market by this individual and door-to-door mobility offer.

The distribution of this business idea is elaborated in the field "Channels". In this scenario, existing apps and the service counters or sales stands of the mobility providers are used. Furthermore, advertising should be displayed in the form of posters at bus stops and in local newspapers. Apart from that, the incorporation of social networks is crucial to reach the younger generation directly. In the next field, "Revenue Streams", the revenue sources or methods are specified. In this field, tickets can be booked and paid for directly via the app or, to reach people without a smartphone or the ability to use the app, it is also possible to buy the ticket or subscription directly at the service counter, the driver or at the stop. Next, the "Key Resources" reveal that funding is necessary both to develop and build a platform to standardise the data structure of mobility providers as well as to adapt the infrastructure to the autonomous minibuses (use of sensors and charging stations). Moreover, the required legislation must be passed before the test phase and implementation.

In the area of Key Activities, it becomes obvious once again that the primary task is, first and foremost, the development and provision of the service. This involves booking, trip planning and payment through the app or the website, as well as improving customer service for users through a uniform platform. Lastly, providing data to the authorities and adapting and using the APIs are likewise among the key activities. To implement the business model with success, a number of key partners are needed. Among them are the mobility providers; they must be in favour of the project and committed to make the change. The city government issues the necessary legal approvals, and the software developers are in charge of the implementation. Additionally, it is imperative to consult and involve the vehicle manufacturers from the start in order to supply the vehicles with the necessary software and hardware. The employers' associations guarantee fair and good working conditions for every active employee. As a last point, there are the insurance companies, which take care of insuring the mobility participants.

Regarding the cost structure, operational costs and investment costs can be distinguished. In this scenario, the operational costs comprise all costs that relate to maintaining the websites, apps, and the information system, as well as the costs for data protection, data security, insurance, customer service, marketing and advertising and the associated personnel costs including those of the drivers. The investment costs are mostly the costs for developing the platform and the app with the accompanying design.

4.8 Business Model for implementation of AVs in MaaS

In the general description of potential business models for Scenario 3, it is assumed that the most likely future will be a customer- and citizen-centric intermodal MaaS ecosystem, where private and public MaaS providers connect different transport options into a seamless travel chain supported by, but not only consisting of, AVs (Antonialli et al. 2021). For this purpose, the possible business models were developed in the deliverable “D8.4 Second Iteration Economic Impact”. In the following sections, the different business models for the scenario AV in MaaS are described in detail.

Firstly, the **“Partner network”** is discussed; for a business model to function, partnerships are established with key partners which can serve various functions. In this business model, the public mobility provider acts as a MaaS integrator of BES like: Automotive Service Providers, other public and private mobility providers, and other IT infrastructure service providers. These companies can join the MaaS system as contributors and solution providers for the AVs in public transport (Antonialli et al. 2021). This partner network therefore combines the experience of many companies, but it also requires close collaboration and trust. **„Cooperation with Public MaaS Sub-BES"** can be interesting for the solution providers of AMs in public transport, since only in public tenders the cooperating companies can get competition. This is very favourable in a niche market or a small market segment giving them a secure position (Antonialli et al. 2021). In this business model, a collaborative strategic approach should be established with mutual alignment and integration of all business modules, where every facet of the offer portfolio is listed. Besides the solution customisation, close cooperation in the delivery and customer module, including joint solution development processes and joint marketing activities, is important for the partnership and business success (Antonialli et al. 2021). The AMPT solution providers can deploy their whole solution portfolio to the public MaaS sub-BES and further reinforce their partner and niche position through specialisation. As a consequence, this is a very appealing business opportunity with long-term prospects (Antonialli et al. 2021).

In the third business model, **"Collaboration with Private MaaS Sub-BES"**, AMPT solution providers establish a close relationship with the private MaaS planner by focussing on complementary offerings or complementing the offerings of other partners through their high-level performance. This business scenario highlights that AMPT solution providers can successfully apply their solution portfolio to the private MaaS sub-BES and augment their partner and niche position through specializing on complementary offerings and high performance (Antonialli et al. 2021). This guiding cooperative and synergistic strategic approach produce a mutual alignment and integration of all business model modules, in all areas of the portfolio of offerings. Beyond solution customisation, close cooperation in the delivery and customer module, including joint solution development processes and joint marketing activities, is pertinent to partnership and business success (Antonialli et al. 2021).

In this paragraph, "**Competition within public (A) or private (B) MaaS-Sub-BES"** is evaluated. The solution providers for AMPT can deploy their portfolio to the private and public MaaS sub-BES, but simultaneously participate in competition with other solution providers by specifying USP-focused strategies in the areas of performance leadership, cost leadership etc. or business and technical innovation (Antonialli et al. 2021). This business model is distinctive in its competitive approach to other ATMPT providers, resulting in a strong emphasis on technical/business innovation and USP generation, while tightly aligning business modules in every facet of the offering portfolio. It is marked by the competitive focus, in respect to the innovation pressure, the effort to achieve the unique selling propositions and an emphasis on integration (Antonialli et al. 2021).

In the business model "**Competition / Own (Private) MaaS BES with other (Private & Public) MaaS Sub-BES**", AMPT solution providers are in a competitive and challenging situation to preserve their technical focus and ongoing flexibility against competitors. Moreover, this entrepreneurial behaviour is defined by permanent technical and business innovation and the strive for market success and expansion (Antonialli et al. 2021). "*The analysis of this Business Scenario shows that strong innovative and especially USP-driven / competitive AMPT transportation offerings have to be developed and provided to customers (Value / Delivery / Customer modules) and at the same time a clear alignment and integration of all modules with those of Public (A) or Private (B) MaaS Sub-BES are focused*" (Antonialli et al. 2021). Furthermore, the entire MaaS BES must concentrate on supply, technology, business innovations and USPs that exist in other MaaS. In conclusion, in this business model, the business focus, the competitive focus on new innovations or USPs, and the focus on other MaaS must occur at the same time (Antonialli et al. 2021).

4.9 Implementation Plan

In this section, the Implementation Plan for Scenario 3 is presented, as illustrated in Figure 20 and Figure 21. At first, the business implementation is explained, followed by the necessary steps of the technical and political implementation. Lastly, details on the transformation management are provided. In the second column, several categories are listed for the types of implementations, for which the required or missing functions and positions for a desired implementation are specified.

The first category, People, relates to whether new employees need to be recruited or whether there exists a knowledge gap that can be overcome by additional staff. Next, there is the Process section, where it should be indicated whether a need for new working methods or departments exists. In the Technology section, it should be clarified whether the presently usable technology and IT systems are adequate for the new business model or whether new investments need to be undertaken for this. In the next category, Knowledge and Material, it is noted whether new knowledge must be obtained, or material has to be acquired for the implementation. Lastly, the point Partners explains whether new partners are necessary for the distribution or the implementation of the project. Afterward, for each statement it is determined whether it is a critical point or not, in which time horizon this point has to be addressed (short, medium, long term), which company, department or person is in charge for it and ultimately a status or a comment can be added.

Type of Implementation	Category	Activity	Critical	Time frame	Responsible	Status/ Comments
Business Implementation	People	Engage personal and property protection	Yes	Short term	Mobility providers	AVs without security staff are only allowed to take up journeys after a legal decision has been made
	Process	Speed up the approval process	Yes	Short term	State and city governments	Apply for legislation to introduce new technologies and advancements
	Knowledge & Materials	Experience through implemented AM in projects	No	Short term	Project management MaaS	Contact active and implemented AM in MaaS systems
	Partners	Stakeholder	No	Short term	Project management MaaS	Enter into new partnerships if necessary
Technical Implementation	People	Software development	Yes	Short term	Development department MaaS	Implement AI in MaaS system
	Knowledge & Materials	Monitor technological progress	Yes	Medium term	Project management MaaS	Follow technological developments and update them in the project if necessary
	Partners	AM manufacturer	Yes	Short term	Project management MaaS	Keep AM for transport systems up to date and develop it further
		Stakeholder	No	Short term	Project management MaaS	Follow current development of providers (software developers, AV and AM companies,..)
	Technology	Expansion of the data network of the infrastructure and vehicles	Yes	Short term	Municipality, Infrastructure planner, Mobility provider	At least 4G to ensure data transmission from user, vehicle, infrastructure and platform
		Equipping vehicles with surveillance technology	Yes	Medium term	Mobility provider	Cameras for video recording and hazard detection, otherwise no travel possible without security staff
		Equipping vehicles with surveillance technology	Yes	Medium term	Mobility provider	Cameras for video recording and hazard detection, otherwise no travel possible without security staff

Figure 20: Implementation Plan Scenario 3 Part 1

Type of Implementation	Category	Activity	Critical	Time frame	Responsible	Status/ Comments
Political Implementation	People	Establish regulatory and legal requirements department	Yes	Short term	Gouvernment	Employees who are responsible for the regulatory requirements of MaaS and decide on legislative proposals
	Knowledge & Materials	Sharing experiences	No	Short term	Gouvernment	Exchange of experiences in the area of MaaS implementation from the perspective of legally required specifications
	Partners	Cross-border regulations	No	Medium term	Gouvernment	Uniform regulations and specifications to standardise implementation
Transformation Management	Partners	Achieve Stakeholder acceptance	Yes	Short term	Project management MaaS	Involve stakeholders in the project and respond to requirements

Figure 21: Implementation Plan Scenario 3 Part 2

4.10 SWOT Analysis

One strength is that by implementing Scenario 3 in urban areas, citizens profit from the on-demand service by using AVs as well as through individualised travel planning. Still, this strength is also matched by a weakness: Experience with AVs and retrofitting all modes of transport with sensors and rolling out a nationwide, stable 4G network is still lacking when implementing AVs in the road system and infrastructure. Nonetheless, Scenario 3 also presents the opportunity to continue to improve and develop technologies and to increase the safety of road transport. Additionally, the sustainability goals can be attained, for example through reducing CO_2 emissions by decreasing the mobility of private vehicles. In case the government does not provide support to the project by implementing the necessary laws, the execution of Scenario 3 is endangered.

SWOT Analysis – Scenario 3

Strengths

For the development of Scenario 3

- Required **technologies** are already **available** for implementation
- Political interest in **modernising** the transport system
- **Economic support** for mobility providers
- **High user acceptance**, through improvement of the transport system

Of Scenario 3

- **On-demand** service through AM
- **Door-to-door** service through AM
- Combine trips individually and **seamlessly** and create travel chains
- **Pooling**: Bundling of journeys of different customers in one AM
- **Reduction of negative externalities**: Traffic congestion, noise, emissions

Weaknesses

For the development of Scenario 3

- **Lack of IT systems and experience** in implementing AMs in the infrastructure
- **Expansion of infrastructure and vehicles** with sensors and 4G network is a major challenge
- **Trust of citizens** in automated vehicles must be created

Of Scenario 3

- Creating a **win-win situation**; profitable balance between ecosystem partners
- **Striking a balance** between centralised control PTA and decentralised competition
- Introduction of **standardised API** by different governments of EU countries

Opportunities

Business opportunities:
- AV in Maas has **diverse market segments**. Private areas (airport), Public areas (hospitals, universities)
- Can be **sold** to countries, municipalities and areas

Technological opportunities:
- **High flexibility** in the use and integration of mobility services (ships, ferries)
- Use in **other business areas**: Additional use in the area of logistics, transport of goods, postal service

Application opportunities:
- Additional **employment as a shuttle**, at large events, city tours for tourists

Threats

Government:
- Must **enact policies** for open API and open data
- **Anticipatory government** is needed to create a legal framework for technological developments, otherwise a dominant position of robotaxis could emerge.
- **Laws and regulations cannot keep up** with the speed of technological developments.
- **High complexity** of implementation and uncertainties regarding governance of AI systems

User acceptance:
- **Individual use of AMs** instead of using pooling services.
- **Degrowth movement**: Technological advantage is increasingly discussed and may lead to a decline in adoption

Technological threats:
- **High complexity** of implementation and uncertainties regarding governance of AI systems
- **Development of new mobility services** that cannot be realised with MaaS (air taxis)
- **Security risks** due to hacker attacks
- **IT companies** (Google, Apple, Amazon...) develop their own apps, have access to user data and displace MaaS app providers.
- **Martec's Law**

Cost level:
- **Costly implementation** for municipalities, cities, countries.
- **Updating of technologies** used through continuous developments is needed

Figure 22: SWOT Analysis: Scenario 3

The danger of rapid and constantly accelerating technological change is that organizations and individuals who do not embrace the change quickly will be left behind. These considerations are illustrated by Martec's Law in Figure 23. Here, the Y-axis depicts the "quantity of change" and the X-axis the "time".

Technological change is hard to quantify, however, every individual can feel the speed of technological change, therefore, the line is increasing exponentially rather than linearly (blue curve). On the other hand, the organizations, and individuals adapt to changes logarithmically (red curve), since people require some time to adjust their thinking and behaviour. Thus, technology evolves more rapidly than companies and governments can adopt the change. As a result, the gap between the curves widens over time (Brinker 2013).

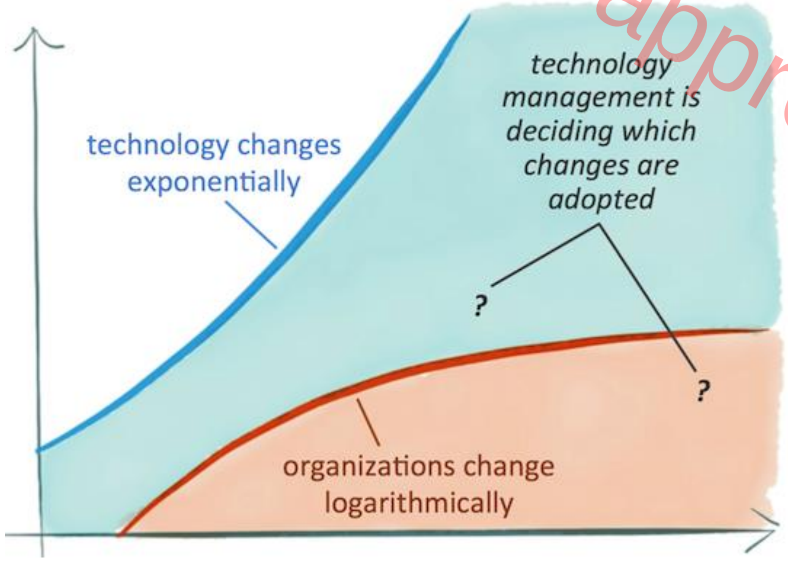

Figure 23 Martec's Law (Brinker 2013)

This leads to the result that digital mobility technologies (e.g., AI, AM) evolve exponentially, whereas mobility concepts (Maas/ITS concepts) and governance concepts (MaaS regulations, open data regulations) as well as the mind-set of the stakeholders are merely shifting logarithmically. This leaves an exponentially growing gap, which makes sure that a co-evolutionary change, which is necessary in theory, is taking place from time to time in disruptive waves of adaptation.

4.11 Scenario 4: Robotaxis

This scenario concerns the expansion of the transport system by using robotaxis. This deployment would not contribute to a transformation in the transport system, but only extend the mobility offer for the citizens. This is due to the fact that robotaxis are not shared by the population, but they only complement or substitute private vehicles. Therefore, robotaxis do not belong to the public transport system (Nemoto et al. 2021). A priority goal in improving transport systems should, however, be to prevent additional traffic and to make an effort to keep private transport out of cities. Chapter 2.4 presents the development status of private providers of robotaxis. These providers could be incorporated into the transport system as private partners utilizing open data and offering customer-oriented mobility services, thereby creating a private MaaS. Nonetheless, this would result in a "laissez-faire" scenario in which authorities and regulation, at EU, national and local level, do not attempt to anticipate the digital and automated transformation of mobility. This would permit private mobility providers to assume a dominant position in the transport system and push out public transport (Nemoto et al. 2021).

4.12 SWOT Analysis Scenario 4: Robotaxis

Incorporating robotaxis into the existent infrastructure of urban areas represents a cost-effective transport option in comparison to public transport, since drivers can be reduced, and the prices can be decreased through the large number of robotaxi providers. Nonetheless, the abundance of providers also produces a weakness, as the additional transport options afforded by the robotaxis and the various providers increase the traffic volume in cities. One reason for this is that the use of private transport does not decline by the same amount when the robotaxi service is introduced in the cities. The added use of robotaxis causes an increase in negative externalities, such as an increase in traffic volume which in turn results in more congestion. Still, already a small change away from private transport to robotaxis can provide the opportunity to travel in a more environmentally friendly way because the robotaxis are electrified. However, citizens switching from private vehicles to robotaxis poses the risk that public transport will be forced back.

SWOT Analysis – Scenario 4	
Strengths • **On-demand** and **door-to-door** service through automated vehicles • **Cost-effective** alternative to public transportation, as many providers are available • **Private ride** is bookable for the user • **Journey** distance is covered **quickly**, as no additional people can book identical vehicle (automated minibus)	**Weaknesses** • **Higher traffic volume** due to the additional implementation of robotaxis • The risk of **congestion** increases and at the same time the average **speed decreases** • Robotaxis do not replace the private vehicle • **Transportation** in one AV of two to four people
Opportunities • **Private cars** are being **replaced** by more environmentally friendly autonomous driving services	**Threats** **Government**: • **Resource consumption increases**, due to additional production of robotaxi fleets **User acceptance:** • **Displacement** of public transport **Technological threats:** • **Security risks** due to hacker attacks **Cost level:** • Fixed costs increase: provision of vehicle fleets, separate arrival and departure to each customer

Figure 24: SWOT Analysis: Scenario 4

5 Recommendation, discussion, and limitations

5.1 Introduction: Pre-Conditions for the implementations

In this section, the pre-conditions for a successful implementation of MaaS into the present transport system are explained. The pre-conditions are grouped into technological and strategic pre-conditions.

Technological Pre-Conditions

In this context, a greater dissemination of smartphones in a 3G network or higher is required; this also holds true for the older population group, because else users will not be able to take full advantage of the potential of MaaS with respect to optimised and personalised travel planning and the integrated payment option. Another technical pre-condition for implementing MaaS is the provision of a reliable and widespread cashless payment system. In addition, a high degree of connectivity between mobility services and users is vital to make reliable real-time information about travel options, timetables, and schedule changes available.

Strategic Pre-Conditions

The foundation of MaaS is not just the technical data integration, but also a cooperation model that is viable strategically, economically, and operationally for all partners. This necessitates a partial connection and integration of processes and business models of the partners in the MaaS system. Nevertheless, it also requires close and trust-based collaboration. This is why it is necessary to create a new business ecosystem in which several companies cooperate to offer a single service from the customer's perspective.

This moves the customer touch point away from the separate mobility service providers to a third party, namely the operator of the MaaS application. This guarantees a decoupling of service provision and customer contact. This MaaS integrator operates as an intermediary toward its customers; usage agreements are made directly between end customers and mobility services. The MaaS integrator's decision not to compete with its partners is also an essential strategic prerequisite. This prevents the MaaS integrator from participating in direct competition with mobility services or even from creating similar and competing mobility services itself. In addition, a balanced distribution of integration costs is required, since MaaS integration presently offers few opportunities for mobility service providers to gain new customers. The costs of technical integration must thus be distributed fairly and realistically among the partners (bcs Bundesverband CarSharing e.V. online).

5.2 Overview of success factors of Scenario 3: AVs in MaaS

A central category of success factors in introducing AVs in MaaS relates to the cost savings associated with the introduction of AMs. Because they are driverless, operators can eliminate the labour costs for drivers. In addition, they enable high spatial, temporal, and functional flexibility when operating, since an AM can operate at any place, any time and can be used as first and last mile (mobility gap filler) or as main mode of transport (Intelligent Transport). However, as long as security driver and / or supervisors in a control room are required by law, this flexibility could have an effect on the labour costs, since they have to be on standby for each trip (Nemoto et al. 2021). Additionally, the introduction of driverless minibuses can have a positive impact on the design of urban areas. This is due to the fact that a change in mobility services eliminates many journeys by private vehicle and thus enables changes in infrastructure, as the need for parking spaces and roads decreases. This could make more urban space available for parks, gardens, and near-natural waterways (Nemoto et al. 2021).

Furthermore, the development of AMs holds the promise of renewing public transport services. By developing and offering MaaS systems the use of private vehicles could be reduced, promoting an optimised and adapted traffic flow in the urban environment (Nemoto et al. 2021).

This also has advantages for bus drivers, taxi drivers, truck drivers and all kinds of land transport companies. Decreasing the volume of traffic and optimising the flow of traffic improves the working conditions of professional drivers. This includes, for instance, the standardised road signs in European cities or the reduced traffic volume (Nemoto et al. 2021). It is foreshadowed that this will give rise to a fear of higher unemployment, which still needs to be examined very closely scientifically in follow-up projects.

The introduction of AMs also generates new jobs, for example in vehicle production, maintenance, and vehicle monitoring. For these occupations, a higher qualification is required, which also leads to higher wages (Nemoto et al. 2021).

In addition, from the point of view of state and local mobility authorities, the expansion of open mobility data, which is necessary when using MaaS systems, would enable a better understanding of traffic flows in cities. As a result, the public mobility services can be tailored to the needs of the customers (Nemoto et al. 2021).

Fittingly, in an interview for the deliverable "Final Stakeholder analysis and AVENUE strategies 2021", a citizens' organisation representative emphasized the urgency of public transport development and innovation. *„Although the automated minibuses not being a main focus of the interviewed organisations, the organisations still acknowledged their potential role in supporting public transport, reducing the environmental footprint of mobility, increasing safety, reliability, and comfort*" (Nemoto et al. 2021).

5.3 Overview of obstacles of Scenario 3: Avs in MaaS

Successful technology change and the introduction of new systems comes with a number of challenges, which can further complicate maintaining the change. Nonetheless, by identifying the obstacles in the best possible way, it is feasible to prepare for the difficulties and address them in time.

In the section on success factors, it was noted that the use of AVs and the implementation of a MaaS system will reduce the need for parking spaces and roads, thereby changing the way urban infrastructure is designed. Yet, the introduction of AMs also necessitates the development of specific structures (Nemoto et al. 2021). Among others, these include road sensors, special signalling equipment, additional digital infrastructure and charging stations (Nemoto et al. 2021). Adapting the infrastructure to the needs of AMs is necessary to conduct further trials in urban environments in the meantime. The lack of infrastructure and the focus on developing infrastructure without considering future mobility trends are barriers to the deployment of AMs (Nemoto et al. 2021). In addition, regulations vary in each country, since the use of AVs is regulated at the national level in the EU. Details can be found in deliverable D9.1.

This also has implications for the development, testing and deployment of the AMs. A unified EU legal framework could simplify the technology development and provide more specific guidelines for vehicle manufacturers and software developers (Nemoto et al. 2021). When new mobility technologies are introduced, care must also be taken that the innovations are not harmful and unruly, therefore they need to be accompanied by legal regulations. That being said, these legal frameworks can also become an impediment, as regulators do not have sufficient expertise regarding the technology or knowledge of the technical specifications. Thus, there is a need to bring the important technological considerations closer to the legislators so that they can be integrated into existing laws (Nemoto et al. 2021). These obstacles in the form of legal requirements and regulations represent merely a small part, because legal regulations are not only needed with regard to mobility technologies and innovations, but for all mobility, which is in a state of transition (Nemoto et al. 2021). Details can be found in the deliverables D9.2, D9.4 and D9.5.

An additional obstacle could be social acceptance, because a large share of end users has not yet had the opportunity to experience the AVs. Therefore, one of the key issues is to acquaint the end user with the technology and to alleviate their worries regarding data protection, cyber security and ethical issues (Nemoto et al. 2021). Related to the question of ethical behaviour, there are also concerns associated with the reliability of AVs and the potential effects on other road users. *"... the connection to cyclists and pedestrians all the accidents, will they stop? Can they stop? Would they recognize all the traffic?" (*Nemoto et al. 2021*).* Questions about the response to complex mixed traffic situations and safety must be resolved for end users (Nemoto et al. 2021). The use of AMs is expected to be in the form of a door-to-door call-out service. However, such use is not categorized as public transport by all governments, but rather as a taxi service. Furthermore, civic organisations voiced concern about the use of this on-demand service of AVs, since they are used as individual transport and thus hence compete with existing public transport (Nemoto et al. 2021). Details can be found in deliverable D8.9.

In addition, the transportation of elderly people or people with reduced mobility by AVs can pose problems. This population relies on the assistance from safety drivers, which cannot be replaced by technology. The solution could be to offer dedicated rides with safety drivers through the app so that the new form of mobility is available to all people (Nemoto et al. 2021).

5.4 Summary and transformation into 5 criteria of recommendations

The beforementioned advantages of the AVENUE vision 2030 can only be achieved through the described disruptive product and system innovation. In Deliverable D8.6 and partly, we have shown the different business scenarios that are possible based on the current mobility environment. These range from the status quo to the vision of a MaaS, which integrates AMs as a fixed and important component, as described in the previous text.

Looking at the results of Deliverable D8.6 and the deliverable on hand, the following recommendations can be summarized before going into more details:

1. Status Quo based (project AVENUE): AMs should be considered as an operational and technical product innovation which is not yet integrated into the existing mobility system. Focus was the performance and security of AM, the creation of an ecosystem (Software, Hardware etc.) to run door-to-door and on demand, like shown in the AVENUE project.

2. AM in MaaS (see chapter 4.4): A genuine system innovation that takes the current mobility system to a higher citizen centric level and creates a Maas with integrated AMs, representing the first stage of the AVENUE vision. As shown in Deliverable D8.6 and above, this would be an innovation, but it does currently not exist. Forms of MaaS do exist, but they do not yet integrate AMs and this must therefore first be implemented as a vision.

3. AM in ITS (see chapter 4.5): When the vision is realised to the extent that a functioning MaaS integrates AMs, large amounts of data will be collected regarding routes, occupation of vehicles, etc. This data should be processed by AI based improvement algorithms over time so that the entire MaaS can be regarded as self-learning and thus as a self-optimizing system. From a strategic maturity level perspective, the efficiency of the system is hereby enabled to be continuously self-evolving.

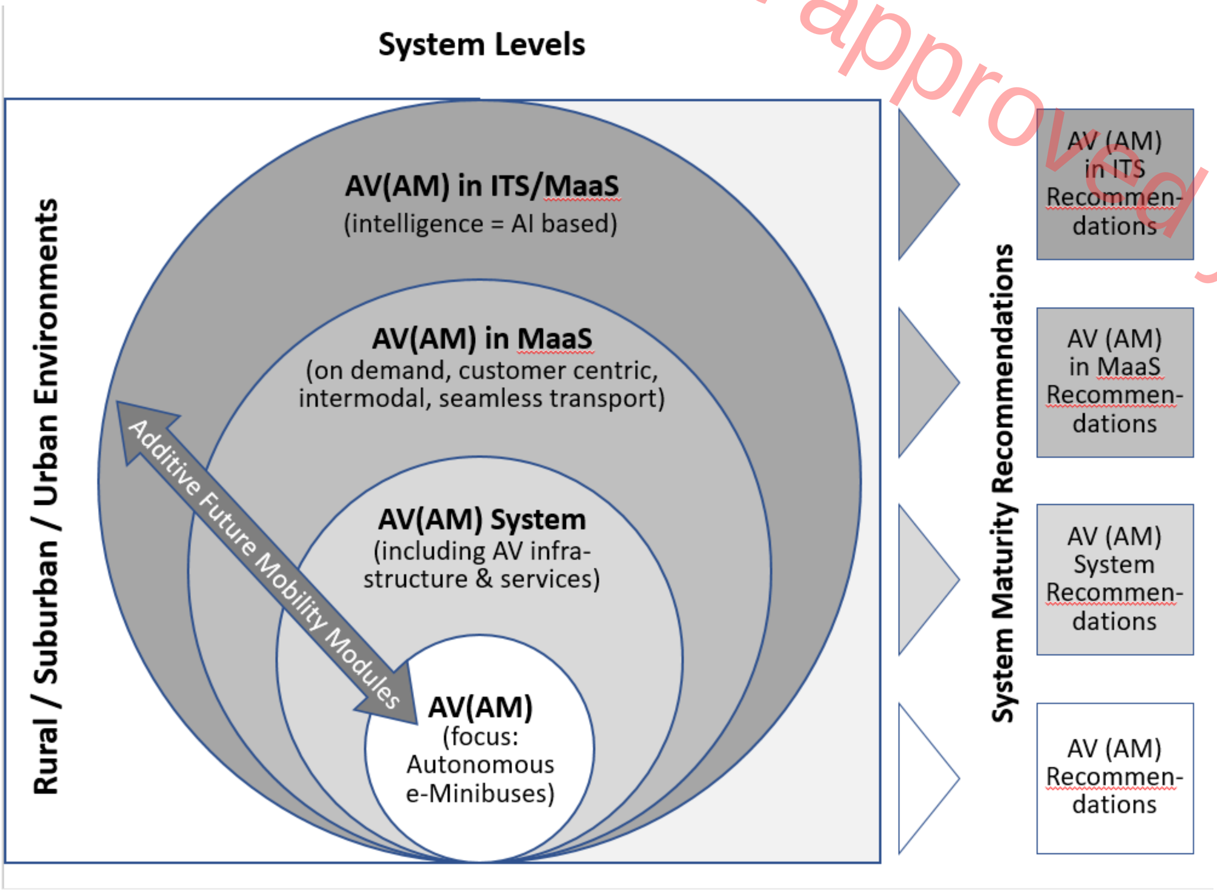

Figure 25: Framework for WP8 → WP9 Transition

Following this summary, a prerequisite for achieving the AVENUE vision 2030 is an alteration of the current mobility paradigm. This current paradigm is based on cheap fossil fuel energy (even if this has recently become no longer the case for the EU due to drastically increased effects of climate change and disruptive shortage of energy resources caused by recent military conflicts), high CO_2 exhausts, individual mobility (product orientation) and a linear economy (Fournier et al. 2018).[8] Altering this mobility paradigm requires social transformations in addition to technical innovations (such as AMs) to accomplish a socio-technical transformation of the mobility system (Geels 2005). A socio-technical transformation requires alterations in society, in business (ecosystem collaboration & marketplaces, governance & management, vehicle/fleet demand & offering side) and in particular for stakeholders such as passengers, transport operators and related companies, technology provider, governance etc. For one, this entails an integration of stakeholders in designing, implementing, and evaluating sustainable solutions for the mobility sector. As an optimum solution, all involved stakeholders should cooperate and agree upon a common purpose centric strategy. This strategy should evolve towards a sustainable mobility system, create

[8] A linear economy is based on the 'take-make-dispose' strategy. For a transition to a more sustainable society, one standard assumption is that the economy should transform into a circular economy. A circular economy is an economic system of closed loops in which raw materials, components and products lose their value as little as possible, and systems thinking is at the core.

value to all stakeholders, contribute to sustainable societal transformations, and provide an answer to societal challenges (the so-called “purpose”).[9]

To fulfil this overarching purpose of serving general safety and sustainability interest, there is a strong need for stakeholders to harmonize different interests and cooperate with each other in an innovative coopetition mode. Known difficulties are that stakeholders will make choices based on knowledge available to them with the aim of maximising their individual gain. The combined outcome of the individual strategies could result in a situation that was not intended and not desired by any of the involved stakeholders (see, for example, the prisoner’s dilemma from game theory by Tucker (1950/1983) in Morrow (2020)).

To establish a mobility system as depicted in the AVENUE vision 2030, some stakeholders could still try to promote individual mobility with private cars or take advantage of the “winner takes it all” phenomenon to capture the value creation to the detriment of other stakeholders or even take control of the entire mobility system in taking control through over a significant mass of captured system relevant data (private MaaS) of the mobility ecosystem and sell it to the system customers (like city governments) and PTAs. It is therefore of crucial importance to coordinate the involved stakeholders and to synchronise operations on a vertical level (between the stakeholders along the different means of transport of the journey) and on a horizontal level (among stakeholders operating the same modality as e.g. different AM) to ensure seamless intermodality and interoperability of the transport system similar to a supply chain (Giusti et al. 2019).

For a successful socio-technical transformation of the mobility sector, this process must be managed, to avoid and overcome diverging interests and resistances. Research showed that 70% of transformation fail, and part of the solution for the path to transformation encompass moving fast, ‘sharing a vision and stretching aspirations’ by leaders and a ‘more holistic and expansive approach to transformation’ McKinsey 2020). In addition, cornerstones for the transformations within the public-sector refer to performance and organizational health (McKinsey & Company 2021).

Hereinafter, we identified transformational challenges on the **technical, economic/business, environmental, social, and governance level** (see deliverable sustainable assessment D8.12). These dimensions are complementary building blocks of a holistic and expansive approach to transformation towards a significantly higher level of sustainability and they can mutually interfere due to the interdependency of the success factors and obstacles. Figure 26 therefore shows the framework for a transition from the current situation to the AVENUE Vision 2030.

[9] Discussions about stakeholders have existed since the 1930s, and Freeman (1984/2018) saw in his comprehensive approach stakeholders as essential to every management process. The stakeholder approach became afterwards so popular that 2018 even Blackrock -the largest asset manager in the world- preferred the stakeholder instead of the shareholder approach to create sustainable value for all stakeholders (Fink 2018; 2021).

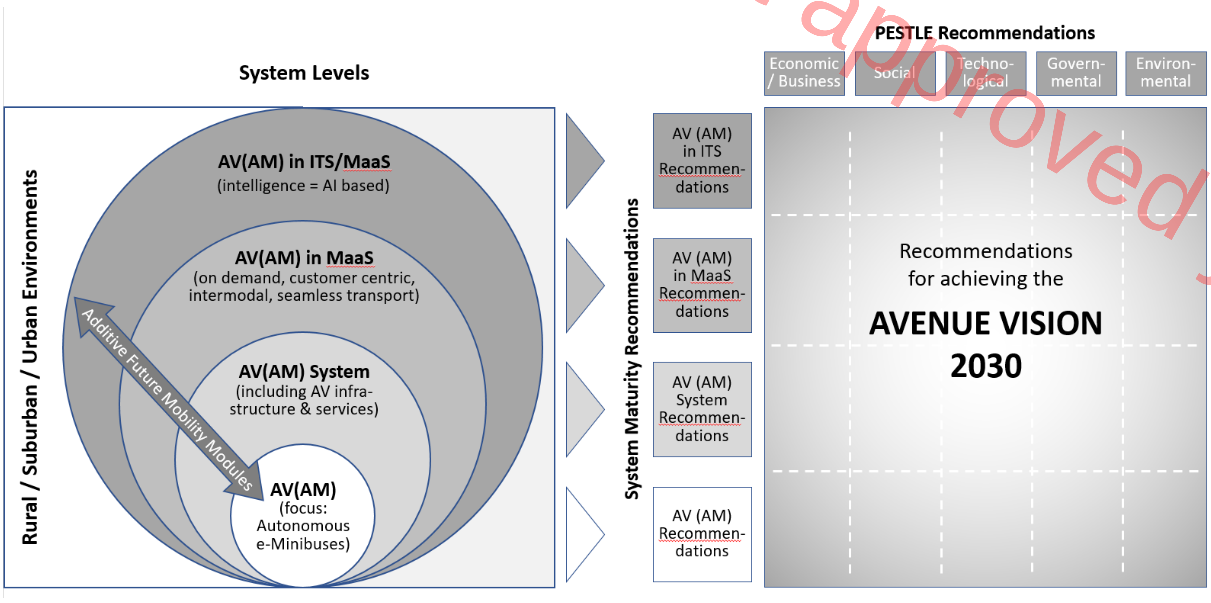

Figure 26: Framework for WP8 → WP9 (Transition) Recommendations

These so-called PESTLE points as a sustainability focused framework are orthogonally impacting the first three (system maturity focused) recommendations and constitute the elaboration of the recommendations for the AVENUE Vision 2030. Next, we present more in detail success factors and barriers that need to be addressed to be able to successfully implement the AVENUE vision 2030. For each of the dimensions, we subdivide into success factors and obstacles for the automated driving system, and separately, for the AM integration in an ITS/MaaS system.

5.5 Technical success factors and obstacles

In reaching the desired vision there are multiple technical obstacles and success factors that must be addressed and solved. Deploying AMs in all environments, both in city – and rural areas require the technology to be able to handle all safety related scenarios as well as to be effective, smart, connected and fully implemented within an ITS infrastructure. The technical obstacles and success factors related to **the automated driving ecosystem** concerns automated technologies, as integral sensory systems, and technologies. The automated driving ecosystem can be defined in the following categories, referring to Table 5 which is specific to the on-demand and door-to-door solution developed by AVENUE. The rating scale for the evaluation of technical obstacles is assessed on a scale from 1 (not relevant) to 5 (most relevant), see details about the methodology in appendix A.

- **Automated shuttle capabilities:**

  Concerning active safety, main factors here are LIDAR & Camera technologies, which detect and avoid obstacles as an integrated part of the decision-making engine. Machine learning algorithms and AI-technologies will enable constant development of the driving capabilities and vehicle positioning in traffic patterns and infrastructure. The perception and ability to determine, which is also related to AI-technologies that will allow the vehicle to build and constantly update a library of objects and obstacles, thus knowing the difference between a car, a bicycle, a truck, a pedestrian and so on. Radar technologies are necessary for performing emergency braking and large item detection. The processing power of AMs and AVs is being developed at a rapid pace across the world and the technologies must be shared to reach the highest possible processing power and therefore both speeds, braking algorithms and other safety related features – ultimately making the AVs able to drive safer and more reliant than regular drivers.

The accident analysis will also lead to passive safety requirements, which must be anticipated, as they are generally structuring for the vehicle platform. Conventional crash tests are not applicable to existing Automated E-Minibuses, and trade-off will have to be quickly established.

- **Automated shuttle environment**
  Main factors here are mapping and commissioning of new routes and updates of already existing routes. The current AMs can only drive on recorded maps by the vehicle manufacturer and are time consuming and costly to record. These recorded maps are not shared with other manufacturers. In the future these “map-routes'' must be shared and constantly updated across Europe to allow AMs to drive everywhere. The processing power of AMs and AVs must be developed at a rapid pace to reach speeds, braking algorithms and other safety related features. Such element is important to ensure the AVs to drive safer and more reliant than regular drivers. All weather sensory systems should be able to operate under all conditions: this robustness is fundamental for vehicle reliability, one major condition for service quality and safety. Currently, heavy rain and snow causes sensors to malfunction and lead to many issues. GNSS, and the ability to position the vehicle with precise measures. The mobility infrastructure of cities and other application areas (e. g. roads, traffic installations & services, roadside sensorics, charging installations, communication technologies, future: AI & digital twin-based traffic management) also plays a crucial part for the implementation of AMs and should be considered in the local development planning. Cybersecurity is finally critical as the laws and standards must be further developed to include AMs.

- **Human involvement**
  The main factor here is the necessity of a safety operator on board of the AMs. Human interaction with AMs is not going to be eliminated, but the transition from on-board safety drivers to remote supervisors and local technicians must be developed and tested. Currently the AMs can only operate with a Safety Driver on-board and in many scenarios with a remote supervisor at the same time, making the implementations very costly. The access for disabled people is finally critical since a human intervention is still necessary. Human-Machine interaction and interface technologies thereby play an increasingly important and critical role for passengers, supervisors, and other stakeholders regarding operations and service applications.

Criteria	Keolis	TPG	SLA	AM	Average	Relevance
Automated Shuttle Capabilities						
Construction Quality	5	4	2	4	**3,8**	Very Relevant
Traffic Regulation & Choice of Roadway	3	3	x	3	**3**	Medium Relevant
Perception & Ability to determine	5	4	x	3	**4**	Very Relevant
Driving Strategy	3	2	1	3	**2,3**	Less Relevant
Interoperability	x	2	x	x	**2**	Less Relevant
Speed of the Shuttles	3	3	x	4	**3,3**	Medium Relevant
Hardware-Related Factors						
Sensor-Position (LIDAR 360°)	3	4	5	4	**4**	Very Relevant
Sensor-Resolution (VLP16 LIDAR)	3	4	2	3	**3**	Medium Relevant
UMTS & 3G - Modem	3	3	1	2	**2,3**	Less Relevant
Charging Time	3	2	1	x	**2**	Less Relevant
5G Networks	3	3	x	2	**2,7**	Less Relevant
Processing Power	5	5	x	3	**4,3**	Very Relevant
Switch	3	2	1		**2**	Less Relevant
Software Related Factors						
Hit-Ratio	3	3	x	1	**2,3**	Less Relevant
Gateway to Fleet Management System	5	4	1	3	**3,3**	Medium Relevant
Automated Shuttle Environment						
Mapping & Modification of Routes	5	4	5	4	**4,5**	Most Relevant
Weather Related Limits						
Sensor-Related	5	4	5	3	**4,3**	Very Relevant
Battery-Related	3	3	5	1	**3**	Medium Relevant
Power-Related	3	3	5	1	**3**	Medium Relevant
City Infrastructural Limits						
Reference Points	3	4	5	4	**4**	Very Relevant
Road Markings	3	3	1	x	**2,3**	Less Relevant
Surface of Roadway	4	3	1	3	**2,8**	Medium Relevant
Digital Infrastructural Limits						
GPS & GNSS Signal	3	4	x	4	**3,7**	Very Relevant
3G/4G Signal	3	4	5	2	**3,5**	Very Relevant
Data Transfer & Updates	5	3	1	x	**3**	Medium Relevant
Legal Limits						
Number of Shuttles on the same Route	3	1	x	4	**2,7**	Less Relevant
Cyber Security	5	5	x	x	**5**	Most Relevant
Human Involvement						
Disabled access without human involvement	x	5	x	x	**5**	Most Relevant
Necessity of on-board safety operator	5	5	x	5	**5**	Most Relevant

Table 5: Evaluation of Technical Obstacles based on AVENUE expert interview (Kéolis (F), Transport Public Genevois (CH), Sales-Lentz Group (L), Amobility (DK) (Beye, Zinckernagel 2021)

Regarding the **AM in a MaaS/ITS ecosystem**, as mentioned above, open Data, open Platforms and open API are key factors to ensure a consequently citizen centric approach and single-point-of-contact applications for travelers in ITS. This openness is a pre-requisite to enable multisided access for stakeholders and especially passengers and integrate all the means of transport to one seamless journey. Through interoperability and intermodality, the system performance and flexibility can be improved, positive mobility externalities enabled, and negative externalities lowered. Open Data, open platforms and open APIs are thus a condition to develop the advantages of AM in MaaS. The described AI loops are the prerequisite to enable an / ITS and their benefits but necessitates a collective effort towards general interest.

This process is challenging to manage as several economic private interests of the related ecosystem are concerned.

These advantages however raise the risk of unauthorized tracking and traceability of passengers (privacy and safety of passenger data) and thus of multiple undesired monitoring possibilities of mobility. In the public discussion on AM in MaaS, open data could lead to a major limitation and therefore needs to be technically secured (Meijer et al. 2014). With the definition of the open standards and regulations for Data (e.g., GDPR) and API, as well as dedicated software-based technologies (leading technologies such as blockchain) strong economic interests are further affected as it is opening an ecosystem to all. A closed ecosystem could enable companies to capture and privatise values from data in particular the related positive externalities. The technical definition of communication protocol, data format and interfaces has thus to be manage by PTA and probably as well on a European level to avoid security issues and ”the winner-takes-it-all phenomenon”. The last point is important as in an extreme case the creation of private MaaS based on automated vehicles could limit the profitability of running mobility businesses but even strongly limit the influence of the PTA in creating own rules for the city mobility ecosystems.

5.6 Economic success factors and obstacles

The current results of AVENUE show within the current **automated driving ecosystem** (AVENUE) the business with AM is not profitable yet due to high driving-related personnel costs (see deliverable D8.6). The main reason for this is that safety drivers are still obliged to be inside the vehicle and remote supervisor are currently still legally forbidden or restricted in most of the European countries. This heavily impacted the profitability of the use of AM in the fleet of PTOs and thus is a main restriction for the usage within the city, suburban or in rural areas. Furthermore, the high acquisition costs of the vehicles and elevated costs of feasibility studies and legal authorisations, infrastructure works, and high annual depreciation are seen as constraints as well.

The non-integration of AM with other means of transport within a MaaS would further reduce the attractivity for passengers in terms of time and usability as several apps must be used. Thus, we currently have no customer centric approach which integrates AM.

In both cases the technology must be improved (see above) and governance (see below) has to be adapted. Regulatory sandboxes for self-driving vehicles could help to test and run new technologies and ease economies of scale and accordingly lower prices for a better diffusion (BMWi 2019). The currently very reserved acceptance and diffusion of AM’s and their integration into mobility networks by private and public PTOs or fleet owners and city/region governments as B2B customers is thereby also due to technology readiness and operations related business risks taking, as well as low subsidizing for this innovative technology.

Integrating **AM in ITS** is in fact one of several possible future scenarios where the expected benefits are the highest due to the integration of societal goals. The later discussed governance will decide about the benefits for the stakeholders and the general interest (see deliverable D8.6 and below). Accordingly, it is expected that the stakeholders which will be negatively affected by serving the general interest could be inhibitors of the required mobility transformation. This could be stakeholders which are willing to take advantage of the “winner-takes-it all phenomenon". The leading stakeholders of the current mobility paradigm, like automotive industry stakeholders and their employees, could also be inhibitors and not willing to adapt to the new constraints. They could slow down the transformation as individual mobility with private cars could be substituted easier by AM in ITS with the consequence of losing shaping the value chain of mobility. The PTOs and PTAs will have to further adapt to the new digital ecosystem and customer centric approach. Especially cities and regional governments could also have to face multilateral obstacles regarding the cost and effort of transformation of a 'running system'. This is because they would have to transform their operational mobility concepts and strategic business ecosystem concepts (including open data, platforms, APIs, towards a new IT concept) from a 'traditionally' characterized type of vehicles and (governmental) business ecosystem towards a balanced, federated, or democratized governance and operational IT concept with AM. Possible obstacles are often notorious shortages of budget as well as the difficulty of a necessary paradigm (mindset) change of often risk averse (non-entrepreneurial) governmental authorities. But even this kind of disruptive (game changing) transformation of the business ecosystem can be guided by individually adapted and designed approaches (e.g., incremental transformation steps, 'think big, but start small').

Finally, all the stakeholders tend to keep their habits: passenger, member of organisations or the organisation itself try to lower the psychological costs of change.

Therefore, AM in ITS will need investments in digitalisation, hardware, software, education etc. As quoted in the Digital Economy and Society Index (DESI) 2021 (European Commission 2022), the availability of employees with digital skills could slow down the digitalisation and dematerialisation of mobility. The comparatively slow digital transformation of companies in many EU countries are linked to "a lack of employees with advanced digital skills" (European Commission 2022). Thus, 55 percent of the companies during 2020 complained about difficulties in hiring IT specialists (European Commission 2022).

5.7 Environmental success factors and obstacles

The **automated driving ecosystem** of AVENUE shows a low environmental impact (see deliverable D8.5). A Life Cycle Assessment (LCA) of the AM deployed within AVENUE shows that its automated technologies account for less than 5% of the total energy used. In a near-future use case, 59% of the AM impact stems from the use phase, while component production accounts for 39% (Huber et al. 2022). In addition, the AM qualification as environmentally friendly depends on many factors such as occupancy, vehicle speed, mileage, and lifetime.

The investigation of the energy demand of automated driving technology and connectivity-related demand shows that, on the one hand, predictive, adaptive and information sharing through vehicle communication with infrastructure and other vehicles improves driving performance (e.g. braking performance) and, consequently, energy consumption. On the other hand, a highly connected vehicle means more data processing within and outside the vehicle, which may outweigh the V2X sustainability. Overall, the energy-saving potential of predictive driving functions is highly likely to outweigh the energy consumption for data transmission (Huber et al. 2022).

The AVENUE environmental impact assessment shows that if the AMs are well utilized in terms of mileage and regularly used by passengers, they will present great advantages over individual vehicles from an environmental point of view (Huber et al. 2022). The AM are seen as complementary vehicle in public transport, and could increase the availability, flexibility, efficiency, and reliability of local public transport (Huber et al. 2022).

More relevant is if and how AM could be integrated **in a MaaS/ITS ecosystem.** Depending on the chosen governance scenario (see D8.6, chapter 3.2) the AM can be used in a separate ecosystem which is in competition with the current means of transport (laissez faire strategy). In this strategy the convenience of the robotaxi e.g. and the customer centricity of the robotaxi provider could substitute public transport, private cars, bikes and even walking. Doing this, additional traffic with the related external costs like congestions, CO_2 emissions, additional space etc. are expected in the city. The suggested AM in a MaaS/ITS on contrary wants to satisfy the best citizen needs and the general interest in levering positive externalities and lowering negative externalities. Enabling positive externalities are possible due to the use of data, intermodality and interoperability.

5.8 Social success factors and obstacles

An important finding of the AVENUE social impact assessment (Deliverable 8.7) is that users and potential users present a positive attitude, and receptive (goodwill) attitude towards the AM. Therefore, there is the potential to convince those who are not yet refusing but open-minded, through well-targeted communication campaigns especially in social media. We defined five target groups of potential users (Unreserved Goodwill; Sceptical goodwill; Undecided; Critical reserved; Unconvinced refusers) which do not only differ in their perception on perceived benefits and concerns, but also on their degree of knowledge, preferred transport system, their willingness to use and pay for travelling with automated minibus, and information sources used to build their attitudes (see for more details deliverable D8.9). The results show that a high level of goodwill among potential users and a high level of satisfaction among users translates into a high level of willingness to use (again). In general, users were highly satisfied with their experiences and most of them are willing to use the automated minibus again. In Copenhagen 76% of users are very willing to use the automated minibus again, in Sion 55% of the survey participants were willing or very willing to use the AM again.

Most important factors for the social acceptance are the (perceived) need for improvement of the current situation and whether the proposed alternative service fulfils this need for improvement. Fears towards a lack of safety or security are currently of less importance for the social acceptance. Furthermore, real experience in the automated minibus, has a general positive effect on the trust in the system. Therefore, an important success factor for the social acceptance of AM, is allowing citizens to use and experience the advantages of AM.

Some critical points encompass the highly sensitive issues of handling user data and data security, and the ethical questions that constantly accompany automated driving (such as the trolley problem which addresses ethical dilemmas (Fagnant and Kockelman 2015, Geisslinger et al. 2021). In addition, the results of a representative survey among citizens (n=1,816) pointed perceived concerns regarding the use of AM. The main concerns are related to the interaction of the AM in unforeseen situations and with other road users (motorized and non-motorized), the liability in the case of an accident, security questions and the risks of hacking the software and misuse of it (Korbee et al. 2022).

In addition, the safety operators also mention that they observe a high level of goodwill for the innovative service. In the opinion of the safety operators the users are highly satisfied, especially considering subjective aspects such as good atmosphere, not least because of the smaller number of passengers.

Based on their observations safety and accessibility are qualities that are also evaluated as satisfactory. In the viewpoint of the safety operators the automated minibuses are fulfilling the needs and demands of the users and contribute to a positive user experience.

A risk for the target groups of unreserved and sceptical goodwill is that they may be disappointed if they recognize actual performance in terms of speed and flexibility as well as effectiveness. To ensure that the high level of goodwill leads to a high level of acceptance of the new systems, it is very important to increase both the speed and the flexibility of use via an on-demand service or at least improved temporal and spatial flexibility in comparison to the existing public transport offers. This positive perception is a good point but has not to be considered as an asset: the perception can change in case of accidents, for example.

Beside the current AVENUE approach, aim of the **integration of AM in an ITS/MaaS system** is to satisfy best passenger needs and to increase the social acceptance. We could thus expect in future that AM could be a real “game-changer” making public and private transports individual and providing a real alternative to individual privately-owned vehicles as it has the potential to increase effectiveness and flexibility for the users and increases the choice for the passenger and at the same time following general interest. The results of a representative survey among 1,816 citizens (of which 1,526 have privately-owned vehicles) in Lyon, Copenhagen, Luxembourg, and Geneva confirm that 45% of car drivers are ‘willing’ (22%) or even ‘very willing’ (23%) to give-up using their own car to use AM to bridge the first and the last mile if this were available. If the service is on-demand and door-to-door, the acceptance could be even higher (Korbee et al. 2022). This has of course to be deepen in future research.

Another alternative could be robotaxi which could satisfy best individual mobility needs without changing means of transport but at the same time lower and privatise positive externalities and increase negative externalities through additional traffic and space. This choice could be better accepted than AM in MaaS in ITS but without serving general interest. The choice between not integrated robotaxi in a MaaS and AM in an MaaS/ITS needs thus to be discussed, organized and formalized in the future governance. AM in an ITS/MaaS is of course the better alternative for the city and their citizens but this needs a transformation towards a new social contract for mobility to avoid social frustration and crisis (Shafik 2021; Rousseau 1762). Special attention should be paid to digital illiteracy to avoid the exclusion of parts of the population through the transformation process.

5.9 Governance success factors and obstacles

Like raised above, the beforementioned limitations are all influenced by the chosen governance. The governance is thus a central issue to enable AM technical ecosystem and the integration of AM in MaaS or ITS.

For **automated minibus and its ecosystem**, the development of regulations for the automated driving ecosystem encompasses amendments of the Vienna Convention on Road traffic and the adoption of a new legal instrument on the use of automated vehicles in traffic at the international level[10]. At regional and national levels, approval for operating automated minibuses without strict requirements for the safety operator (in a first stage) and with a remote supervisor only (in a second stage) should be possible[11], as the related costs and time for type-approval are a key issue for the diffusion of AM. In Member States that did not already issue AV-related provisions, regulatory sandboxes[12] for self-driving vehicles like mentioned before could ease the disruption process and allow to EU stakeholders similar competition conditions than in other more liberal parts of the world to test and run new technologies and ease the diffusion. Moreover, a legislative database at European level which bring up to date and real-time information about the fast-growing automated vehicles legislation (e.g. type-approval, commercial, cybersecurity of vehicle, definitions, infrastructure and connected vehicles, insurance and liability, licensing and registration, operation on public roads, safety operator requirements etc.) on local, state, and regional regulations is missing. This could simplify the planning of all the stakeholders like vehicle manufacturers, deployers of AM, transport operators, states, municipalities etc. and encourage the diffusion of the AM technologies and the improvement of the transport system. The USA are a good example how such a database could be managed (NCSL 2022).

On the level of city or local governments it will be necessary to design, implement and supervise individual technical (vehicle, IT) certification and licensing concepts for AM's and their integration into MaaS according to respective regulations or standards (similar to TÜV as governmentally authorized organization in Germany) as well as related training courses for operational personnel (experts).

City or local governments are also at the best place to understand the local mobility needs and where AM could provide new offers and/or improve the existing services (as feeders).

The *governance* is thus crucial to balance these interests, even though it is possible that the creation of closed ecosystems such as monopolies could weaken the power of PTA and the capability of balancing interests. Further, this approach is a technical and innovative approach which believes in progress and science and uses dematerialised consumption to save resources for a sustainable development (mobility) path. It will have to convince the growing scepticism which arises in discussions around concepts such as "degrowth" or "frugality",

[10] See amongst others the work of UNECE's Group of Experts on drafting a new legal instrument on the use of automated vehicles in traffic (GoE LIAV).

[11] See for instance the French and German legal frameworks adopted in 2021, as well as the EU Commission's Commission Delegated regulation of 20 June 2022 as regards the technical requirements for […] fully automated vehicles produced in small series […], C(2022) 3823 final, and the Implementing regulation of 5 August 2022 […] as regards […] the type-approval of the automated driving system, C(2022) 5402 final, described in Deliverable 9.1.

[12] As suggested by Art. 53 and 54 Proposal for a Regulation laying down harmonised rules on artificial intelligence (COM(2021) 206 final).

which promote a change in consumer behaviour through renunciation to save resources (sufficiency strategy).

For **AM integrated in MaaS or ITS ecosystem**, public institutions play a crucial role to develop an interoperable, standardized and connected data landscape across diverse sectors, including the mobility sector in particular through dedicated legal frameworks. The benefits of interoperable, standardized and connected data comprehend improvements and new offers in public services, an increase in administrative efficiency, data-driven politics making and delivery value of open data (Domeyer et al. 2021). The regional and national data strategies are as important as well: they address requirements for data protection and data privacy. Some challenges for interoperable and connected data are due to the fact that public and private data remain scattered, that they cannot be accessed digitally and are not interoperable (referring to obstacles that prevent the combination and joint processing of data) (Domeyer et al. 2021).

To tackle these issues European and national strategies for integrated data-management are needed, in addition to infrastructure and setting technical standards for "fast and automated data exchange is only possible through harmonized data formats and standards" (Domeyer et al. 2021). The 'European Data Strategy' aims at creating a single market for data, and one of the main goals is to create safer and cleaner transport systems (European Commission 2020c). For AM in MaaS or ITS, open API and Open Data are accordingly a prerequisite and a key to realise interoperability and coordination of all the stakeholders of the mobility system. As a result, seamless trips to satisfy citizen needs and acceptance become possible.

This raises at the same time the difficult question and discussions for regulation who will benefit from the use of data? This is clear for data collected in case of an accident, as it will help to understand the causes and to build anonymised lesson learned, for the benefit of all actors, as the feedback is shared. For other data, while private persons could be interested to refrain sharing their personal data for privacy, safety or security reasons, private companies are keen to collect these data to create new profitable business models ("winner takes it all", advertising or other forms of value capturing) but also to satisfy better the needs of customer. The use of data is further necessary to allow OEMs to optimise AM and make the drive more reliable and safer or to realise the loops described in chapter 4. The PTOs could use data to optimise the use of the fleet and the PTA to serve the general interest. A balance between the interests of the individual data provider (the mobility user and their stakeholders, GDPR) and the legitimate interests of the community in using the data to serve general interest has thus to be found and managed. These discussions should be held at European, national, and local level. This requires a less administrative corporate culture of the PTAs to manage the transformation and in particular to find the right equilibrium between the numerous stakeholders towards a society's unity for sustainable mobility (purpose). A decentral governance model which unify the mobility network and supports a federated democratic decentralised mobility platform using distributed ledger technologies (DLT, so called Web3) to "integrate stakeholders and different technologies in a non-discriminatory and equal way" (Schmück et al. 2021) could accordingly be chosen. As a result, the beneficiary of the system would be directly the data subject and not an intermediary party which owns the mobility platform and the customer touch point (Schmück et al. 2021). Other federated based governance strategies using so called substantive platforms to serve the general interest between stakeholders could be used as an alternative. Aim is to integrate on one side economical dimensions to satisfy the (mobility) needs and on the other side political issues (through collective deliberation) to preserve the commons and enable a purpose within a community. Links to all the stakeholders enables the definition of the needs, the rules, and structures of the ecosystem without an intermediary. The substantive platforms can be various and depends on the chosen valuation which can be based on (classical) markets, on off-markets (based on donation, reciprocity and/or redistribution) or on hybrid forms combining market and off-markets valuation. These new models are still exploratory. They respect GDPR by design (ethics by design) (Vercher-Chaptal et al. 2021).

Regarding data protection and data privacy, the GDPR is an advantage for personal privacy data protection, safety, and security, but it entails complex and challenging implementation in the field of connected and automated vehicles, and obstacle for AI (see the beforementioned loops).

From a legal perspective, many challenges are ahead, such as the following, amongst others. As regards privacy and personal data protection, certain key concepts (e. g. "personal data", "identifiable natural person", "anonymous information" and "processing") are defined and might be interpreted in such a way that the rules of the GDPR would apply, to such extent that this would hinder, require additional investment, or slow down the development of the processing activities described under Sections 3 to 5 above.

Regarding the data flows between the different stakeholders described under Section 4 above, the distinction between "controller" and "processor", taking into account the concepts of joint-controllership, controllers in common and sub-processors, is complex (Leveraging Big Data for Managing Transport Operations 2019). "Controller" is any person or entity which determines the purposes and means of the processing of personal data, and the "Processor" only processes personal data on behalf of the controller. Hence, identifying the role of each actor intervening in this context and his underlying obligations might prove to be difficult

Merely technically collected data (i.e., non-personal data) or personal data anonymized through the "GDPR filter" or through another technique will be provided to the MaaS data and service platform operator. This data could, due to the transformational impact of big data analytics, become personal data or even sensitive data and thus trigger the application of the GDPR and further privacy and data protection laws (Leveraging Big Data for Managing Transport Operations 2019).

The potentially high volume of (personal and non-personal) data collected by AM may be assimilated to big data analytics, which challenge certain core assumptions of the EU data protection law, such as data minimisation and purpose limitation (Leveraging Big Data for Managing Transport Operations 2019).

The scope of the e-Privacy Directive (lex specialis to the GDPR) is considerably broader and does not only apply to personal data, but rather to all information regardless of the nature. Consequently, this setting requires an assessment of which processing activities may fall in the scope of the e-Privacy Directive and subsequently which requirements the e-Privacy Directive imposes on stakeholders with regard to these processing activities. Furthermore, where personal data are involved, the interaction between the GDPR and the e-Privacy Directive needs to be examined closely (European forum and oBsErvatory for OPEN science in transport 2020). The (current) lack of standards for open API's might trigger coordination issues and it should be ensured that Member States apply the same standards to avoid the creation of technical barriers.

Finally, it is important to note that there are different governing approaches from public authorities for MaaS development (See Table 6). The beforementioned economic and environmental scenarios show that the governance determines if the rules serve the general interest and promote sustainable mobility and accordingly the technical, social, economic, and environmental impacts. A governing by authority on one side which put forward the general interest can be imagined as well as a governing by "laissez-faire" (e.g., voluntary lack of regulation or minimalistic regulation) on the other side where few private companies could take advantage from the "winner-take its all phenomenon" of the mobility ecosystem and capture the expected benefits for private purposes. In the case of "laissez-faire", potential competitors would be excluded and could not find a viable business model anymore. Even a threatening of Public Transport Authorities might be imagined when the private terms and conditions of the ecosystem of a private MaaS substitutes to the public laws of the PTA. This has already been observed in other European markets. The lack of speed of adapting the rules of the PTA to the disruptive changes in mobility could hence generate the same problem than the EU had to experience before introducing the DMA (Digital Market Act). Aim of the DMA is to ensure the proper functioning of the internal market, by promoting effective competition in digital markets, in particular a contestable and fair online platform environment. More specifically, the DMA's objectives are i) to address market failures to ensure contestable and competitive digital markets for increased innovation and consumer choice, ii) to address gatekeepers' unfair conduct and iii) to enhance coherence and legal certainty to preserve the internal market (European Commission 2020d). As the DMA is not likely to apply to the mobility sector, an anticipatory approach for the local, national, and European mobility markets which takes the specificities of the transport sector into account through a dedicated "mobility data act" is most likely needed and would accordingly be recommendable as well.

Governing approaches	*Corresponding actions expected in the development of MaaS schemes*
Governing by authority	• Develop specific legislation/regulation enforcing the development of MaaS in a top-down fashion • Procure MaaS to a third-party through traditional tender mechanisms
Governing by enabling	• Initiate public–private interactions • Define vision with strong quantitative objectives • Provide funding • Influence negotiations in favour of MaaS and leverage MaaS opponents using horizontal network governance
Governing by doing	• Develop a MaaS solution in-house in a closed manner • Minimise collaboration with third parties
Self-governing	• Provide all government employees with a MaaS solution to show the example for citizens to follow
Governing by laissez-faire	• Refuse to get involved in the development of MaaS • Adopt a wait-and-see approach

Table 6: Expected actions from public authorities in the development of MaaS and the different governing approaches (Audouin and Finger 2019)

6 Conclusion

For all initial questions about ‘why and how to integrate AV in the city transport system to serve general interests’, the AVENUE vision could provide a convincing conceptional solution approach and a pragmatic transformation concept based on the hypothesis that automated minibuses integrated into intermodal transport and MaaS or better ITS can be a promising game changer in urban mobility. The AM, deployed on-demand and door-to-door, will provide more mobility choices, effectiveness, and flexibility for all citizens, including better accessibility for people with reduced mobility (PRM) and potentially better acceptance of AVs based on positive experiences.

As argued above, a coopetition governance scenario as well as open data schemes (open data, open platforms, open interfaces, and protocols) are further key factors to guarantee fair competition between public and private mobility providers, avoiding dominant position and ‘the winner takes it all’ effects. In addition, AVs coupled to ITS and AI are expected to make the transport systems more reliable, safe, efficient and flexible combining incremental and disruptive innovation (concept called ambidexterity), and thus antinomic goals. As a result, the transport system becomes through ITS and AM citizen centric, inclusive, and sustainable enabling positive externalities and lowering negative externalities. The citizen centric approach could thus become purpose centric serving the general interest to the best for all stakeholders. This vision is a key for acceptance and thus coherent with the SUMP concept of a holistic approach and the requirement of the EU Green Deal (European Commission 2020a), EU Sustainable and Smart Mobility Strategy (European Commission 2020b; European Commission 2021) and the European Data Strategy (European Commission 2020c).

Through the vision concept, the EU could gain on sovereignty with AM in ITS and become the mobility system leader in purpose centric – this means citizen centric, responsible, independent, and sustainable for all stakeholders - mobility which respects human and individual rights (data privacy and security, GDPR), by aligning and utilizing future (technical and business) mobility innovations for this purpose. This could be an alternative to the path of development chosen by China and USA.

Of course, this approach is a socio-technical and innovative approach which believes in progress and science and uses dematerialised consumption to save resources for a sustainable development (mobility) path (McAfee 2019). It will have to convince the growing scepticism which arouses in discussions around concepts such as “degrowth” or “frugality” which promotes a paradigmatic change in consumer behaviour through renunciation to save resources. This so called ‘sufficiency strategy’ asks people to consume consciously and since around 13% of consumer spending by European citizens is spent on mobility, this issue is an important factor (Statista 2020). Our vision shows a future path of how dematerialisation of mobility through AM and ITS could save resources and without sacrificing individual mobility needs and comfort (Linz 2004; Mauch et al. 2001).

This vision is the basis to structure and deduct our transition goals, recommendation, and transition roadmap to design the future (public) transportation service. The future Horizon Europe project ULTIMO (Safe, Resilient Transport and Smart Mobility services for passengers and goods) will implement parts of the concept. The concept will further be presented at Transportation Research Area Conference 2022 (TRA, Lisbon) (Fournier et al. 2022).

APPENDIX A

Methodological Procedure for assessing automated vehicles

For technical assessment of the automated vehicles, a two-part procedure was chosen. This procedure is described in the following subchapters.

3.1 Assessment of Technical Obstacles

The initial situation is based on previously examined technical obstacles to the implementation and use of automated shuttles from various pilot projects (Bürkle 2019). For re-evaluation purposes, a summary of the technical obstacles that refers to the first examination and reporting was distributed to selected experts from the public transport operators within the AVENUE consortium. The aim included receiving feedback on the current technical obstacles. Existing changes and newly identified obstacles should be listed and described in a summary. With the provided summary, the experts were asked to assess the relevance of the described technical obstacles for the implementation of AVENUE. The applied rating scale is equal to the previous reporting conducted, to identify and describe potential changes coherently. By asking the experts to rate the relevance of the technical barriers in addition to their description, two steps of the method were covered. The experts were asked to rate the technical obstacles (existing and new ones) from 1, less relevant to 5, very relevant. With the experts' contributions, the average ratings could be calculated. The gathered results of the assessment formed the basis of further expert interviews.

Rating Scale	Description
1: Not relevant (NR)	The obstacle is solved or has no influence on the implementation and operation of the automated Minibuses.
2: Less relevant (LR)	The obstacle exists but does not really influence the implementation and operation of the automated Minibuses.
3: Medium relevant (MR)	The obstacle exists and influences the implementation and operation of the Minibuses from time to time.
4: Very relevant (VR)	The obstacle influences the implementation and operation of the Minibuses. Once in a while the operation of the Minibuses must be stopped due to the obstacle.
5: Most relevant (MoR)	The obstacle influences the implementation and operation of the Minibuses significantly. Due to the obstacle, the operation cannot be guaranteed.

Table 7: Rating scale for the evaluation of technical obstacles

3.2 Expert Interviews

As mentioned in the previous chapter, the results from the first step of the method formed the basis for the expert interviews. The subsequent phase encompasses interviews conducted with the diverse experts from the AVENUE consortium, in which more specific attention was devoted to the obstacles and technical advancements achieved through the AVENUE project. With the gathered results, the questions for the expert interviews could be prepared accordingly. Additionally – as the subject of technical obstacles and advancements constitutes a considerable complexity – the semi-structured interview approach was applied (Galletta 2012) . This approach was chosen in order to have a reliable basis to address this complexity and to benefit from the experts' knowledge for the interpretation of the results (Galletta 2012).

The expert interviews were conducted in two separated parts. The first part relates to obtaining new information on the technical obstacles as well as on the technical developments within AVENUE. Concerning the implementation of an on-demand service, the second part includes challenges and obstacles occurred with the deployment of the Application Programming Interface. Based on this separation, the PTOs were considered in the first part of the interviews. In the second part, representatives of the vehicle manufacturer and the provider for the fleet orchestration platform were interviewed. For preparation reasons, a guideline including the questions and consent was provided to each expert. Due to the separation of the interviews, two guidelines with different questions were created.

3.3 Expert Selection

For the first part of the interviews, the public transport operators have been taken into consideration as they have in-depth knowledge of the progress of the AVENUE project. This aspect justified the selection of the experts in the sense that they were also interviewed in the first examination or later started participating within AVENUE. Hence, they can show the technical advancements as well as existing and potential new obstacles for the deployment of automated Minibuses in public transport.

3.4 Data analysis

The consolidation and analysis of the data was based on the expert evaluations and interviews (part one) and the expert interviews regarding API-specific barriers (part two).

Analysis of part one

As mentioned in, providing a summary of the technical barriers from the last examination enabled a basis for obtaining an update on the technical obstacles. With the PTO's evaluation of the already known and new technical obstacles, a profile emerged regarding their relevance. With the subsequent expert interviews, this topic was dealt with in more detail. The results of the expert interviews include the technical obstacles and the technical advances that were achieved at each demonstration site.

Analysis of part two

About API-specific obstacles, the results from the associated expert interviews from part two are outlined. Hereby the elaborations of the experts were linked in a manner that the current obstacles for enabling an overall on-demand driving system are concisely described. Overall, the analysis comprises two parts, which each of specifically addresses the results of the expert interviews. For a better understanding, the methodology is presented in the following visualization.

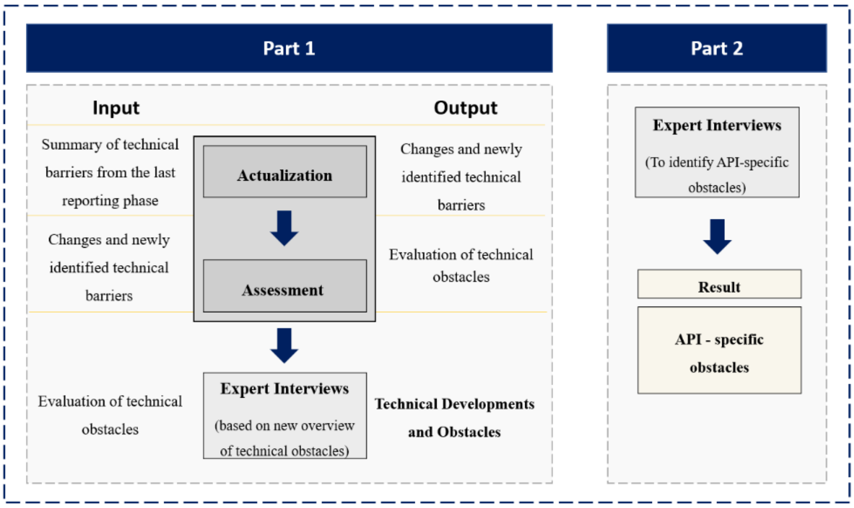

Figure 27: Methodological Procedure

APPENDIX B

H2020 AVENUE D9.3 RECOMMENDATIONS

Number	Short title	Recommendation	Proposal	Chapter(s)	Page(s)
D9.3_a	**Automated minibus (AM)**	Improve safety and security to allow higher speed and outside supervisors	Usage of GDPR complied to AI	6.5	57 to 58
D9.3_b	**Automated minibus infrastructure**	Allow route modifications and smooth driving, address cybersecurity issues	Improve vehicle location log, open Map, emphasis on cybersecurity	6.5	58
D9.3_c	**Open data, open API, open Protocol**	AI loops as prerequisite for ITS but risk of unauthorized tracking	Open data, open protocols, and open API to facilitate a citizen-centric system	6.5	59 to 60
D9.3_d	**Making profitable business models**	Development of AI for transition from onboard safety drivers to remote supervisors	Introduce look-in effects, open data, open API, open protocols, and related governance	6.6	61
D9.3_e	**Integration of automated shuttles in a MaaS/ITS environment**	Transformation of mobility concepts of cities to implement AMs in MaaS to increase attractivity for passengers	Adaptation of technology and governance	6.5 and 6.6	59 and 60
D9.3_f	**Using the ecological advantage of AMs**	No laissez-faire strategy, need good usage strategy for AMs to have advantage over individual vehicles	Integration of AM in MaaS/ITS ecosystem	6.7	62
D9.3_g	**Strengthening the positive attitude**	Convince more people to use AMs as general attitude is positive towards them	Communication campaigns (i.e., social media)	6.8	62
D9.3_h	**Enabling real user experience**	Enable citizens to experience AMs	Increase speed and flexibility for advantage over other public transport	6.8	62
D9.3_i	**Enabling a change in the mobility paradigm**	Provide a solution that is as attractive as use of private car, reducing disadvantages and increasing advantages	Using AM in MaaS/ITS	6.8	63
D9.3_j	**Safety operator-related governance**	Costs and time for type approvals are key issues for diffusion of AM	Encourage approval for operating AMs without strict requirements	6.9	64
D9.3_k	**Legislative database**	Legislative database could simplify planning and encourage diffusion and improvement of technology	Design legislative database at European level	6.9	64
D9.3_l	**Governance for citizen-centric AMs in MaaS**	Have technical certification and licensing concepts according to respective regulations or standards in place	Design, implement and supervise technical certification and licensing concepts	6.9	64

Bibliography and References

Alazzawi, Sabina; Hummel, Mathias; Kordt, Pascal; Sickenberger, Thorsten; Wieseotte, Christian; Wohak, Oliver (2018): Simulating the Impact of Shared, Autonomous Vehicles on Urban Mobility – a Case Study of Milan. SUMO 2018- Simulating Autonomous and Intermodal Transport Systems 2, 94-76. DOI: 10.29007/2n4h.

Antonialli, Fabio; Fournier, Guy; Jaroudi, Ines; Mira-Bonnardel, Sylvie; Thalhofer, Michael (2021): D8.4 Second Iteration Economic impact. Available online at https://cordis.europa.eu/project/id/769033/results.

Araghi, Y.; Larco, N.; Doll, C.; Vonk Noordegraaf, D. M.; Bouma, G.M. & Krauss, K. (2020): Drivers and Barriers of Mobility-as-a-Service in urban areas. Available online at https://www.isi.fraunhofer.de/content/dam/isi/dokumente/ccn/2020/tra2020_drivers_and_barriers_final-after-reviews-19-10-2019.pdf, checked on 07-Sep-21.

Audouin, Maxime; Finger, Matthias (2019): Empower or Thwart? Insights from Vienna and Helsinki regarding the role of public authorities in the development of MaaS schemes. In *Transportation Research Procedia* 41, pp. 6–16. DOI: 10.1016/j.trpro.2019.09.003.

bcs Bundesverband CarSharing e.V. online: Mobility as a Service: Chance für die Verkehrswende, Herausforderung für die Partner des Umweltverbunds. Available online at https://carsharing.de/themen/umweltverbund/mobility-as-a-service-chance-fuer-verkehrswende-herausforderung-fuer-partner, checked on 01-Oct-21.

Becker, Henrik; Balac, Milos; Ciari, Francesco; Axhausen, Kay W. (2020): Assessing the welfare impacts of Shared Mobility and Mobility as a Service (MaaS). In *Transportation Research Part A: Policy and Practice* 131, pp. 228–243. DOI: 10.1016/j.tra.2019.09.027.

Becker, Henrik; Balać, Miloš; Ciari, Francesco; Axhausen, Kay W. (2018): Assessing the welfare impacts of shared mobility and Mobility as a Service (MaaS). DOI: 10.3929/ethz-b-000286485.

Bestmile (2020): The Critical Role of APIs in Mobility Services. Available online at https://bestmile.com/company-blog/the-critical-role-of-apis-in-mobility-services/, checked on 7/13/2021.

BMWi (2019): Making space for innovation - The handbook for regulatory sandboxes. Available online at https://www.bmwk.de/Redaktion/EN/Publikationen/Digitale-Welt/handbook-regulatory-sandboxes.pdf?__blob=publicationFile&v=2, checked on 11-Oct-22.

Brachman, Ronald J.; Levesque, Hector J. (2022): Machines like us. Toward AI with common sense. Cambridge Massachusetts: The MIT Press.

Brinker, Scott (2013): Martec's Law: Technology changes exponentially, organizations change logarithmically. Available online at https://chiefmartec.com/2013/06/martecs-law-technology-changes-exponentially-organizations-change-logarithmically/, updated on 13-Jun-13, checked on 30-Sep-21.

Bürkle, Tim (2019): Autonomous Shuttles. Technical Obstacles for the Diffusion, Implementation and the Deployment.

Business Roundtable (2019): Business Roundtable Redefines the Purpose of a Corporation to Promote 'An Economy That Serves All Americans'. Available online at https://www.businessroundtable.org/business-roundtable-redefines-the-purpose-of-a-corporation-to-promote-an-economy-that-serves-all-americans, checked on 11-Oct-22.

Cabral, L.; Haucap, J.; Parker, G.; Petropoulos, G.; Valletti, T.; van Alstyne, M. (2021): The EU Digital Markets Act. JRC122910. Publications Office of the European Union. Luxembourg (JRC). Available online at https://publications.jrc.ec.europa.eu/repository/handle/JRC122910.

Capgemini (2020): The future of Mobility as a Service (MaaS). Which model of MaaS will win through? Available online at https://www.capgemini.com/wp-content/uploads/2020/12/Capgemini-Invent-POV-Maas.pdf.

Childress, Suzanne; Nichols, Brice; Charlton, Billy; Coe, Stefan (2015): Using an Activity-Based Model to Explore the Potential Impacts of Automated Vehicles. In *Transportation Research Record* 2493 (1), pp. 99–106. DOI: 10.3141/2493-11.

Clement, Reiner; Schreiber, Dirk; Bossauer, Paul; Pakusch, Christina (2019): Internet-Ökonomie. Grundlagen und Fallbeispiele der digitalen und vernetzten Wirtschaft / Reiner Clement, Dirk Schreiber, Paul Bossauer, Christina Pakusch. Fourth edition. Berlin, Heidelberg: Springer Gabler.

Clewlow, Regina R.; Mishra, Gouri S. (2017): Disruptive Transportation: The Adoption, Utilization, and Impacts of Ride-Hailing in the United States. Institute of Transportation Studies, University of California, Davis, Research Report UCD-ITS-RR-17-07. Available online at https://escholarship.org/uc/item/82w2z91j.

Coyle, Diane; Diepeveen, Stephanie; Kay, Lawrence; Tennison, Jeni (2020): The Value of Data. Bennett Institute, ODI.

Cruise online. Autonomous Vehicle Technology. Available online at https://getcruise.com/technology/, checked on 20-Sep-21.

Cruise online (1). Self Driving Cars. Available online at https://getcruise.com/, checked on 20-Sep-21.

Deloitte (2019): Urbane Mobilität und autonomes Fahren im Jahr 2035. Available online at https://www2.deloitte.com/de/de/pages/trends/urbane-mobilitaet-autonomes-fahren-2035.html, checked on 14-Sep-21.

Domeyer, Axel; Hieronimus, Solveigh; Klier, Julia; Weber, Thomas (2021): Government data management for the digital age. McKinsey & Company. Available online at https://www.mckinsey.com/industries/public-and-social-sector/our-insights/government-data-management-for-the-digital-age?cid=other-eml-alt-mip-mck&hdpid=faf57223-411c-4522-a595-23ac64af0812&hctky=2808780&hlkid=6bb6d6343b2340ab873cc6668394c8b0#0&cid=app, checked on 8/11/2021.

EasyMile online: Vehicle Solutions. Available online at https://easymile.com/vehicle-solutions, checked on 20-Sep-21.

ERTICO – ITS Europe (2019): MOBILITY AS A SERVICE (MAAS) AND SUSTAINABLE URBAN MOBILITY PLANNING.

ETSI (2021): Automotive Intelligent Transport Systems (ITS). Available online at https://www.etsi.org/technologies/automotive-intelligent-transport, checked on 7/20/2021.

European Commission (2016): European accessibility act - Related documents. Available online at https://ec.europa.eu/social/main.jsp?catId=1202&langId=en&moreDocuments=yes, checked on 11-Oct-22.

European Commission (2020a): A European Green Deal. Available online at https://ec.europa.eu/info/strategy/priorities-2019-2024/european-green-deal_en#actions.

European Commission (2020b): Sustainable and Smart Mobility Strategy. Available online at https://ec.europa.eu/info/law/better-regulation/have-your-say/initiatives/12438-Sustainable-and-Smart-Mobility-Strategy.

European Commission (2020c): The European Data Strategy. Available online at https://ec.europa.eu/commission/presscorner/detail/en/fs_20_283.

European Commission (2021): Mobility Strategy. A fundamental transport transformation: Commission presents its plan for green, smart and affordable mobility. Available online at https://ec.europa.eu/transport/sites/default/files/2021-mobility-strategy-and-action-plan.pdf.

European Commission (2022): (EU Comm) Implementing regulation C(2022) 5402 final.

European forum and oBsErvatory for OPEN science in transport (2020): Open Science in transport research: legal issues and fundamental principles. Available online at https://beopen-project.eu/storage/files/beopen-d41-open-science-in-transport-research-legal-issues-and-fundamental-principles.pdf, checked on 11-Oct-22.

Fagnant, Daniel J.; Kockelman, Kara (2015): Preparing a nation for autonomous vehicles: opportunities, barriers and policy recommendations. In *Transportation Research Part A: Policy and Practice* 77, pp. 167–181. DOI: 10.1016/j.tra.2015.04.003.

Fournier, G.; Thalhofer, M.; Chrétien, P.; Boos, A.; Korbee, D.; Jaroudi, I. et al. (2022): System innovation in transport with automated minibuses and ITS: the citizen centric approach of AVENUE. Transport Research Arena (TRA) Conference. Lisbon.

Fournier, Guy; Baumann, Manuel; Gasde, Johannes; Yasin, Katharina Kilian (2018): Innovative mobility in rural areas - the case of the Black Forest. In *IJATM* 18 (3), p. 247. DOI: 10.1504/IJATM.2018.093420.

Fournier, Guy; Boos, Adrian; Wörner, Ralf; Jaroudi, Ines; Morozova, Inna; Nemoto, Eliane Horschutz (2020): Substituting individual mobility by mobility on demand using autonomous vehicles. a sustainable assessment simulation of Berlin and Stuttgart. In *Int. J. Automotive Technology and Management,* 20, Article 4, pp. 369–407, checked on 4/24/2019.

Fraedrich, Eva; Beiker, Sven; Lenz, Barbara (2015): Transition pathways to fully automated driving and its implications for the sociotechnical system of automobility. In *Eur J Futures Res* 3 (1), p. 91. DOI: 10.1007/s40309-015-0067-8.

Galletta, Anne (2012): Mastering the Semi-structured Interview and Beyond: From Research Design to Analysis and Publication (Qualitative Studies in Psychology): New York University Press.

Geisslinger, Maximilian; Poszler, Franziska; Betz, Johannes; Lütge, Christoph; Lienkamp, Markus (2021): Autonomous Driving Ethics: from Trolley Problem to Ethics of Risk. In *Philos. Technol.* 34 (4), pp. 1033–1055. DOI: 10.1007/s13347-021-00449-4.

Giusti, Riccardo; Manerba, Daniele; Bruno, Giorgio; Tadei, Roberto (2019): Synchromodal logistics: An overview of critical success factors, enabling technologies, and open research issues. In *Transportation Research Part E: Logistics and Transportation Review* 129, pp. 92–110. DOI: 10.1016/j.tre.2019.07.009.

Grisoni, Anahita; Madelenat, Jill (2021): Le véhicule autonome : quel rôle dans la transition écologique des mobilités ? With assistance of FORUM VIES MOBILES. LA FABRIQUE ECOLOGIQUE. Available online at https://www.lafabriqueecologique.fr/app/uploads/2020/02/Rapport-Complet_Ve%CC%81hicule-autonome-et-Transition-e%CC%81cologique_La-Fabrique-Ecologique-Forum-Vies-Mobiles-1.pdf.

Hassani, Jamal El (2018): Les entreprises de mobilités bientôt dépossédées de leurs données ? Journal du Net. Available online at https://www.journaldunet.com/economie/transport/1417359-loi-mobilites-ouverture-donnees-transport-open-data/.

Hein, Andreas; Schreieck, Maximilian; Riasanow, Tobias; Setzke, David Soto; Wiesche, Manuel; Böhm, Markus; Krcmar, Helmut (2020): Digital platform ecosystems. In *Electron Markets* 30 (1), pp. 87–98. DOI: 10.1007/s12525-019-00377-4.

Heineke, Kersten; Kampshoff, Philipp; Kellner, Martin; Kloss; Benedikt (2019): Change vehicles: How robo-taxis and shuttles will reinvent mobility. McKinsey & Company.

Huber, Dominik; Viere, Tobias; Horschutz Nemoto, Eliane; Jaroudi, Ines; Korbee, Dorien; Fournier, Guy (2022): Climate and environmental impacts of automated minibuses in future public transportation. In *Transportation Research Part D: Transport and Environment* 102, p. 103160. DOI: 10.1016/j.trd.2021.103160.

Hurst, Aaron (2016): The purpose economy. Expanded and updated how your desire for impact, personal growth and community is changing the world. Second paperback printing ; expanded and updated. Boise Idaho: Elevate.

Intelligent Transport: RABus: the autonomous bus trial underway in Baden-Württemberg. Available online at https://www.intelligenttransport.com/transport-articles/122746/rabus-trial/, checked on 25-Oct-22.

Iyer, Lakshmi Shankar (2021): AI enabled applications towards intelligent transportation. In *Transportation Engineering* 5, p. 100083. DOI: 10.1016/j.treng.2021.100083.

Kamargianni, Maria; Matyas, Melinda; Li, Weibo; Schäfer, Andreas (2015): Feasibility Study for "Mobility as a Service" concept in London.

Korbee, D.; Naderer, G.; Fournier, G. (2022): The potential of automated minibuses in the socio-technical transformation of the transport system. Transport Research Arena (TRA) Conference. Lisbon.

Lazarus, Jessica; Shaheen, Susan; Young, Stanley E.; Fagnant, Daniel; Voege, Tom; Baumgardner, Will et al.: Shared Automated Mobility and Public Transport. In : Road Vehicle Automation, vol. 4, pp. 141–161.

Leveraging Big Data for Managing Transport Operations (2019): Deliverable 4.1 Report on the characterization of the barriers and limitations.

Levesque, Hector J. (2018): Common sense, the Turing test, and the quest for real AI. First MIT paperback edition. Cambridge, Massachusetts: The MIT Press.

Liang, Weixin; Tadesse, Girmaw Abebe; Ho, Daniel; Li, Fei-Fei; Zaharia, Matei; Zhang, Ce; Zou, James (2022): Advances, challenges and opportunities in creating data for trustworthy AI. In *Nat Mach Intell*. DOI: 10.1038/s42256-022-00516-1.

Linz, Manfred (2004): Weder Mangel noch Übermaß: Über Suffizienz und Suffizienzforschung. In *Wuppertal Papers* (145).

Litman, Todd (2021): Autonomous Vehicle Implementation Predictions Implications for Transport Planning. Victoria Transport Policy Institute.

Liu, Jian; Li, Yinzhen; Li, Jun (2015): Coopetition in Intermodal Freight Transport Services. In *Discrete Dynamics in Nature and Society* 2015, pp. 1–11. DOI: 10.1155/2015/680685.

Lucca, Natalie (2022): AI-research project started for sustainable mobility - WirelessCar. Available online at https://www.wirelesscar.com/ai-research-project-started-for-sustainable-mobility/, updated on 17-Mar-22, checked on 11-Oct-22.

MaaS Aliance (2019): EU projects explore common standard for digital mobility services. Available online at https://maas-alliance.eu/2019/01/24/eu-projects-explore-common-standard-for-digital-mobility-services/, checked on 7/14/2021.

Mahmoodi Nesheli, M.; Li, L.; Palm, M.; Shalaby, A. (2021): Driverless shuttle pilots: Lessons for automated transit technology deployment. In *Case Studies on Transport Policy*. DOI: 10.1016/j.cstp.2021.03.010.

Matthes, Florian; Bondel, Gloria: TP2.1: API Economy and API Ecosystems. Available online at https://tum-llcm.de/en/project/ap2/tp21/, checked on 7/13/2021.

Mauch, Ursula; North, Nicole; Pulli, Raffael (2001): Between Efficiency and Sufficiency. The Optimal Combination of Policy Instruments in the Mobility Sector towards Sustainable Development. In Ruth Kaufmann-Hayoz, Heinz Gutscher (Eds.): Changing Things — Moving People. Basel: Birkhäuser Basel, pp. 133–150.

May, Anthony D.; Shepherd, Simon; Pfaffenbichler, Paul; Emberger, Günter (2020): The potential impacts of automated cars on urban transport: An exploratory analysis. In *Transport Policy* 98 (2), pp. 127–138. DOI: 10.1016/j.tranpol.2020.05.007.

McAfee, Andrew (2019): More from less. The surprising story of how we learned to prosper using fewer resources--and what happens next. First Scribner hardcover edition. New York: Scribner.

McKinsey & Company (2021): Government transformations in times of extraordinary change: Key considerations for public-sector leaders. Available online at https://www.mckinsey.com/industries/public-and-social-sector/our-insights/government-transformations-in-times-of-extraordinary-change-key-considerations-for-public-sector-leaders, checked on 8/22/2022.

Meijer, Ronald; Conradie, Peter; Choenni, Sunil (2014): Reconciling Contradictions of Open Data Regarding Transparency, Privacy, Security and Trust. In *J. theor. appl. electron. commer. res.* 9 (3), pp. 32–44. DOI: 10.4067/S0718-18762014000300004.

Merlin, Louis (2017): Comparing Automated Shared Taxis and Conventional Bus Transit for a Small City. In *JPT* 20 (2), pp. 19–39. DOI: 10.5038/2375-0901.20.2.2.

Meyer, Jonas; Becker, Henrik; Bösch, Patrick M.; Axhausen, Kay W. (2017): Autonomous vehicles: The next jump in accessibilities? In *Research in Transportation Economics* 62 (1), pp. 80–91. DOI: 10.1016/j.retrec.2017.03.005.

Milakis, Dimitris; Snelder, Maaike; van Arem, Bart; van Wee, Bert; Homem De Almeida Correia, Gonçalo (2017): Development and transport implications of automated vehicles in the Netherlands: scenarios for 2030 and 2050. European Journal of Transport and Infrastructure Research, Vol 17 No 1 (2017) / European Journal of Transport and Infrastructure Research, Vol 17 No 1 (2017). DOI: 10.18757/ejtir.2017.17.1.3180.

Nagel, Kai; Bischoff, Joschka; Leich, Gregor; Maciejewski, Micha (Eds.) (2019): Simulation-based analysis of the impacts of fleets of autonomous vehicles on urban traffic. Fachgebiet Verkehrssystemplanung und Verkehrstelematik. Berlin, February 18. Institut für Land und Seeverkehr, TU Berlin.

NCSL (2022): Autonomous Vehicles State Bill Tracking Database. Available online at https://www.ncsl.org/research/transportation/autonomous-vehicles-legislative-database.aspx, checked on 8/23/2022.

Nemoto, Eliane Horschutz (2022): Towards a new sustainable mobility paradigm. The role and impacts of automated minibuses in the mobility transition. PhD Thesis. CentraleSupelec, Paris. Université Paris-Saclay.

Nemoto, Eliane Horschutz; Jaroudi, Ines; Fournier, Guy (2021): Introducing Automated Shuttles in the Public Transport of European Cities: The Case of the AVENUE Project. Nathanail E.G., Adamos G., Karakikes I. In: Nathanail E.G., Adamos G., Karakikes I. (eds) Advances in Mobility-as-a-Service Systems. CSUM 2020. Advances in Intelligent Systems and Computing: Springer, Cham (1278).

Niles, John (2019): Full Potential of Future Robotaxis Achievable with Trip-Based Subsidies and Fees Applied to the For-Hire Vehicles of Today. Mineta Transportation Institute Publications.

Rayle, Lisa; Dai, Danielle; Chan, Nelson; Cervero, Robert; Shaheen, Susan (2016): Just a better taxi? A survey-based comparison of taxis, transit, and ridesourcing services in San Francisco. In *Transport Policy* 45, pp. 168–178. DOI: 10.1016/j.tranpol.2015.10.004.

Rogg, Johannes (2021): White Paper: ITxPT and Information Technology Standards for Public Transport. Delivering flexible, advanced Intelligent Transport Systems through Open Standards. Trapeze Group. Available online at https://trapezegroup.co.uk/itxpt-technical-white-paper/?utm_source=Email+marketing&utm_medium=email&utm_campaign=IT+-+industry+Insight+-+E-mobility+-+Trapeze+Group+-+09+July+2021&utm_term=Read+our+latest+Transport+Tech+Industry+Insight&utm_content=https%3a%2f%2femails.intelligenttransport.com%2frussellpublishinglz%2f&gator_td=MYOPaxduAAShzmyuCrZFtBL0rc3UKIX7gIrZeKyipk9sAOGS7ajoOkC1Ii7wzNnICooBw1Cf7rYkn1CPBkxjdwZuFxAt0kbvcukaWd%2fDPIePpGLZRb5lEnM1Mx%2bBO7yoldDwU7d5B095%2byCInpINxGnari%2bfbDc14U0gPtFDfQjs35%2bY0Ef9qM9k2lJzjCZ9TTpXdEoytTa%2f%2bIFgYFQhcfLgplKZGBMsQAZxtNDwmo8rdzDStOuo2DLtsi6JmpwX, checked on 7/13/2021.

Rousseau, J..J. (1762): Du contrat social. Amsterdam.

Ruter (2019): THE OSLO STUDY. HOW AUTONOMOUS CARS MAY CHANGE TRANSPORT IN CITIES. REPORT. With assistance of COWI, PTV GROUP. Oslo.

Scherk, Johannes; Pöchhacker-Tröscher, Gerlinde; Wagner, Karina (2017): Künstliche Intelligenz. Artificial Intelligence. BMVIT Bereich Innovation.

Schmück, Kilian; Sturm, Monika; Gassmann, Oliver (2021): Decentralized Platform Ecosystems for Data-Sharing and Digital Trust in Industrial Environments. In Oliver Gassmann, Fabrizio Ferrandina (Eds.): Connected Business. Cham: Springer International Publishing, pp. 127–136.

Shafik, Minouche (2021): What we owe each other. A new social contract / Minouche Shafik. London: Vintage Digital.

Sixt (2021): Mobileye und SIXT bringen Robotaxis nach Deutschland. Available online at https://www.sixt.de/magazine/news/robotaxi-mobileye-sixt/, updated on 08-Sep-21, checked on 20-Sep-21.

Sochor, Jana; Arby, Hans; Karlsson, I. MariAnneC.; Sarasini, Steven (2018): A topological approach to Mobility as a Service: A proposed tool for understanding requirements and effects, and for aiding the integration of societal goals. In *Research in Transportation Business & Management* 27, pp. 3–14. DOI: 10.1016/j.rtbm.2018.12.003.

Sochor, Jana; Karlsson, I. C. MariAnne; Strömberg, Helena (2016): Trying Out Mobility as a Service: Experiences from a Field Trial and Implications for Understanding Demand. In *Transportation Research Record* 2542 (1), pp. 57–64. DOI: 10.3141/2542-07.

Statista (2020): Europäische Union: Anteil von Verkehr an den Konsumausgaben der privaten Haushalte, aufgeschlüsselt nach Mitgliedstaaten im Jahr 2020. Available online at https://de.statista.com/statistik/daten/studie/1219892/umfrage/anteil-der-konsumausgaben-fuer-verkehr-an-den-gesamtausgaben-in-den-laendern-der-europaeischen-union/, updated on 11-Oct-22, checked on 11-Oct-22.

Strategyzer AG online: Business Model Canvas. Available online at https://www.strategyzer.com/canvas/business-model-canvas, checked on 26-Aug-21.

The Economist (2022): The era of big-tech exceptionalism may be over. Available online at https://www.economist.com/leaders/2022/07/27/the-era-of-big-tech-exceptionalism-may-be-over, updated on 11-Oct-22, checked on 11-Oct-22.

Toledano, Joëlle (2020): GAFA. Reprenons le pouvoir! Paris: O. Jacob.

Trafi online. Available online at https://www.trafi.com/, checked on 06-Sep-21.

UITP (2017): Autonomous vehicles: a potential game changer for urban mobility. Available online at https://www.uitp.org/sites/default/files/cck-focus-papers-files/PolicyBrief_Autonomous_Vehicles_LQ_20160116.pdf, checked on 2/9/2020.

UNESCO (2021): AI for the Planet: Highlighting AI innovations for sustainable mobility and smart cities, 2021. Available online at https://www.unesco.org/en/articles/ai-planet-highlighting-ai-innovations-sustainable-mobility-and-smart-cities, checked on 11-Oct-22.

Vercher-Chaptal, Corinne; Acosta Alvarado, Ana Sofia; Aufrère, Laura; Brabet, Julienne; Broca, Sebastien; Smichowski, Bruno Carballa et al. (2021): There Are Platforms as AlternativeS. Entreprises plateformes, plateformes collaboratives et communs numeriques. Available online at https://hal.archives-ouvertes.fr/hal-03413930/document, checked on 11-Oct-22.

Vleugel, J. M.; Bal, F. (2017): More space and improved living conditions in cities with autonomous vehicles. In *Int. J. DNE* 12 (4), pp. 505–515. DOI: 10.2495/DNE-V12-N4-505-515.

Waymo online (1). Waymo One. Available online at https://waymo.com/intl/es/waymo-one/, checked on 20-Sep-21.

WEforum (2020): Will robo-taxis cause radical disruption - or gridlock? Available online at https://www.weforum.org/agenda/2020/01/will-robo-taxis-bring-radical-disruption-to-our-streets-or-gridlock/, checked on 10/5/2022.

Whim online: How to get there. Available online at https://whimapp.com, checked on 06-Sep-21.

Zha, Liteng; Yin, Yafeng; Yang, Hai (2016): Economic analysis of ride-sourcing markets. In *Transportation Research Part C: Emerging Technologies* 71 (Part A), pp. 249–266. DOI: 10.1016/j.trc.2016.07.010.