automated vehicles to Evolve to a New Urban Experience

DELIVERABLE

D9.5 AVENUE beyond business plan

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 programme under grant agreement No 769033

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Document Information

Grant Agreement Number	769033
Full Title	Automated vehicles to Evolve to a New Urban Experience
Acronym	AVENUE
Deliverable	D9.5 AVENUE beyond business plan
Due Date	31.08.2022
Work Package	WP9
Lead Partner	Autonomous Mobility
Leading Author	Chrisitan Zinckernagel, Nanna May Felthaus, Sophie Green
Dissemination Level	Public

Document History

Version	Date	Author	Description of change
0.1	03.03.2022	Christian Zinckernagel, Nanna Felthaus, Christian Bering, Sophie Green, Amobility	First draft
1.0	29.10.2022	Christian Zinckernagel	Final version
1.1	5.11.2022	Dimitri Konstantas	Final form adaptation

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Acronyms

ADS	Automated Driving Systems
AI	Artificial Intelligence
AM	Automated Mobility
API	Application Protocol Interface
AV	Automated Vehicle
BM	Bestmile
BMM	Business Modelling Manager
CAV	Connected and Automated Vehicles
CB	Consortium Body
CERN	European Organization for Nuclear Research
D7.1	Deliverable 7.1
DC	Demonstration Coordinator
DI	The department of infrastructure (Swiss Canton of Geneva)
DMP	Data Management Plan
DSES	Department of Security and Economy - Traffic Police (Swiss Canton of Geneva)
DTU test track	Technical University of Denmark test track
EAB	External Advisory Board
EC	European Commission
ECSEL	Electronic Components and Systems for European Leadership
EM	Exploitation Manager
EU	European Union
EUCAD	European Conference on Connected and Automated Driving
F2F	Face to face meeting
FEDRO	(Swiss) Federal Roads Office
FOT	(Swiss) Federal Office of Transport
GDPR	General Data Protection Regulation
GIMS	Geneva International Motor Show
GNSS	Global Navigation Satellite System
HARA	Hazard Analysis and Risk Assessment
IPR	Intellectual Property Rights
IT	Information Technology
ITU	International Telecommunications Union
LA	Leading Author
LIDAR	Light Detection And Ranging
MEM	Monitoring and Evaluation Manager
MT	MobileThinking
OCT	General Transport Directorate of the Canton of Geneva
ODD	Operational Domain Design
OEDR	Object And Event Detection And Response
OFCOM	(Swiss) Federal Office of Communications
PC	Project Coordinator
PEB	Project Executive Board
PGA	Project General Assembly
PRM	Persons with Reduced Mobility
PSA	Group PSA (PSA Peugeot Citroën)

PTO	Public Transportation Operator
PTS	Public Transportation Services
QRM	Quality and Risk Manager
QRMB	Quality and Risk Management Board
RN	Risk Number
SA	Scientific Advisor
SAE Level	Society of Automotive Engineers Level (Vehicle Autonomy Level)
SAN	(Swiss) Cantonal Vehicle Service
SDK	Software Development Kit
SLA	Sales Lentz Autocars
SMB	Site Management Board
SoA	State of the Art
SOTIF	Safety Of The Intended Functionality
SWOT	Strengths, Weaknesses, Opportunities, and Threats.
T7.1	Task 7.1
TM	Technical Manager
TPG	Transport Publics Genevois
UITP	Union Internationale des Transports Publics (International Transport Union)
V2I	Vehicle to Infrastructure communication
WP	Work Package
WPL	Work Package Leader

Executive Summary

This deliverable investigates the business models potential for a range of applications of autonomous vehicles. The deliverable uses the business model canvas framework in order to identify relevant partners, channels, customer segments, channels etc. in the different use cases: hospital logistics, Bus Rapid Transit (BRT), Airport infrastructure, tourist city centre services and urban first/last mile transportation.

A transition road map with 3 transition goals, for the use cases to become viable business models are provided. The goals are based on two (2) categories: *level of autonomy* and *maximum speed of vehicles.* The status quo is a maximum vehicle speed of 18 km/h with a safety steward on board, and the transition goals each increment on either category at each step. Goal 1 has a maximum vehicle speed of 18 km/h with no safety steward, Goal 2 has a maximum speed of 30 km/h with a safety steward on board and Goal 3 includes a maximum speed of 30 km/h without a safety steward.

The transition goals are deemed necessary in order for the business cases to provide the necessary reduction of costs and/or service levels which is key in providing the different value propositions.

Important stakeholders are identified and their role to reach AVs in ITS is investigated. Policy makers, urban/city planners, sustainable energy partners, vehicle vendors, public & private investors, implementation partners, public transport authorities and system partners are all important stakeholders, essential for the development and implementation of viable AV business models.

Lastly, recommendations regarding the implementation of autonomous vehicles in ITS are presented. The recommendations are divided into legal, safety, economic/system, infrastructure and technical recommendations. The recommendations are based on the multiple autonomous vehicle deployments under the AVENUE project and are joined in this final beyond business plan report, as they are key to enabling viable business plans in the future.

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 on the basis of 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 pre-scheduled 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

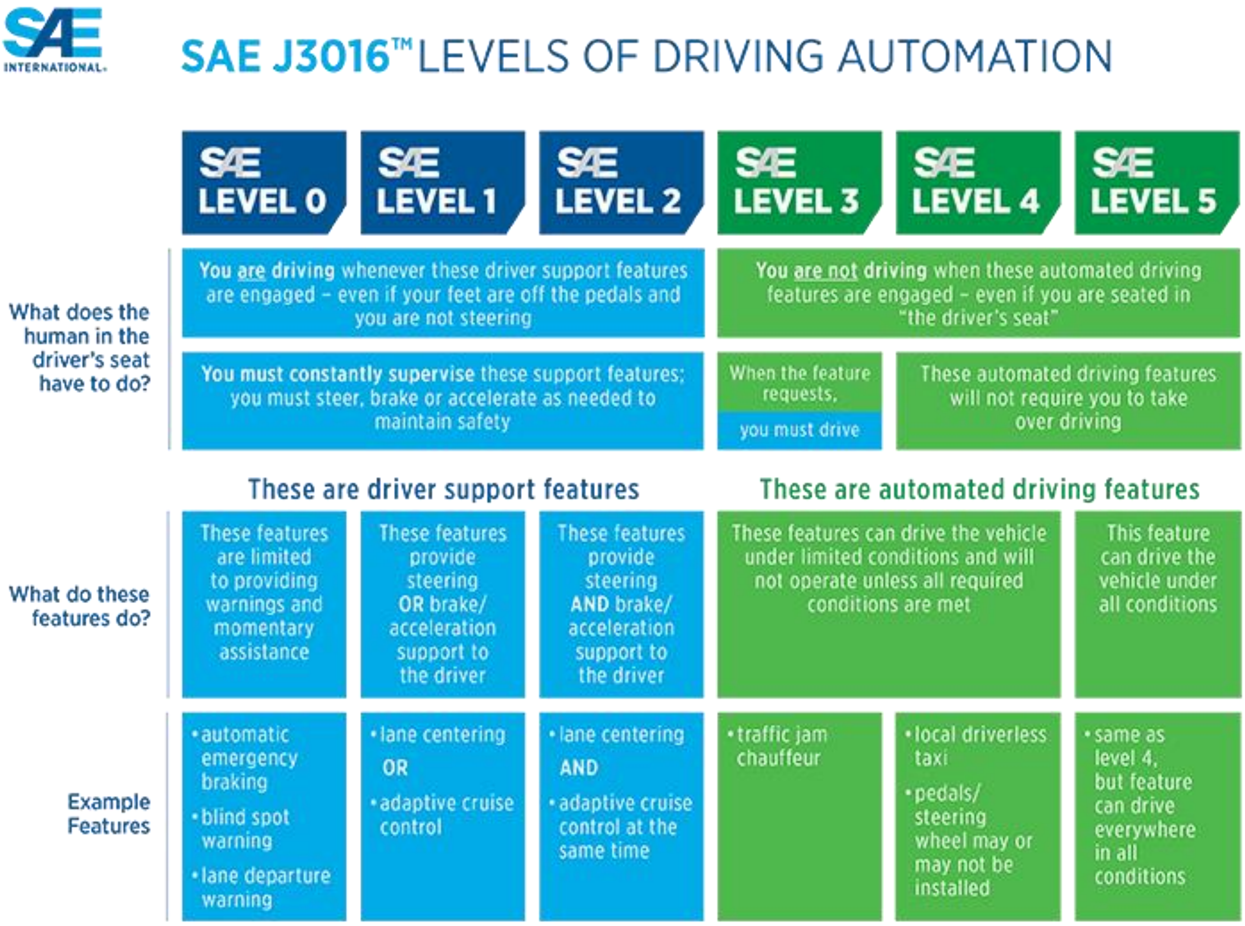
A self-driving car, referred to in the AVENUE project as **a Fully Automated Vehicle** (**AV**), also referred as Autonomous Vehicle, is a vehicle that is capable of sensing its environment and moving safely with no human input.

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 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 1: *SAE Driving Automation levels (©2020 SAE International)*

1.2.1 Autonomous 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 behavior 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 in 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 surrounding 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 takes into account all available vehicles in the services area, the passenger request, the operator policies, the street conditions (closed streets) and sends 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 them or wait behind them, based on the defined policies. For example with small changes in its route the AVENUE mini-bus 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, and communicate with infrastructure via V2I interfaces (ex. red light control).

The mini-buses 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 metres, and considering that the vehicle must safely stop in case of an obstacle on the road (which will be "seen" at less than 40 metres distance) we cannot guarantee a safe braking if the speed is more than 25 Km/h. Note that technically the vehicle can make a harsh break and stop with 40 metres in high speeds (40 -50 Km/h) but then the break would be 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 2 provides an overview of the AVENUE sites and OODs.

	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 2: *Summary of AVENUE operating site (+ODD components)*

1.3 Preamble

Work package WP9: Transition Roadmap for Autonomous Vehicle public transport takes into account the recommendations to public authorities, the transition roadmap for service quality, safety and reliability, cost-attractiveness, smart-city infrastructure and the exploitation of AVENUE's disruption on urban transport automation. This deliverable introduces the transition concept of the steps necessary to reach the vision: AVs in ITS.

Taking the status-quo into account new business models are defined and described in the business model canvas. Each business model targets potential clients and PTAs all existing in ITS. The goal is to showcase the potential commercial value of the different business models taking into account what is necessary to get there.

Important stakeholders are described taking into account their role in future applications of AVs. Important Transition recommendations are identified supporting the road ahead trying to reach future transport solutions in ITS.

All the recommendations are inserted from other AVENUE deliverables based on the work conducted during the 52 months of the project.

2 Introduction

This report describes the future business models of AVs in ITS. Each of the business models described focuses on different ways of utilising autonomous vehicles in both private and public transport. At the core of all the business models are high utilisation of the technology benefiting from the autonomous driving not needing a driver in the vehicle. This will overall provide more effective use of the vehicles with long service hours and low cost.

The report is structured in the following sections:

- **Status Quo descriptions:**
  A description of where we are today with the technology, the legislation and the commercial degree of utilisation. At the moment there is still no positive commercial use of the technology as a driver is still necessary inside the vehicle.

- **Stakeholder overview:**
  A description of necessary stakeholders in the future system to accommodate AVs in ITS. Today the advancements of the technology and implementation of services is carried out by few. Many stakeholders in the system of private and public transport have to be involved in the ecosystem - allowing the utilisation of AVs to benefit the modern society.

- **Transition Goals and Business Models:**
  From where we are today (Status-Quo) much has to be done before the AVs can be fully usilisied in ITS. Some simple steps towards the future are outlined and different business models are described using the business tool: Business model canvas. The business models are defined based on different commercial - and technical maturities, linked to the transition steps.

- **Transition Recommendations:**
  A summary of the recommendations developed and defined in AVENUE across all partners during the 52 months of duration. The recommendations are presented, linking to original reports in the categories: Legal recommendations, Safety recommendations, Economic/system recommendations, Infrastructure recommendations, Social recommendations and Technical recommendations

- **Discussion:**
  A discussion looking at how to meet the recommendations as well as how to take the different steps towards complete autonomous private and public transport.

3 Status Quo description

The Horizon 2020 AVENUE project has pushed the industry and stakeholders forward in their ambitions to achieve sustainable and commercially viable business models with AVs across the public transport industry. Major steps have been taken already, as e.g. testing legislation makes it possible to conduct proof of concept projects (PoC), technology is continuously developing and especially also on integrations towards on-demand ride-sharing and ride-pooling services. However on a high level several areas are currently still holding back the industry in the scalable deployment of AVs across the EU.

For this section the status quo of the industry and the current gaps towards scalable deployment will be addressed, on high a level, through the following topics:

- Legislation
- Technology
- Commercial setup

The transition and recommendations for further development is further explained and referenced in section 5.

3.1 Legislation

Currently legislation for AVs are fragmented across European Nations, meaning each country has on their own implemented legislation for approval and testing of autonomous vehicles. Significant progress is being made, in terms of providing a European legislative framework for approval of autonomous vehicles. However, with the status quo of legislation in Europe the entry barriers can be rather high for both new vehicle manufacturers, PTAs and PTOs, because of country specific regulations and requirements which currently will drive higher implementation costs for new projects starting up. For more information about legal recommendations see section 5.1.

3.2 Technology

The industry is currently making the first steps towards projects with Level 4 driverless operation, and major developments have been happening the last years towards full driverless operation. Still technology needs to develop even further both in terms of capabilities like higher speeds and in terms of safety systems and redundancy in features and functionalities. The current stage of the technology has high impacts on the cost levels of both actual prices for vehicles, as development is still in a high degree necessary, but also in terms of implementation as many vehicles are still reliant on time and resource consuming validation phases before live operation, some vehicles might rely on larger infrastructural changes, which then again impacts the implementation cost of AVs.

3.3 Commercial setup

As described in the 2 above sections, legislation and technology maturity is driving cost up when it comes to implementation of AV projects. High implementation costs combined with the need for currently still having a Safety Driver onboard the AVs, does at the current stage make competition with traditional traffic use-cases difficult. High implementation costs can be justified by significant savings once implemented, however those savings will only be available once technology has reached a maturity level of Level4 driverless operation. The status quo does still require significant development before the technology and service are ready to be implemented at scale on commercial terms.

The status quo descriptions provided in the above three (3) sections clarifies the need for continuous development of both technology and legal framework, but these developments are also highly reliant on continuous investments in PoCs, infrastructure, research and much more.

4 Stakeholder overview

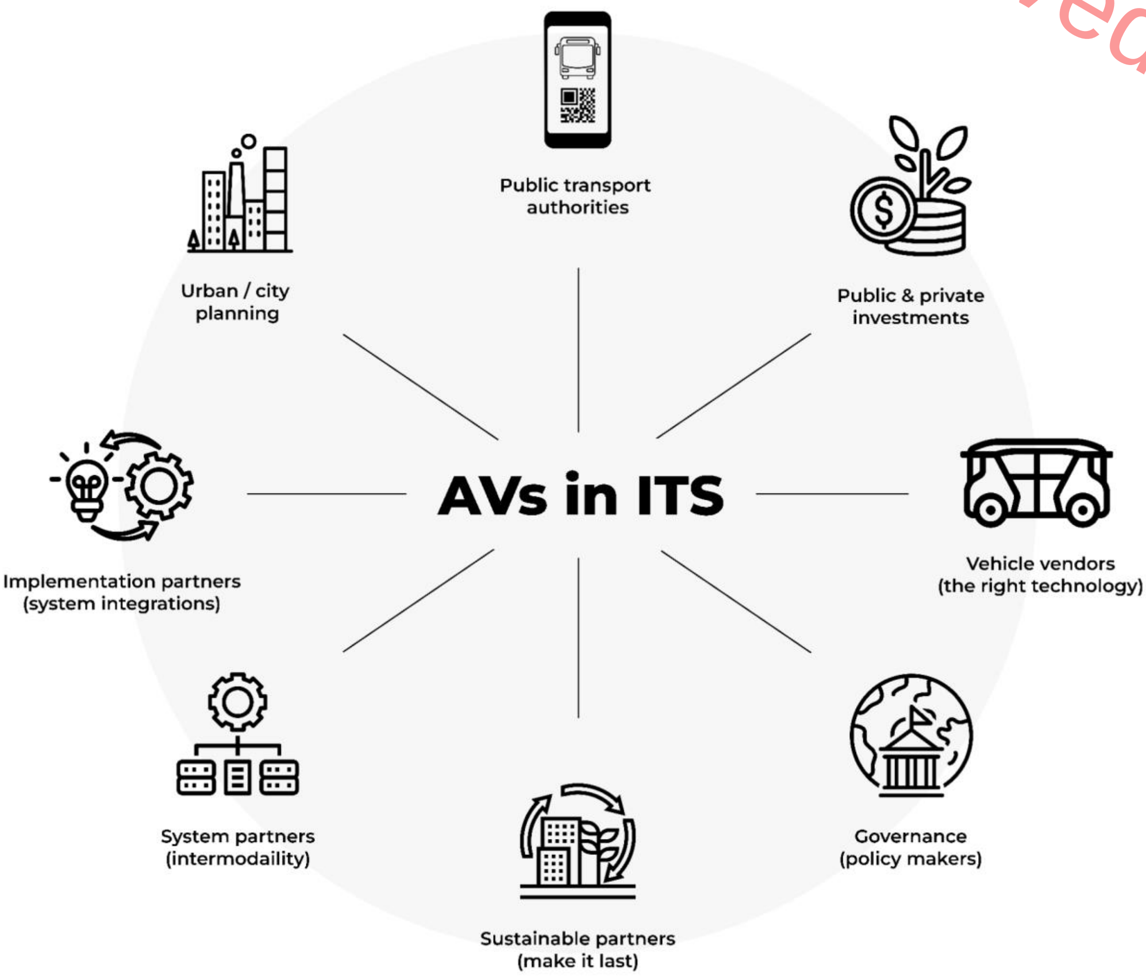


Figure 1: *Stakeholders overview for AVs in ITS*

Governance (policy makers)
It is important to engage with policy makers, as governance to support AVs is a crucial barrier to overcome to facilitate implementation in ITS. AVs are generally under strict legislation as they must integrate with the existing transport system. Making sure that future laws and legislation accommodates the implementation of AVs, will depend entirely on policy makers, why they should be close collaborators in making viable business models.

Urban/city planning
When planning the future of cities, implementation of AVs in ITS should be considered. New and existing infrastructure should be altered to accommodate new autonomous vehicle types. A close collaboration with urban planners and other local decision makers is important in order to ensure vehicle/infrastructure compatibility and standardisation.

Sustainable partners (make it last)

Partners such as green energy providers, should be engaged as it is in their interest to transform the transport sector to run greener energy sources. Keeping them in the loop to support charging infrastructure and advocate for greener means of transport can be a valuable partnership for AV rollout.

Vehicle vendors (the right technology)

In order to support the future business models of AVs in ITS, the right autonomous vehicles have to be available. This means both in terms of offering individual transport with many different needs, like carrying things, travelling with children, moving goods, MaaS transport and private transport but also in terms of the autonomous software. The vehicles available today are not able to meet all these demands and we are reliant on the technology to develop rapidly and alot. All vehicles have to be at least SAE level 4 with all the redundant safety features necessary. At the same time autonomous technologies like lidars, radars, cameras etc. have to be mature enough for the prices to come down, making the purchase price of AVs lower. At the moment the purchase and implementation cost of the AVS are too high.

Public & private investments

Both private and public investments in AVs are needed in order to mature the vehicle technology. In order to be able to deliver a better product for the end user in terms of technology - both software and hardware - as well as operations, experience is required. Getting the required experience will need public subsidiaries and investments from private actors.

Implementation partners

As the landscape for AVs are changing from vehicle vendors handling the entire supply chain related to everything from platform to operations. Vehicle vendors will not be able to have the full responsibility for the value chain, as it is unlikely that any vendor would e.g. hire site-crew in several countries, know country legal requirements and so on. For this implementation partners, system integrators and PTOs will be crucial stakeholders and partners.

Public transport authorities

In order to implement autonomous vehicles in an inclusive and accessible way, where shared mobility will mean fewer driven kilometres, and not more, it is essential to integrate with already existing public transport. By engaging with public transport authorities and being able to integrate AVs with their existing systems, we pave the road for better intermodality in the transport system.

System partners (intermodality)

Intermodality is entirely dependent on accessibility of the transport service in question. Proper integration with existing systems such as booking or payment services, has to be in place to allow for intermodality in the transport system. To be able to integrate several transport services to an intelligent transport system (ITS), legal alignment between modi is essential, why engagement of systems partners is key to enable intermodality.

5 Transition Goals and Business Models

In the following five (5) different use-cases with five (5) different business models will be presented. Each business model is based on different levels of transition goals. The transitions goals will be further elaborated below, the purpose is to outline the key themes for development from a technical perspective and their dependency on deployment of AVs in different use-cases.

5.1 Transition goals

In order for the use cases to become a viable business model, some steps for transitions are provided. These different goals for transition will potentially unlock new and other use-cases than the ones described in this chapter. However, they are deemed necessary especially in order for the business cases to provide the necessary reduction of costs and service levels, which - as it will be demonstrated - is key in providing the different value propositions.

Figure 2: *Transition goals*

The transitions goals can be divided into two (2) categories:

1. Level of autonomy
2. Maximum Speed of vehicles

Other categories could naturally also impact the ability for a viable business model to prevail, however, for the following business models, these two (2) categories are deemed most relevant.

Autonomy impacts the ability to take out the safety steward, which moreover equals the potential for increasing service hours and over longer periods of operation the cost compared to operation with a traditional driver, the cost is also assumed to be reduced.

The maximum allowed speed of the AVs also impacts the business models significantly, as customers/users are expected to choose the AV service over other means of transport and thereby the service must offer similar quality in transportation, hence the travel speed must be comparable with e.g. a personally owned car.

In the following these transition goals will be used to clarify the maturity of each of the described business models. The maturity of each model will also benefit from further exploitation and development of both technology and partners i.e. to reduce implementation costs and increase readiness for mature AV services to be integrated at scale.

5.2 Methodology: Business model canvas

As a tool for explaining future Business Models for AVs, the Business Model Canvas has been applied. The Business Model Canvas is a template used for strategic development of new business models and/or for documenting already existing business models. The Canvas consists of 9 building blocks which are; customer value proposition, customer segments, channels, customer relationships, revenue streams, key resources, key partners, key activities, and cost structure[1].

A visualisation of the Business Model Canvas is displayed in the figure below.

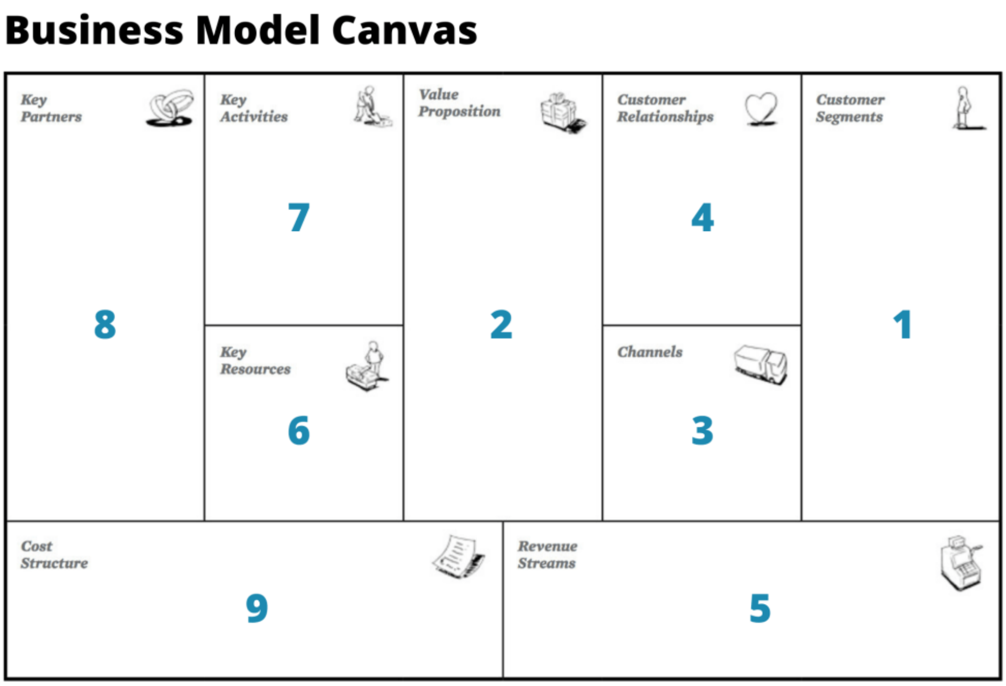


Figure 3: *Business model Canvas*

[1] https://www.strategyzer.com/canvas/business-model-canvas and https://www.businessmodelsinc.com/en/inspiration/tools/business-model-canvas

Customer value proposition
The customer value proposition describes what the unique proposition towards customers is, meaning what kind of gains can customers gain by using the product or service. The value proposition could also seek to solve an issue/pain for the customer.

Customer segments
Customer segments explain the type of customers the product or service seeks to engage with. A product and service can serve multiple customers, and for the purpose of this report customers are understood as the ones paying for the AV service, which is not necessarily - or in some cases - rarely the same as the end-user of the service.

Channels
The channels assess the ways to communicate and deliver the product or service to the defined customer segments.

Customer relationships
The questions to be answered in this category relates to how customer relationships will be maintained and developed in order to deliver on the defined value proposition.

Revenue streams
The revenue streams will outline how and through which pricing mechanism the business will generate and capture value.

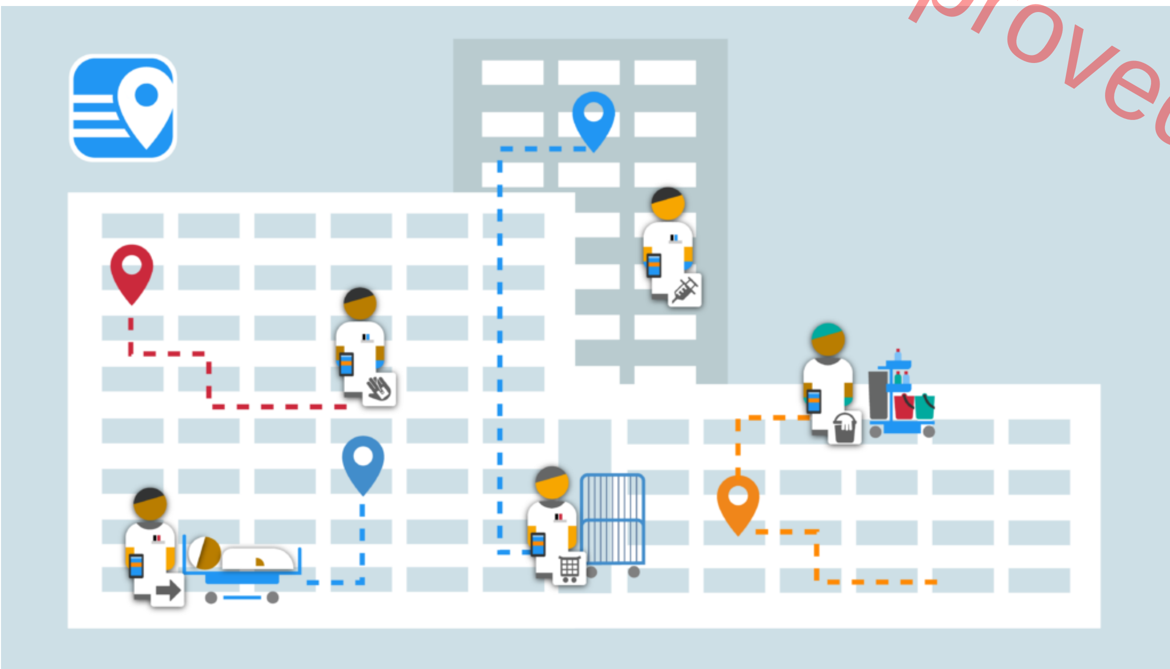
Key resources
The Key ressources show the indispensable assets which are necessary in order to deliver and supply customers with the product or services.

Key partners
Key partners should show which partners are necessary, as other stakeholders might have access to some of the key resources or key activities necessary to succeed with the business model.

Key activities
Key activities shows the key tasks and performance indicators necessary to both deliver on the value proposition and maintain costs and revenues

Cost structure
Once an understanding of the business model infrastructure is clear through the above parameters, a clear overview of the cost associated with these key activities, resources and channels.

5.2.1 Hospital logistics (passengers, bags and freight)



Description of the use case

As it has been demonstrated at the AVENUE sites in Denmark, Slagelse and Belle Idee, moving passengers within hospital areas is an attractive use-case. This service is traditionally either covered by the hospital themselves or by PTAs conducting these internal trips at the hospital. For larger hospital sites it is frequently necessary for patients to have to travel between departments at the hospital. The use case can also cover staff moving around the hospital and/or to/from a public transport stop or a near-by parking facility.

Beyond what has been part of the AVENUE sites, this service could also cover the internal movement of goods and equipment inside a hospital. This type of multi-usage of a service can both increase the internal value for the hospital but also further increase cost as trips are assumed to increase when adding package delivery to the service, this will however be dependent on the level of autonomy.

The Business model

In the below canvas the business model for hospital transportation is presented. The business model is dependent on transition goal 1 to be achieved in order for scalability to be in place. This is necessary as high implementation cost of AVs and higher prices on AVs in general (compared to traditional cars/taxis) will demand the cost savings from taking out the safety driver. However, a higher speed should not be required, as oftentimes the subjects needed to be moved within the hospital (passengers or freight) are not time critical.

The customer segments could be either public transport providers, who transport the passenger to, from or internally on hospital sites, or hospital service handling internal transport of goods or passengers. It would bring value to patients and hospital staff, as it would provide a greener transport service with better use of on-site cars requiring less parking space. For patients it would most likely contribute to a faster and more dynamic transport experience with less complexity for public transport drivers, who would be able to make efficient moves of passengers meaning a lower operational cost. For hospital staff a joined transport service for patents and freight could mean reduced complexity for internal logistics as well as in patient transport handling, which could lead to a cost reduction. Moreover the hospital could benefit from an increased sustainable hospital profile.

The project would rely on a B2B project organisation where operations are planned and evaluated through weekly meetings, sharing of data and operational reports. The B2B relationship would be based on service level agreements and contracts and would cover communications, stakeholder handling and sourcing.

For public transport providers a dynamic pricing based on trips through the use of a passenger travel card would be the main revenue stream.

For hospital service the revenue stream would most likely be a full service flat fare pricing on a monthly or project period basis, with uptime requirements. Also a mix with both a flat fare and an additional per trip fare could be considered.

The key resources would be level 4 vehicles for passenger transportation, maintenance and supervision crew, garage and charging facilities, operations office, the required electricity infrastructure to be in place and vehicle spare parts to support operations.

The key activities would be the delivery of an operations service. This includes supervision, maintenance and cleaning, vehicle integrations with existing systems and booking of trips as well as optimisations of trips/ driven kilometres.

The key partners in a public transport service would be the hospital in question, vehicle vendors and their support teams, dispatch management software, the municipality and other public and local authorities. As a hospital service it would be the dispatch management service system in collaboration with the hospital service to handle trip booking, as well as the vehicle vendor and support teams. Most likely also public and local authorities and the municipality would be a partner in this scenario.

The cost structure would include the purchase of level 4 vehicles, including software licences, garage facilities,staff for operations (supervisors and safety stewards), cost related to project management and integrations of systems. Moreover a maintenance cost and the upfront investment in spare parts and tools would be part of the cost structure.

Business model canvas: Hospital logistics (Passengers & freight)

KEY PARTNERS	KEY ACTIVITIES	VALUE PROPOSITION	CUSTOMER RELATIONSHIPS	CUSTOMER SEGMENTS

Who are the key partners?
 	
Public transport provider:
• Hospital
• Vehicle vendor & support
• Dispatch management system
• Municipality
• Public & local authorities
 	
Hospital service:
• Dispatch management PTA partner
• Minicipality
• Public & local authorities
• Vehicle vendor & support
	What are the activities that has to be performed everyday to deliver the value proposition?
	
	Operations delivery:
	• Supervision
	• Maintenance & cleaning
	• Booking of trips
	• Uptimisation of driven km's
	• Vehicle integrations
	
	KEY RESOURCES
	
	What are the resources needed to deliver the value proposition?
	
	• Level 4 vehicle
	• Maintenance crew
	• Supervision crew
	• Garage / charging facilities
	• Operations office
	• Electricity infrastructure
	• Vehicle spareparts
		What is the value delivered to the customers? What is the customer need that the value proposition addresses?
		
		Public transport provider:
		• Greener transport services
		• Better use of on-site cars
		• Less parked cars
		• Better experience for patients
		  • Faster
		  • More dynamic
		• Less complexity for employees
		  • More efficient moves
		  • Less cost
		
		Hospital service:
		• Sustainable hospital profile
		• Cost reduction
		• Improved services (freight combined with passengers)
		  • Reduced complexity for internal logistics
		  • Reduced complexity in passenger handling
			What relationships does each customer segment expect to be established and maintained?
			
			B2B relationship:
			• Service level agreements
			• Contracts
			• Communication
			• Stakeholder handling
			• Sourcing
			
			CHANNELS
			
			How do customer segments want to be reached?
			
			Project organisation in B2B:
			• Weekly meetings
			• Data reports
			• Operations reports
			• Milestones
				Who are the customers?
				
				Public transport provider:
				• Tendering transport needs on public hospitals and other public areas
				  • Passenger transport
				  • Included in public transport
				  • Travel card etc.
				
				Hospital service:
				• Hospitals with infrastructure
				  • Movement of patients
				  • Movement of freight
				• Hospitals wanting to reduce complexity and amount of cars on site
				• Private transport

COST STRUCTURE	REVENUE STREAMS

What are the important costs related to deliver the value proposition?
 	
• Purchase of vehicle
• Software licenses
• Garage facilities (rent, heating, water etc.)
• Staff for operations
  • Supervisors
  • Safety stewards
• Project management cost
• Implementation cost
• Maintenance cost (spare parts)
	How do customers reward the business for the value provided to them?
	
	Public transport: dynamic pricing (pay per trip as allready known model)
	• Travel card or other use of public transport pricing
	
	Full service: flat fare pricing (monthly payment b2b with uptime requirements)
	• PTA or private tender for transport need
	
	Mix (per per trip combined with full service)

Figure 4: *Business model canvas for hospital logistics use case*

5.2.2 BRT (designated lanes)

Description of the use case

Bus Rapid Transit or commonly known as BRT is a high capacity transit system based on buses operating in designated lanes. As a means of transport its features are similar to that of metro or light rails, but consisting of one single lane (in each direction) on existing roads with operating buses. With the use of Converted High Occupancy Vehicles it is possible to transport up to 45,000 passengers in one direction per hour.[2] The designated lanes can contribute to reducing delays, accidents, congestion, etc, and makes it possible to travel at high speed compared to other road users. This Incentivises modal shift for private car owners, as BRT most often will enable faster travel times during rush hours and within city centres. The construction of BRT systems is simple compared to other transit systems. As existing road lanes can be converted to BRT lanes, less infrastructural changes are needed, compared to other modes with similar capacity. This means less up-front investment is required to start operation. BRT works in particular well for hub-to-hub transport, for example to connect suburban areas, universities or airports with cities or for connecting busy transit hubs within large cities.

Incorporating autonomous technology with BRT (ABRT) is a win-win implementation, as not only does the autonomous technology enable more frequent departures, due to its lower personnel costs, the environment around the designated lanes integrate especially well with the autonomous vehicles' software. As the nature of designated lanes means no other road users, this also minimises the complexity of the traffic environment.

With adequate installation and use of ITS the vehicles can moreover interact with traffic lights, crosswalks, and other systems to optimise traffic flow, essentially creating the foundation for a smart city traffic system with minimal investment using the existing infrastructure.

The Business model

The use-case or service is typically offered by PTAs offering a public transport service to citizens through their platform and traditional channels. The value of BRT is already existing today, as it offers a more sustainable and faster transportation solution for pendlers travelling to and from work. The opportunity to implement AVs in BRT is hence obvious from a cost reduction perspective, as the cost of bus drivers would decrease. However, the transition demands more than driverless operation, as the key value proposition is an alternative solution to privately owned cars, and thereby speed becomes critical. This means that in order to scale this business model for BRT the market is dependent on development beyond the 3 described transition goals, as speed capabilities must be beyond 60 km/h.

The customer segments would in this case be public transport authorities. It would enable a more sustainable high capacity transport system with faster transfer times through cities. This would enable increased flow through cities. This as well as the fact that regular car lanes are converted to bus lanes incentivise a modular shift away from private cars resulting in less congestion in the city in question.

[2] https://www.acea.auto/files/20th_SAG_HR.pdf

The project would most likely be handled by a project organisation based on service level agreements, uptie excellence, project and stakeholder communication. The B2B relation would likely be created through tenders and handle sourcing and public transport measures.

Revenue would be made through dynamic pay per trip pricing or through monthly or yearly subscription services, as known from public transport today. The resources required would be level 4 High Occupancy Vehicles, maintenance and supervision crew, garage and charging facilities, operations office, the required electricity infrastructure to be in place and vehicle spare parts to support operations.

The key activities would be the operation including supervision, maintenance and cleaning as well as scheduling (including changes, service and uptime). The partners would be the municipalities in which the BRT service would operate, government and other public authorities, vehicle vendors and their support teams and the PTA in question in order to do system and process integrations.

In particular, the purchase of level 4 high speed HOVs would make up a part of the costs. Moreover license for software, Garage facilities, staff for operations such as supervisors and/ or safety stewards would make up the operational cost. Cost for project management , implementation as well as maintenance also adds to the total cost.

Business model canvas: BRT for PTAs (designated lanes)

KEY PARTNERS	KEY ACTIVITIES	VALUE PROPOSITION	CUSTOMER RELATIONSHIPS	CUSTOMER SEGMENTS

Who are the key partners?
 	
• **Municipalities**
• **Governments**
• **Public authorities**
• **Vehicle vendor & support**
• **PTA (for integrations and processes)**
	What are the activities that has to be performed everyday to deliver the value proposition?
	
	Operations delivery:
	• **Supervision**
	• **Maintenance & cleaning**
	• **Scheduling (changes, service uptime)**
		What is the value delivered to the customers? What is the customer need that the value proposition addresses?
		
		• **Sustainable maas transport**
		• **Faster transport through cities**
		  • **max capacity in maas**
		• **Dynamic use of vehicles**
		  • **max passengers moved**
		  • **less used vehicles**
		• **Increased flow through the city**
		• **Less private cars in traffic**
		  • **less congestion**
			What relationships does each customer segment expect to be established and maintained?
			
			B2B relationship (via tendors):
			• **Service level agreements**
			• **Contracts**
			• **Communication**
			• **Stakeholder handling**
			• **Sourcing**
			• **Public transport meassures**
				Who are the customers?
				
				• **PTA (Public transport authorities)**
				  • **Indirectly: Moving people in public transport via maas solution BRT**

	KEY RESOURCES What are the resources needed to deliver the value proposition? • **Level 4 vehicle** • **Maintenance crew** • **Supervision crew** • **Garage / charging facilities** • **Operations office** • **Electricity infrastructure** • **Vehicle spareparts**		CHANNELS How do customer segments want to be reached? **Project organisation in B2B:** • **Service level agreement** • **Uptime excellence** • **Project communication** • **Stakeholder communication**	

COST STRUCTURE	REVENUE STREAMS

What are the important costs related to deliver the value proposition?
 	
• **Purchase of vehicle level 4 high speed**
• **Software licenses**
• **Garage facilities (rent, heating, water etc.)**
• **Staff for operations**
  • **Supervisors**
  • **Safety stewards**
• **Project management cost**
• **Implementation cost**
• **Maintenance cost (spare parts)**
	How do customers reward the business for the value provided to them?
	
	Public transport: dynamic pricing (pay per trip as allready known model)
	• **Travel card or other use of public transport pricing**
	
	Full service: flat fare pricing (monthly payment b2b with uptime requirements)
	• **PTA or private tendor for transport need**
	
	Mix (per per trip combined with full service)

Figure 5: *Business model canvas for BRT for PTAs*

5.2.3 Airport infrastructure (passengers, bags and freight)

Description of the use case

The airport infrastructure use case is a multi-functional service, where AVs can be used for both the transportation of bags, passengers and other equipment on a given air-site. Air-sites are highly controlled environments and already fully monitored sites. This makes the technical requirements towards the specific vehicles rather simplistic, compared to i.e. urban traffic on public roads. The potential is most likely highest in airports where shuttle buses are already being used today to transport passengers from gate to aircraft.

The use case also holds the potential to unlock other service areas, such as transportation of equipment and luggage.

The Business model

Speed for passenger transportation is assumingly not the most important factor, if transition goal 2 could be achieved then the use case and business model would probably be viable over time, as the cost reduction holds the potential savings to make the business case scalable and viable.

However, the service also requires high uptime and higher implementation costs due to safety clearance on air sites, meaning the cost reduction must be significant and it will thereby most likely only be relevant for larger airports in the coming years. However, private production or office sites might also be relevant customers for this type of service.

The service could provide more sustainable airport logistics with less personnel on the ground area meaning reduced costs and risk and possibly higher service availability.

The service would be provided through a project organisation handling service level agreements, uptime excellence, project and stakeholder communication. Moreover, ensuring integrations with logistics systems and the safety organisation of the site. The relationship would most likely be established through tenders and also involve the sourcing related to the project.

The revenue stream could look like a dynamic pricing payment per passenger, bag or package or a flat fare pricing for the full service ona monthly, yearly or project period basis. The resources would as in the other business models as well be level 4 vehicles for the transport of passengers or freight. Also maintenance and supervision crew, garage and charging facilities, operations office, electricity infrastructure and vehicle spare parts to support operations should be in place.

The key activities are trip management based on logistics systems integration with the customer in question. Also the operation including remote control supervision, maintenance and cleaning as well scheduling is included in the activities. Especially a high service level in terms of remote control and maintenance response time is important when working with high efficiency logistics sites, as delays might result in great losses.

The partners should be the airports or production sites in question to integrate with respective logistics systems. Moreover the vehicle vendors and their support teams would be partners in ensuring as fast response times as possible.

Purchase of vehicles accommodating all required transport needs (passengers and freight) including their associated licences would make up a large part of the cost. Moreover garage and charging facilities, staff for operations and project management, maintenance service and the upfront investment for implementation would contribute to the cost.

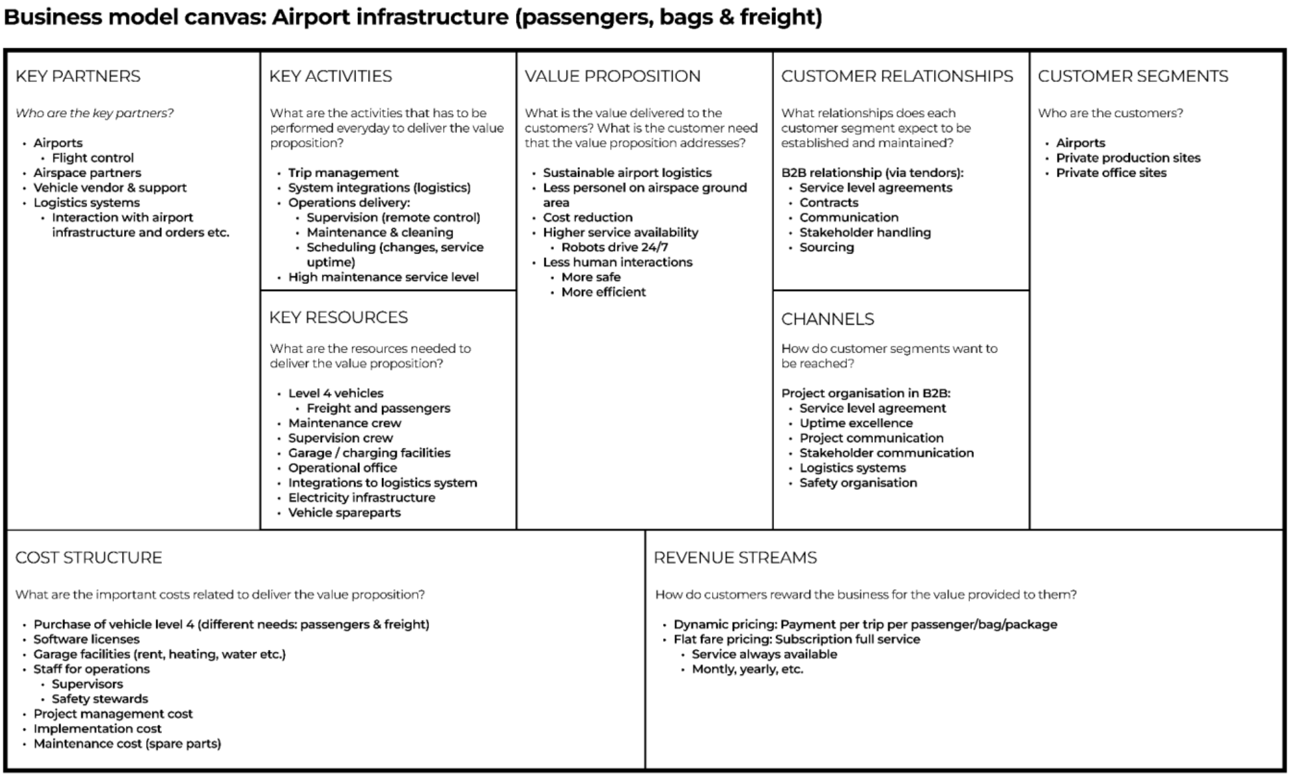
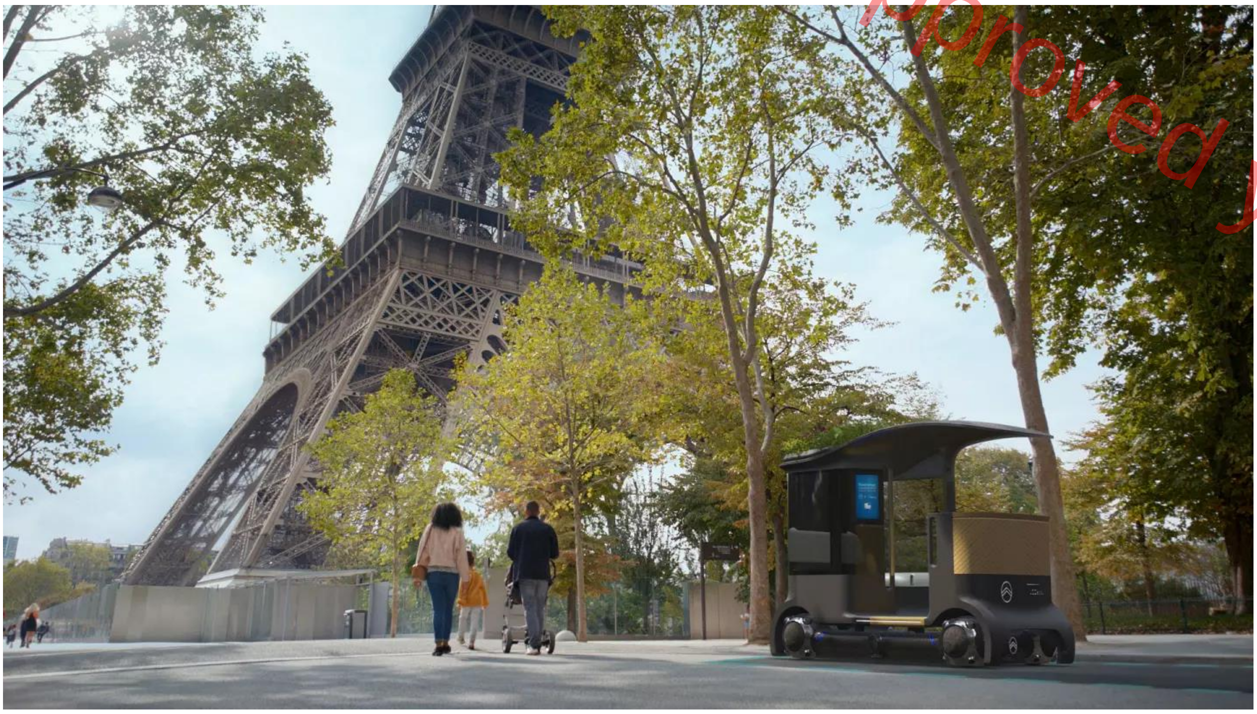


Figure 6: *Business model canvas for airport infrastructure*

Tourist city centre service



Description of the use case

Tourist buses in larger cities are an already existing business model. With the use of AVs as a supplement or alternative to vehicles in this existing business model, tourists can visit the same places, but using a more sustainable city transport in terms of cost and emissions. AVs with no safety driver could also increase flexibility in availability and service hours, as there will be no reliance on a human busdriver to fulfil the service.

This would help promote the city's attractions and could also work as a promotion platform for private city stakeholders such as restaurants, hotels or other private attractions. Using the vehicle platform for advertisement or direct transport options to certain locations, could be a great possibility to increase visitors to certain places.

Compared to dynamic first mile/ last mile transportation, requirements for AVs in terms of route is lower, as the route can be fixed with the same pick-up and drop-off points (PUDOs) rather than dynamic PUDOs. This means more certainty for route planning and scheduling offering a better service for tourists and visitors.

The Business model

The customers would for this type of business be cities/municipalities, larger cultural organisations and tourist attractions within that city. These customers could benefit from a sustainable city transport for tourists and visitors as well as promotion of that city and its services.

The customers are to be reached through B2B project organisations with weekly meetings, data and operational reporting and project milestones. B2B relationships should be established with municipalities and tourist/ travel agencies and client communications should include MaaS integrations and communications as well as trip information and changes.

Revenue should be generated through pricing structures known from regular public transport by dynamic pricing using a travel card or other means of public transport pricing. Revenue could also be generated with a full service flat fare paid by PTA or a private tender for transport needs like a municipality or tourism organisation.

Key partners would be municipalities, tourist attractions such as museums and galleries, local restaurants and shops, travel agencies and public transport providers. The activities would be delivery of an operational service including supervision, maintenance and cleaning as well as scheduling and route planning activities. The service would require level 4 vehicles and would depend on transition goal 1. Moreover a maintenance and supervision crew would be required alongside garage facilities, operatinasoffice, electricity infrastructure and vehicle spare parts.

The vehicles, their spare parts, software licences and garage facilities would make up a large party of the cost structure. Moreover, staff for maintenance and supervision as well as project management and implementation would be part of the total costs.

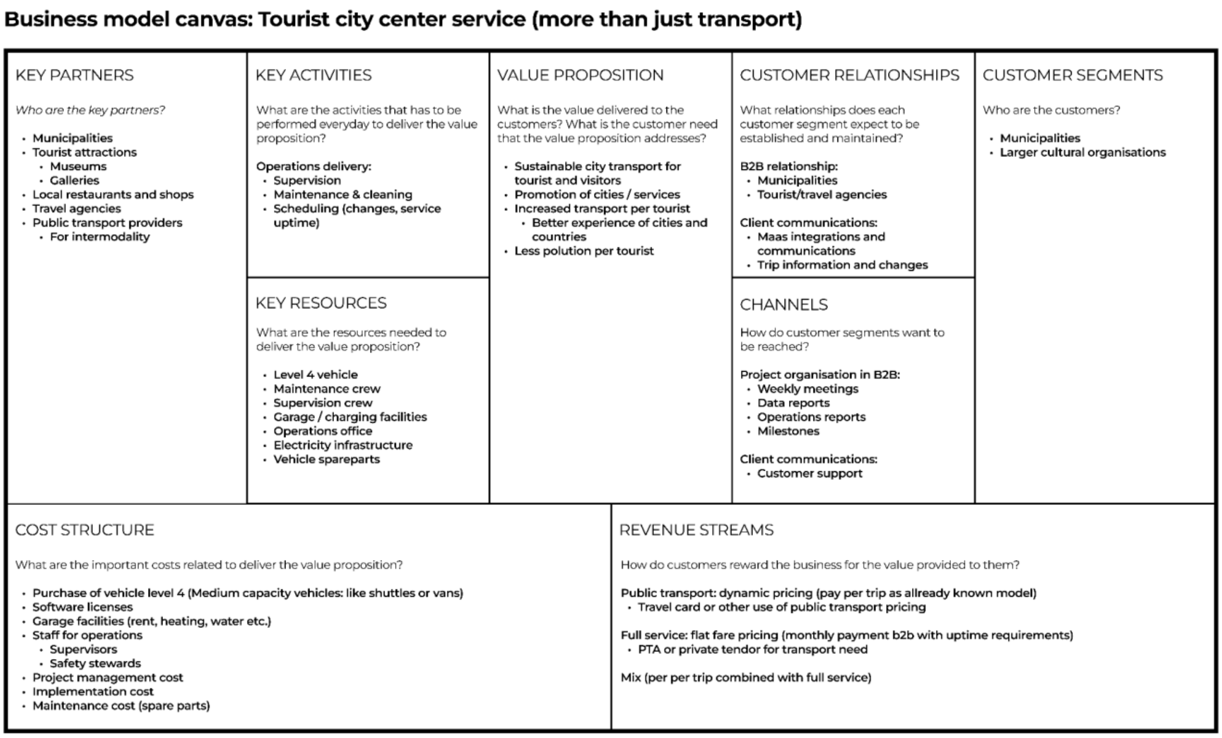


Figure 7: *Business model canvas for tourist city centre service*

5.2.4 Urban last mile (on-demand door to station)

Source: **Future scenarios – Logistic 2036, Daimler**

Description of the use case

In a public transport system where bus and rail services might cover the main part of a trip, people still need to first walk, drive or use another method to get to and from the nearest station or stop. The first and last leg of the trip are referred to as the 'first mile/last mile'. In the case of freight transport the last mile delivery is defined as the movement of goods from a transport hub to the final delivery destination[3].

The use of on-demand, shared, autonomous vehicles has often been predicted as an ideal first-mile/last-mile service. This due to its autonomous nature, where no driver must be present to drive, vehicles can be equally available even during off-peak hours, where transport demand is lower. Moreover the fact that the service is shared and on-demand would reduce the vehicle fleet in comparison to serving the first or last mile with private car ownership .

[3]**https://www.eea.europa.eu/publications/the-first-and-last-mile/download#:~:text=Although%20bus%20and%20rail%20services,first%20mile%2Flast%20mile'.**

The Business model

Business model canvas: Urban last mile (on-demand, door-to-door)

KEY PARTNERS

Who are the key partners?

- Other transport providers
  - intermodality across options
- Municipalities
- Government
- Public authorities
- Vehicle vendor & support
- Software providers

KEY ACTIVITIES

What are the activities that has to be performed everyday to deliver the value proposition?

Operations delivery:
- Supervision
- Maintenance & cleaning
- Scheduling (changes, service uptime)
- Trip management
  - Pooling, optimisation
- Customer support

KEY RESOURCES

What are the resources needed to deliver the value proposition?

- Level 4 vehicle fleet
  - Covering all passenger needs
- Booking app - like Uber
- Maintenance crew
- Supervision crew
- Garage / charging facilities
- Operations office
- Electricity infrastructure
- Vehicle spareparts

VALUE PROPOSITION

What is the value delivered to the customers? What is the customer need that the value proposition addresses?

- Sustainable, shared, effective personalised last mile transport
- Less polution
- Cheaper compared to private ownership
- Intermodality
  - Take into account all needs
- More safe
- Mobility equality
- Less parking
  - increased utilisation

CUSTOMER RELATIONSHIPS

What relationships does each customer segment expect to be established and maintained?

Client communications:
- Service level agreements
- Contracts
- Customer support
- Maas integrations and communications
- Trip information and changes

CHANNELS

How do customer segments want to be reached?

Booking & management of trips:
- App interface
- Web interface
- Phone booking
- Local communication

CUSTOMER SEGMENTS

Who are the customers?

Freight clients:
- Hub-to-home
- Hub-to-institution
- Hub-to-X...

Travelling customers:
- Passengers
  - with many transport demands
  - from house-to-station
  - from station-to-office
  - from house-to-school
  - from house-to-shop
  - from X-to-X....

COST STRUCTURE

What are the important costs related to deliver the value proposition?

- Purchase of vehicle level 4 (many vehicles to serve larger areas)
- App licenses
- Dispatch management system
- Software licenses
- Garage facilities (rent, heating, water etc.)
- Staff for operations
  - Supervisors
  - Safety stewards
- Implementation cost
- Maintenance cost (spare parts)

REVENUE STREAMS

How do customers reward the business for the value provided to them?

- Dynamic pricing: Payment per trip per passenger
- Flat fare pricing: Subscription service
  - Montly, yearly, etc.
- Package delivery service
  - Full utilisation of vehicles
- Public subsidiaries

Figure 8: *Business model canvas for urban first-mile/last-mile transport*

Good first and last mile options can make it easier to cover the distance before and after the main part of the trip and increase the flexibility of the supply of sustainable modes, thereby improving their attractiveness and increasing their service area. Moreover they allow more destinations to be reached within the same time budget, meaning good options can incentivise transport modal shift from private car ownership to public/shared transport. As urban areas are focal points in the transport network, first and last mile options — even if they are used in an urban context — are also relevant for longer distance transport, as they may influence the choice made for longer distance trips both for passenger and freight transport.

The customer segments for a first mile/last mile system based on shared, on-demand, autonomous vehicles could be both freight clients and travelling customers, being passengers. Freight customers could benefit from e.g. a hub-to-home solution, where packages are delivered from a central freight hub to customers' home addresses. Passengers with many different transport needs and demand schedules could benefit from autonomous door-to-door solutions such as house-to-station, -school or -shop, station-to-office and other x-to-x use cases.

The solution would give the users value in terms of a sustainable, shared, effective and personal last mile transport service, improving intermodality in the transport system. The service would ideally provide a transport service that is less pollutive, cheaper compared to private car ownership and more safe. By being cheaper compared to car shared mobility equality is increased, as more people have access to the service, and by eliminating the incentive for private car use the service would require less parking space. Moreover an increased utilisation of the vehicles in a combined vehicle fleet can be expected.

Client communication efforts play a big role in customer relationship management in this business model. Being able to communicate efficiently to the users of the service is essential, as information about the trip and possible detours to accommodate shared transport as well as how to locate your vehicle should come directly from the operator to the users device. The channel would most likely be through a booking system app. Other customer relationships include service level agreements and contracts with customers.

Revenue streams could be either dynamic pricing, with payment per trip per passenger or by flat fare pricing in a subscription service, where the passenger can pay for a month, year, etc. For full utilization of the vehicles and the service also package delivery could be increasing the revenue. Moreover it would be realistic to believe that a public subsidiary would be a part of the revenue stream in order to support the large up-front investments required for the implementation of a transport system of this type.

To operate and profit from a first mile/last mile transport system based on autonomous vehicles it would require a SAE level 4 vehicle fleet, covering all passengers' needs as some of the key resources. This includes wheelchair users, the ability to bring a stroller and having access to a baby car seat etc. Additionally, an app or great integration with MaaS systems in order to provide a user interface for booking, as known from services like Uber, is required. Also resources like a supervision crew, maintenance crew, vehicle garage with charging facilities, operations office, electricity infrastructure and vehicle spare parts must be in place in order to provide smooth and reliable operations.

The key activities as an operator in urban last mile systems would be such as supervision, maintenance, scheduling, and customer support. Moreover it would be necessary with some level of trip management including trip pooling and route optimisation for shared trips. This could however be outsourced to other partners handling dispatch management, but this would require further integrations with the vehicle software.

To provide an urban first mile/last mile service, key partners would be other transport providers in order to ensure intermodality across options. Moreover municipalities, government and other local and national, public authorities would play a role in approving and supporting such a transport system. The specific vehicle vendors and software providers would be a partner in collaborating on vehicle/software capabilities, support and integration with other transport means, ITS and potentially MaaS systems.

The purchase of SAE level 4 vehicles is a large part of the cost structure, as many vehicles are needed to serve an area. Moreover costs related to app licences, dispatch management systems and software are essential in order to provide the service. Moreover, will cost related to support functions such as garage facilities for the vehicles including charging, heatings etc., and salaries for supervisors and initially safety stewards be required. Implementation costs related to mapping, shipping and wrapping of vehicles are required as well as maintenance costs for acquiring tools and spare parts for the operation.

In order to become a viable, profitable service offering real value to its users the service is dependent on at least transition goal 3 and preferably beyond as higher speed is essential in order to serve all roads and thereby all passengers in an urban area.

6 Transition Recommendations

Based on 4 years of research and multiple autonomous vehicle deployments, the AVENUE project has generated recommendations in different important areas regarding the implementation of autonomous vehicles. The recommendations are divided into legal, safety, economic/system, infrastructure and technical. Each set of recommendations has been generated in individual reports of the project and now collected in this final beyond business plan report.

6.1 Legal recommendations

From D9.1 Legal recommendations, read more in deliverable D9.1.

- **D9.1_1: Public transportation first**
  Push public transportation in the field of automated vehicles during the upcoming legislative processes

- **D9.1_2: Harmonisation and standardisation**
  Harmonise the legal branches concerned by automated vehicles and encourage standardisation as much as possible

- **D9.1_3: Prepare authorities**
  Type-approval and other authorities should coordinate themselves and collaborate with stakeholders in order to facilitate and anticipate the deployment of automated vehicles

- **D9.1_4: Specific type-approval**
  Create an ordinary type-approval framework for automated minibuses enabling commercial deployment for PTO's and remote supervision of automated minibuses

- **D9.1_5: Define passive safety requirements**
  Passive safety requirements for automated minibuses should be defined urgently and carefully

- **D9.1_6: Improve accessibility**
  Use the current momentum for improving accessibility standards and legislation, encourage development and researches in this field

- **D9.1_7: Ensure compliance with personal privacy provisions**
  Address the major personal privacy and cybersecurity threats posed by the deployment of automated vehicles through legislation and provide guidance on how to comply with the current privacy framework

- **D9.1_8: Antitrust**
  Regulate access to automated vehicle's data and define open datasets and application protocol interfaces in order to avoid potential market distortions and anti-competitive behaviors

- **D9.1_9: Effective civil liability**
  Protect future victims by fair and quick compensation mechanisms; adapt and reform the existing liability mechanisms to the complexity of establishing liability in the context of accidents implying automated vehicles

- **D9.1_10: Define and create proper infrastructure**
  Automated vehicles will rely on updated road and communication infrastructures that should be discussed and defined today

- **D9.1_11: Driving permits**
  Amend the existing training of new drivers to the upcoming changes and new functionalities and requirements of automated vehicles

- **D9.1_12: Criminal liability**
  New undesirable behaviours will arise that need to be addressed through adequate criminal offences and potentially new liability schemes

6.2 Safety recommendations

From D9.2 Final transition roadmap for safety and service quality, read more in D9.2.

- **D9.2_1 : multi pillar approach**
  As requested for Automated Driving System (Validation Method for Automated Driving, VMAD from UNECE WP29/GRVA), use a multi-pillar approach to get robustness, with ODD scenarios, virtual testing, real world usage monitoring, systematic incident reporting and audit.

- **D9.2_2 : incident registering**
  Organise the systematic registering of all incidents leading to accidents or compromising the service quality, for example punctuality (including vandalism and all unacceptable behaviours…).

- **D9.2_3 : incident data collection**
  In case of an incident, keep and protect data according to GDPR, so lessons can be learned and formalised after analysis and anonymisation by trusted organisations, under PTA control.

- **D9.2_4 : AD disengagements and safety indicator**

Refuse Automated Driving disengagement frequency proposed by U.S. actors as a safety indicator (or as a safety demonstrator…): disengagements are not representative of safety issues, and should stay free to improve safety and avoid accidents.

- **D9.2_5 : injury indicator and target**
  Replace rare fatalities by road user injuries (including AM passengers, pedestrians, cyclists…) per hour of service to get a measurable indicator, with a target close to one per million hours of service (10-6 I/h), to be consistent with the existing results of public transportation.

- **D9.2_6 : target mitigation for market introduction**
  For first commercial applications, accept a higher rate of injuries (e.g. 10-5 I/h) during a transition phase, but request systematic reporting and build the improvement process, driven by lesson learned and regulation to avoid regressions.

- **D9.2_7 : trusted organisations for lessons learned coming from incidents**
  Organise trusted analysis of incident data, with the same type of data protection guarantees and technical skills as for road accident analysis, already defined and used for scientific analysis or juridical treatment.

- **D9.2_8 : data analysis and virtual test tools**
  Reuse the same tool chain among trusted organisations in Europe, could be SALSA for data analysis, could be MOSAR for scenario library, as they are already used for ADS validation.

- **D9.2_9 : improvement process**
  Share the lesson learned and require best practice application, with aim to lock earnings using regulation when main actors of Automated transportation are able to apply best practices.

- **D9.2_10 : traffic fluidity**
  Request the application of pertinent driver strategies to solve issues when the traffic is blocked, using the remote control for action, with modern tools to decide, including digital twins.

- **D9.2_11 : different usages and regulations**
  Dissociate liaison needs between town and suburbs (or rural usage) from central town usage (low speed in a busy and vulnerable traffic), requesting very different passive safety characteristics.

- **D9.2_12 : passive safety requirements**
  Existing tests are not adapted to such usage: establish quickly ambitious and reasonable targets for road user protection and for passenger protection, as it is structured for vehicle development.

- **D9.2_13 : street user protection**
  Promote innovation for active road user protection when driving in streets, avoiding injuries of citizens, e.g. with adapted new technologies, analogue to airbags inside cars.

- **D9.2_14 : performance limitation**
  Require automatic performance adaptation to street typology (e.g. pedestrian street), to traffic reality (e.g. busy, with many vulnerable road users) and to passenger postures.

- **D9.2_15 : passenger coaching**
  Reduce performance when passengers are not seated or not belted, inform passengers of such a situation to get the requested behaviours, as well when somebody is blocking the door closing.

- **D9.2_16 : vehicle maintenance**
  Introduce maintainability requirements in the vehicle certification rules to get in-service reliability (condition for safety and quality) with realistic maintenance.

- **D9.2_17 : cybersecurity**
  As fundamental to avoid dangerous misuses and highly dependent of the system architecture, act early in the commercial projects, organising European audits, providing best standards

- **D9.2_18 : design norms**
  Require ISO 26262 and ISO/PAS 21448 application for Functional Safety and Safety Of the Intended Functionality (SOTIF), as requested and now applied for future private cars.

- **D9.2_19 : automated private cars**
  In towns, consider public transportation at controlled and low speed as a priority, preparing potential next steps. In terms of social interest, Automated Minibus has high potential, but the automatization of private cars in towns can be considered as optional.

6.3 Economic/system recommendations

From D9.3 Roadmap for cost attractiveness, read more in D9.3.

- **D9.3_4: Making profitable business models for PTOs and stakeholders of the transport system**
  To enable profitable business models for PTOs and the other stakeholders of a transport system, the AM should be improved with AI to introduce supervisors instead of safety drivers, with on-demand and door-to-door features and the integration in a MaaS/ITS. Robotaxis as competitors to conventional Mass Transport systems should be forbidden (see governance). To create value for all the stakeholders (citizen, transport providers, city etc.) and avoid closed ecosystems, look-in effects and market power through the “winner takes it all effect”, open data, open API and open protocols and the related governance should be introduced (related to c and e).

- **D9.3_5: Integration of automated minibuses in MaaS/ITS to satisfy citizen needs**
  Currently, there is no real customer-centric approach which integrates AMs in a MaaS to enable a flexibility which is nearly as convenient but much cheaper than a car. An integration of AMs with other means of transport within a MaaS through an App would increase the attractivity for

passengers in terms of time, space, function (on-demand and door-to-door) and usability. Therefore, technology and governance must be adapted. City and regional governments especially would have to transform their operational mobility concepts and strategic business ecosystem towards a balanced, federated, or democratised governance and operational concept with AMs.

6.4 Infrastructure recommendations

From D9.4 Smart city infrastructure, read more in D9.4.

- **D9.4_1: SAFESTRIP material**
  For SAFESTRIP, a cold plastic (LIMBOPLAST D480) for rumble strips is the most recommendable material for the main application case (transversal invisible strip on a motorway).

- **D9.4_2: Material adhesion**
  Adhesion testing of the chosen marking material is performed by conducting a pull-off test, following ISO 4624:2002. The chosen material fulfils the recommended bond strength of 3 N/mm² for Road marking systems. This includes:
  - Adhesion between encapsulation material and primer (Double test average 7,2 N/mm²)
  - Adhesion between Encapsulation Material and Cold Plastic Top Coat (Double test average 5,1 N/mm²)

- **D9.4_3: Usage limitations**
  It is recommended that road markings intended for moving vehicles should be reflectorized if the density of traffic so requires and if lighting is poor or there is no lighting.

- **D9.4_4: Number/density of strips proposed per pilot site**
  It is recommended that one strip should be made of two parts placed adjacent to each other on the road pavement. The material of the strip is recommended to be elastic in order to be able to bend but not fold. The total height of the construction in order to be eligible in all AVENUE pilot sites has to be 10 mm including the cable and the mounting plates, while the length of each cable should be 5m. It is recommended that the strips should be installed in every crucial spot of the highways (dangerous turn etc.) and generally in every 1 to 1.5 km depending on the road infrastructure quality. The length of the AVENUE pilot is different among the pilot sites. In case of Geneva is 2.1 km which is the maximum among all. In case of Copenhagen is 1.3 which is the shortest route met in the pilot sites. Thus, the proposed distance between the installed strips varies among the different AVENUE sites. According to the above recommendations, in case of Geneva pilot site, 3 strips should be used as minimum in order to make the specific technological solution functional. In case of Copenhagen pilot site, the number of strips recommended as minimum is 2.

- **D9.4_5: Infrastructure and communication**

The application of C-ITS technologies, specifically SAFESTRIP, covers a wide range of services, various transport situations and involves different actors. To match driver's increasing expectation to receive all information on traffic and safety conditions seamlessly across Europe, a hybrid communication approach is needed, i.e. by combining complementary communication technologies. On vehicle and on infrastructure side, the used C-ITS technologies should be flexible regarding the communication technology, easing the inclusion of future technologies. Since the SAFE STRIP system is modular and the single components follow existing standards, e.g. ETSI TS 102 687 (2018), enhancements are possible.

- **D9.4_6: Interoperability**
  Interoperability at all levels is a key element for the success of C-ITS technology. The system as a whole needs to be able to interact with all vehicles and other features, across borders and transport modes at all levels: infrastructure, data, services, applications and networks. Applicable EU-standards, as defined in the standardisation mandate M/453 EN (2009), serve to apply deployment specifications. Test procedures should check the interoperability with other "Day 1 C-ITS services" with the aim of creating the conditions for EU-wide interoperability. Interoperability in case of SAFESTRIP, as recommended, has been ensured in the through existing data communication standards. However, interoperability in some special cases, in which no existing standards apply, is recommended to be validated in detail, e.g. regarding the variance in virtual tolling solutions applied across the European countries.

- **D9.4_7: Market introduction**
  For the final market introduction, it is recommended to follow the C-ITS government framework and security policy defined by the European Commission (2017b) based on roles defined in ISO 17427 (2018). This is not a standardisation of technology but following the standard on the application framework will likely benefit the implementation.

6.5 Social recommendations

From D9.3 Roadmap for cost attractiveness, read more in D9.3.

- **D9.3_7: Strengthening the positive attitude**
  An important finding of the AVENUE social impact assessment (Deliverable 8.7) 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.

- **D9.3_8: Enabling real user experience in the AMs**
  Real experience in the AMs has a generally positive effect on trust in the system. Therefore, an important success factor for the social acceptance of AMs is enabling citizens to use and experience its advantages. To ensure that the high level of goodwill leads to a high level of acceptance, it is very important to increase both speed and flexibility of use via an on-demand

service or at least improved temporal and spatial flexibility in comparison to the existing public transport offers.

- **D9.3_9: Enabling a change in the mobility paradigm**
  Using AM in MaaS/ITS could 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) and increasing many advantages (e.g., accessible, and available for anybody and any trip demand). As first surveys have shown a change in the mobility behaviour towards sustainable citizen centric mobility could be realised without a coercive transportation policy.

6.6 Technical recommendations

From D2.3 Final gap analysis, read more in deliverable D2.3..

- **D2.3_1: Construction Quality**
  Better build quality is necessary - type approved vehicles is recommended

- **D2.3_2: Traffic Regulation & Choice of Roadway**
  Not as flexible as a driver - need of safety operator to move the shuttle manually. Vehicles give way to all other road participants, regardless of the rules due to the fixed sensory system.

- **D2.3_3: Perception & Ability to Determine**
  No classification of traffic lights and signs yet fully integrated and the shuttles cannot distinguish between the obstacles, e.g. people versus animals, snow flakes versus big rain drops etc. Should be further developed.

- **D2.3_4: Driving Strategy**
  Unnatural driving behaviour (hard braking, different acceleration) could cause issues in traffic. Need a better redundant safety system to remove the need of an onboard attendant to overcome all situations - not commercial with safety steward onboard.

- **D2.3_5: Interoperability**
  Isolated system. Needs to be comparable with other systems like regular cars etc.

- **D2.3_6: Sensor-Position (LIDAR 360°)**
  Blind spots and no-detection areas need to be removed.

- **D2.3_7: Sensor-Resolution (VLP16 LIDAR)**
  Currently no reliable detection of moving objects and its direction - need to be included. Camera systems can be used for both object detection, categorization and as redundant safety systems to LIDARS and RADARS.

- **D2.3_8: UMTS & 3G-Modem (4G/5G)**
  Problematic transfer of pictures and videos due to lack of bandwidth of the modem - needs to be further developed - taking 5G into account.

- **D2.3_9: Charging Time**
  Charging time of the vehicle is more than 4 hours and currently gives 8 hours of driving - for full utilisation of a fleet the charging time has to be lowered significantly.

- **D2.3_10: HitRatio**
  The shuttle relies on a high hit ratio, meaning that the shuttle is seeing what was recorded when the route was mapped. Since roads change a lot in urban areas due to construction, snow, etc. the shuttle experiences a low HitRatio and cannot continue - a more dynamic mapping system has to be developed - perhaps 3rd party mapping companies can keep maps updated etc.

- **D2.3_11: Mapping & Modification of Routes**
  Operation is limited to pre-mapped routes and pre-defined stops - newer systems exist using pre-mapped areas or camera technologies to record areas via other cars etc.

- **D2.3_12: Sensor-Related**
  Detection of rain and snow as an obstacle, or aberrancy between camera/sensor perception and 3D-Map (low HitRadio) causes the shuttle to stop and needs to be perfected.

- **D2.3_13: Batterie-Related**
  Charging and de-charging problems in cold weather (0 degrees celsius or lower) meaning that certain areas in the world are too cold. Needs to be investigated.

- **D2.3_14: Power-Related**
  Breakdown of shuttle in very warm weather (40 degrees celsius or higher) meaning that certain areas in the world are too warm. Needs to be investigated.

- **D2.3_15: GPS & GNSS Signal**
  Can disappear without a live base station (local antenna setup by operator). Base stations can lose signal from time to time and cause low HitRatio (no driving) - recommended to use 5g networks and phone networks to triangulate the position of the vehicle with satellites etc.

- **D2.3_16: 3G/4G Signal**
  City infrastructure and bad signal-areas, can cause the shuttle to lose 3G/4G meaning low HitRatio (no driving) - recommended to use 5G and phone networks to position and maintain connectivity.

- **D2.3_17: Passenger counting**

Lack of means to count passengers to estimate occupancy (as this is crucial for a real on-demand system, and without safety operators there need to be automatic means to do so) - systems like CERTH have shown in AVENUE that it can be solved. Systems have to be integrated in vehicles for better environmental surveillance and feedback.

From D9.3 Roadmap for cost attractiveness, read more in D9.3.

- **D9.3_1: Automated minibus (AM)**
  The automated minibus should use GDPR complied AI to improve safety and security, allow higher speed to increase the acceptance, get rid of the safety driver in the vehicle and introduce supervisors outside the vehicle to enable viable business models for the PTO (see below).

- **D9.3_2: Automated minibus infrastructure**
  Improved ability to position and locate the vehicle as well as an open map should be provided to avoid malfunctions of driving and to allow route modification and smooth driving. Cybersecurity issues are currently not sufficiently addressed.

- **D9.3_3: Open data, open API, open Protocol**
  Open Data, open APIs and open protocols are conditions to develop the advantages of AMs in a Mobility-as-a-Service (MaaS) environment. Data generated by AM can enable AI loops (see chapter 4.5) in an Intelligent Transport System (ITS) and facilitate a citizen centric system innovation which could make transport system more efficient (costs, safety, security, pollution, space etc.), more flexible and thus resilient and serving thus general interests.

7 Discussion

As investigated in the previous, stakeholders such as technology providers, system integrators, private and public investors are required to invest time and money in order to achieve viable business models leading to a sustainable implementation of AVs in ITS. However, all stakeholders presented in this report are individually dependent on one another and can act as catalysts for each other's involvement and reward. Technological developments are crucial in terms of reaching the presented transitioning goals of increasing the speed and taking out the on-board safety steward. However, these technological advancements can not be achieved without investments from public and private actors and without willingness to integrate systems. Developing a platform suitable for implementation of autonomous vehicles in terms of enabling MaaS, is crucial in order to achieve intermodality between PTOs. This means that additional investments in systems integration is required, from both PTAs as well as other public and private investors, before a viable business model can be achieved.

Additionally, a BRT use case, as presented in this report, could enable a faster rollout, which should engage stakeholders in working together. Through private and public investments in the infrastructure needed, this could provide better development opportunities for vehicle technology, leading to viable business models.

Moreover, by engaging legislators to work toward establishing frameworks for area and type approvals, implementation costs could be reduced, beneficial to all stakeholders.