Automated Vehicles to Evolve to a New Urban Experience

DELIVERABLE

D8.4 Second Iteration Economic impact

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			3.1-3.3 and 3.5-3.8 (Business scenario) chapter 5 (externalities)

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Acronyms

ADS	*Automated Driving Systems*
AI	*Artificial Intelligence*
AMPT	*Automated Minibuses for Public Transport*
API	*Application Protocol Interface*
AV	*Automated Vehicle*
BES	*Business Ecosystem*
BMM	*Business Modelling Manager*
CAPEX	*Capital Expenditures*
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*
DMP	*Data Management Plan*
DWL	*deadweight loss*
DSES	*Department of Security and Economy Traffic Police*
DTU test track	*Technical University of Denmark test track*
EAB	*External Advisory Board*
EASI-AV©	*Economic Assessment of Services with Intelligent Automated Vehicles*
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	*Federal Roads Office*
FEDRO	*(Swiss) Federal Roads Office*
FOT	*(Swiss) Federal Office of Transport*
GDPR	*General Data Protection Regulation*
GHG	*GREENhouse gas*
GIMS	*Geneva International Motor Show*
GNSS	*Global Navigation Satellite System*
GWP	*Global warming potential*
HARA	*Hazard Analysis and Risk Assessment*
IPR	*Intellectual Property Rights*
IT	*Information Technology*
ITU	*International Telecommunications Union*
ICEV	*internal-combustion engine vehicles-*
KPI	*Key Performance Indicators*
LA	*Leading Author*
NEEDs	New energy externalities development for sustainability
NMVOC	*non-methane volatile organic compound*
NMT	*non-motorised transport*
NO	Nitrogen oxides
MaaS	*Mobility as a service*
MEM	*Monitoring and Evaluation Manager*
OCT	*General Transport Directorate of the Canton of Geneva*
ODD	*Operational Domain Design*
OEDR	*Object And Event Detection And Response*
OFCOM	*Federal Office of Communications*
OPEX	*Operation Expenditures*
PC	*Project Coordinator*
PCU	*Passenger Car Unit PCU*
PEB	*Project Executive Board*
PGA	*Project General Assembly*
PRM	*Persons with Reduced Mobility*
PRS	*Product related Service*
PSA	*Group PSA (PSA Peugeot Citroën)*
PTO	*Public Transport Operator (French: TPO)*
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	*Cantonal Vehicle Service*
SDK	*Software Development Kit*
SMB	*Site Management Board*
SoA	*State of the Art*
SOTIF	*Safety Of The Intended Functionality*
SUMP	*Sustainable Urban Mobility Plan*
SWOT	*Strengths, Weaknesses, Opportunities, and Threats.*
TCO	*Total Cost of Ownership*
TCM	*Total Cost of Mobility*
TDM	*Transportation Demand management*
TM	*Technical Manager*
TPO	*Transport Publique Operateur (engl. PTO)*
TTW	*Tank-to-Wheel*
UITP	*Union Internationale des Transports Publics*
VAS	*Value Added Service*
VKm	*vehicle kilometre travelled*
VSL	*Value of statistical life*
VOT	*Value of time*
VOLY	Value-of-statistical life
WP	*Work Package*
WPL	*Work Package Leader*
WTT	*WELL-TO-TANK*

Executive Summary

The AVENUE project aims to design and carry out full scale demonstrations of urban transport automation by deploying fleets of automated mini-buses in European cities. Within the project, the Work Package 8 (WP8), task T8.3 aims to evaluate the environmental, economic and social implications of implemented urban and suburban automated full-scale demonstrators.

This deliverable D8.4 deepens the insights presented in the deliverable D8.3 taking into account the remarks of the internal and external reviewers on previous D8.3. All remarks are addressed along the document with a short synthesis in the conclusion.

After the definition of the Sustainability Assessment framework and the Avenue Assessment framework on Section 2, this deliverable presents and details four business scenarios for the AVENUE services in Section 3 explaining all the relevant elements, stakeholders and possible business models within the contexts of Mobility-as-a-Service.

To assess the economic impact of AV of AVENUE in cities, we will first describe potential key scenario parameters to test the external cost of introducing the shuttles in cities. Section 5, the team proposes a macro-calculator tool for externalities at the city level based on data from the testing sites of the project. The methodology to calculate the externalities is detailed as well as the fleet calculator which is used to support the different scenarios planning to assess the impact of on-demand AV integrated in public transport in cities.

The economic impact is analysed at two levels: the local (micro) level and the macro level. On section 4, the micro level economic analysis is presented as a business case for the focused Business Scenario 1. The aim is to understand how the local economic balance of an automated fleet can be assessed before its deployment in a specific context. The pre-assessment is needed by policy makers or local government to take the decision of an automated fleet implementation. he pre-assessment must take into account the context, the targeted service specifications, the total cost of service deployment including externalities. WP8 T8.3 proposes a decision support tool that helps decision makers to calculate and analyze the economic impact on a micro level of automated collective vehicles before or after the service implementation. The tool is designed as a decision support tool. It aims to evaluate the economic impact of automated shuttle deployment either ante- or post implementation.

Section 5, the macro level analysis broadens the perspective by providing a complete qualitative analysis of the foreseen AVENUE services scenarios. A macro-calculator tool for externalities at the city is presented level based on data from the testing sites of the project. The methodology to calculate the externalities is detailed as well as the fleet calculator which is used to support the different scenarios planning to assess the impact of on-demand AV integrated in public transport in cities. At last, section 6 presents the overall conclusions of this deliverables and the next steps to be taken in the project.

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 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.

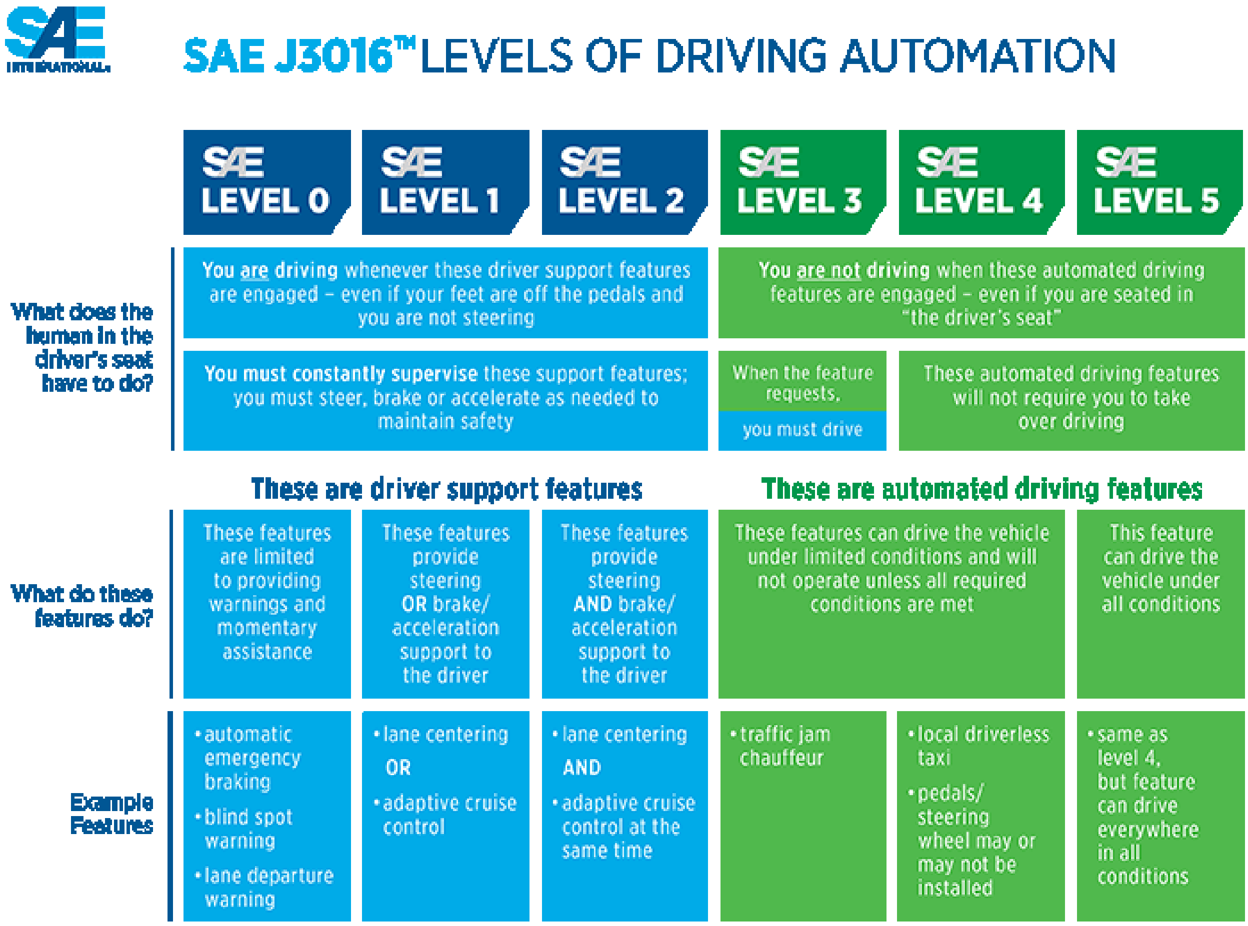
1.2 Fully Automated Vehicles

A self-driving car, referred in the AVENUE project as **an 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.



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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 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 takes into account 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 them or wait behind them, based on the defined policies. For example, with small changes in its route the AVENUE shuttle is able to bypass a parked car, while it will slow down and follow behind a slowly moving car. The AVENUE vehicles 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 shuttles 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 mini-busses.

1.3 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.

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1.4 Automated Vehicles

A self-driving car, referred in the AVENUE project as **an Automated Vehicle** (**AV**) is a vehicle that is capable of sensing its environment and moving safely with no human input. The choice of Automated vs Automated was made in AVENUE since, in the current literature, most of the vehicle concepts have a person in the driver's seat, utilize a communication connection to the Cloud or other vehicles, and do not independently select either destinations or routes for reaching them, thus being “automated”. The automated vehicles are considered to provide assistance (at various levels) to the driver. In AVENUE there will be no driver (so no assistance will be needed), while the route and destinations will be defined automatedly (by the fleet management system). The target is to reach a system comprising of vehicles and services that independently select and optimize their destination and routes, based on the passenger demands. In relation to the SAE levels, the AVENUE project will operate SAE Level 4 vehicles (see Figure 1).

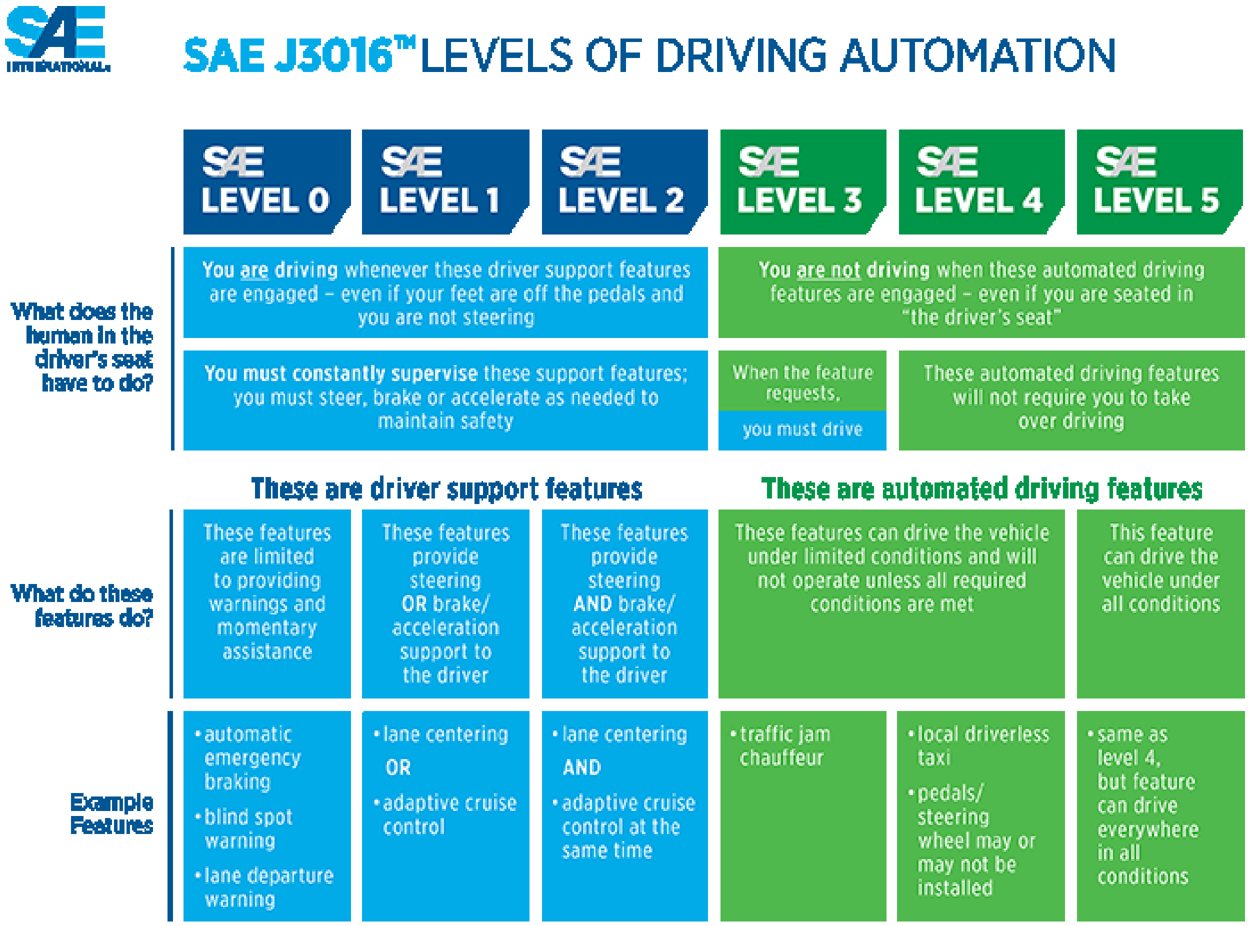

Figure 1. SAE levels of automation (©2020 SAE International)

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2 Methodology

This iteration of the deliverable presents different analysis tools to assess the costs and implications of the deployment of the Automated vehicles for public transport. It also presents strategic business design for AVENUE business scenarios. First, it starts by defining the Sustainable Urban Mobility Plans since it is the foundation of the sustainability assessment and by consequence the economic assessment. Second, it presents the AVENUE assessment framework as well as the resulting sustainable assessment. Finally, the methodology also defines the business strategy analysis adopted in this iteration.

2.1. Sustainability assessment: The SUMP Concept

Sustainable Urban Mobility Plan (SUMP) has been widely recognised, targeting sustainable and integrative planning processes to deal with the complexity and dynamicity of urban mobility (Eltis, 2020). It embraces new modes of transport, e.g. micro-mobility, automated and connected vehicles, and new concepts as Mobility as a Service (MaaS), shared mobility and so on.

The concept of SUMP comprehends the integration of all modes of transport, public and private, motorised and non-motorised and a long-term planning vision. It targets to improve the mobility accessibility, sustainability and citizens' well-being (European Commission, 2013).

SUMP is defined as *"a strategic plan designed to satisfy the mobility needs of people and businesses in cities and their surroundings for a better quality of life. It builds on existing planning practices and takes due consideration of integration, participation, and evaluation principles." (Rupprecht Consult, 2019)*

And it is guided by eight principles (Chinellato and Morfoulaki, 2019):

1) Aim of sustainable mobility for the 'functional urban area'
2) Assessment of current and future performance
3) Long-term vision as well as a clear implementation plan
4) Development of all transport modes in an integrated manner
5) Cooperation across institutional boundaries
6) Involvement of citizens and relevant stakeholders
7) Arrangements for monitoring and evaluation
8) Quality assurance

SUMP provides general guidelines for planning and implementation. It is composed by four main phases: i) Preparation and context analysis; ii) Strategy development; iii) Measure planning; iv) Implementation and monitoring.

Therefore, the present deliverable 'Economic impact assessment' aims to contribute bringing concepts, tools and findings that could support SUMP by addressing: the long-term vision and diverse business scenarios for AVs; a user centric approach and the integration of AVs with the different modes of transport. The outcomes from the business scenarios analysis, Total Cost of Ownership (TCO), Total Cost of Mobility (TCM) for AVs and mobility externalities could provide valuable inputs for instance for the SUMP phases 'Preparation and context analysis' and 'Strategy and Development' aiming the deployment of AVs to enhance public transport.

2.2 Avenue assessment framework

WP8 focuses on the environmental, economic and social assessment of the trials of AVENUE. It adopts an interdisciplinary approach to better conduct different analyses. It also helps to better understand the complexity of deploying new form of mobility in urban areas and as part of the transportation system. The goal is to implement a new mobility that is beneficial for the city and complementary to public transport. For instance, the surveys realized within the social assessment provide important insights to predict scenario for the automated vehicles and to calculate direct and indirect costs. Even more, the Life Cycle Assessment (LCA) is a source of environmental data that could be used to calculate environmental externalities. To better understand he different connections to the economic impact analysis, the AVENUE assessment framework is presented on Figure 2.

The framework describes three major axes: data input, methods and analysis, social economic, and environment assessments, and the concluding assessment which depends on the stakeholder analysis and the use cases of deployment. This figure will be further explained in the second iteration of the sustainability deliverable.

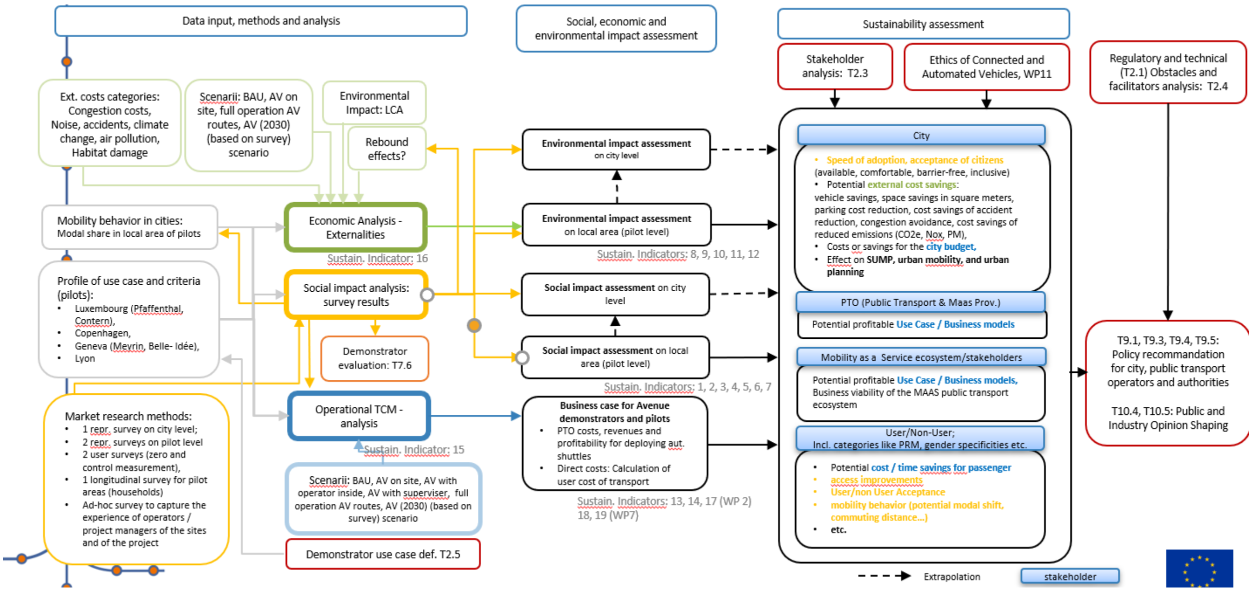


Figure 2. Framework of the AVENUE assessment of WP8

The following parts focus on the sustainable assessment axe and specifically on the stakeholder analysis and the demonstrator use cases because they contribute to the actual economic analysis.

In this framework, the stakeholders' analysis from WP2 as well as the ethics study of connected and automated vehicles from WP11 combined with the different economic tools help paint a picture on the impacts of these vehicles on different stakeholder groups. The use cases are divided based on potential impact on: the city, the public transport operator, the mobility as a service MaaS ecosystem, and the citizens.

The stakeholder analysis from WP2 is carried out on the city level. The assessment is in the form of interviews. The interviews are conducted with representatives of the stakeholders groups. It helps study in-depth the objectives of the key actors and the interactions between them. The insights collected play a role in determining the different business use cases, and to predict their feasibility and consequences (Feys et al., 2020). Moreover, understanding the relations between the stakeholders will also lead to better policy that is based on a participatory approach (Edelenbos, 1999). Even more, this study also helps in predicting future scenarios of use of automated vehicles in cities. These scenarios are further tested using the economic (externalities calculations, profitability analysis) .

Use cases are developed to showcase realistic situations that represents the interactions between the different stakeholders but to also reflect the mobility behaviour of users. The analysis takes into account the business development needs of the transport operators as well as the public interest of cities and citizens (Gebhardt et al. 2016). The different context of the AVENUE cities gives valuable insights in end-use behavioural patterns. This helps to further elaborate targeted and long-term use cases with different models of services integration. For instance, the shuttles as part of a mobility platform where the integrator is private and/or public. The use cases concern business development opportunities but also could provide the backbone for deployment scenarios within the cities.

Accordingly, the analysis falls within the overall AVENUE assessment where it contributes further to enriching, not only the economic assessment, but also the environmental and social assessment.

2.3 Economic assessment framework

The Economic Assessment Framework

The economic assessment is integrated in the WP8 framework and follows the people centric vision of mobility of the EU (German EU Council Presidency 2020) and UITP (UITP 2020). This vision is coherent with SUMP framework as mobility of people should respect the environment and be inclusive. The economic assessment framework analyses accordingly business scenario and externalities for several stakeholders like user and potential user, PTOs, cities and the new business ecosystems is a modular approach for a comprehensive analysis, identification, analysis & evaluation and planning of businesses for AVENUE. The planning modules are defined as follows:

1. **Analysis of the individual Status Quo Business Scenario (‘As-Is Use Case’)** ***→ ECP task***
   The As-Is Use Case is representing the Status Quo Business Scenario of AVENUE (PTO centred Ecosystem) as starting point of future focused business planning.

2. **Identification of applicable Future Business Scenarios (‘To-Be Use Cases’)** ***→ HSPF / Siemens***
   Possible To-Be Use Cases are representing Future Business Scenarios of AVENUE. The To-Be Use Cases are elaborated by a systematic identification methodology leading to a systemic model resulting in the Future Scenarios: 1. Automotive centred Ecosystem, 2. New Mobility Provider centred Ecosystem, 3. Customer/Citizen centred intermodal MaaS Ecosystem.

3. **Elaboration of operational Business Cases for the Status Quo Business Scenario** ***→ ECP task***
   Operational Business Cases are defined as Profitability Analyses. They are relevant only for the As-Is Use Case (PTO centred Ecosystem) due to the detailed availability of data of the Status Quo Scenario from AVENUE Use cases from pilot regions in the EU.

4. **Economic Analysis of Expected Externalities for cities for Business Scenarios & Use Cases** ***→ HSPF task in collaboration with environmental assessment task***
   Externalities are defined as positive or negative external impacts on the environment caused by AVENUE. These impacts are analyzed qualitatively and quantitatively by dedicated methods as a basis for conclusions, recommendations and improvement measures.

5. **Identification of Business Opportunities** ***→ HSPF / Siemens***
   Future Business Scenarios (To-Be Use Cases) are the examination field for the identification of attractive future Business Hunting Fields (Business Action or Business Innovation Fields) within an analytical analysis. Business Hunting Fields themselves are representing portfolios of promising Business Opportunities which have to be elicited, analyzed and evaluated within a creative expert based process.

7. **Identification of Business Strategies** ***→ Siemens / HSPF***
   Selected most promising Business Opportunities are the elaboration field for strategic business planning and thus for the definition of Business Strategies. Business Strategies represent a set of multi-functional promising Strategies (suggested strategic directions) covering different relevant perspectives of business activities of a socio-technical system.

8. **Definition of Business Model Concepts** ***→ Siemens / HSPF***
   Business Strategies are the strategic basis and guidance for the further exploitation of Business Opportunities by deployment into innovative Business Model concepts as a

promising logical story of how to run a business successfully. Business Models for AVENUE are suggested in a more general way for clusters of future businesses due to the open variability of application fields.

9. **Elaboration of operational <u>Business Cases</u> for intended Future Business Scenarios**
→ analog to elaboration in 3.

This task can only be approached by business planners after having conducted the tasks 4. - 8. (systematic elaboration of concrete business models) and defining concrete hypotheses for strategic directions (goals & strategies) and operational (e.g.) data and constraints.

Focusing an efficient qualitative approach of a strategic Business Planning for the Economic Assessment Framework, a practice proven 4 step approach has been applied as described in the items:

1. & 2. (Status Quo & Future) Business Scenarios Characterization	→	**Design Step 1**
5. Business Opportunities Identification	→	**Design Step 2**
7. Business Strategies Identification	→	**Design Step 3**
8. Business Models Definition	→	**Design Step 4**

In this Economic Assessment Framework these steps are titled as evolutionary 'Design Steps'. Each of the so-called 'Design Steps' are refined by a set of complementary methods (templates) for description or characterization, analysis, evaluation or design (see Figure 3).

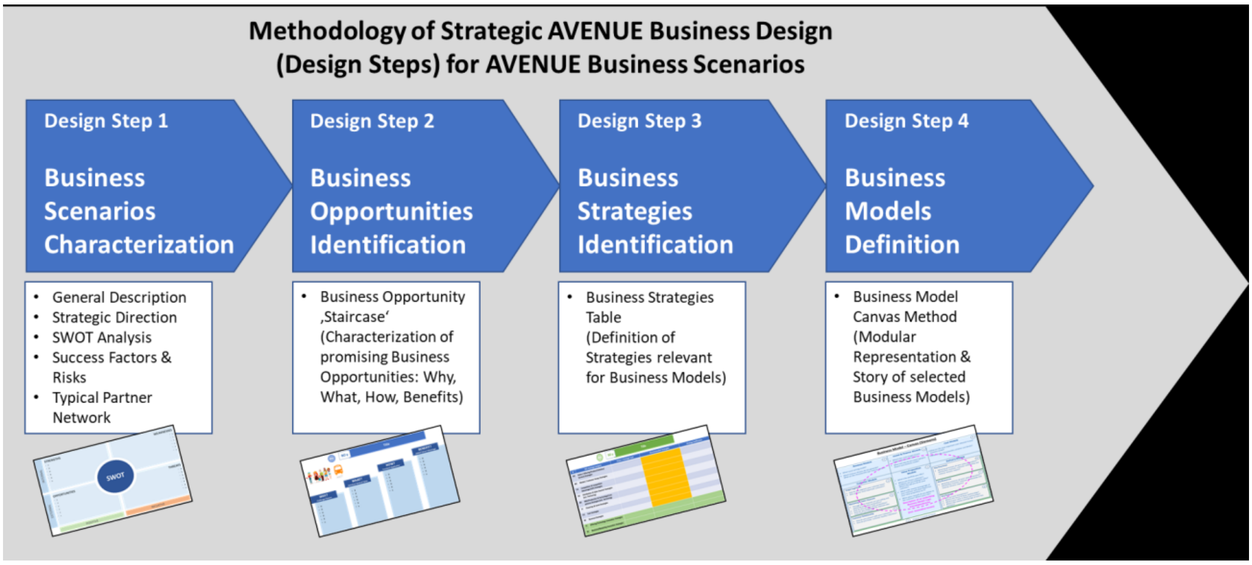


Figure 3. Methodology of Strategic AVENUE Business Design for AVENUE Business Scenarios

With this systematic methodological Economic Assessment Framework, the following elaborations have been conducted. They are intended as pragmatic guiding suggestions for structuring, analyzing, reflecting and planning of concrete future AVENUE businesses, e.g. as a user guide and high-level blueprint for AVENUE business planners.

This methodological approach of 'Design Steps' has been applied to alternative Business Scenarios (BS1 – BS4) which have been identified. Together they represent a conceptional Framework of building blocks for further elaborations of strategic business planning focusing the business with Automated Minibuses for Public Transport (AMPT)[1] as shown in (figure 4):

[1] AMPT = Automated Minibuses for Public Transport

Owner	Business Scenarios (relevant for AVENUE)	[redacted]	S1 General Business Characterization	S2 AVENUE Business Opportunities	S3 AVENUE Business Strategies	S4 AVENUE Business Models
		[redacted]	Bus. Ecosystem Definition, Bus. Potentials, Bus. Perspectives, Examples, etc.	Opp. Description, Opp. Evaluations	Ecosystem Strategies, Market Strategies, Offering Strategies, Competitor Strategies, Customer / Citizen Strategies, Functional Strategies (R&D, Marketing, etc.), Innovation Strategies, etc.	Business Model Canvas (e.g. Osterwalder/Pigneur, Siemens) (incl. Value Proposition [Values/Benefits, Cost / Time / Performance Benefits, etc.] / Offerings / Innovations / USPs for relevant Stakeholders), Cost Model, Revenue Model, Invest & Finance Model, Customer Model, Delivery Model), SWOT, Evaluation, etc.
ECP	**BS 1** TPO Centred Ecosystem (Traditional Approach currently applied at the 6 AVENUE Pilots)	AVENUE – Trad. Approach	tbd. by ECP	tbd. by ECP	tbd. by ECP	tbd. by ECP, based on Business Case Calculator (quantitative business profitability analysis based on an integrated cost/revenue calculation)
HSPF /SAG	**BS 2** Automotive Centred Ecosystem	Moia, car2go			*Which successful business (vision, goal, strategy, business opportunities, business models) can AVENUE play in each of the four different scenarios?*	
HSPF /SAG	**BS 3** New Mobility Provider Centred Ecosystem	Uber, UberPool, Lyft-US, blablalines				
HSPF /SAG	**BS 4** Customer/ Citizen Centred Intermodal MaaS Ecosystem	MaaS-Global, Clever Shuttle-DB, Moia, Moovel, City Mapper, MoovIT, Uber				

Figure 4: Conceptional Framework of Strategic Business Planning for AMPT

In the following chapters the Design Modules (Task Building Blocks) determined by Business Scenarios vs. Design Steps within the Economic Assessment Framework are elaborated characterizing alternative AVENUE businesses from a general and highly aggregated point of view. They are prepared for being focused and refined to a concrete AVENUE application scenario offered by a likewise concrete tender.

3 Business Scenarios

Goal of this chapter is to develop a method concept and basic framework for the general identification of As Is (Past/Status Quo) and main To Be (Future) Business Scenarios as well as the identification and selection of most promising Business Opportunities within each of these Business Scenarios. Both are the basis for the detailed elaborations within the subsequent subchapters.

3.1 The Mobility Ecosystem approach as the central success factor

Platform based digital Business Ecosystems are regarded as success factors for companies in the highly competitive 'Age of Digitalization'. Triggered by this megatrend, Mobility Ecosystems are transforming all their assets (strategies, offerings, processes, collaborative relations, etc.) to be ready for platform based digital businesses with horizontal or vertical business partners and end users. In this sense Mobility Business Ecosystems (BES[2]) are regarded as core networks of players in the mobility market. This mobility market can be represented by the existing Status Quo Business Scenario as well as by various possible alternative Future Business Scenarios (BS). Especially multimodal seamless transportation needs - integrating AMPT's as a missing link - are predestined for applying digital technologies and leveraging virtual collaboration approaches within mobility ecosystems. With AMPT, public transport offering could be individualised, much more attractive and thus a real alternative to individual vehicles. The following elaborations regard Mobility Ecosystems as a precondition for the success of AMPT's and their related partners and offerings. In this sense Mobility Ecosystems are regarded as the central success factor for AVENUE and the basis for future scenarios.

[2] BES = Business Ecosystem

3.2 Development of a conceptional grid for business scenarios

As an extension of an existing empirical Study (McKinsey)[3] identifying the competitive landscape for the individual automotive market for the past & present as well as the future (2030), the following competitive landscape (Business Scenarios) for Automated Shuttles for Public Transport (AMPT) has been derived using an analogue structure.
This empirical study shows that in the past and present (Status Quo) established automotive OEMs and their traditional business ecosystems (e.g. suppliers) are competing generally with one another as separate players. In the future (horizon 2030) competition will happen in a complex market landscape with digital business ecosystems of established and new players (integrators). At the same time there are further game changing shifts or extensions of the transportation market upcoming: from unimodal to multimodal mobility providers, from offering platforms to interaction platforms, from ownership to Mobility-as-a-Service, and more.
These disruptive competition developments and general Business Scenarios can be also detected in the market for AMPT's due to the fact that both subdomains of the superordinated automotive domain are technologically extremely related or identically (e.g. sensor technologies, automated driving) and businesswise also very comparable (e.g. archetypical categories of mobility competitors). For this reason, it is valid to adapt the empirical Study from McKinsey in an analogue way for the competitive landscape of AMPT's. Additional to this adapted Business Scenario concept there is a strong trend or development of MaaS and data space ecosystems to be recognized within the public mobility sector, which has to be regarded and which extends the so defined Business Scenario concept. This fits also to the new strategy of the European Union where "smart digitalisation presents great opportunities for future-proof mobility" and where it is expected that "integrated multimodal transport ecosystem" will emerge to realise these opportunities. The new ITS Directive 2021 is being drafted accordingly (see German EU Council Presidency 2020). These adaptions are displayed in (figure 5):

[3] Adapted from McKinsey: https://www2.ineel.mx/vehiculo_electrico/documentos/automotive-revolution.pdf, Mohr, Detlev; Kaas, Hans-Werner: Automotive revolution - perspective towards 2030. How the convergence of disruptive technology-driven trends could transform the auto industry. In: McKinsey & Company 2016. Online verfügbar unter https://www2.ineel.mx/vehiculo_electrico/documentos/automotive-revolution.pdf, zuletzt geprüft am 08.11.2020.

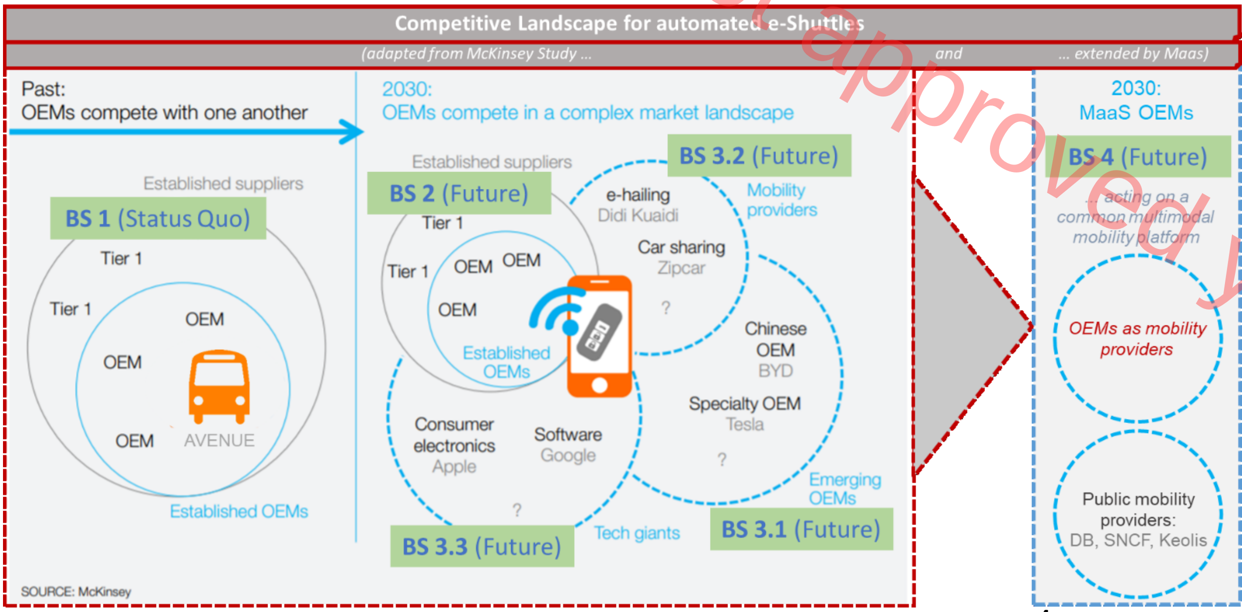


Figure 5. Competitive Landscape for Automated Shuttles for Public Transport (AMPTs[4])

While the Business Scenario of the Status Quo (or Past) in this AMPT adapted concept is titled as (BS 1), there will be a competition of several AMPT providers with according Business Ecosystems (BES) in the future AMPT market (horizon: 2030) which represent separate Future Business Scenarios. All Business Scenarios identified this way are:

1. **Status Quo Scenario – BS 1**
   PTO centred Business Ecosystems

2. **Future Business Scenario – BS 2:**
   Automotive (OEM) Provider centred Business Ecosystems

3. **Future Business Scenario – BS 3:**
   New Mobility Providers centred Business Ecosystems

4. **Business Scenario – BS 4:**
   Mobility-as-a-Service (MaaS) centred Business Ecosystems

Regarding the **New Mobility Providers centred Business Ecosystems (BS 3)** the following Sub-Scenarios – categorized by their technology or business origin – can be identified according to their business origin (either data business, or mobility transaction business, or technological/business innovators). This way the Business Scenario BS 3 are refined into 3 further categories:

1. **Business Scenario – BS 3.1:** Business Ecosystem Providers with data based origin
2. **Business Scenario – BS 3.2:** Business Ecosystem Providers with transaction based origin
3. **Business Scenario – BS 3.3:** Business Ecosystem Providers with innovation based origin

The conceptual extension of the Business Scenario with Mobility-as-a-Service (MaaS) centred Business Ecosystems – **Business Scenario - BS 4** provides additional subcategories of Business Ecosystems which will be analyzed in depth in a further conceptional analysis:

[4] AMPT = Automated Minibuses for Public Transport

1. **Private integrated Mobility-as-a-Service (MaaS)** centred Business Ecosystems
2. **Public integrated Mobility-as-a-Service (MaaS**) centred Business Ecosystems
3. **Private & Public (both) integrated Mobility-as-a-Service (MaaS)** centred Business Ecosystems

Summarizing all 4 Business Scenarios and identified refinements the following final framework of Business Ecosystem Scenarios (BES) (see figure 6) can be displayed, defining the conceptional grid for all subsequent strategic business planning elaborations for AMPT's:

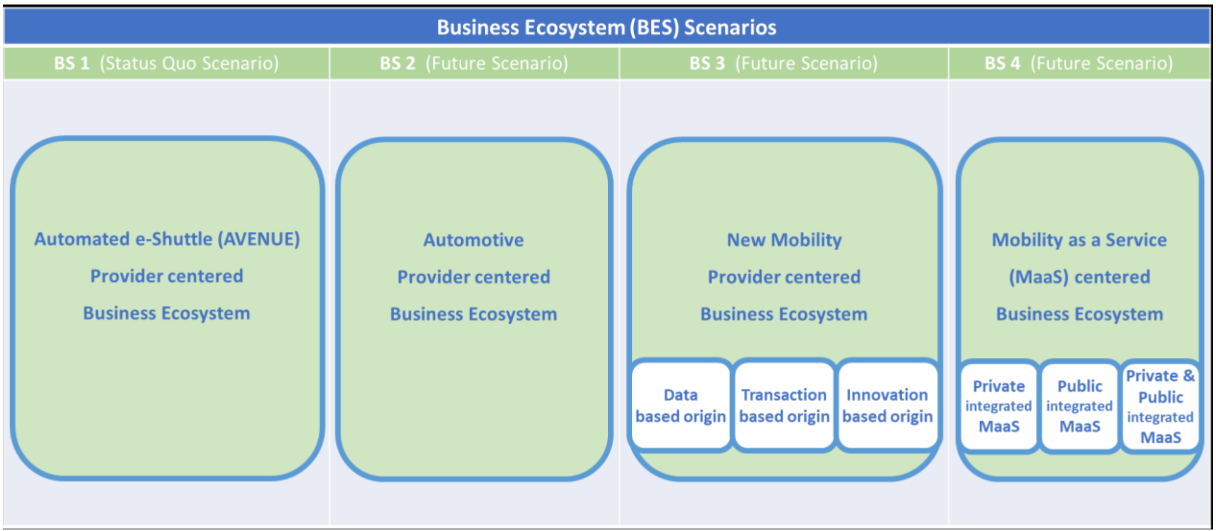


Figure 6. Framework of Business Ecosystem (BES) Scenarios

The Business Scenarios and Subscenarios displayed in this conceptional grid can be characterized in a preliminary and high-level way by first comparing definitions describing the different background and focus as well as main differentiating characteristics and emphases (see figure 7):

Business Ecosystem (BES) Scenarios			
BS 1 (Status Quo Scenario)	**BS 2** (Future Scenario)	**BS 3** (Future Scenario)	**BS 4** (Future Scenario)
Automated e-Shuttle Provider (AVENUE) centered Business Ecosystem	Automotive Provider centered Business Ecosystem	New Mobility Provider centered Business Ecosystem	Mobility as a Service (MaaS) centered Business Ecosystem
• **Mix** of **unimodal** and **multimodal approaches** • Automotive provided centred, new mobility provided centred and MAAS centred business ecosystems (BS 2-4) **in embryonal maturity statuses** • **AVENUE** as a consortium of complementary partners for automated e-shuttles **tries to develop its own business ecosystem** within the developing market situation described above • **Financial and resource basis** as well as **market coverage** and **customer access** are **very limited** • Currently **no integration with other platforms** / ecosystems available • **Strong competition** (e.g. EasyMile, smarter together) with similar platform / ecosystems based on automated e-shuttle innovations	• **Automotive Manufacturers** become **customer-oriented mobility** & **service providers** through product- and market diversification • Existing business models are facing **digitalization, connectivity** and **disruptive innovations** in vehicle technologies. • **Shift of value creation** from **automotive (i.e. vehicle) offerings** towards **usage of user and vehicle data.** • Integrated **digital service innovations** are needed in order to meet **changing customer requirements**	**Digital transformation** enables **competitors from different industries** to appear as new players on the market: 1. **New DATA BASED mobility providers or internal startups from IT-Tech giants** diversify their offering portfolio by extending their ecosystems with mobility services 2. **New TRANSACTION BASED mobility providers or transaction platform startups** are entering the market with innovative digital mobility services and providing transaction platforms for partners and citizens 3. **New INNOVATION BASED mobility providers or emerging OEMs and automotive technology startups** are trying to conquer the market through e-mobility and automated vehicles, which will provide innovative products, solutions, services and infrastructures	• **MaaS Providers** connect different modalities of transport to **intermodal seamless travel chains.** • Maas offerings provide a **fully integrated** and seamless transport for dedicated passenger journeys, enabled by integrated **ticketing concepts, tariff packages and information & communication technologies (ICT)** • MaaS systems allow consumers to purchase **multimodal mobility services** offered by central or distributed mobility providers (TPOs) on a **common single platform** • Mobility providers and ecosystems from BS1/2/3 **are integrated in a complementary & synergetic** way

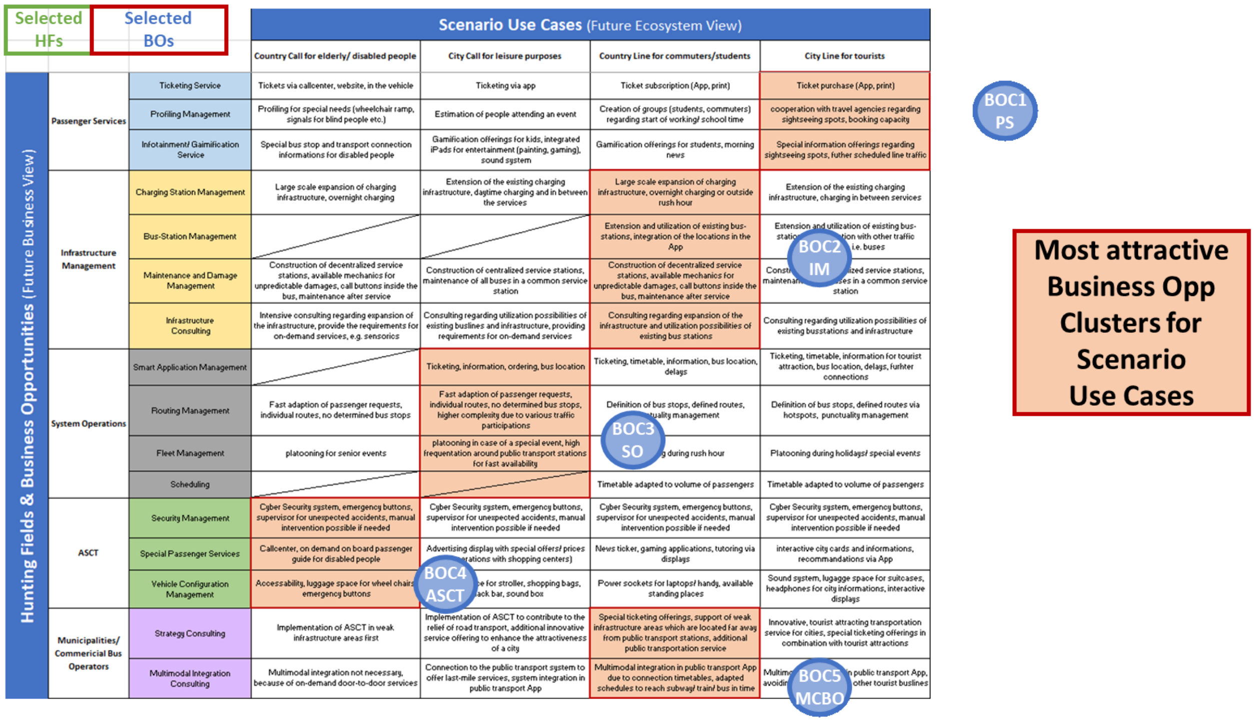
Figure 7. High Level Characterization of Business Ecosystem (BES) Scenarios

The Business Scenarios characterized and defined this way are further on regarded as 'Action Fields' for this strategic AMPT study representing a reference frame for detailed elaborations.

3.3 Identification of Business Opportunities with-in Business Scenarios

After the conceptional development of AVENUE **Business Scenarios** to be characterized in details within **Design Step S1**, it is a main goal of this study to provide a methodology to identify and describe attractive AVENUE **Business Opportunities** (or at least Business Opportunity Clusters) further on elaborated within **Design Step S2**. Business Opportunities are regarded as strategic action fields for which promising AVENUE **Business Strategies** are designed within **Design Step S3** as strategic guidance of promising AVENUE **Business Models** identified within **Design Step S4**.

A useful basis for identifying Business Opportunities are the previously identified Hunting Fields and their according Business Opportunities (Clusters) elaborated from AVENUE Use Cases (AVENUE Deliverable 2019, see figure 8):



Hunting Fields & Business Opportunities (Future Business View)		Scenario Use Cases (Future Ecosystem View): Country Call for elderly/ disabled people	City Call for leisure purposes	Country Line for commuters/students	City Line for tourists
Passenger Services	Ticketing Service	Tickets via callcenter, website, in the vehicle	Ticketing via app	Ticket subscription (App, print)	Ticket purchase (App, print)
	Profiling Management	Profiling for special needs (wheelchair ramp, signals for blind people etc.)	Estimation of people attending an event	Creation of groups (students, commuters) regarding start of working/ school time	cooperation with travel agencies regarding sightseeing spots, booking capacity
	Infotainment/ Gaimification Service	Special bus stop and transport connection informations for disabled people	Gamification offerings for kids, integrated iPads for entertainment (painting, gaming), sound system	Gamification offerings for students, morning news	Special information offerings regarding sightseeing spots, futher scheduled line traffic
Infrastructure Management	Charging Station Management	Large scale expansion of charging infrastructure, overnight charging	Extension of the existing charging infrastructure, daytime charging and in between the services	Large scale expansion of charging infrastructure, overnight charging or outside rush hour	Extension of the existing charging infrastructure, charging in between services
	Bus-Station Management			Extension and utilization of existing bus-stations, integration of the locations in the App	Extension and utilization of existing bus-statio[illegible]tion with other traffic i.e. buses
	Maintenance and Damage Management	Construction of decentralized service stations, available mechanics for unpredictable damages, call buttons inside the bus, maintenance after service	Construction of centralized service stations, maintenance of all buses in a common service station	Construction of decentralized service stations, available mechanics for unpredictable damages, call buttons inside the bus, maintenance after service	Const[illegible]ized service stations, maintenan[illegible]ses in a common service station
	Infrastructure Consulting	Intensive consulting regarding expansion of the infrastructure, provide the requirements for on-demand services, e.g. sensorics	Consulting regarding utilization possibilities of existing buslines and infrastructure, providing requirements for on-demand services	Consulting regarding expansion of the infrastructure and utilization possibilities of existing bus stations	Consulting regarding utilization possibilities of existing busstations and infrastructure
System Operations	Smart Application Management		Ticketing, information, ordering, bus location	Ticketing, timetable, information, bus location, delays	Ticketing, timetable, information for tourist attraction, bus location, delays, furhter connections
	Routing Management	Fast adaption of passenger requests, individual routes, no determined bus stops	Fast adaption of passenger requests, individual routes, no determined bus stops, higher complexity due to various traffic participations	Definition of bus stops, defined routes, [illegible]uality management	Definition of bus stops, defined routes via hotspots, punctuality management
	Fleet Management	platooning for senior events	platooning in case of a special event, high frequentation around public transport stations for fast availability	[illegible] during rush hour	Platooning during holidays/ special events
	Scheduling			Timetable adapted to volume of passengers	Timetable adapted to volume of passengers
ASCT	Security Management	Cyber Security system, emergency buttons, supervisor for unexpected accidents, manual intervention possible if needed	Cyber Security system, emergency buttons, supervisor for unexpected accidents, manual intervention possible if needed	Cyber Security system, emergency buttons, supervisor for unexpected accidents, manual intervention possible if needed	Cyber Security system, emergency buttons, supervisor for unexpected accidents, manual intervention possible if needed
	Special Passenger Services	Callcenter, on demand on board passenger guide for disabled people	Advertising display with special offers/ prices [illegible]rations with shopping centers)	News ticker, gaming applications, tutoring via displays	interactive city cards and informations, recommandations via App
	Vehicle Configuration Management	Accessability, luggage space for wheel chairs, emergency buttons	[illegible]e for stroller, shopping bags, [illegible]ack bar, sound box	Power sockets for laptops/ handy, available standing places	Sound system, lugagge space for suitcases, headphones for city informations, interactive displays
Municipalities/ Commericial Bus Operators	Strategy Consulting	Implementation of ASCT in weak infrastructure areas first	Implementation of ASCT to contribute to the relief of road transport, additional innovative service offering to enhance the attractiveness of a city	Special ticketing offerings, support of weak infrastructure areas which are located far away from public transport stations, additional public transportation service	Innovative, tourist attracting transportation service for cities, special ticketing offerings in combination with tourist attractions
	Multimodal Integration Consulting	Multimodal integration not necessary, because of on-demand door-to-door services	Connection to the public transport system to offer last-mile services, system integration in public transport App	Multimodal integration in public transport App due to connection timetables, adapted schedules to reach subway/ train/ bus in time	Multim[illegible] public transport App, avoidi[illegible] other tourist buslines

Figure 8. Adaption of Hunting Fields and Business Opportunity Clusters (vertical categories) for competitive elaborations for AMPT Ecosystems

These Hunting Fields and Business Opportunities (vertical categories) from the previous AVENUE Deliverable have been originally identified to identify Passenger Scenario Use Cases regarding passenger (end user) groups. In this context of competitive Business Scenarios with PTOs however they are beneficial as well and can be reused and adapted for Business (Opportunity) Ecosystem purposes, where all stakeholders of an identified Business Opportunity are interacting with each other in order to generate value for every player (i.e. AVENUE, other AMPT system providers, PTOs, passengers).
Combining these Hunting Fields and Business Opportunities with the now focused Business Scenarios BS2 - BS3 (BS3.1, BS3.2, BS3.3) within a matrix, they have been creatively reinterpreted, evaluated and selected towards 'most promising' Business Opportunities & Business Opportunity Clusters (green fields) - represented by competitive ecosystem applications - for the mentioned Business Scenarios (see figure 9).

	Selected HFs (Hunting Field = Future strategic business field)	Selected BOs	Business Scenarios: Automotive Centred (BS2) Daimler	New Mobility Provider Centred (BS3): New Data based Google	New Mobility Provider Centred (BS3): New Transactions Based Uber	New Mobility Provider Centred (BS3): New Innovation Based Tesla	MaaS Centred (BS4)
Hunting Fields & Business Opportunities (Future Business View) input from Opportunity proposal BO 2019	Shuttle solutions (vehicle)	Vehicle Operations	Conduction of operation of automotive providers shuttle fleet or automotive branded shuttle fleet	Partnership regarding vehicle/fleet operations within new data based providers ecosystem	Operation partnership within transaction based ecosystem and sharing of transaction fees	Conduction of operation of new innovation based providers shuttle fleet or new innovation based branded shuttle fleet	
		Vehicle Sales	Sales of vehicles to automotive providers	Sales of vehicles to new data based mobility providers	Sales of vehicles to new transaction based mobility providers	Sales of vehicles to new innovation based mobility providers	
		Vehicle Leasing/Rental/Licensing	Leasing/Rental/Licensing of vehicle concepts to automotive providers	Leasing/Rental/Licensing of vehicle concepts to new data based mobility providers	Leasing/Rental/Licensing of vehicle concepts to new transaction based mobility providers	Leasing/Rental/Licensing of vehicle concepts to new innovation based mobility providers	
		Vehicle Concept consulting	Consulting of automotive providers regarding possible vehicle concepts for individual use cases	Consulting of new data based mobility providers regarding possible vehicle concepts for individual use cases	Consulting of new transaction based mobility providers regarding possible vehicle concepts for individual use cases	Consulting of new innovation based mobility providers regarding possible vehicle concepts for individual use cases	
		Vehicle Design/Adaption	Individual fitting of the shuttles regarding special customer needs e.g. wheel chair ramps, luggage space, power sockets, etc.	Individual fitting of the shuttles regarding special customer needs e.g. wheel chair ramps, luggage space, power sockets, etc.	Individual fitting of the shuttles regarding special customer needs e.g. wheel chair ramps, luggage space, power sockets, etc.	Individual fitting of the shuttles regarding special customer needs e.g. wheel chair ramps, luggage space, power sockets, etc.	
	Shuttle components/ technology	Vehicle components/ technology Operations					
		Sales of components/technology	Sales of patents and technological USPs to automotive providers	Sales of patents and technological USPs to New data based mobility providers	Sales of patents and technological USPs to New transaction based moblity providers	Sales of patents and technological USPs to New innovation based moblity providers	
		Leasing/Rental/Licensing of components/technology	Leasing/Rental/Licensing of patents and technological USPs to automotive provider	Leasing/Rental/Licensing of patents and technological USPs to new data based mobility providers	Leasing/Rental/Licensing of patents and technological USPs to new transaction based mobility providers	Leasing/Rental/Licensing of patents and technological USPs to new innovation based mobility providers	
	Product Related Service (PRS)	Vehicle Maintenance / spare parts (Vehicles / Batteries / Sensoric Equipment / Infotainment)	Construction of decentralized service stations, available mechanics for unpredictable damages, emergency call buttons inside the vehicle, maintanance after service	Construction of decentralized service stations, available mechanics for unpredictable damages, emergency call buttons inside the vehicle, maintanance after service	Construction of decentralized service stations, available mechanics for unpredictable damages, emergency call buttons inside the vehicle, maintanance after service	Construction of decentralized service stations, avaible mechanics for unpredictable damages, emergency call buttons inside the vehicle, maintanance after service	
		Vehicle fleet management	Manage, plan, control and monitor autonomous shuttle fleets for automotive mobility providers	Manage, plan, control and monitor autonomous shuttle fleets for new data-based mobility providers	Manage, plan, control and monitor autonomous shuttle fleets for new transaction-based mobility providers	Manage, plan, control and monitor autonomous shuttle fleets for new innovation-based mobility providers	indirect integration of AVENUE System (BS2/3 Components) -> business parts
		PRS for Battery, Sencoric Equipment, Infotainment, Vehicle	Offer PRS for automotive providers (maintenance of sensoric equimpment, battery, ...)	(x)	x	Battery production / maintanance / sales /leasing,	
	Value Added Service (VAS)	Data based Services	Analyse/tracking/tracing/prediciton/routing/(cyber) security tools for automotive providers	x	(Analyse/tracking/tracing/prediciton/routing/(cyber) security tools for new transaction based mobility providers)	(Analyse/tracking/tracing/prediciton/routing/(cyber) security tools for new innovation based mobility providers)	
		Ticketing Services	Ticketing concepts (App/website), Ticket subscriptions	Ticketing concepts (App/website), Ticket subscriptions	Ticketing concepts (App/website), Ticket subscriptions	Ticketing concepts (App/website), Ticket subscriptions	
		Passenger Services	Security / Comfort /Entertainment services through e.g. on board passenger guide, health care services, food services, gamification offerings, Callcenter support, on board passenger guide, interactive displays, personalized recommendations via App, cooperations with travel agencies regarding sightseeing spots/booking capacity	Security / Comfort /Entertainment services through e.g. on board passenger guide, health care services, food services, gamification offerings, Callcenter support, on board passenger guide, interactive displays, personalized recommendations via App, cooperations with travel agencies regarding sightseeing spots/booking capacity	Security / Comfort /Entertainment services through e.g. on board passenger guide, health care services, food services, gamification offerings, Callcenter support, on board passenger guide, interactive displays, personalized recommendations via App, cooperations with travel agencies regarding sightseeing spots/booking capacity	Security / Comfort /Entertainment services through e.g. on board passenger guide, health care services, food services, gamification offerings, Callcenter support, on board passenger guide, interactive displays, personalized recommendations via App, cooperations with travel agencies regarding sightseeing spots/booking capacity	
	Infrastructure	Infrastructure Service and Maintenance	large scale expansion of charging infrastructure, build up and manage infotainment, IT, cyber security, comfort, healthcare infrastructure	large scale expansion of charging infrastructure, build up and manage infotainment, IT, cyber security, comfort, healthcare infrastructure	large scale expansion of charging infrastructure, build up and manage infotainment, IT, cyber security, comfort, healthcare infrastructure	large scale expansion of charging infrastructure, build up and manage infotainment, IT, cyber security, comfort, healthcare infrastructure	
		Operating Models					
		Infrastructure Design/Adaption					
		Infrastructure as a Service					
		Leasing/Rental/Licensing Models					
		Infrastructure sales					
		Infrtastructure management					
		Infrastructure Concept consulting	Consulting regarding utilization possibilities of existing infrastructure / expansion of the infrastructure / requirements for IT & Data infrastructure / requirements for on-demand services	Consulting regarding utilization possibilities of existing infrastructure / expansion of the infrastructure / requirements for IT & Data infrastructure / requirements for on-demand services	Consulting regarding utilization possibilities of existing infrastructure / expansion of the infrastructure / requirements for IT & Data infrastructure / requirements for on-demand services	Consulting regarding utilization possibilities of existing infrastructure / expansion of the infrastructure / requirements for IT & Data infrastructure / requirements for on-demand services	
	Total AVENUE System						direct Integration of total AVENUE System

Figure 9. Identification of most promising Business Opportunity Clusters & Opportunities (green)

This selection of most promising Business Opportunity Clusters (BO 1 – BO 4) obtained this way can be assigned to the Business Scenarios (BS 2 & BS 3) evaluated or justified for differentiated relevance using the SWOT analysis method (see figure 10):

			SWOT Justification of Business Opportunities	
BS2	Automotive Centred Ecosystem (BS2)		• Lack of competencies of software • Outsourcing of non-core services • Lack of user-related data of OEMs • Since AVENUE is already testing Automated shuttles, they have more experience from which the OEMs can benefit	**BO 1** Provide **Value Added** Automated E-Shuttle **Services (VAS)** to **Automotive Centered** Mobility Providers
BS3	New Mobility Provider Centred Ecosystem (BS3)	New Data Based Ecosystem (BS3.1)	• Lack of competencies in the field of vehicle construction • Since AVENUE is already testing with Automated shuttles, they have more experience (special equipment, placement of sensors, placement of seats) from which new data based mobility providers can benefit	**BO 2** Provide Automated E-Shuttle **Solutions** to **New Data Based** Mobility Providers
		New Transactions Based Ecosystem (BS3.1)	• Transaction based mobility provider does not offer shuttle solutions so far • AVENUE can earn a share of the driving costs • High level of initial investment required which can be bypassed	**BO 3** Provide Automated E-Shuttle **Solutions** to **New Transaction Based** Mobility Providers
		New Innovation Based Ecosystem (BS3.1)	• High level of initial investment to build a service network can be bypassed • Complex fleet management can be efficiently handled by AVENUE	**BO 4** Provide **Product Related** Automated E-Shuttle **Services (PRS)** to **New Innovation Based** Mobility Providers

Figure 10. Assignment of most promising Business Opportunity Clusters (BO1-4) to Business Scenarios BS2 & BS 3

After the identification and rough characterization of Business Opportunities for BS2 & BS3 it is necessary to find a conceptual form for the classification of most relevant MaaS Business Ecosystem patterns which have been empirically identified (Fournier, 2020) as 'Customer/ Citizen Centred Intermodal MaaS centred Ecosystems' (see Figure 11).

The current transportation offer could be described as a unimodal. There is a clear separation between individual means of transport, and private and public transport providers (public transport, taxis, Uber, etc.). Due to the introduction of smart mobility, such as automated vehicles and shared mobility, this model is changing (UITP, 2019a).

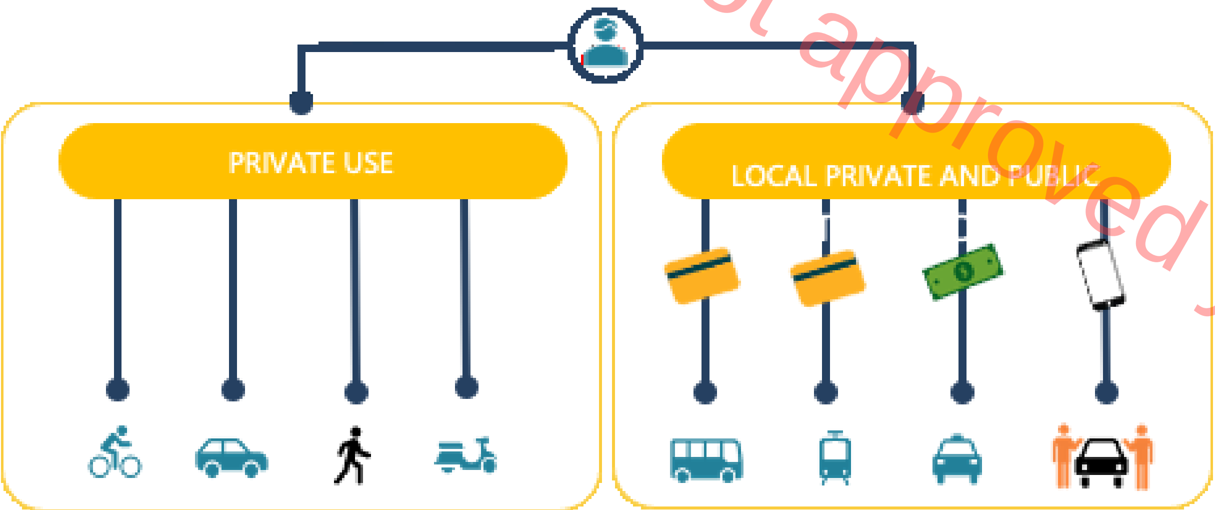


Figure 11. 'Customer/ Citizen Centred Intermodal MaaS centred Ecosystems' (Fournier, 2020)

Policymakers are trying to advocate for an intermodal integration to replace car centricity (Roland Berger, 2018). MaaS is positioned to offer solutions to shift towards a citizen-centred intermodal ecosystem. Under this approach, MaaS plays the role of a provider of services but also of a mobility integrator. The MaaS concept focuses on the passenger's needs while considering the needs of the different stakeholders. By optimising on-demand services and relying on new digitalised features, the user could access an integrated and digital platform, and book one journey combining different means of transport (private, public) with one ticket. Integrated ticketing and smart card schemes could lead to a better travel experience and a stronger collaboration between public and private transport (OECD, 2016). The digital platform combines end-to-end trip planning, booking, and ticketing which facilitates door-to-door journeys (Goodall et al. 2017)

The following Customer centric MaaS Providers are systemically interconnected with the Mobility integrator as a central role (see Figure 12):

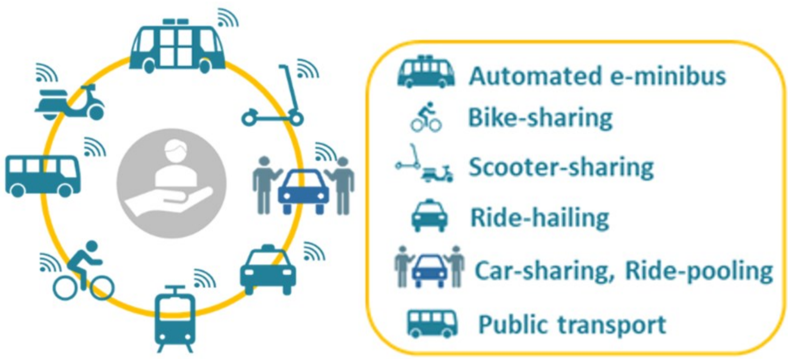


Figure 12. Customer- centric MaaS Provider and Mobility integrator (Fournier, 2020)

According to UITP (2019a), a MaaS provider or an integrator is responsible for the framework connecting transport operators and citizens and providing access to mobility services. An integrator could be a public transport authority, public or private transport operator, or a telecommunication/banking company. The role of the integrator also defines the boundaries of this ecosystem. An integrator is responsible for customer and data monetization, commissioning, advertising, as well as big data (Roland Berger, 2018). Thus, it is essential to identify who should be the MaaS integrator that could potentially "attract the maximum customers to produce the maximum benefits for sustainable and affordable mobility" (UITP 2019a). The integrator requires access to essential transport, ticketing, and passenger data. The main concern for the transport operator would be the loss of customers if they were to make their data accessible to a third party. Thus, an integrator must be unbiased, fair, innovative, and reliable, even more, they must be capable

of processing and combining data from different transport and infrastructure operators (UITP, 2019b).
This topic is more relevant due to the deployment of automated vehicles and shared automated vehicles. More specifically, on demand-automated e-minibuses could be integrated into the public transport system, as feeders to public transport stations or as area-based on-demand vehicles. To avoid repeating the car-centric model with AVs, the UITP (2017) recommends the deployment of Avs in the form of shared fleets that are integrated with public transport, this is established through an integrated MaaS platform. Hence, the MaaS operator has the power to influence mobility behavior (UITP, 2017). MaaS business models rely on the power balance between private and public transport (Pickford and Chung, 2019). This part presents the potential MaaS integrators
There are 3 basic patterns for MaaS ecosystem configurations:

1. MaaS ecosystem Pattern 1: Private transport operator is the integrator
2. MaaS ecosystem Pattern 2: Public transport operator is the integrator
3. MaaS ecosystem Pattern 3: Public and private transport operators are the integrators

MaaS ecosystem Pattern 1 (Private transport operator is the integrator) can be represented in the following graphical schematics (see

Figure 13):

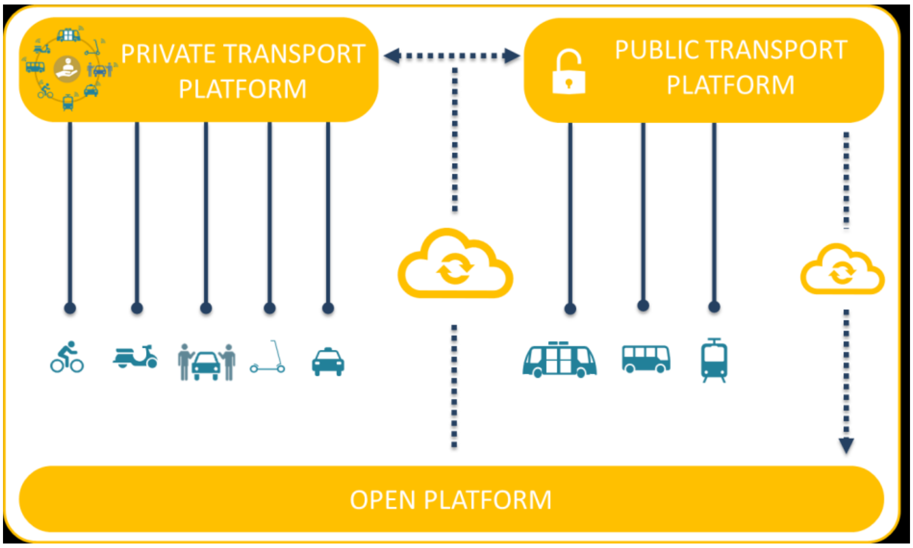


Figure 13. Private transport operator is the integrator (Fournier, 2020)

In this scenario, private transport is competing with public transport rather than both parties assuming complementary roles. It is characterized with a monopoly of data, where the private operators do not share their data with the public operators. Thus, private transport is most likely to prioritize their transport services over public ones (Pickford and Chung, 2019). However, the user has access to customer-centric data. This case further increases the division between the transport operators and the MaaS operators. The consequences are a divided vision on achieving intermodal transport, fragmented market, ambiguity concerning data sharing and privacy, and no collaboration among the different stakeholders (Roland Berger, 2018). This approach is less effective and is eventually less sustainable as it leads to the displacement of public transport as well as an increased in urban traffic and by consequence, an increase in external costs.

MaaS ecosystem Pattern 2 (Public transport operator is the integrator) can be represented in the following graphical schematics (see Figure 14):

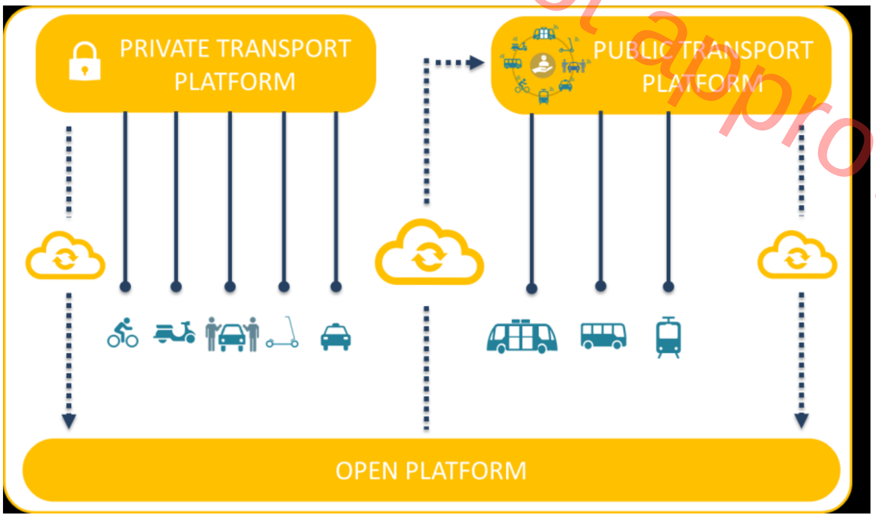


Figure 14. Public transport operator is the integrator (Fournier, 2020)

With public transport as an integrator, data is shared to an open platform, and it provides integrated customer-centric data to passengers. This could reduce the privatization of urban transport services and secure the position of public transport (UITP, 2017). However, if the MaaS integration is the responsibility of public transport, it might lead to less competitive services (Arby, 2016).

MaaS ecosystem Pattern 3 (Public and private transport operators are the integrators) can be represented in the following graphical schematics (see

Figure 15):

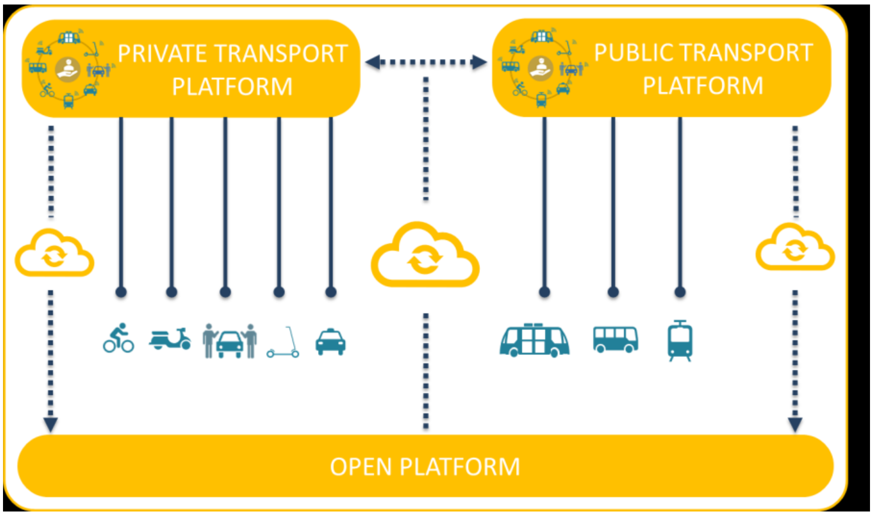


Figure 15. Public and Private transport operators are the integrators (Fournier, 2020)

With both sides as an integrator, it is expected to have a fully integrated market with fair competition, the public and private platform provide data to both the open platform and private platform while providing integrated customer-centric data to the passengers. In this model, fixed standards for data sharing, as well as open and fair exchange of data, lead to mutual trust between private and public sectors. Consequently, this model generates benefit for all stakeholders and enhances services quality (Pickford and Chung, 2019). If cities work in collaboration with private MaaS operators, they can set regulations protecting passengers data while integrating the private operators' services into open platforms. The traditional public transport is complementary to shared mobility through a platform that is regulated by a public authority, and AVs are integrated into a well-connected local transport network (UITP, 2020)

Eventually, MaaS provide services for all citizens rather than limiting the access to few who can afford it. This approach is already being implemented in Europe in the form of a public-private partnership: MaaS Alliance. It includes private and public operators, including Uber (Gindrat, 2019). This model is effective and sustainable since it relies on the collaboration between private and public transport to support shared mobility and reduce traffic, air pollution and parking problems (MaaS Alliance 2017).
The positioning of the 3 identified MaaS Business Ecosystem patterns within a matrix of the two dimensions: 1. Role of Maas Integrator, and 2. Input Provider to Open MaaS Platform, allows the analysis of further pattern options and their potential relevance for MaaS Business Opportunities (see Figure 16):

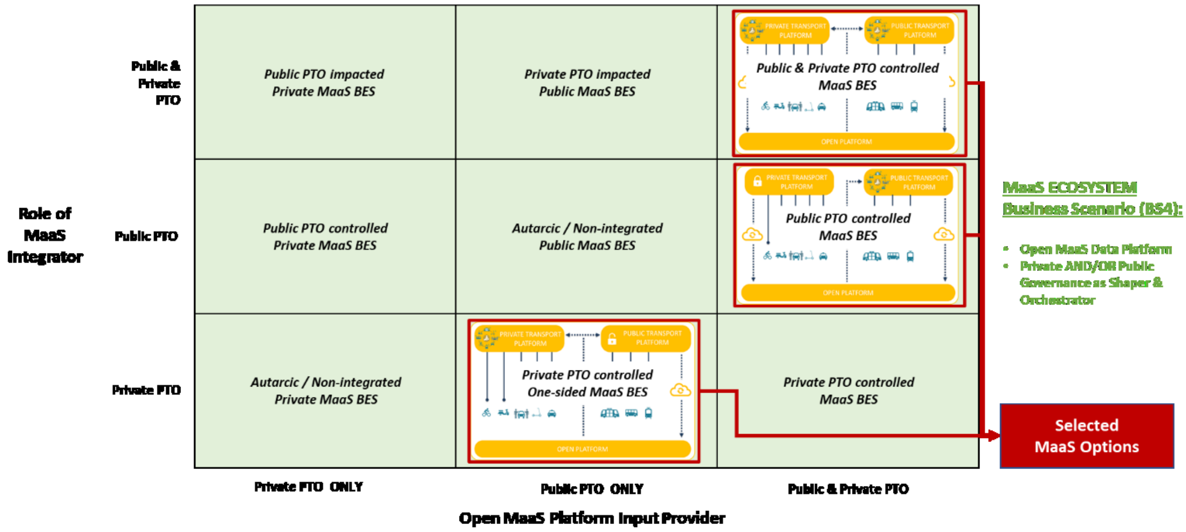


Figure 16. Classification Matrix for Positioning of most relevant MaaS Ecosystem Patterns (Patterns identified by G. Fournier)

In Addition to **MaaS Business Opportunities (BO5-BO8)** there's basically another **‚Non-Integration' Business Opportunity** relevant for automated e-shuttles businesses within **public MaaS Business Ecosystems** – additional to the module focused Business Opportunities BO1 - BO4 – where singular private unimodal transport platforms are not integrated with a common public MaaS platform and **thus in competition** with this (see Figure 17).
This **Business Opportunity for MaaS Business Ecosystems** however is already covered by the **Business Opportunity 4 (BO4 – New Mobility Providers)** and thus need not be elaborated separately anymore.

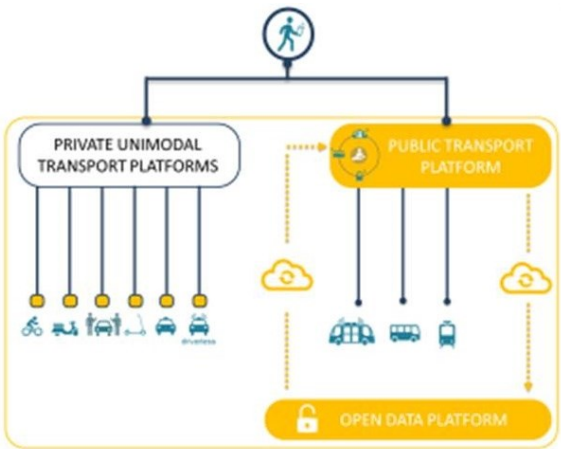


Figure 17. Classification Matrix for Positioning of most relevant MaaS Ecosystem Patterns (Fournier, 2020)

The 3 selected MaaS patterns evaluated above are the starting point for the extraction of MaaS Ecosystem Business Opportunities for the MaaS Ecosystem Business Scenario BS4. As a conceptional model it is useful to differentiate between Private or Public PTO as Sub-Ecosystem Integrator (Dimension 1) as well as to differentiate between Collaborative or Competitive Ecosystem Relation (Dimension 2). This model allows the identification of 4 significantly different Business Opportunities (see Figure 18 and Figure 19).

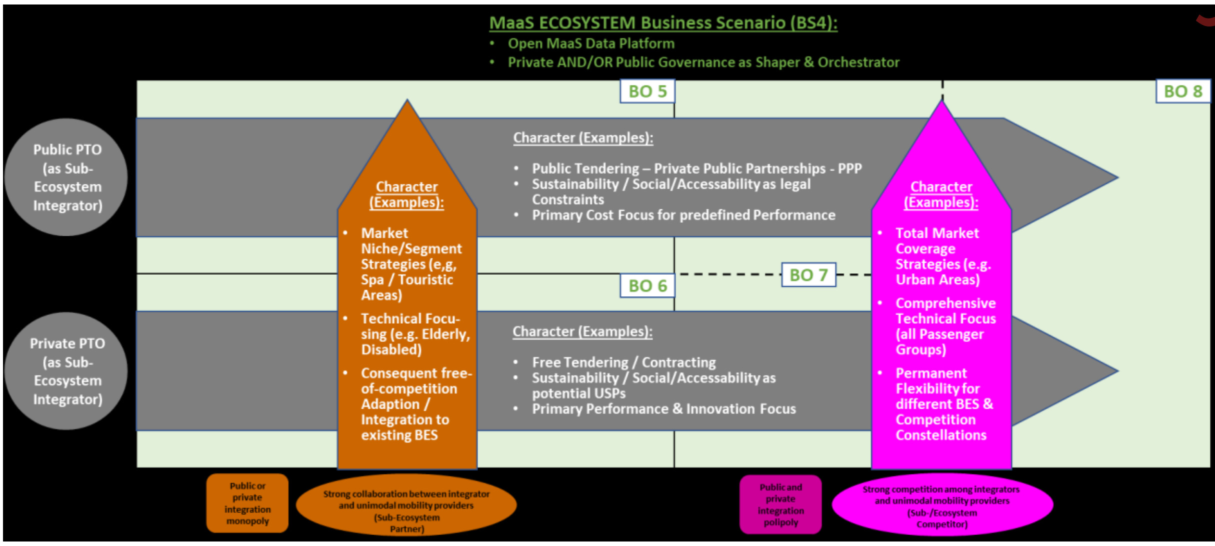


Figure 18. Conceptional design for the identification of the 4 MaaS Ecosystem Business Opportunity Clusters

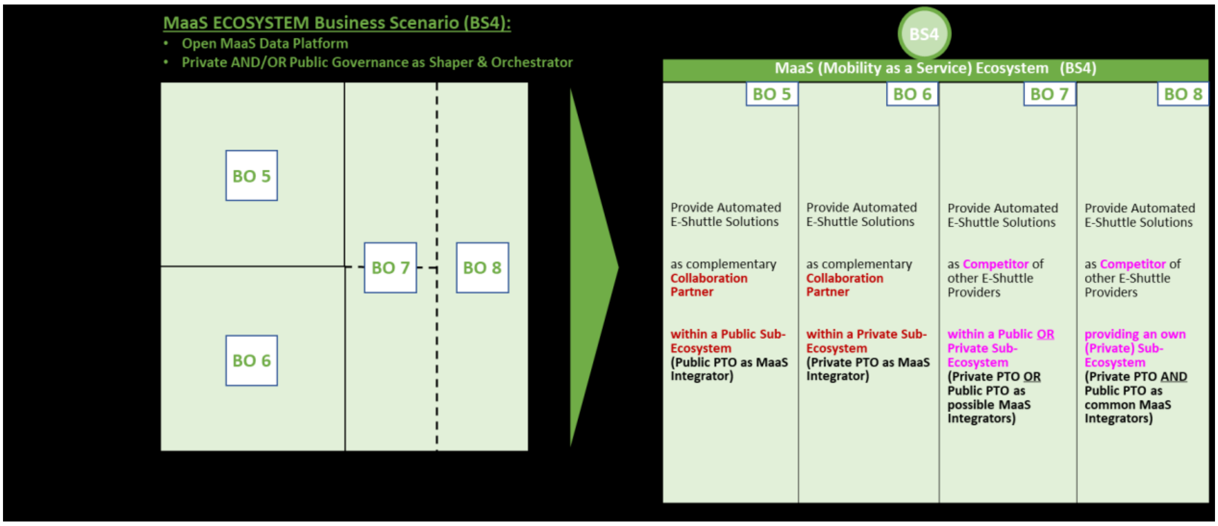


Figure 19. Rough Characterization of MaaS Ecosystem Business Opportunity Clusters

These 4 identified and significantly different MaaS Ecosystem Business Opportunities can be illustrated by using the previous platform pattern representations. As a proof of empirical evidence concrete examples for these 4 MaaS Ecosystem Business Opportunities have been identified and added to the concept representation (see bubbles in figure 20):

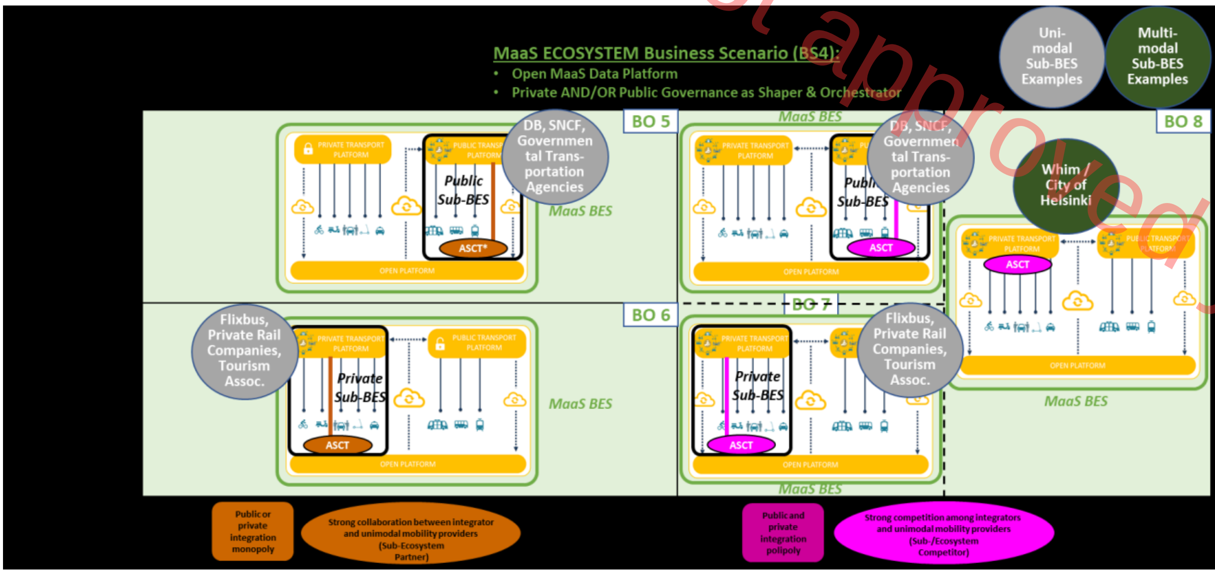


Figure 20. Application of most relevant MaaS Ecosystem Patterns to MaaS Ecosystem Business Opportunity Clusters

The 4 significantly different MaaS Ecosystem Business Opportunities can be characterized individually in details and in a clearly distinguishing way by several criteria aspects (see

Figure 21 and

Figure 22):

1. **Data Accessibility**
2. **Collaboration Rules**
3. **Partnership**
4. **Strategic Focus**
5. **Switching to other Ecosystem**

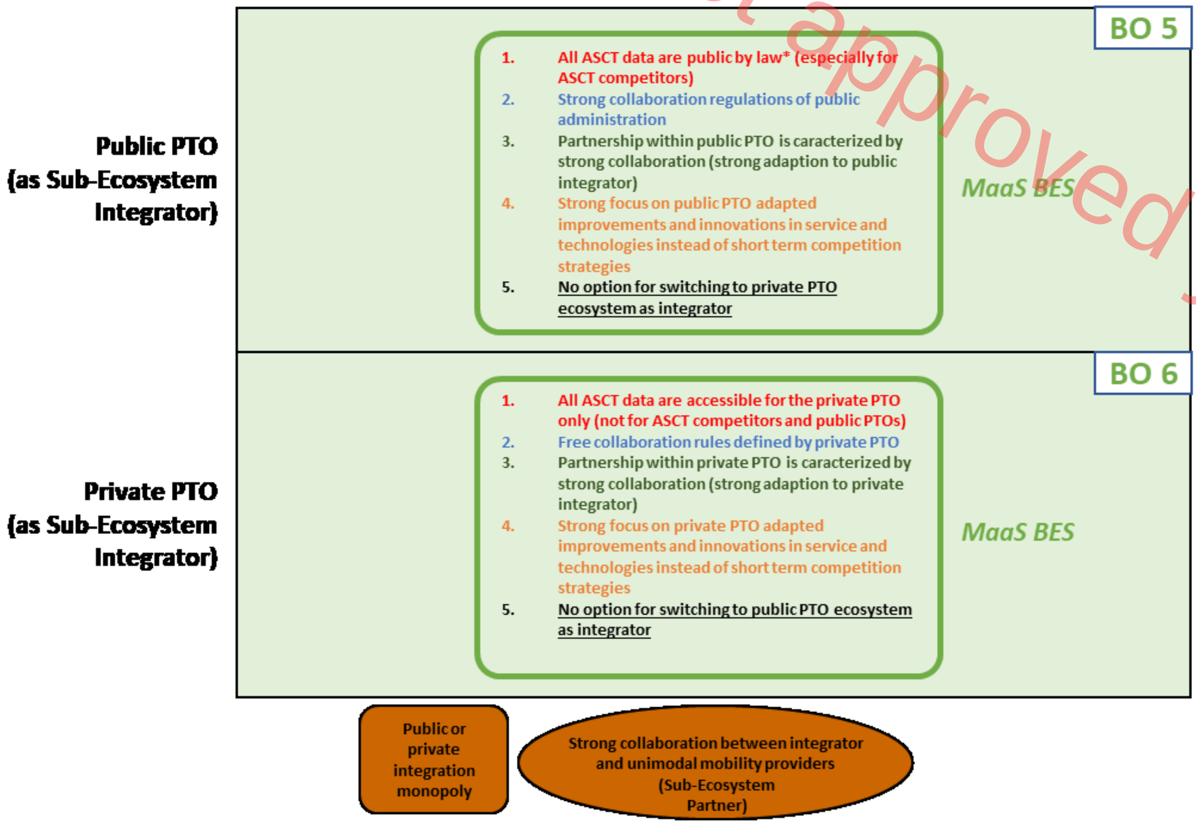


Figure 21. Detailed Characterization of MaaS ECOSYSTEM Business Scenario (BS4): Business Opportunity Clusters BO5 & BO6

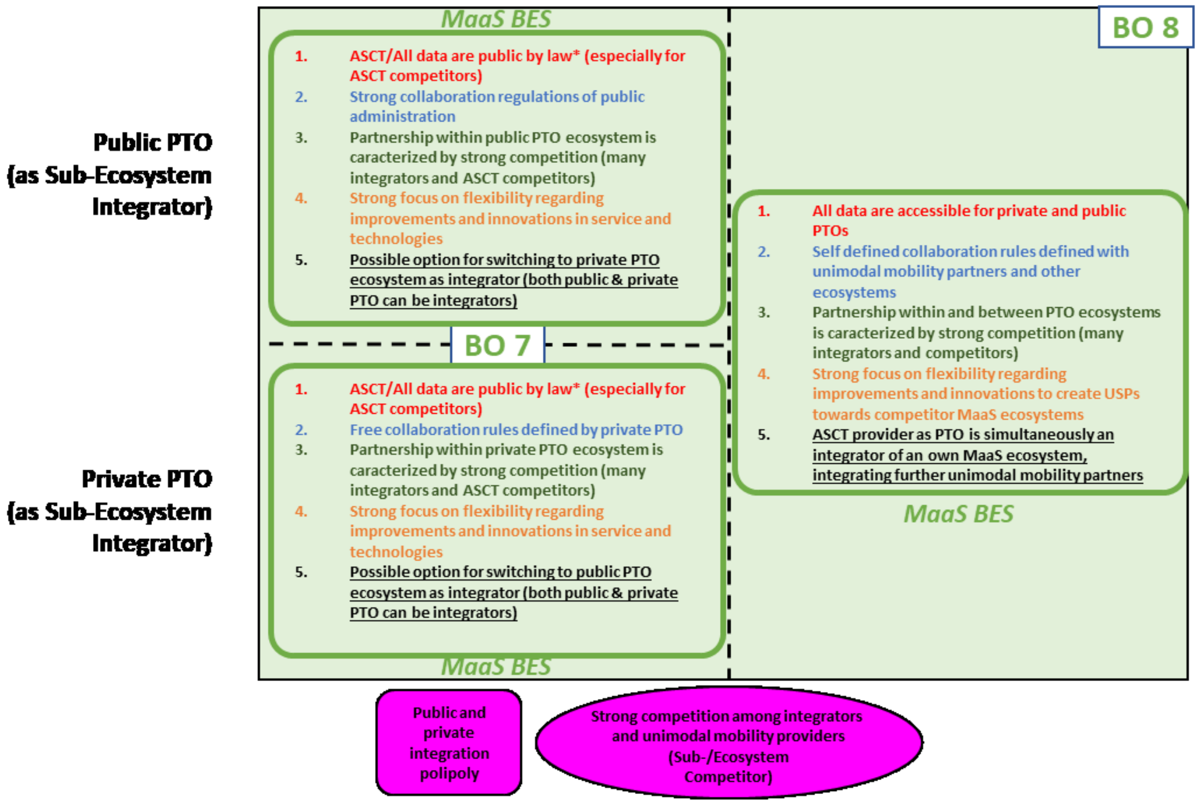


Figure 22. Detailed Characterization of MaaS ECOSYSTEM Business Scenario (BS4): Business Opportunity Clusters BO7 & BO8

A final total overview shows all 8 Business Opportunities / Clusters (BO1-8) which have been evaluated, prioritized and selected by the previous methodologies (see Figure 23):

Figure 23. Final Overview of Business Ecosystem Opportunities Clusters for Business Scenarios

This conceptional Overview about the interdependencies of Business Scenarios – consisting of most attractive Ecosystems BS2 (Automotive Centred Ecosystem), BS3 (New Mobility Provider Centred Ecosystem) [BS3.1, BS3.2, BS3.3] and BS4 (MaaS Ecosystem) – and the according selected, most promising Business Opportunities (functional Business Opportunities: BO1-BO4 and MaaS Business Opportunities BO5-BO8), the basis for the subsequent elaborations on strategic planning building blocks.

Regarding the high aggregation level of business scenarios and its business opportunities it is important to regard and utilize the subsequent design modules for the business scenarios as rough directional strategic guidelines and recommendation suggestions or motivational examples for further analyses, discussions and refinement focused on the concrete acquisition use case which AVENUE as a potential entrepreneurial provider is facing.

3.4 Business scenario 1: PTO centred ecosystem

a) Business Characterization and Definition (BS 1)

This scenario entails the current autonomous transportation offers with automated shuttles by Public Transport Operators (PTOs) and other stakeholders, including demonstrations, trials and regular services.

On a worldwide benchmark study carried out by Antonialli (2021a), the author identified 176 experimentations that unfold in 142 cities spread over 32 countries enabled by 20 different autonomous shuttles manufacturers (Figure 24). However, not only due to the current technological limitations of automation for mixed-traffic conditions, but also due to regulatory constraints and consumer acceptance, only 5.71% of these deployments were regular permanent services. The majority were short to mid-term trials (81.15%) with the aim of allowing consumers to examine, use and test the services, and the remaining 13.14% were showcases to promote the technology and the services.

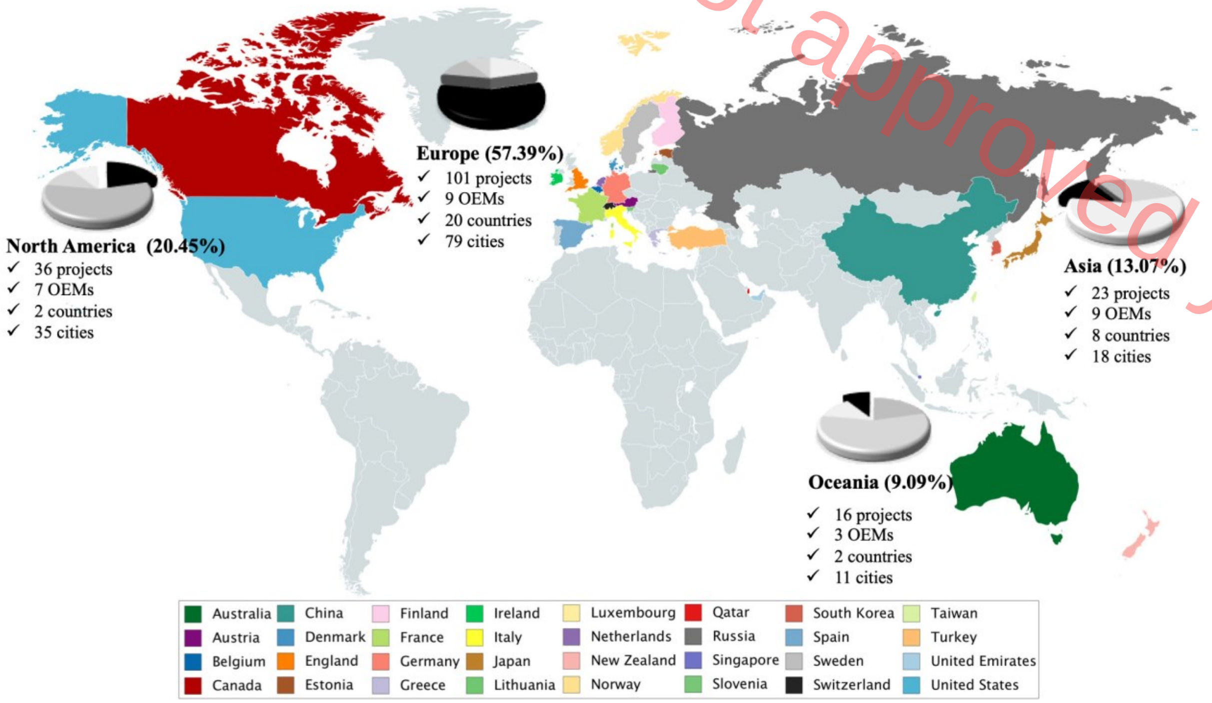


Figure 24. Worldwide experimentations with Automated Shuttles for Collective Transport (Antonialli, 2021a).

As observed in Figure 24, Europe is on the lead in the number of projects. From the 32 countries presented in the sample, the continent holds 20, comprising a total of 101 of the 176 projects (57.39%). According to Antonialli (2021, p.10) "such figures may be explained by the fact that the continent is also on the lead when it comes to the number of shuttles deployed by its manufacturers, and also currently holds 17 projects related to vehicular automation funded by the European Commission programme Horizon 2020, being one of them, the AVENUE project.

As stated by the author, one of the first services with Automated Shuttles was offered by the Dutch company 2getthere. Their first applications were pilot tests with automated guided shuttles on dedicated lanes at Amsterdam's Schiphol airport in 1997, and in Rotterdam's business park Rivium in 1999. On the other hand, the major advances in AVCTs tests in mixed-traffic conditions occurred from 2014 onwards with the emergence of two pioneering French start-ups: Navya and Easymile. According to Antonialli (2021a), from the 176 sampled deployments, the two companies together accounted for a total of 78.5% of the number of shuttles used, and more than half (51.13%) of the total of experimentations were in mixed-traffic conditions.

As stated by Mira-Bonnardel, Antonialli and Attias (2020, p.4), "Automated Shuttles can be described as a "technology push" innovation. In this sense, in order for them to succeed in the market, it is essential for the general public to be acquainted with the technology and its use forms, not only to cease their inherent human curiosity but also as a way to build trust". Thereby, due to this inherent "technology push" nature of the deployments, as for the revenue models, since the majority of experimentations were either showcases or short to mid-term trials, Antonialli (2021) concluded that they were mainly offered free of charge to riders (95.73% of the total sample), being subsidised either by the PTO, a municipality, a research project and/or other stakeholders. In the other few sampled cases were the commute was paid to a PTO (4.27%), the adopted revenue model was similar to what these companies usually do (ticketing and/or subscriptions).

Regarding the service ecosystem (or the network of partners) for the deployment of such services, Antonialli (2021a) proposes a generical stakeholder and value flows framework that can be seen in Figure 25.

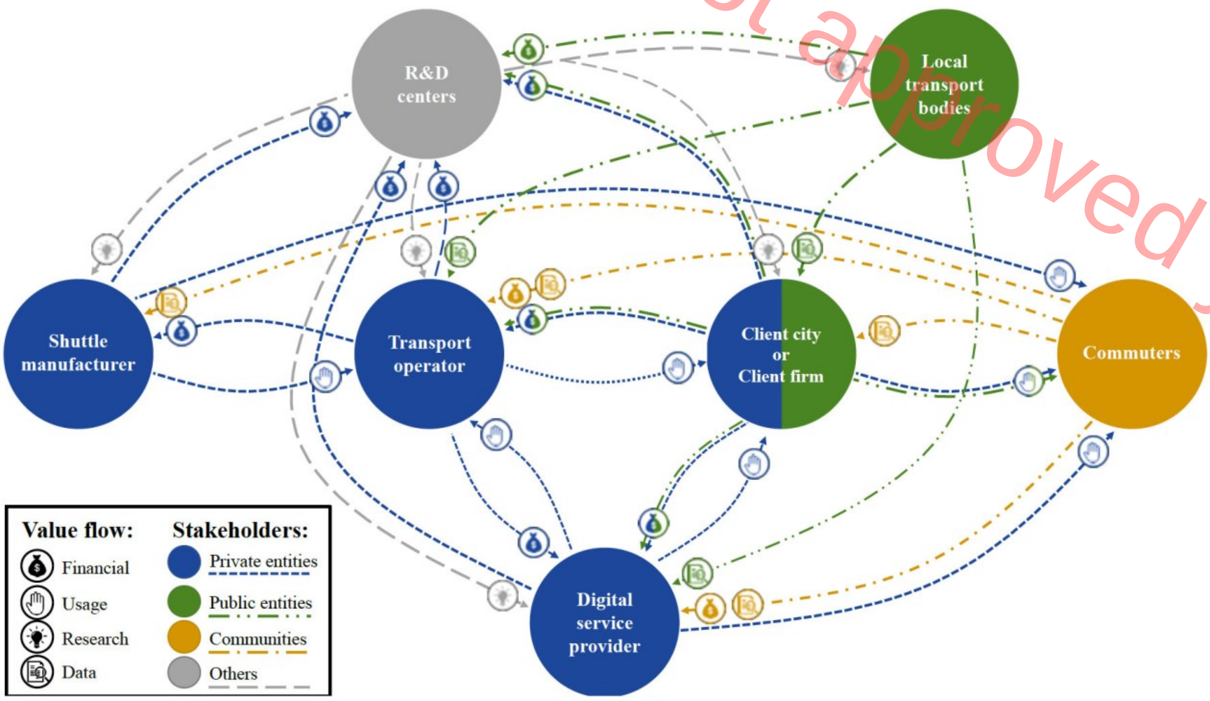


Figure 25. Automated Shuttles generical stakeholders and value flows (Antonialli, 2021a).

Starting from the shuttle manufacturer on Figure 25, it has the option to sell (or lease) their Automated Shuttles to a transport operator, which in turn will financially compensate the manufacturer (Antonialli, 2021a, p.21). Next, by possessing the shuttles, the transport operator will offer transportation services to: 1) a client city (which by means of a concession will allow the transport operator to offer services to the end consumers-commuters) or, 2) a client firm (which by means of a transport contract will provide commute to its employees).

Still according to the author, a second alternative is the transport operator partnering with a digital service provider to enhance users' experience by offering customised mobility services whether in relation to route planning, forms of payment, infotainment features, and so on. Thus, the digital service provider will act as a platform operator for online mobility services.

At last, is also important to highlight the role of local transport authorities – responsible for legislation and supervision of other stakeholders involved in the ecosystem, and also the importance of R&D centers for the technical and marketing advances of the whole ecosystem.

b) Business Opportunities and Strategies (BS 1)

According to Mira-Bonnardel, Antonialli and Attias (2020, p.9), "commuters and city's inhabitants are now, more than ever expecting a new type of mobility that is more sustainable but also more flexible than the everyday mobility they have been used to for a long time. If they claim to be ready to share their mobility, they also require a customized mobility. In the framework of Mobility-as-a-Service, the city's authorities have to supply their voters with shared on-demand mobility."

As pointed out by Barrett, Santha and Khanna (2019, p.3) from the L.E.K. consulting group, there is no universally accepted definition of on-demand public transport, however they chose to define it as a "form of publicly subsidized transport that takes multiple passengers within a predefined area from one place to another on a next-available, or pre-book basis". Thereby, not all on-demand transport services are the same, the authors state that their business models and level of service may vary considerably from context to context, and across key dimensions such as route (flexible, fixed or semi-fixed), schedule (flexible or fixed), fleet (size and variety), relationship to existing public transport network (supplementing or replacing existing routes), technology (digital platforms that may be integrated with the PTO app or via stand-alone applications), service area (urban core, urban fringe, rural areas) and, branding (PTOs may choose separate branding for the DRT service, may or may not identify the platform provider, etc.).

In this regard, Antonialli (2021b) proposes a framework to categorize the different levels of on-demand services that a PTO can offer to their local communities with the Automated Shuttles (see Figure 26).

Figure 26. Levels of on-demand services for public transport with Automated Shuttles (Antonialli, 2021b).

These on-demand mobility configurations go beyond seeing an Automated Shuttle simply as a new product but rather as a new system, the product-service system (PSS) (Tukker, 2004), combining technological innovation with service and market innovation. The PSS may be developed within new business models for diversifying the options the users and the revenue sources for the PTOs.

As exemplified by Mira-Bonnardel (2021) and as shown in Figure 27, during peak-hours (from 6 to 9 a.m. and, from 5 to 8 p.m.) the shuttles can be used for predetermined journeys with regular schedule and fixed-stops by (for instance) taking commuters to and from their neighborhoods to trunk-lines or by taking children to/from schools (thus being within levels 0 and 1 proposed on Figure 26). However, in off-peak hours (from 9 a.m. to 5 p.m. and, from 8 p.m. to 6 a.m.), they can be used for several tailored-made journeys upon request (fitting the proposed levels 3, 4 and 5). During these off-peak times, AVCTs could be used for transportation of goods (last mile) in city centers for retailers and individuals, transportation for targeted user-groups (people with reduced mobility, leisure centers, care centers, etc.), transportation for city tours and outings, and even night transportation for specific and emergency requests (as a night bus for people returning home from bars and parties, for emergency transport of injured or sick people, specific delivery of goods, etc.) (Mira-Bonnardel, 2020).

Time Slot	Mobility Services
6-9 AM Point-to-Point	Transportation with predetermined stops for regular, fixed time mobility (employees and schoolchildren)
9-5 PM On-demand	Transportation of goods (last mile) in city centers for retailers and individuals, with booking and connection to track the delivery process in real time
	Transportation for targeted needs (people with reduced mobility, leisure centers, care centers, specific goods, etc.)
	Transportation for disabled people at set times
	Transportation for city tours and outings
5-8 PM Point-to-Point	Transportation with predetermined stops for regular, fixed time mobility (employees and schoolchildren)
8-6 AM On-demand	Night transportation for specific and emergency requests (like injured or sick people, delivery, deliveries for hospitals, tourist trips, etc.) Specific requests should be privately funded (individuals, travel agencies, retailer associations, etc.)

Figure 27. Business Model scenarios for a typical week day for an Automated Shuttle service (Mira-Bonnardel, 2021).

According to Mira-Bonnardel, Antonialli and Attias (2020) and Mira-Bonnardel (2021), these scenarios allow a wide range of journey requests that have to be optimized by alternating point-to-point journeys with on-demand ones.
Thus, mobility-on-demand (for people or for goods) is the cornerstone for a TCO owned autonomous fleet that could easily be combined with conventional, regular transport management featuring predetermined stops and times.

3.5 Business scenario 2: Automotive centred ecosystem

Within this chapter all **4 Design Steps for Strategic Business Planning for Business Scenario 2 – Automotive centred Ecosystem** mentioned in the conceptional grid (see chapter 2 – methodology, figure x) - are elaborated:

1. **AVENUE Business Scenario 2 Characterization**
   – for Automotive centred Ecosystem,
2. **AVENUE Business Opportunity Identification (most promising)**
   – within Business Scenario 2: Automotive centred Ecosystem,
3. **AVENUE Business Strategies Identification**
   – for most promising Automotive centred Ecosystem Opportunity within Business Scenario 2,
4. **AVENUE Business Model Definition**
   – for most promising Opportunity within Business Scenario 2, guided by suggested Business Strategies.

a) Business Characterization (BS 2)

The Characterization of Business Scenario 2 is elaborated by the following methods or templates addressing the most relevant issues relevant for the concrete strategic planning (see Figure 28 and Figure 29):

1. BES General Description and Practice Examples

2. BES Strategic Direction
3. BES General Evaluation
4. BES Success Factors & Risks
5. Typical exemplary Traditional BES – Partner Network

BES General Description and Practice Examples

The General Description of the Automotive centred Ecosystem provides main descriptional issues of understanding and identified practice examples of typical companies representing the Business Scenario for the Automotive centred Ecosystem.

The hypothesis for the Description of this Business Scenario is that established automotive manufacturers are diversifying their technology, product, service and business/market portfolio as well as the according business infrastructures by the AMPT business. The characterization of this Business Scenario shows that there is a broad existing variety of offerings and business types from established automotive manufacturers as starting basis for the AMPT business with simultaneous consideration of trends in digitalization, technology and business innovation. As a general conclusion it can be determined that established automotive manufacturers will make a disruptive shift from their current business to become consequently customer-oriented diversified mobility providers.

BES General Description	BES Examples
• Existing business model is influenced by **digitalization, connectivity** and **disruptive innovations** in vehicle technologies (1)	• **Bike Sharing** GoBike (Ford) — Ford GoBike
• **Shift of value creation** from the **automotive product** towards **business models based on the usage of user and vehicle data** (2)	• **Car Sharing** (one-way point to point rentals) SHARE NOW (formerly: car2go & DriveNow) — SHARENOW
• Integrated **digital service innovations** are needed in order to meet **changing customer requirements** (3)	• **Ride Hailing** FREE NOW (formerly: myTaxi) — FREE NOW
➡ Manufacturers will become **customer-oriented mobility** and **service providers** through product- and market diversification (3)	• **Ride Pooling** MOIA (Volkswagen); e-PALETTE (Toyota) — MOIA; e-Palette
	• **Casual carpooling** Flinc (Daimler) — flinc

Figure 28. BES General Description and Practice Examples (Business Scenario 2)[5]

BES Strategic Direction

The Strategic Direction for the Automotive centred Ecosystem (BES) analyzes the general strategic orientation (Purpose & Goals and Vision) and characteristic emphases of Business Opportunities, General Strategies and Business Models for this Business Scenario. These issues are the basis for further refinement in the subsequent subchapters of this Business Scenario.

The hypothesis for the Strategic Direction of this Business Scenario is that the diversification of technologies, products, services and businesses/markets require fundamental shifts in thinking and acting by dedicated and integrated strategic concepts for AMPT businesses for being successful.

[5] Strelow, Michael; Wussmann, Marius (2016): Digitalisierung in der Automobilindustrie. In: *Iskander Business Partner GmbH*. Online verfügbar unter https://i-b-partner.com/wp-content/uploads/2016-09-06-Iskander-RZ-Whitepaper-Digitalisierung-in-der-Automobilindustrie-DIGITAL.pdf, zuletzt geprüft am 03.11.2020.

The analysis of this Business Scenario shows that it is necessary to innovate technologies and business strategies and models for AMPTs as well as taking calculated risks and a widened and integrated scope of mobility than before. As a general conclusion it can be determined that a certain degree of mind and strategic shift towards openness for partnerships (i.e. with autominibus specialists like AVENUE) for fast ramp up, integration, and general customer mobility orientation will be essential for AMPT diversification success.

BES Topic	Characterization
Purpose & Goals	- **Exploit existing and identify new markets** through **development of mobility services** (market diversification) due to decreasing sales of new cars (pandemic effects, technological disruption => electronification/robotics/automation, emission scandals, regulatory environmental restrictions) => **set the rules** and maintain **leading role in the mobility sector** + create **new sources of income** (1) - React to **changing business customer and citizen requirements/behavior** => focus on **shared mobility concepts instead of vehicle ownership** - Catch up on the **latest technological trends** (electrification of drive train, automated driving, connected driving) - React to **changing business strategies of TPOs** (e.g. leasing instead of buying, subcontracting) - Increase **innovation potential** - **Pressure to identify new innovative business models and strategies regarding future disruptions** - **Increased engagement in public mass transportation due to regulatory trend regarding avoidance of congested cities**
Vision 2030	- Become **#1 customer-oriented mobility** and **service providers** that not only produce and sell cars, but also offer mobility services (1) - **Maintain and extend leading position** in the automotive and mobility market under optimal utilization of current trends
Business Opportunities	- **Opening up** and better **penetration of the market** through **partnerships** - **Investments** and **venture capital** in **mobility start-ups** to gain access to technologies and capabilities - Compensate decreasing sales by **selling fleets to mobility providers** - Increase in revenue through **new vehicle financing models** (3) - Develop new and improve existing **data based services** - **Increase value creation** by covering a **larger part of the customer journey**
General Strategies	- **Partnering** with mobility platform companies or other OEMs to **access** their large **customer bases** and benefit from **risk diversification** (2) (4) - Establish a new product/service in a new market through product diversification (1) (4) => **Diversification of modalities** (bikes, e-scooters, bus/shuttles,…) => **Diversification of services** (mobility services, vehicle services, financing models, roadside assistance,…)
Business Model Types	- **Revenue Model** (e.g. Leasing)

Figure 29. BES Strategic Direction (Business Scenario 2)[6]

BES General Evaluation

For a deeper understanding of the Business Scenario – Automotive centred Ecosystem it is essential to analyze it by using the SWOT method. In this context the SWOT analysis expresses 4 central business planning relevant factors for scenario stakeholders and business ecosystems:
a. the general opportunities (on a higher abstraction level of concrete business opportunities) provided by this business scenario, b. the general threats within this business scenario, c. the general strengths of business ecosystems or players supported by this business scenario, d. the general weaknesses which business ecosystems or players are facing within this business scenario.

The hypothesis for the SWOT analysis of this business scenario is that the strengths of long-term automotive experiences and other potentials (e.g. financial power, brand, manufacturing) will be beneficial for AMPT engagement – weaknesses will be compensated by partnerships with AMPT providers and innovation effort e.g. in digitalization or specific AMPT business competency to exploit the opportunities (e.g. digitalization, market potentials, business models) and defend potential threats like revenue decrease of traditional vehicle businesses, innovation delays, etc..

[6] Accenture GmbH (2015): Wie die Autoindustrie die Chancen der Digitalisierung richtig nutzt, 2015
springerprofessional.de (2019): Digitale Dienstleistungen in der Automobilbranche. Online verfügbar unter https://www.springerprofessional.de/digitale-dienstleistungen-in-der-automobilbranche/16235598, zuletzt aktualisiert am 15.04.2019, zuletzt geprüft am 20.10.2020.
springerprofessional.de (2019): Digitale Dienstleistungen in der Automobilbranche. Online verfügbar unter https://www.springerprofessional.de/digitale-dienstleistungen-in-der-automobilbranche/16235598, zuletzt aktualisiert am 15.04.2019, zuletzt geprüft am 20.10.2020.
Arthur D Little (2019): Automated Mobility Journal. Online verfügbar unter https://www.adlittle.com/en/automated-mobility-journal, zuletzt aktualisiert am 11.12.2019, zuletzt geprüft am 21.10.2020.
Spulber, Adela; Dennis, Eric Paul; Wallace, Richard; Schultz, Michael (2016): The Impact of New Mobility Services on the Automotive Industry
Bea, Franz Xaver; Haas, Jürgen (2019): strategisches Management
Janasz, Tomasz (2018): Paradigm Shift in Urban Mobility. Wiesbaden: Springer Fachmedien Wiesbaden.

The analysis of this Business Scenario shows that it requires a multi-factor analysis for the specific situation of the automotive manufacturer to balance positive and negative issues to manage the disruptive mind offering and business shift from traditional to future (i.e. AMPT) businesses.
As a general conclusion it can be determined that automotive provider specific SWOT strategies can solve this core task for business success balancing all 4 segments of this analysis.

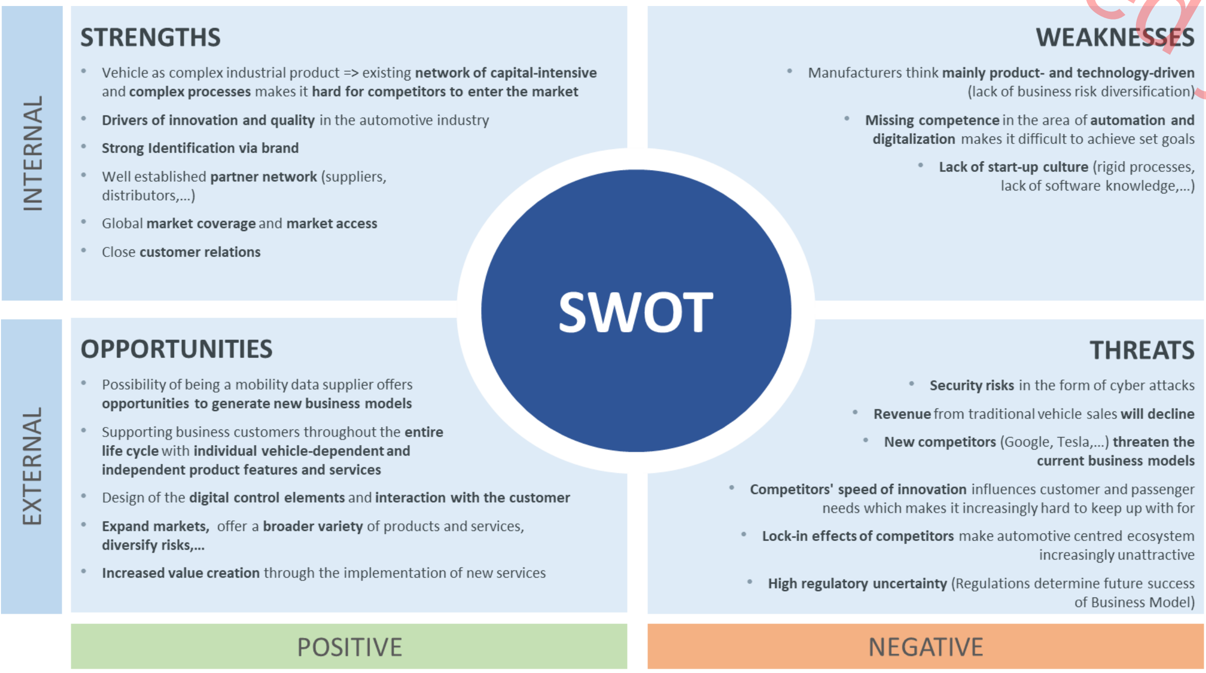


Figure 30. BES General Evaluation (Business Scenario 2)

<u>BES Success Factors & Risks</u>

A fundamental focus for strategic planning of business ecosystems is the identification of Success Factors and Risks for entrepreneurial behavior for the setup and management of Business Ecosystems within the Business Scenario of Automotive centred Ecosystems.

The hypothesis for the Success Factors and Risks of this Business Scenario is that many success factors for an engagement of automotive manufacturers into the AMPT business are strongly fulfilled (e.g. strong brand, market infrastructures, manufacturing capabilities, finances etc.) and business risks can be strongly compensated by adequate partnerships (e.g. with AMPT specialized providers).
The analysis of this Business Scenario shows that there are success factors as well as risks or pitfalls on every level and facet (market, offering, finance, capacities/potentials) of the AMPT business diversification that are interdependent and each for itself critical.
As a general conclusion it can be determined that the individual analysis of success factors and risks and their prioritization and application to the diversification and transformation process (i.e. strategies for make or buy, and partnering with AMPT specialists) is critical to the general AMPT business success of automotive manufacturers.

Success Factors	Risks
1. Global **market coverage** and **market / customer access**	1. **Lack of competences** in the field of mobility IT technology, data-based services and automated driving compared to new market entrants (Data giants, startups,…)
2. **Strong brand identification**	2. Trend moves from **ownership** of vehicles to **mobility services => core competencies no longer needed**
3. Well established global **partner network (vehicles, product related services, supplier network, distribution network…)**	3. **Many new and highly innovative competitors** enter the market
4. **Long time business and technology experience** in automotive production (battery / e-vehicles, automated driving)	4. Large **automotive corporations** with rigid processes and hierarchic decision processes impede **innovative strength**
5. **Broad financial basis** for ecosystem development	5. **Regulatory framework is still in development and not clearly defined by government** (Regulations on local, regional, country and global level determine success of business model)
6. Starting from a medium maturity level of ecosystems	6. **IT infrastructures are not sufficiently available in many regions**
7. **Existing activities and experiences** in the field of public transportation (e.g. Daimler Evobus)	7. **Vehicle infrastructures e.g. charging stations are still in an embryonal status**
8. **Large R&D, production and innovation capacities / potentials** for vehicles	8. **IT security risks**

Figure 31. BES Success Factors & Risks (Business Scenario 2)

Typical exemplary BES – Partner Network

For a pragmatic strategic planning of a business ecosystem within this business scenario it is beneficial to have an idea of an archetypical model of a partner network as an exemplary structure of a Business Ecosystem represented by typical ecosystem partners as well as the central ecosystem lead partner (as ecosystem management platform owner) shaping and orchestrating this Business Ecosystem.

The hypothesis for the Partner Network of this Business Scenario is that there will be a coexistence of the traditional and future (digital and multimodal focused) ecosystems and ecosystem businesses of the automotive manufacturers. In this sense the analysis of typical or exemplary ecosystems this Business Scenario shows that today the traditional automotive centred BES partner ecosystem (consisting of BES platform, partner network, partners, etc.) for offerings (products, services, etc.) like cars, buses, trucks are evolving towards new situations (digitalization, shared economy, new services, etc.). In the future these ecosystems have to be extended by additional vehicles like AMPTs to create a new digital multimodal ecosystem with a respective platform and partner network.
As a general conclusion it can be determined that it will be a challenging but often necessary task for traditional automotive manufacturers to evolve their traditional BES not only by further modality partners towards a multimodal offering portfolio and BES, but also by synergetic application of digitalization technologies and other trends for consequent customer centricity.

Regarding the Future Business Ecosystem - Partner Network of Automotive centred Ecosystem Scenario it is important to remark that automotive providers are continuing to make business with their ‘traditional’ but evolving BES partners and offerings impacted by new technological and business trends. However, they are sustaining, complementing and synergetically integrating their ‘traditional’ BES with ‘digital multimodal’ BES due to the high synergy potential of technologies and businesses in the future.

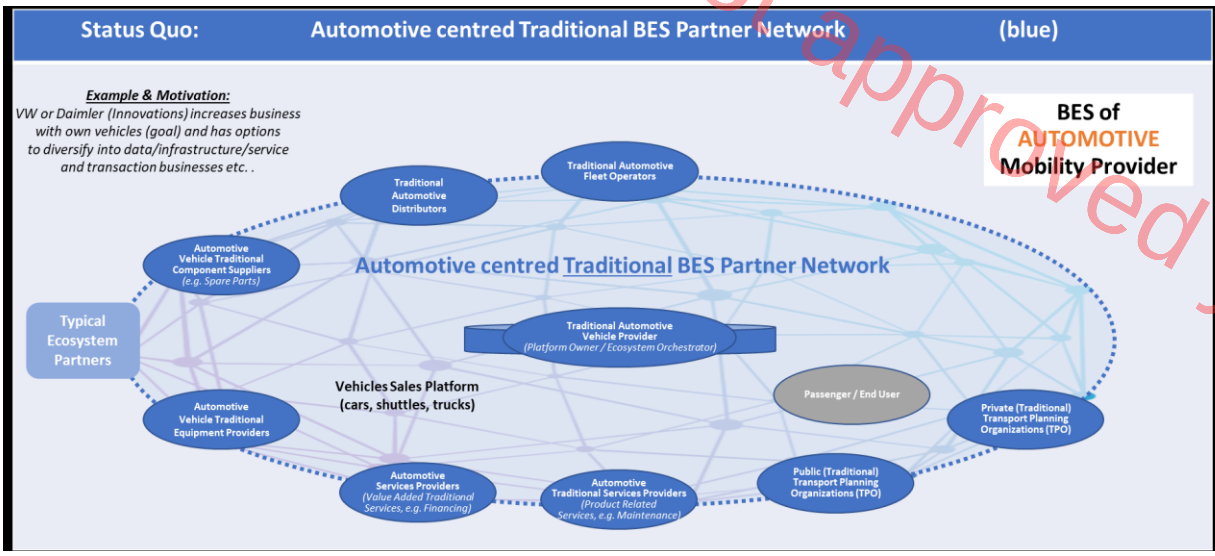


Figure 32. Typical exemplary Traditional BES – Partner Network (Business Scenario 2)

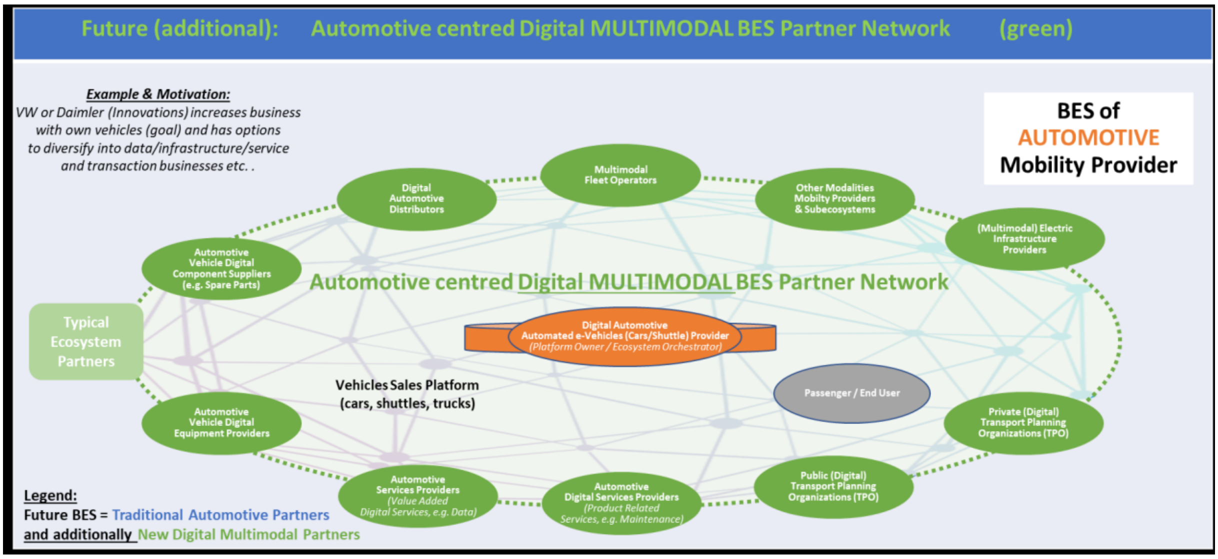


Figure 33. Typical exemplary Future BES – Partner Network (Business Scenario 2)

b) Business Opportunities for Automotive centred Ecosystem (Business Scenario 2)

Referring to the table of relevant Business Opportunities within Business Scenarios from Chapter 3 (Business Scenarios – Concept Overview, Identification of most promising Business Opportunity Clusters & Opportunities, Figure x) the most promising Business Opportunity (BO 1) for the Automotive centred Ecosystem has been identified as: 'Value Added AMPT Services for Automotive centred Mobility Providers'.
For characterizing this Business Opportunity on a general level, it is beneficial to use a 'staircase' of sequential core questions as a simple standardized method (see figure x). A more detailed analysis and evaluation of this selected Business Opportunity can be only conducted after a concrete business use case has been detected.

The hypothesis for the Business Opportunity of this Business Scenario is that Value Added AMPT Services are a highly attractive business for future automotive centred mobility providers due to the fact that the most profitable types of businesses are based on any type of digitalization / 'big data'

(generated by passengers, AMPT-vehicles, AMPT infrastructure, etc.) as well as services focusing passenger centricity (e.g. routing, physical comfort, safety. etc.).
The analysis of this Business Scenario shows that Value Added AMPT Services can be systematically designed and strategically planned from former deficits (gaps/lacks) in gathering and analyzing data and passenger requirements, generating offerings with value driven features fulfilling tangible and intangible passenger values and benefits.
As a general conclusion it can be determined that Value Added AMPT Services is a necessary and profitable complementary business for AMPT-diversified automotive centred mobility providers.

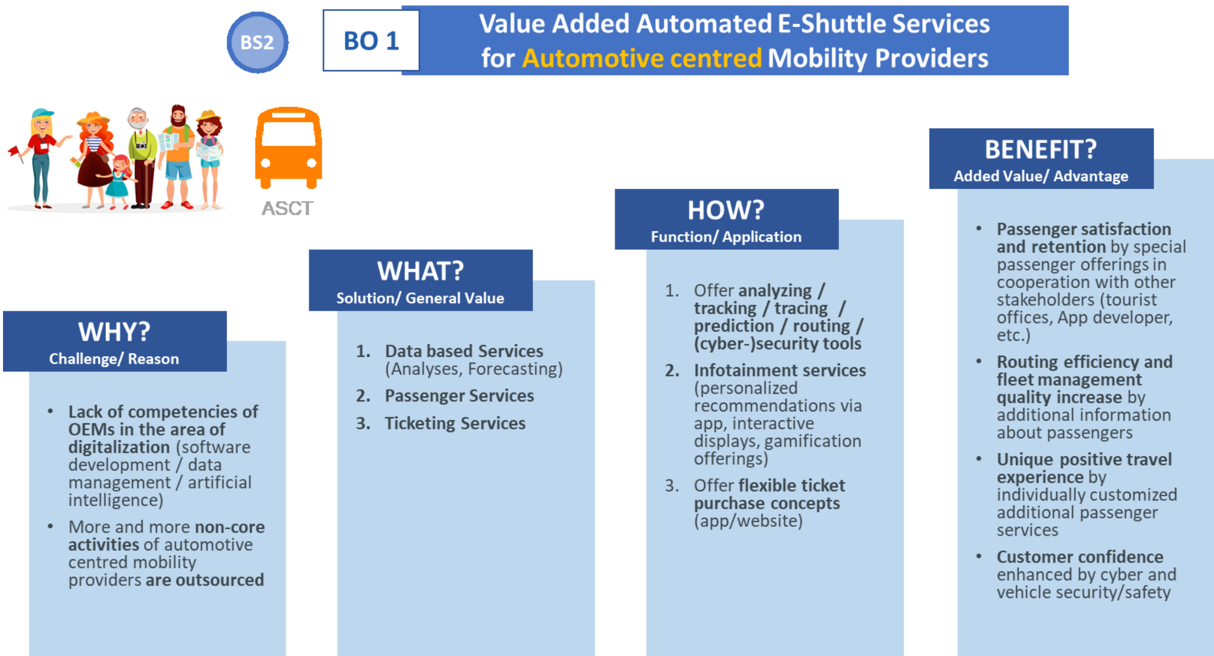


Figure 34. Business Opportunity Staircase (Business Scenario 2)

c) Business Strategies for Automotive centred Ecosystem (BS 2)

The typical and most promising Business Strategies for the selected most promising Business Opportunity BO1 within this Business Scenario have been identified by a sequence of strategic core issues which are most relevant for the further definition of future business models.
These categories of strategies have been purposefully selected to be focused to the typical building blocks of a business model canvas elaborated in the next subchapter.
Additionally to the assignment to business model modules, it is inevitable for the completeness of a set of business strategies to highlight the core innovation strategies (e.g. business / technology / management innovations for and across each module), which are central for a successful conduction of these businesses (see Figure 35):

BS2 | BO 1 | Value Added Automated E-Shuttle Services for Automotive centred Mobility Providers

ID	BES Strategy Category	Vision / Strategic Goal (WHAT)	Recommended Strategies (HOW)	Strategy Justification (WHY)
VO	**Value / Offering (Product/Solution/ Service) Strategies**	Availability of complementary VAS offerings for ASCT for every customer demand	– Offer **complementary VAS** (e.g. Data based Services (Analyses, Forecasting) Passenger Services, Ticketing Services) **for ASCT** within the automotive centred mobility ecosystem	- Need for an extensive portfolio of aligned and up-to-date VAS
MC	**Market / Customer Group Strategies**	Common marketing strategies and exploiting existing market coverage of automotive providers	- **Utilizing/Adapting of existing markets** from automotive providers and **alignment of marketing strategies** with automotive providers	- Utilizing existing market coverage and access of automotive provider for VAS purposes
CA	**Competition & Competition Advantage/USPs Strategies**	Eliminate potential competitors by permanent and close collaboration with automotive provider	- **Extension/complementation of the USP portfolio** of automotive providers by specific public transportation VAS USPs - **Utilizing of common IPs as technological synergy effects (e.g. patents)** with the automotive centred mobility provider	- Common IPs provide a protection shield against the external competitors - Close collaboration and technical/ business alignment with automotive provider as protection against competitors
SD	**Distribution & Sales Channel Strategies (incl. Partnering)**	Utilizing existing distribution network and sales channels of automotive providers	- **Close collaboration in distribution and sales (networks)** to **market coverage** and **market access** - Branding strategy: **utilizing of existing well known automotive provider brand**	- Synergy effects regarding cost/effort, sales network and increase of sales success by collaborative concepts
RD	**R&D/Production & Technology/Com-petency Strategies (incl. Partnering)**	Permanent R&D/Production/Technology collaboration for an aligned development of VAS	- **Cooperation/collaborative R&D of VAS** with offering providers (vehicle/modul/infrastructure etc.) within the automotive centred mobility ecosystem	- Need for an extensive portfolio of VAS - Close and up-to-date development of VAS solutions aligned to offering and solutions of other ecosystem providers
FI	**Financing & Invest Strategies**	Invest goal: longterm business partnership with automotive provider Financing goal: multisided/distributed financing sources	- Financing by **multisided business revenues** (e.g. VAS platform fees, analyses for automotive providers and other ecosystem partners) - Invest into **ASCT specific VAS businesses or VAS technologies** prioritised by automotive centred mobility provider	- Invest: Securing longterm business partnership - Financing: Risk diversification for financing sources
CO	**Cost Strategies**	- Minimum costs for given performance - Maximum performance/quality for fix costs	- Public tenders: **Target Costing strategy** focused on budget of public PTOs - Private tenders: **Flexible cost strategy** dependend from performance/ quality target of private PTOs	- Defined or negotiated within tenders/contracts
RE	**Revenue Strategies**	Common revenues (sales, operations, rental, leasing etc.) together with other ASCT offerings within an integrated solution for PTOs	Flexible, individual or integrated revenues from: - **Performance based Contracting** - **Sales, rental, leasing revenues** - **Operations business fees**	- Continous revenues by integrated revenue concepts by automotive centred ecosystem solutions
TI	**Offering/Technology Innovation Strategies**	Close collaboration and partnership within automotive centred ecosystem allows a flexible, fast and proactive adaption of the trends for offerings, technologies, competencies etc. for development of future driven VAS	**Adaption of innovation goals and strategies** from automotive mobility provider for VAS innovations: e.g. - **Modularization strategy** - **Fast customizing strategy** **Transfer of all autonomous driving technology from car to shuttle**	**Consequent collaboration and deep partnership** with automotive mobility provider provides stable strategic direction for **VAS offerings, technologies and competencies**, but also takes the risk of unilateral dependency from business success of the automotive mobility provider
BI	**Business/Marketing Innovation Strategies**	Close collaboration and partnership within automotive centred ecosystem allows a flexible, fast and proactive adaption of the trends for market demands for development of future driven business concepts	**Utilizing and adaption of marketing and business strategies** of the automotive mobility providers for VAS business concepts: e.g - **Adaption of market coverage and marketing strategies** of automotive providers - **Intensification of culture and innovation potential of AVENUE as start up company** - Branding strategy: **utilizing of existing well known automotive provider brand**	**Consequent collaboration and deep partnership** with automotive mobility provider provides stable strategic direction for **VAS businesses**, but also takes the risk of unilateral dependency from business success of the automotive mobility provider

Figure 35. Business Strategies Table (Business Scenario 2)

d) Business Models for Automotive centred Ecosystem (BS 2)

The typical Business Model BO1 (characterized by its complementary systemically interacting modules and its integrating logical story) for a selected Business Opportunity within this Business Scenario derived from and guided by the previously identified Business Strategies has been defined based on a business model canvas template defined in (Figure 36).

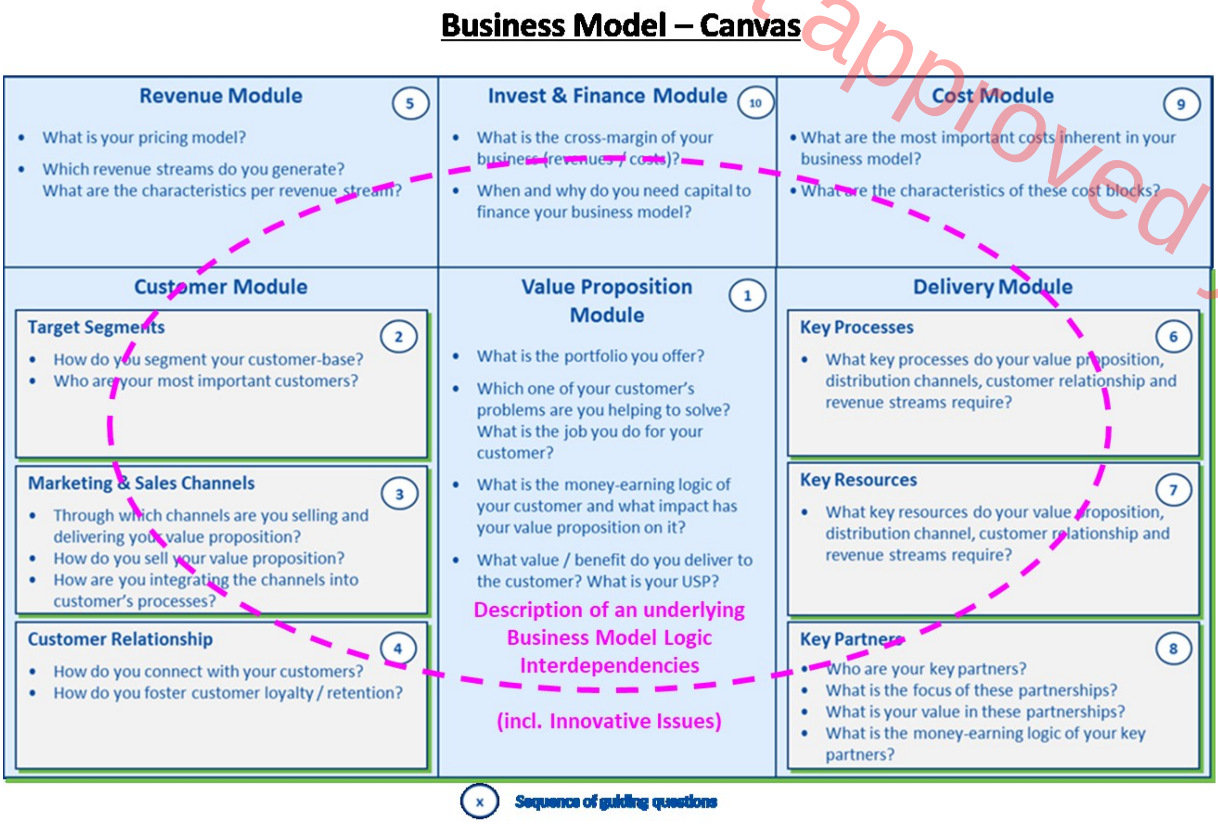


Figure 36. Concept & Guiding Questions for the Application of the Business Model Canvas (Osterwalder[7], modified by Siemens)

By applying this Business Model canvas template to the present Business Opportunity and Strategy it is important to remark that the suggested Business Model has to be regarded as a more general suggestion following consequently the previously defined Opportunity and Strategies. Many generic business models suggested from the literature (e.g. St. Gallen Business Model Navigator and others[8]) have to be regarded as further specified suggestions for business model variants and patterns for the subsequently elaborated and more general Business Model. Only after analyzing a concrete Business Use Case it is possible to analyze these suggestions as valuable refinements.

<u>Business Model – BS 2</u>

The hypothesis for the Business Models of this Business Scenario is that all modules for the respective business model with their building blocks are conceptionally integrated and aligned for each of the individual value added AMPT businesses, like data based or physical vehicle services, passenger services, etc.. Also, it is assumed that this category of services provides a signification contribution to the total profit volume of the AMPT business.
The analysis of this Business Scenario shows that especially intangible (i.e. data based) values / benefits for passengers, AMPT (minibus) providers, and automotive centred mobility providers are providing a nearly unlimited flexibility and bandwidth of offerings and businesses which can be

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[7]https://www.strategyzer.com/canvas/business-model-canvas?kw=%2Bosterwalder%20%2Bcanvas&cpn=8150275091&utm_campaign=S-EMEA-Branded-strategyzer=&utm_medium=cpc=&utm_source=google=&utm_term=%2Bosterwalder%20%2Bcanvas&utm_campaign=S-EMEA-Branded-strategyzer&utm_source=adwords&utm_medium=ppc&utm_content=:8150275091:kwd-370328503612:%2Bosterwalder%20%2Bcanvas:c:b&hsa_acc=8970299481&hsa_cam=8150275091&hsa_grp=85806354138&hsa_ad=397672404417&hsa_src=g&hsa_tgt=kwd-370328503612&hsa_kw=%2Bosterwalder%20%2Bcanvas&hsa_mt=b&hsa_net=adwords&hsa_ver=3&gclid=Cj0KCQiA3smABhCjARIsAKtrg6JIJ51Cvuje_eRXqlqlI5BlVJ4tE-EjL7CmklsJF3556vZe6Ya3AFwaAgKPEALw_wcB

[8] https://www.alexandria.unisg.ch/224941/7/Business%20Model%20Navigator%20working%20paper.pdf

supported by a big variety of Business Model types collected in numerous publications (e.g. multisided models like freemium model, licensing/performance based/etc. models).
As a general conclusion it can be determined that it is recommended to generate a separate sub-BES (sub platform, partner network, governance concept, etc.) specifically for Value Added data based AMPT Services due to huge evolution / innovation potential and variety of offerings and necessary management of specialized partners. Furthermore, each of the Value Added AMPT Services requires a specifically designed business model following predefined digitalization strategies.
The generally elaborated Business Model for Value Added AMPT Services for Automotive Centred Mobility Providers is represented in the following (figure 37):

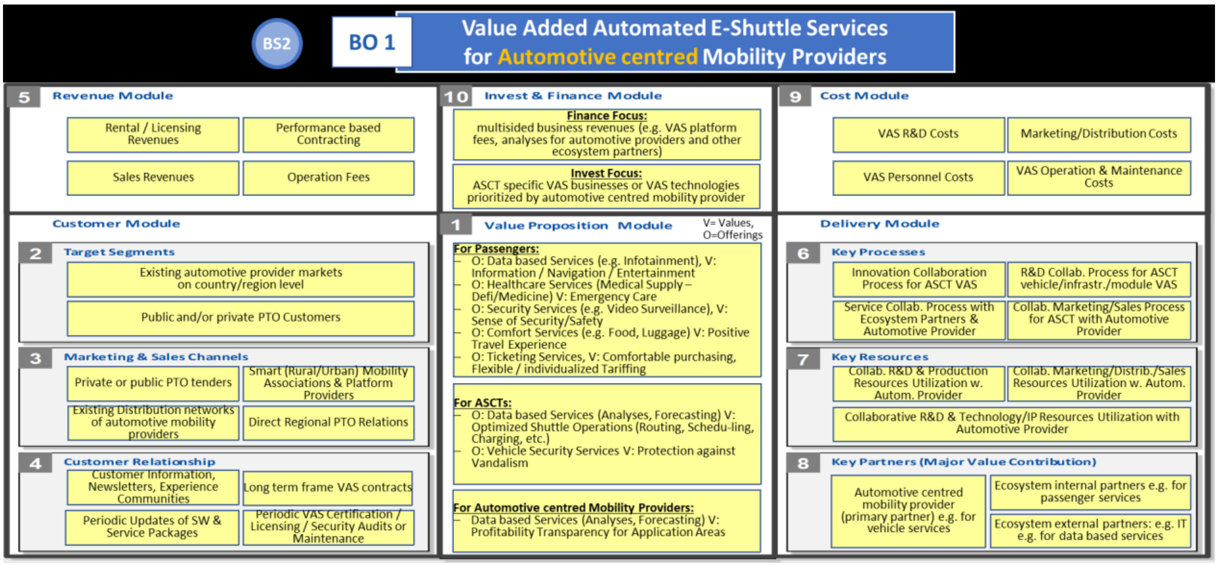


Figure 37. Business Model Canvas (Business Scenario 2)

<u>Business Model Story – BS 2</u>

As indicated as a dotted line in the Business Model Canvas Template it is beneficial for the understanding of Business Model logic to explain the integration and interaction of the modules of the Business Model in the sense of a logical 'Business Model Story' and in the form of a easy-to-understand 'elevator pitch' (see figure 38):

The hypothesis for the Business Model Stories of this Business Scenario is that the extremely high innovation potential requires a dedicated correlation / interaction / synergy management, a. within each Value Added AMPT Services business model modules for the respective offering / business, b. among these Value Added AMPT Services business models, and c. between these Value Added AMPT Services and other business models of the AMPT business components of the Automotive centred Mobility Provider.
The analysis of this Business Scenario shows that this multi-level and multi-relation task is a complex but nevertheless highly beneficial challenge for the Automotive centred Mobility Provider.
As a general conclusion it can be determined that Business Ecosystem related business model complexity management for Value Added AMPT Services (especially with data based businesses) regarding values, partners and interactions / correlations are a central success factor for the whole AMPT business.

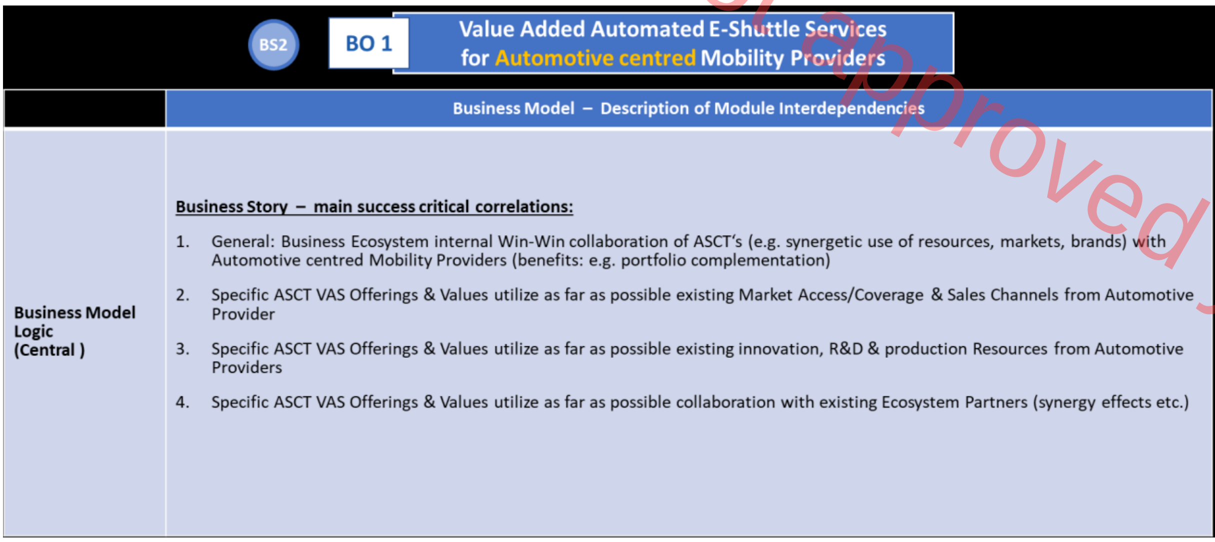


Figure 38. Business Model Story (Business Scenario 2)

3.6 Business scenario 3: New Mobility Provider centered Ecosystem

Within this chapter all **4 Design Steps for Strategic Business Planning for Business Scenario 3** – mentioned in the conceptional grid - are elaborated:

1. AVENUE Business Scenario Characterization,
2. AVENUE Business Opportunity Identification,
3. AVENUE Business Strategies Identification,
4. AVENUE Business Model Definition.

a) Business Characterization (BS 3)

The Characterization of Business Scenario BS 3 is elaborated by the following methods or templates addressing the most relevant issues relevant for the concrete strategic planning:

1. BES General Description and Practice Examples
2. BES Strategic Direction
3. BES General Evaluation
4. BES Success Factors & Risks
5. Typical exemplary Traditional BES – Partner Network

<u>BES General Description and Practice Examples</u>

The General Description of the New Mobility Provider centred Ecosystem provides main descriptional issues of understanding and identified practice examples of typical companies representing the Business Scenario for the Automotive centred Ecosystem.

The hypothesis for the Description of this Business Scenario is that there will be 3 significant categories or types of New Mobility Providers of AMPTs and their ecosystems in the future originating from different industries, perspectives and businesses: 1. data-based businesses, 2. transaction-based businesses, 3. innovation-based businesses. Besides the established automotive providers (BS 2) they could or will play a major role in the AMPT market.

The analysis of this Business Scenario shows that there are already many renowned companies from these 3 categories in the starting blocks (see figure x) with the technological and business potential to create diversified ecosystems with AMPT products portfolio and businesses as a core component.
As a general conclusion it can be determined that new mobility providers from each of these categories could or will be serious AMPT players in the mobility market for different reasons (e.g. data/software power, financial power, innovation power, network power).

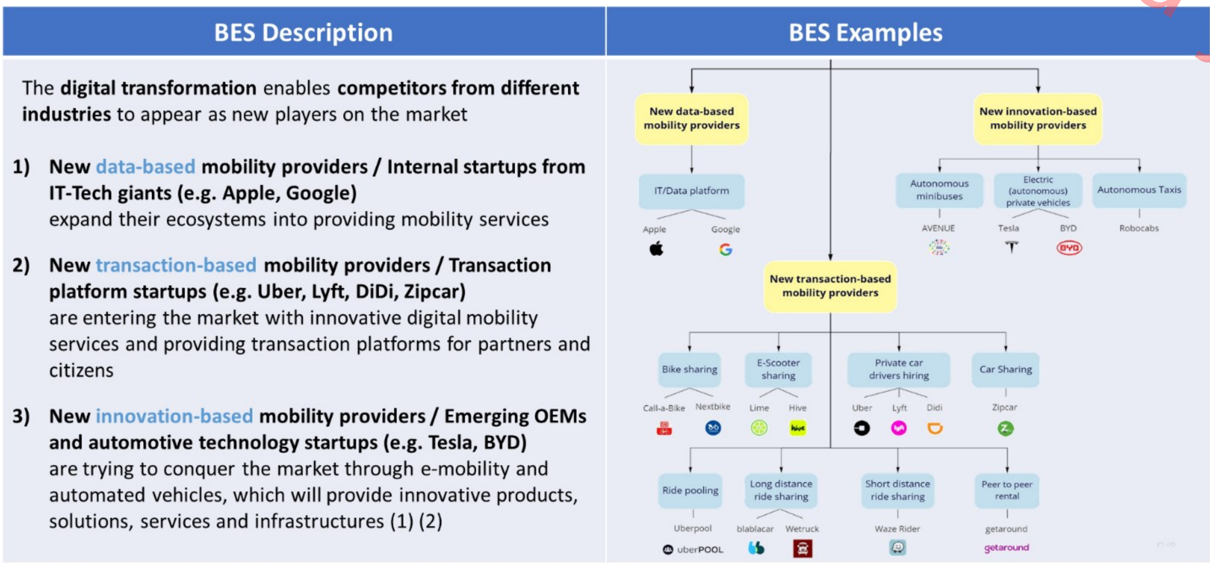


Figure 39. BES General Description and Practice Examples (Business Scenario 3)

<u>**BES Strategic Direction**</u>

The Strategic Direction for the New Mobility Provider centred Ecosystem (BES) analyzes the general strategic orientation (Purpose & Goals and Vision) and characteristic emphases of Business Opportunities, General Strategies and Business Models for this Business Scenario. These issues are the basis for further refinement in the subsequent subchapters of this Business Scenario.

The hypothesis for the Strategic Direction of this Business Scenario is that New Mobility Providers without specific competency of AMPTs are entering the market by diversification of their mobility offering and business portfolios, extending their previous BES Purpose, Vision, Strategies and Business Models with those of the AMPT business and focusing on this.
The analysis of this Business Scenario shows that entering a new promising AMPT market, the technological and business setup requires a significant ramp up or transformation of the whole BES business concept accompanied by high effort, business or technology innovation power and financial invest. However, the more technology or business related the previous businesses have been, the easier the transformation will be – the less it is, the more attractive is the probability of a respective acquisition of an AMPT specialist.
As a general conclusion it can be determined that the Strategic Direction of a New Mobility Provider centred Ecosystem including AMPTs and related BES needs to be redefined, adapted, or defined comprehensively. Depending on the previous business setup there's a big chance for specialized AMPT providers to collaborate synergetically as a complementary BES partner.

BES Topic	Characterization
BES Purpose	- New mobility providers try to **establish themselves** with innovative technologies and business models **in the mobility market** - **Diversification** of companies from other domains (e.g. IT / Communication) into the **mobility sector** - With different competencies (IT, communication, automotive technology) companies try to **position themselves on future mobility markets** and exploit market potentials with innovative ideas and new business models
BES Vision	1) Market leadership from ecosystems based on IT and Data platform competence and current leadership in IT markets 2) Market leadership from ecosystems based on communication / transaction platform competencies 3) Market leadership from ecosystems based on innovation and technology platform competencies
BES Business Opportunities (First Ideas)	- **Entering** the **automotive market** through **high investments** in emerging mobility ecosystem - Offer **broader variety of mobility services** and **gain customer contacts** through **partnerships** with OEMs - **Development of new or existing market segments** through new business models, services, products and/or technologies - Examples: IT based services, communication services, innovative vehicle technologies, innovative infrastructure services, innovative VAS (value added services) / PRS (product related services)
General BES Strategies	1) Data/ IT based innovation / diversification strategies 2) Communication and transaction-based innovation / diversification strategies 3) Vehicle and technology-based innovation / diversification strategies 1)/2)/3) **Offer a variety of services** to consumers to provide a unique user experience in order **to keep customers loyal** to the mobility services ecosystem
Business Model Types	1) **Data / IT based** platform startup business models 2) **Transaction based** platform startup business models 3) **Vehicle / technology based** startup business models

Figure 40. BES Strategic Direction (Business Scenario 3)

BES General Evaluation

For a deeper understanding of the Business Scenario – New Mobility Provider centred Ecosystem it is essential to analyze it by using the SWOT method. In this context the SWOT analysis expresses 4 central business planning relevant factors for scenario stakeholders and business ecosystems:
a. the general opportunities (on a higher abstraction level of concrete business opportunities) provided by this business scenario, b. the general threats within this business scenario, c. the general strengths of business ecosystems or players supported by this business scenario, d. the general weaknesses which business ecosystems or players are facing within this business scenario.

The hypothesis for the General Evaluation of this Business Scenario is that New Mobility Provider centred Ecosystems can find a manageable playing field for mastering the challenge of a BES extension by AMPT engagement.
The analysis of this Business Scenario shows that the strengths of the New Mobility Provider centred Ecosystems (e.g. data business, technology innovations, transaction networks) can enhance the AMPT business significantly and the weaknesses are compensated by AMPT specialized companies (like AVENUE), both in order to ramp up fast into the AMPT market, seize opportunities and fend off threats.
As a general conclusion it can be determined that New Mobility Provider centred Ecosystems can manage the challenge of stepping or expanding into the lucrative AMPT business by individual and dedicated strategies (e.g. AMPT partnerships).

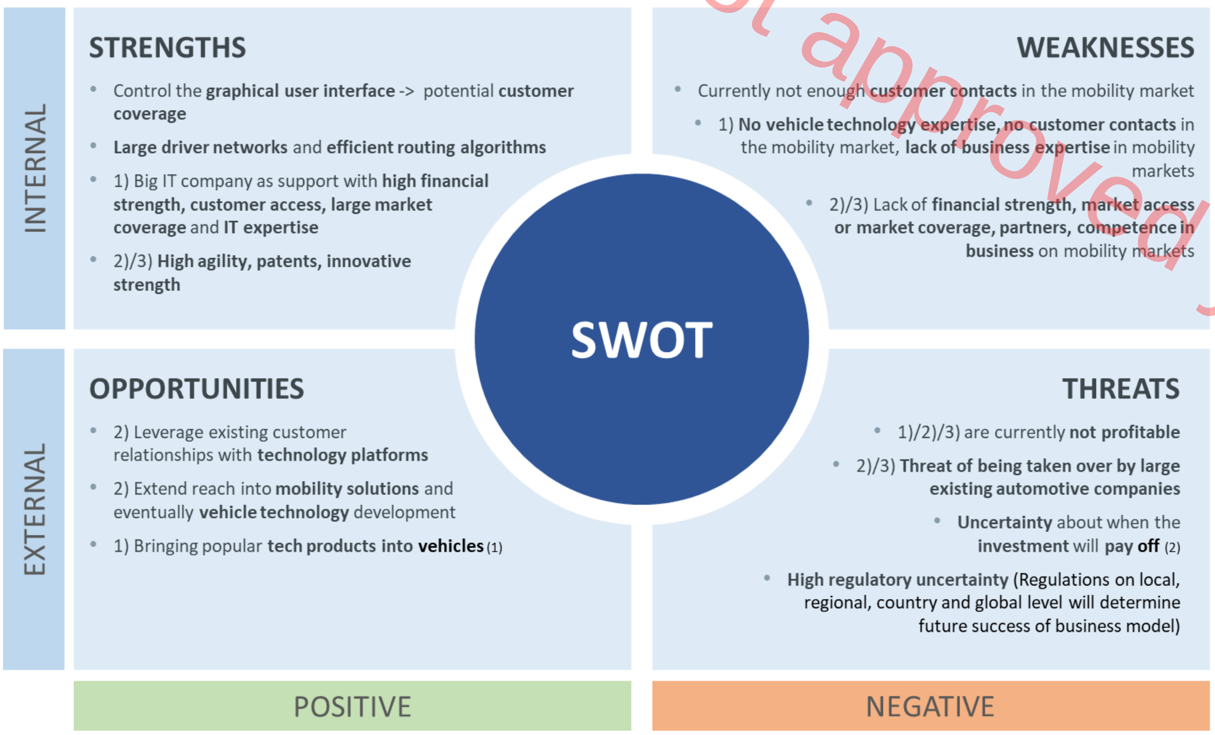


Figure 41. BES SWOT Analysis (Business Scenario 3)

<u>BES Success Factors & Risks</u>

A fundamental focus for strategic planning of business ecosystems is the identification of Success Factors and Risks for entrepreneurial behavior for the setup and management of Business Ecosystems within the Business Scenario of New Mobility Provider centred Ecosystems.

The hypothesis for the Success Factors and Risks of this Business Scenario is that they have their cause in the individually different entrepreneurial challenge when diversifying into a new AMPT market.

The analysis of this Business Scenario shows that depending from the individual origin of the New Mobility Provider centred Ecosystems other success factors support the transition or expansion into the AMPT market, while these 'newcomers' are facing general external and internal risks which have to be mitigated. As a general conclusion it can be determined that only the individual analysis of success and risk factors for New Mobility Provider centred Ecosystems are the basis for deriving individual and adequate business strategies.

Success Factors	Risks
1) - **High financial basis** for acquiring technology partners - **Market coverage** and **customer access** - **High innovative strength** in IT technology, data-based services and automated driving - **High impact of IT-giants** on mobility platform worldwide 2) - High **management flexibility** due to low hierarchies - **Competencies in management** of digital ecosystems (virtual network of partners) => often more important than technological competencies (e.g. Uber) 3) - Strong **technological competencies** (e-vehicles, automated vehicles) => patents for key technologies (e.g. battery management, power train, electrical engine)	**1)** - **Regulatory framework is still in development** and not clearly defined by government (Regulations on local, regional, country and global level determine success of business model) - **IT infrastructure is not sufficiently available** in many regions - **Vehicle infrastructure** (e.g. charging stations) is still **in an embryonal status** - IT **security risks** 2) - **Lack of trust** in new companies - **Lack of financial means** - Potential attractive **technology and service partners are already involved** in renowned **automotive ecosystems** - Threat of **being taken over by large companies** - **Lack of broad technological competencies** **3)** - **Lack of trust** in new companies

Figure 42. Success Factors & Risks (Business Scenario 3)

<u>**Typical exemplary BES – Partner Network**</u>

For a pragmatic strategic planning of a business ecosystem within this business scenario it is beneficial to have an idea of an archetypical model of a partner network as an exemplary structure of a Business Ecosystem represented by typical ecosystem partners as well as the central ecosystem lead partner (as ecosystem management platform owner) shaping and orchestrating this Business Ecosystem.

Typical exemplary BES – Partner Network – New data-based Mobility Provider

The hypothesis for the Partner Network of this Business Scenario is that the New data-based Mobility Provider is the Orchestrator and Platform Owner of a Mobility BES-Partner Network, providing own vehicles and/or diversifying into the transaction and vehicle business, profiting from its own data services.
The analysis of this Business Scenario shows that besides the platform management task the core offering / competency of the New data-based Mobility Provider lies in Value Added Digital Services (i.e. data services) - additionally to the offerings / competencies of other relevant BES partners.
As a general conclusion it can be determined that the New data-based Mobility Provider manages the BES based on its originating core competency and core business.

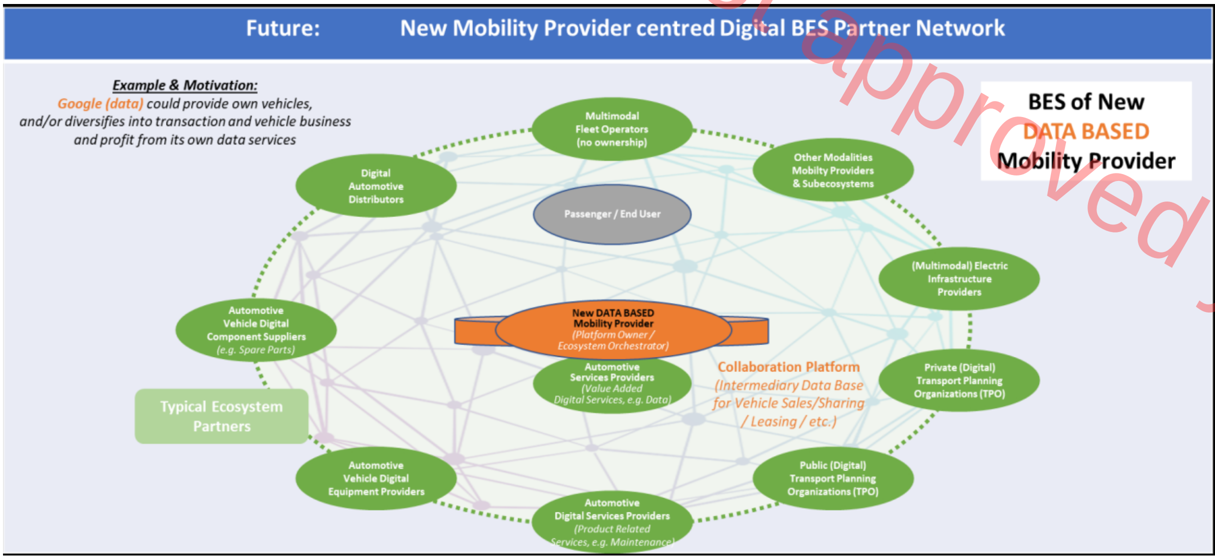


Figure 43. Typical exemplary BES – Partner Network – New Data Based Mobility Provider (Business Scenario 3)

Typical exemplary BES – Partner Network – New transaction-based Mobility Provider

The hypothesis for the Partner Network of this Business Scenario is that the New transaction-based Mobility Provider is the Orchestrator and Platform Owner of a Mobility BES-Partner Network, increasing business with innovative vehicles (e.g. AMPTs) with options to diversify into vehicle / infrastructure / service data businesses.
The analysis of this Business Scenario shows that besides the platform management task the core offering / competency of the New transaction-based Mobility Provider lies in Transaction Services (i.e. network services) - additionally to the offerings / competencies of other relevant BES partners.
As a general conclusion it can be determined that the New transaction-based Mobility Provider manages the BES based on its originating core competency and core business.

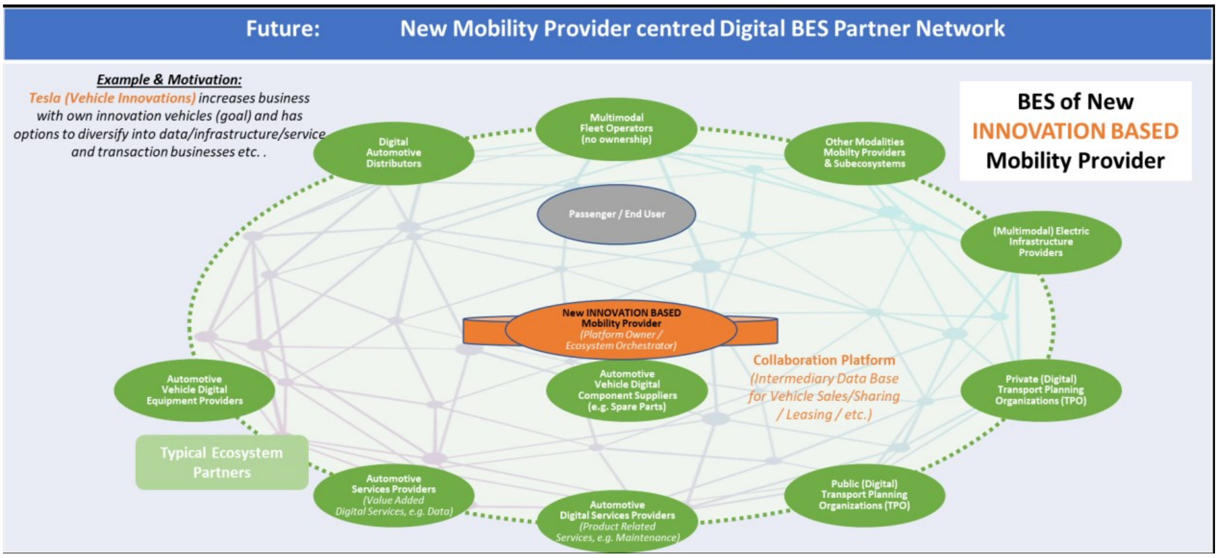


Figure 44. Typical exemplary BES – Partner Network – New Innovation Based Mobility Provider (Business Scenario 3)

Typical exemplary BES – Partner Network – New innovation-based Mobility Provider

The hypothesis for the Partner Network of this Business Scenario is that the New innovation-based Mobility Provider is the Orchestrator and Platform Owner of a Mobility BES-Partner Network, increasing business with own innovative vehicles (e.g. AMPTs) with options to diversify into data / infrastructure / service and transaction businesses.
The analysis of this Business Scenario shows that besides the platform management task the core offering / competency of the New innovation-based Mobility Provider lies in the supply of Automotive Vehicle Digital Components (i.e. spare parts) - additionally to the offerings / competencies of other relevant BES partners.
As a general conclusion it can be determined that the New innovation-based Mobility Provider manages the BES based on its originating core competency and core business.

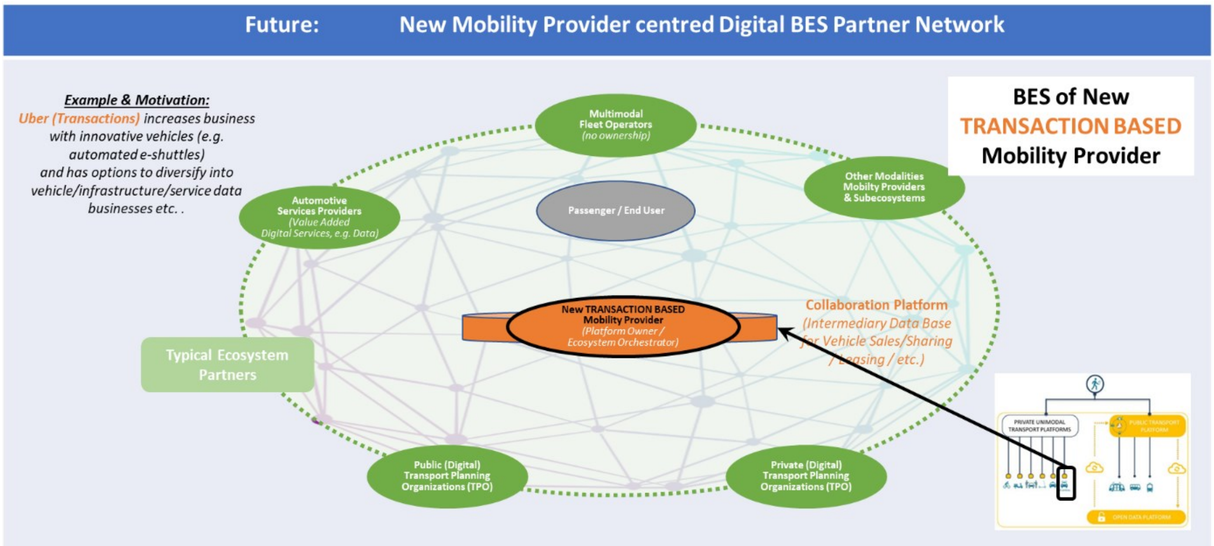


Figure 45. Typical exemplary BES – Partner Network – New Transaction Based Mobility Provider (Business Scenario 3)

b) Business Opportunities (Business Scenario 3)

Referring to the table of relevant Business Opportunities within Business Scenarios from Chapter 3 (Business Scenarios – Concept Overview, Identification of most promising Business Opportunity Clusters & Opportunities, Figure x) the most promising Business Opportunities (BO 2-4) for the New Mobility Provider centred Ecosystem have been identified as: ‘Provide AMPT Solutions to New data-based Mobility Providers’ (BO 2), ‘Provide AMPT Solutions to New transaction-based Mobility Providers’ (BO 3), and ‘Providing Product-Related Services (PRS) to New innovation-based Mobility Providers’ (BO 4).
For characterizing these Business Opportunity on a general level, it is beneficial to use a ‘staircase’ of sequential core questions as a simple standardized method). A more detailed analysis and evaluation of these selected Business Opportunities can be only conducted after a concrete business use cases have been detected.

The most promising Business Opportunities BO2, BO3, BO4 for this Business Scenario have been characterized by a ‘staircase’ of sequential core questions (see Figure 46/Figure 47/Figure 48)

Business Opportunity - New data-based Mobility Provider

The hypothesis for the Business Opportunity of this Business Scenario is New data-based Mobility Providers are completely lacking AMPT competencies and this can be taken as an opportunity for AMPT providers to provide respective comprehensive offering solutions via BES partnerships.

The analysis of this Business Scenario shows that AMPT construction, production, fleet operation and other competencies are lacking where AMPT specialized companies can provide value to the respective BES.
As a general conclusion it can be determined that AMPT Solutions is a promising offer to New data-based Mobility Providers and their BES.

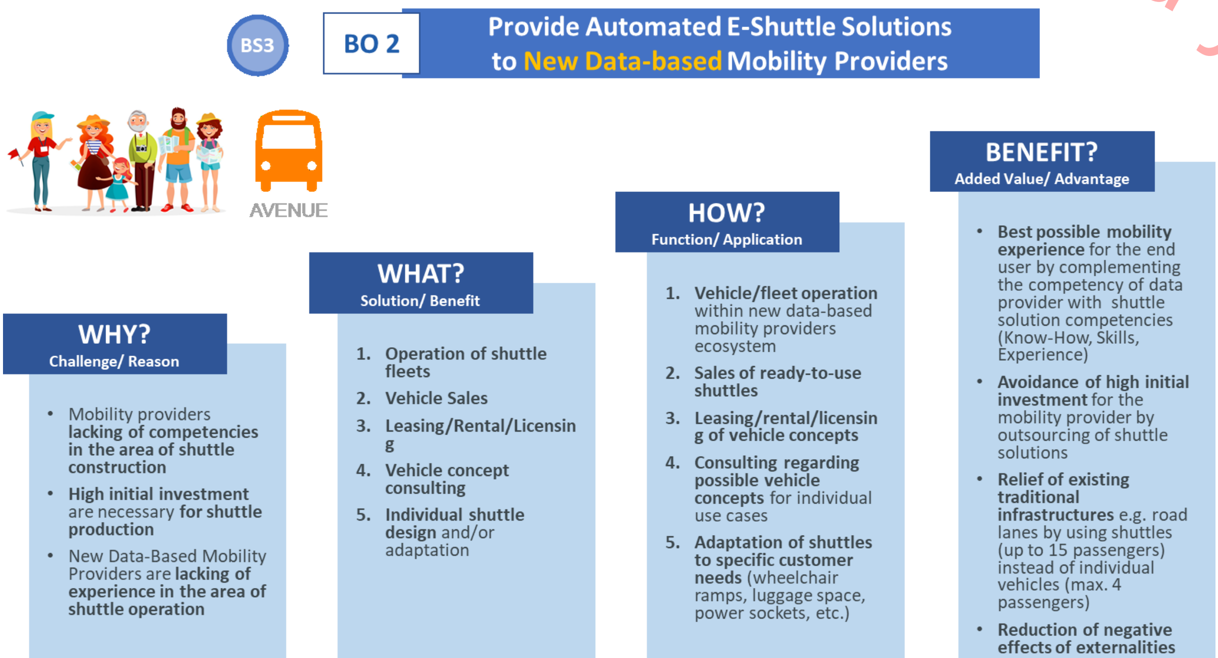


Figure 46. Business Opportunities Staircase - New Data Based Mobility Provider (Business Scenario 3)

The hypothesis for the Business Opportunity of this Business Scenario is New transaction-based Mobility Providers are (just like New data-based Mobility Providers) completely lacking AMPT competencies and this can be taken as an opportunity for AMPT providers to provide respective comprehensive offering solutions via BES partnerships.
The analysis of this Business Scenario shows that complete AMPT solutions (operations, sales, design, etc.) and other competencies are lacking where AMPT specialized companies can provide value to the respective BES.
As a general conclusion it can be determined that complete AMPT Solutions is a promising offer to New transaction-based Mobility Providers and their BES.

Business Opportunity - New transaction-based Mobility Provider

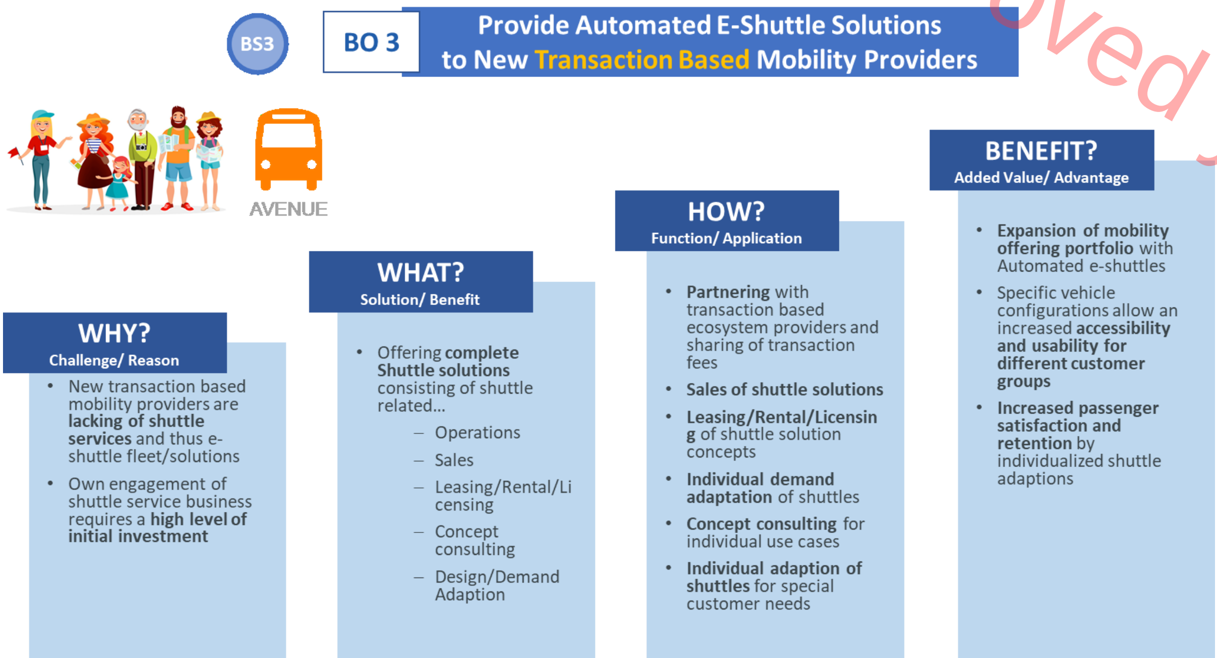


Figure 47. Business Opportunities Staircase - New Transaction Based Mobility Provider (Business Scenario 3)

Business Opportunity - New innovation-based Mobility Provider

The hypothesis for the Business Opportunity of this Business Scenario is New innovation-based Mobility Providers are often lacking PRS (product related services) competencies and this can be taken as an opportunity for AMPT providers to provide respective comprehensive offering solutions via BES partnerships.

The analysis of this Business Scenario shows that PRS for AMPTs (fleet management, vehicle & component maintenance, etc.) are lacking where AMPT specialized companies can provide value to the respective BES.

As a general conclusion it can be determined that PRS for AMPTs is a promising offer to New innovation-based Mobility Providers and their BES.

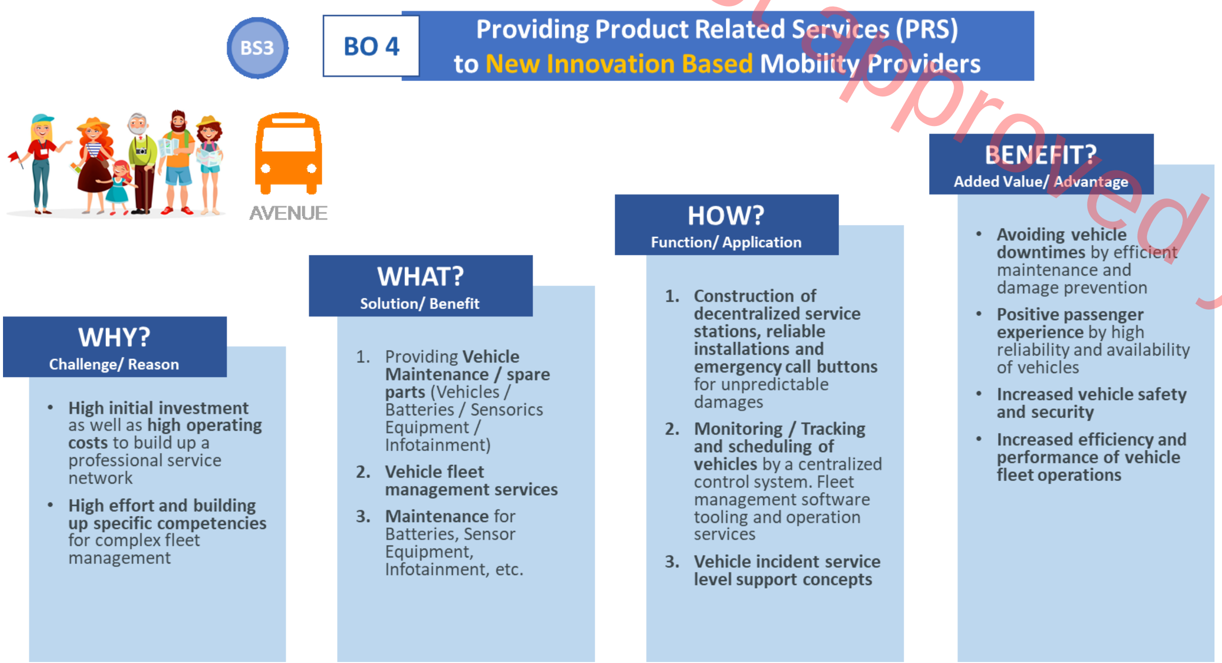


Figure 48. Business Opportunities Staircase - New Innovation-Based Mobility Provider (Business Scenario 3)

The hypothesis for the Business Opportunity of this Business Scenario is New innovation-based Mobility Providers are often lacking PRS (product related services) competencies and this can be taken as an opportunity for AMPT providers to provide respective comprehensive offering solutions via BES partnerships.
The analysis of this Business Scenario shows that PRS for AMPTs (fleet management, vehicle & component maintenance, etc.) are lacking where AMPT specialized companies can provide value to the respective BES.
As a general conclusion it can be determined that PRS for AMPTs is a promising offer to New innovation-based Mobility Providers and their BES.

c) Business Strategies (Business Scenario 3)

The typical and most promising Business Strategies for the most promising Business Opportunities BO1, BO3, BO4 within this Business Scenario have been identified by a sequence of strategic core issues that are most relevant for the further definition of future business models. These strategy categories are focused on the typical building blocks of a business model canvas, and additionally highlighting the core innovation strategies relevant for successful conduction of these businesses. (see Figure 49/Figure 50/Figure 51)

<u>Business Strategies - New data-based Mobility Provider</u>

The hypothesis for the Business Strategies of this Business Scenario is generally that AMPT technologies, solutions and businesses are consequently aligned and integrated with the data-based technologies, solutions and businesses of the Mobility Providers in every facet of the strategies portfolio.
The analysis of this Business Scenario shows for example AMPT components and solutions strategies are adapted with IoT based technology strategies to transfer data, marketing strategies are integrated between AMPT and data businesses, revenue strategies are aligned with data strategies (e.g. at performance contracting). Furthermore marketing & sales strategies are integrated with market strategies of 'data giants' (e.g. branding).

As a general conclusion it can be determined that the more passengers, vehicles, services, infrastructures etc. and thus also AMPTs are regarded as data exchanging bodies, the higher the strategic synergies and integration is requested and necessary.

BS3 | BO 2 | Provide Automated E-Shuttle Solutions to New Data-based Mobility Providers

ID	BES Strategy Category	Vision / Strategic Goal (WHAT)	Recommended Strategies (HOW)	Strategy Justification (WHY)
VO	**Value / Offering (Product/Solution/ Service) Strategies**	Offer the best possible mobility experience for the end user by complementing the competency of data provider with shuttle solution competencies (Know-How, Skills, Experience)	- **Offer IoT-based ASCT solution concepts** (e.g. operation, sales, leasing, rental, licensing, consulting) for new data-based mobility provider	- Requirement of the customer access and data to offer new mobility solutions
MC	**Market / Customer Group Strategies**	Common marketing strategies and exploiting existing market coverage of new data-based mobility providers	- **Utilizing and alignment of market/marketing strategies** with new data-based mobility providers	- Utilizing existing market coverage and access of new data-based mobility providers for ASCT solution purposes
CA	**Competition & Competition Advantage/USPs Strategies**	Eliminate potential competitors by permanent and close collaboration with new data-based mobility providers by innovative ASCT technology/solutions	- **Utilizing of common IPs as synergy effects (e.g. patents)** with the new data-based mobility provider	- Common IPs provide a protection shield against the external competitors - Close collaboration and technical/ business alignment with new data-based mobility providers as protection against competitors
SD	**Distribution & Sales Channel Strategies (incl. Partnering)**	Utilizing existing distribution network and sales channels (e.g. platform) of new data-based mobility provider	- **Close collaboration in distribution and sales** related to **market coverage** and **market access** - Branding strategy: utilizing of well known data-based mobility provider brand	- Synergy effects regarding cost/effort, sales network and increase of sales success by collaborative concepts
RD	**R&D/Production & Technology/Com-petency Strategies (incl. Partnering)**	Permanent R&D/Production/Technology collaboration for an aligned development of ASCT solution concepts	- **Cooperation of R&D strategies** with new mobility providers to improve continuously ACST shuttle solution and adapt it to customer requirements	- Need for adaptation of shuttles to specific customer needs (wheelchair ramps, luggage space, power sockets, etc.) - Close and up-to-date development of ASCT solutions aligned to offering and solutions of other ecosystem providers
FI	**Financing & Invest Strategies**	- Invest goal: longterm business partnership with new data-based mobility provider - Financing goal: multisided/distributed financing sources	- Invest into **ASCT businesses or ASCT technologies** prioritised by new data-based mobility providers - Financing by **various business revenues from ASCT** Offerings/Solutions/Technologies/Consulting	- Invest: Securing longterm business partnership - Financing: Risk diversification for financing sources
CO	**Cost Strategies**	- Minimum costs for given performance - Maximum performance/quality for fix costs	- Public: **Target Costing strategy** focused on budget of public tenders - Private: **Flexible cost strategy** dependend of performance/ quality target	- Defined or negotiated within tenders/contracts
RE	**Revenue Strategies**	Common revenues (sales, operations, rental, leasing, consulting etc.) together with other ASCT offerings within an integrated solution for PTOs	Flexible, individual or integrated revenues from: - **Performance based Contracting** - **Sales, operation, rental, leasing, consulting revenues** from ASCT solution concepts - **Sharing of transaction fees**	- Continous revenues by integrated revenue concepts by new data-based mobility providers ecosystem solutions
TI	**Offering/Technology Innovation Strategies**	Close collaboration and partnership within new data-based centred ecosystem allows a flexible, fast and proactive adaption of the trends for offerings, technologies, competencies etc. for development of future driven ASCT solutions	- **Adaption of innovation goals and strategies** from new data-based mobility providers for ASCT: e.g. - **Flexible innovation of the drive systems** - **Modularization strategy** - **Fast customizing strategy** - **Consulting** of new data-based mobility providers **regarding possible vehicle concepts for individual use cases** - **Data-Management of ASCT**	**Consequent collaboration and deep partnership** with new data-based mobility provider provides stable strategic direction for **ASCT offerings, technologies and competencies**, but also takes the risk of unilateral dependency from business success of the new data-based mobility provider
BI	**Business/Marketing Innovation Strategies**	Close collaboration and partnership within new data-based centred ecosystem allows a flexible, fast and proactive adaption of the trends for market demands for development of future driven ASCT business concepts	**Utilizing and adaption of marketing and business strategies** of the data-based mobility providers for ASCT business concepts: e.g - **Adaption of market coverage and marketing strategies** of automotive providers - Branding strategy: **utilizing of existing well known data-based provider brand**	**Consequent collaboration and deep partnership** with new data-based mobility provider provides stable strategic direction for **ASCT businesses**, but also takes the risk of unilateral dependency from business success of the new data-based mobility provider

Figure 49. Business Strategies Table - New Data-Based Mobility Provider (Business Scenario 3)

Business Strategies - New data-based Mobility Provider

The hypothesis for the Business Strategies of this Business Scenario is generally that AMPT technologies, solutions and businesses are consequently aligned and integrated with the data-based technologies, solutions and businesses of the Mobility Providers in every facet of the strategies portfolio.

The analysis of this Business Scenario shows for example AMPT components and solutions strategies are adapted with IoT based technology strategies to transfer data, marketing strategies are integrated between AMPT and data businesses, revenue strategies are aligned with data strategies (e.g. at performance contracting). Furthermore marketing & sales strategies are integrated with market strategies of 'data giants' (e.g. branding).

As a general conclusion it can be determined that the more passengers, vehicles, services, infrastructures etc. and thus also AMPTs are regarded as data exchanging bodies, the higher the strategic synergies and integration is requested and necessary.

BS3	BO 3	Provide Automated E-Shuttle Solutions to New Transaction Based Mobility Providers		
ID	**BES Strategy Category**	**Vision / Strategic Goal**	**Recommended Strategies**	**Strategy Justification**
VO	**Value / Offering (Product/Solution/ Service) Strategies**	Offer the best possible mobility experience for the end user by complementing the competency of transaction-based mobility provider with shuttle solution competencies (Know-How, Skills, Experience)	- Offer **a fleet of ASCT vehicles and solutions** (e.g. operation, sales, leasing, rental, licensing, consulting) specificaly disgned and with automated interaction with transaction-based platform	- Expansion of mobility offering portfolio with ASCT
MC	**Market / Customer Group Strategies**	Common marketing strategies and exploiting existing market coverage of transaction-based mobility providers	- **Utilizing and alignment of market/marketing strategies** with transaction-based mobility providers	- Utilizing existing market coverage and access of transaction-based mobility providers for ASCT solution purposes
CA	**Competition & Competition Advantage/USPs Strategies**	Eliminate potential competitors by permanent and close collaboration with transaction-based mobility providers by innovative ASCT technology/solutions	- **Utilizing of common IPs as synergy effects (e.g. patents)** with the transaction-based mobility providers	- Common IPs provide a protection shield against the external competitors - Close collaboration and technical/ business alignment with transaction-based mobility providers as protection against competitors
SD	**Distribution & Sales Channel Strategies (incl. Partnering)**	Utilizing existing distribution network and sales channels (e.g. platform) of transaction-based mobility providers	- **Close collaboration in distribution and sales** related to **market coverage** and **market access** - Branding strategy: **utilizing of well known transaction-based mobility providers**	- Synergy effects regarding cost/effort, sales network and increase of sales success by collaborative concepts
RD	**R&D/Production & Technology/Com-petency Strategies (incl. Partnering)**	Permanent R&D/Production/Technology collaboration for an aligned development of ASCT solution concepts	- **Cooperation of R&D and innovation strategies** with transaction-based mobility providers to improve continuously ACST shuttle solution and adapt it to customer requirements	- Need for adaptation of shuttles to specific customer needs (wheelchair ramps, luggage space, power sockets, etc.) - Close and up-to-date development of ASCT solutions aligned to offering and solutions of other ecosystem providers
FI	**Financing & Invest Strategies**	- Invest goal: longterm business partnership with transaction-based mobility providers - Financing goal: multisided/distributed financing sources	- Invest into **ASCT businesses or ASCT technologies** prioritised by new transaction-based mobility providers - Financing by **multisided business** revenues (e.g. **transaction fees**)	- Invest: Securing longterm business partnership - Financing: Risk diversification for financing sources
CO	**Cost Strategies**	- Minimum costs for given performance - Maximum performance/quality for fix costs	- Public: **Target Costing strategy** focused on budget of public tenders - Private: **Flexible cost strategy** dependend of performance/ quality target	- Defined or negotiated within tenders/contracts
RE	**Revenue Strategies**	Common revenues (sales, operations, rental, leasing, consulting etc.) together with other ASCT offerings within an integrated solution for PTOs	- Flexible, individual or integrated revenues from: - **Performance based Contracting** - **Sales, operation, rental, leasing, consulting revenues** from ASCT solution concepts - **Revenue Sharing** strategy (**transaction fees**)	Continous revenues by integrated revenue concepts by new transaction-based mobility providers ecosystem solutions
TI	**Offering/Technology Innovation Strategies**	Close collaboration and partnership within new transaction-based centred ecosystem allows a flexible, fast and proactive adaption of the trends for offerings, technologies, competencies etc. for development of future driven ASCT solutions	- **Adaption of innovation goals and strategies** from new transaction-based mobility providers for ASCT: e.g. - **Flexible innovation of the drive systems** - **Modularization strategy** - **Fast customizing strategy** - **Consulting** of new transaction-based mobility providers **regarding possible vehicle concepts for individual use cases** - **Design a fleet of ASCT/solution with optimal interaction with transaction platforms**	**Consequent collaboration and deep partnership** with new transaction-based mobility provider provides stable strategic direction for **ASCT offerings, technologies and competencies**, but also takes the risk of unilateral dependency from business success of the new transaction-based mobility provider
BI	**Business/Marketing Innovation Strategies**	Close collaboration and partnership within new transaction-based centred ecosystem allows a flexible, fast and proactive adaption of the trends for market demands for development of future driven ASCT business concepts	- **Sharing of transaction fees** by partnership with new transaction-based ecosystem - **Intensification of culture and innovation potential of AVENUE as start up company** - **Utilization of competencies in the management of digital ecosystems** and **the resulting network of partners from** new transaction-based mobility providers	**Consequent collaboration and deep partnership** with new transaction-based mobility provider provides stable strategic direction for **ASCT businesses**, but also takes the risk of unilateral dependency from business success of the new transaction-based mobility provider

Figure 50. Business Strategies Table - New Transaction Based Mobility Provider (Business Scenario 3)

Business Strategies - New innovation-based Mobility Provider

The hypothesis for the Business Strategies of this Business Scenario is generally that new innovation-based Mobility Providers are themselves often technology and / or solution innovators e.g. in the automotive or even AMPT sector. In this case it is necessary to analyze the strategies portfolio of the New innovation-based Mobility Providers and offer complementary PRS strategies in order enhance the common market position and to avoid unnecessary competition.

The analysis of this Business Scenario shows for example that strategies as AMPT component or vehicle maintenance (e.g. spare parts) businesses or fleet management services may be an attractive BES partnering offering for New innovation-based Mobility Providers to achieve common business goals of technology ramp up, market coverage and penetration as well as synergetic revenue increase.

As a general conclusion it can be determined that a close complementary and synergetic BES partnership collaboration among mobility innovators on various strategy levels can be a promising way for mutual support and busines success.

BS3 | BO 4 | Providing Product Related Services (PRS) to New Innovation Based Mobility Providers

ID	BES Strategy Category	Vision / Strategic Goal	Recommended Strategies	Strategy Justification
VO	Value / Offering (Product/Solution/ Service) Strategies	Offering complementary PRS with new innovation-based mobility providers to ensure a positive and safe passenger experience by high reliability and increased vehicle safety and security	Offer/Provide Product Related Services for new innovation-based mobility provider: e.g. - **Vehicle Maintenance / spare parts** (Vehicles / Batteries / Sensorics Equipment / Infotainment) - **Vehicle fleet management services** - **Maintenance** for Batteries, Sensor Equipment, Infotainment, etc.	- Need for an extensive portfolio of aligned and up-to-date PRS
MC	Market / Customer Group Strategies	Common marketing strategies and exploiting existing market coverage of new innovation-based mobility providers	- **Utilizing/Adapting of existing markets** from automotive providers and **alignment of marketing strategies** with new innovation-based mobility providers	- Utilizing existing market coverage and access of new innovation-based mobility providers for PRS purposes
CA	Competition & Competition Advantage/USPs Strategies	Eliminate potential competitors by permanent and close collaboration with new innovation-based mobility providers by common patents for key technologies (e.g. battery management, power train, electrical engine)	- **Utilizing of common IPs as technological synergy effects (e.g. patents for key technologies)** with the new innovation-based mobility provider - **Extension/complementation of the USP portfolio** of new innovation-based mobility provider by specific PRS USPs	- Common IPs provide a protection shield against the external competitors - Close collaboration and technical/ business alignment with new innovation-based mobility providers as protection against competitors
SD	Distribution & Sales Channel Strategies (incl. Partnering)	Utilizing existing distribution network and sales channels of new innovation-based mobility provider	- **Close collaboration in distribution and sales (networks)** to **market coverage** and **market access** - Branding strategy: **utilizing of existing well known new innovation-based mobility provider brand**	- Synergy effects regarding cost/effort, sales network and increase of sales success by collaborative concepts
RD	R&D/Production & Technology/Com-petency Strategies (incl. Partnering)	Permanent R&D/Production/Technology collaboration for an aligned development of PRS	- **Cooperation/collaborative R&D and innovation strategies of PRS** with offering providers (vehicle/modul/infrastructure etc.) within the new innovation-based centred mobility ecosystem	- Need for an extensive portfolio of PRS - Close and up-to-date development of PRS solutions aligned to offering and solutions of other ecosystem providers
FI	Financing & Invest Strategies	- Invest goal: longterm business partnership with new innovation-based mobility provider - Financing goal: multisided/distributed financing sources	- Financing by **various business revenues from PRS** Offerings/Solutions/Technologies - Invest into **ASCT specific PRS businesses or PRS technologies** prioritised by new innovation-based mobility provider	- Invest: Securing longterm business partnership - Financing: Risk diversification for financing sources
CO	Cost Strategies	- Minimum costs for given performance - Maximum performance/quality for fix costs	- Public tenders: **Target Costing strategy** focused on budget of public PTOs - Private tenders: **Flexible cost strategy** dependend from performance/ quality target of private PTOs	- Defined or negotiated within tenders/contracts
RE	Revenue Strategies	Common revenues (e.g. Vehicle maintenance, vehicle fleet management) together with other PRS offerings within an integrated solution for PTOs	Flexible, individual or integrated revenues from: - **Performance based Contracting** - **Vehicle/spare parts maintenance** - **Operations business fees from vehicle fleet management**	Continous revenues by integrated revenue concepts by new innovation-based centred mobility ecosystem solutions
TI	Offering/Technology Innovation Strategies	Close collaboration and partnership within new innovation-based centred ecosystem allows a flexible, fast and proactive adaption of the trends for offerings, technologies, competencies etc. for development of future driven PRS solutions	- **Utilization of strong technological competencies (e.g. e-vehicles, automated vehicles) of new innovation-based mobility providers** - **Adaption of the innovative strength (e.g. patents)**	**Consequent collaboration and deep partnership** with new innovation-based mobility provider provides stable strategic direction for **PRS offerings, technologies and competencies**, but also takes the risk of unilateral dependency from business success of the new innovation-based mobility provider
BI	Business/Marketing Innovation Strategies	Close collaboration and partnership within new innovation-based centred ecosystem allows a flexible, fast and proactive adaption of the trends for market demands for development of future driven PRS business concepts	**Utilizing and adaption of marketing and business strategies** of the new innovation-based mobility providers for PRS business concepts: e.g - **Adaption of market coverage and marketing strategies** - Branding strategy: **utilizing of existing well known new innovation-based provider brand** - **Intensification of culture and innovation potential of AVENUE as start up company**	**Consequent collaboration and deep partnership** with new innovation-based mobility provider provides stable strategic direction for **PRS businesses**, but also takes the risk of unilateral dependency from business success of the new innovation-based mobility provider

Figure 51. Business Strategies Table - New Innovation Based Mobility Provider (Business Scenario 3)

d) Business Models (Business Scenario 3)

The typical Business Models BO2, BO3, BO4 (characterized by its complementary systemically interacting modules and its integrating logical story) for this Business Scenario derived from and guided by the previously identified Business Strategies have been defined based on the business model canvas template defined in chapter 3.2.

Using these exemplary and suggested business models is important to notice that they have to be regarded as business model categories, aggregating multiple business model subtypes for each module mentioned and suggested from the literature (e.g. St. Gallen Business Model Navigator and others[9]) (see Figure 52/Figure 53/Figure 54)

Business Model and Business Model Story - New data-based Mobility Provider

The hypothesis for the Business Models of this Business Scenario is that the business model for AMPT solutions by AMPT providing partners (e.g. AVENUE) is as far as possible aligned and integrated with the business model of the New data-based Mobility Provider.
The analysis of this Business Scenario shows that this synergetic alignment and integration should be conducted in all modules of the business model due to the fact that digitalization and thus data related issues (AMPT solution features / value & delivery module, sales & marketing / customer module, revenue module, etc.) and the impact of 'data giants' are a key success factor for the AMPT business.

[9] https://www.alexandria.unisg.ch/224941/7/Business%20Model%20Navigator%20working%20paper.pdf

As a general conclusion it can be determined that the strong synergetic partnership and thus complementary business model integration between AMPT and New data-based Mobility Providers has to be analyzed designed individually and guided by the respective module strategies in order to achieve a completely aligned business model consistency.

The generally elaborated Business Model for AMPT Solutions provided to New data-based Mobility Providers for New Mobility Provider centred BES is represented in the following (figure x):

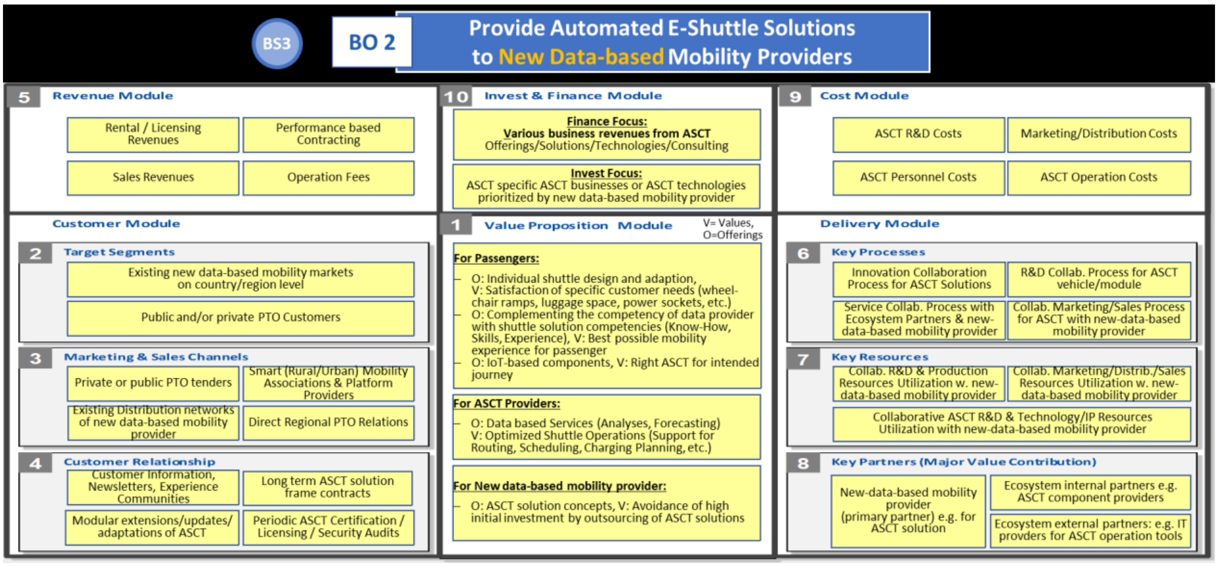


Figure 52. Business Model - New Data Based Mobility Provider (Business Scenario 3)

The hypothesis for the Business Model Story of this Business Scenario is that the guiding collaborative and synergetic strategy approach leads to a reciprocal alignment and integration of all business model modules.
The analysis of this Business Scenario shows that the all modules of the business model from the New data-based Mobility Provider (data technologies & business) are impacting and integrated with the corresponding modules of the AMPT business model.
As a general conclusion it can be determined that a consequent integration of AMPT business models with those from New data-based Mobility Providers are the key for a successful BES partnership.

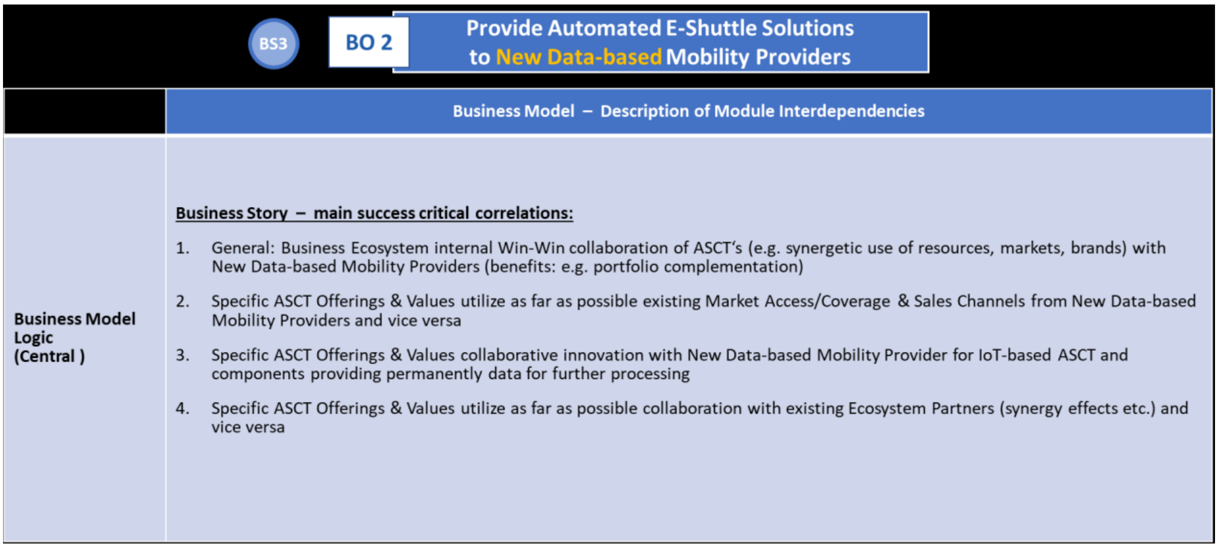


Figure 53. Business Model Story - New Data Based Mobility Provider (Business Scenario 3)

Business Model and Business Model Story – New transaction-based Mobility Provider

The hypothesis for the Business Models of this Business Scenario is that the business model for AMPT solutions by AMPT providing partners (e.g. AVENUE) is as far as possible aligned and integrated with the business model of the New transaction-based Mobility Provider.
The analysis of this Business Scenario shows that this synergetic alignment and integration should be conducted in all modules of the business model due to the fact that digitalization and thus transaction related issues (AMPT solution features [e.g. minibuses customized for passenger needs - robustness, comfort or accessibility] / value & delivery module, sales & marketing / customer module, revenue module, etc.) and the requirements of 'transaction business focused companies' are a key success factor for the AMPT business.
As a general conclusion it can be determined that the strong synergetic partnership and thus complementary business model integration between AMPT and New transaction-based Mobility Providers has to be analyzed designed individually and guided by the respective module strategies in order to achieve a completely aligned business model consistency.

The generally elaborated Business Model for AMPT Solutions provided to New transaction-based Mobility Providers for New Mobility Provider centred BES is represented in the following (figure 54):

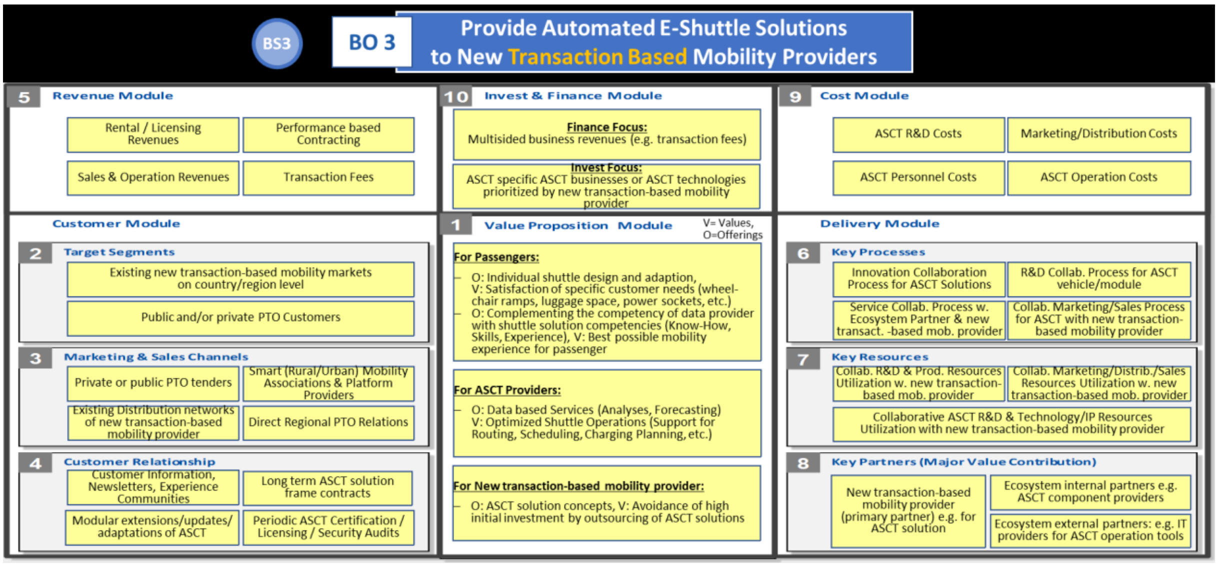


Figure 54. Business Model - New Transaction Based Mobility Provider (Business Scenario 3)

The hypothesis for the Business Model Story of this Business Scenario is that the guiding collaborative and synergetic strategy approach leads to a reciprocal alignment and integration of all business model modules.
The analysis of this Business Scenario shows that the all modules of the business model from the New transaction-based Mobility Provider (transaction concept & business) are impacting and integrated with the corresponding modules of the AMPT business model.
As a general conclusion it can be determined that a consequent integration of AMPT business models with those from New transaction-based Mobility Providers are the key for a successful BES partnership.

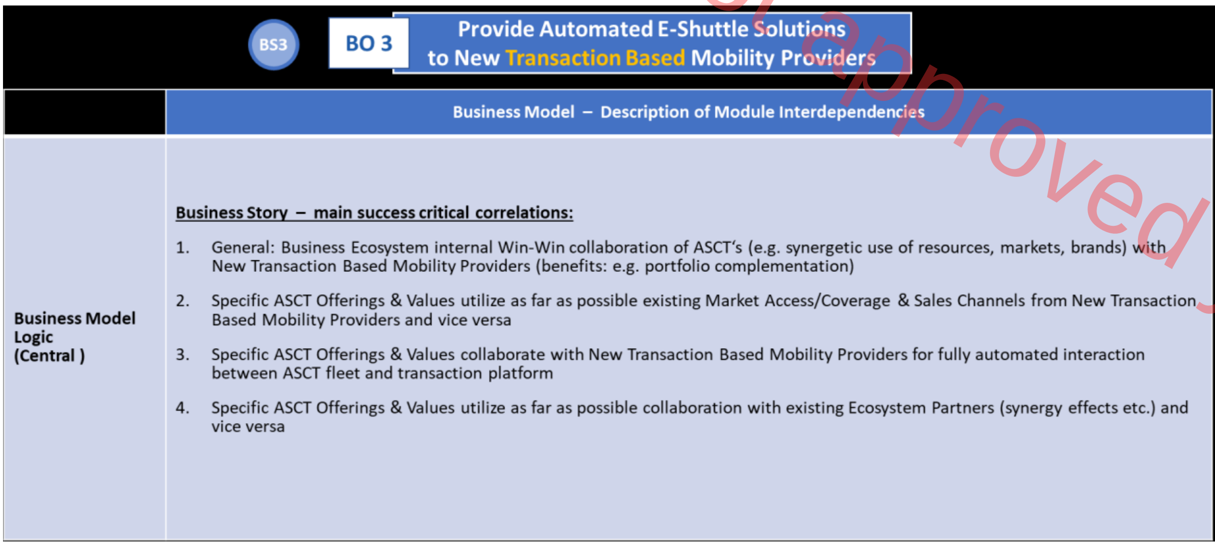


Figure 55. Business Model Story - New Transaction Based Mobility Provider (Business Scenario 3)

Business Model and Business Model Story – New innovation-based Mobility Provider

The hypothesis for the Business Models of this Business Scenario is that the business model by AMPT providing partners (e.g. AVENUE) for Providing Product related Services (PRS) to New innovation-based Mobility Providers is as far as possible aligned and integrated with the business model of the New innovation-based Mobility Provider.
The analysis of this Business Scenario shows that this synergetic alignment and integration between both innovator business models (AMPT and other New innovation-based Mobility Provider) should be conducted in all modules of the business model due to the fact that product related services (PRS) are technologically and businesswise complementary and dependent from each other in the sense of a value chain. In this sense innovation-based companies and AMPT PRS providers are close partners of the same value chain.
As a general conclusion it can be determined that the strong synergetic BES partnership and thus complementary business model integration between AMPT and New innvation-based Mobility Providers has to be analyzed designed individually and guided by the respective module strategies in order to achieve a completely aligned business model consistency.

The generally elaborated Business Model for AMPT Solutions provided to New innovation-based Mobility Providers for New Mobility Provider centred BES is represented in the following (figure 56):

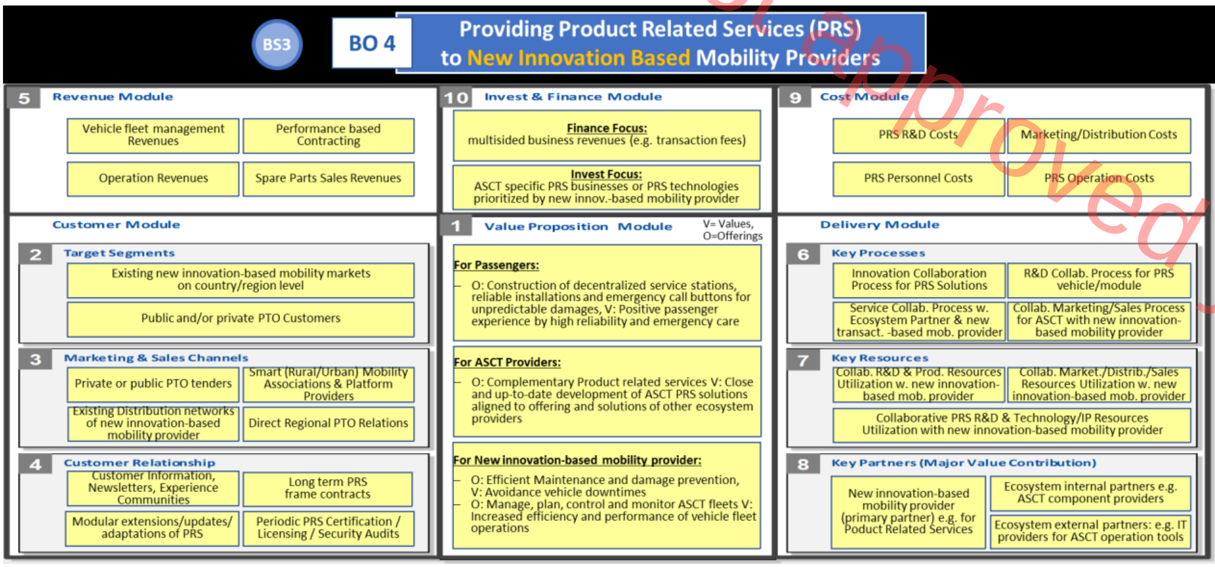


Figure 56. Business Model - New Innovation Based Mobility Provider (Business Scenario 3)

The hypothesis for the Business Model Story of this Business Scenario is that the guiding collaborative and synergetic strategy approach leads to a reciprocal alignment and integration of all business model modules.
The analysis of this Business Scenario shows that the all modules of the business model from the New innovation-based Mobility Provider (product or technology innovation concept & business) are impacting and integrated with the corresponding modules of the AMPT PRS business model.
As a general conclusion it can be determined that a consequent integration of AMPT business models with those from New innovation-based Mobility Providers are systemically mandatory and beneficial.

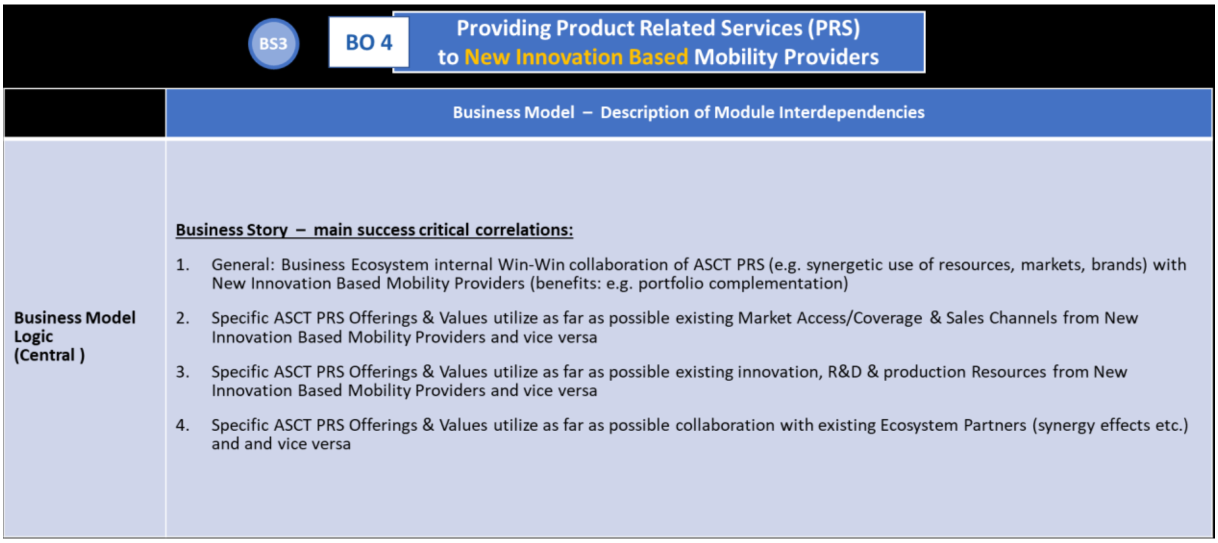


Figure 57. Business Model Story – New Innovation Based Mobility Provider (Business Scenario 3)

3.7 Business scenario 4: Customer/Citizen Centred Intermodal MaaS centred Ecosystem

Elaborations on this Business Scenario are available but still in improvement progress and will be provided at the next iteration of the deliverable.

3.8 Final Remarks on Business Scenarios

For the practical application of the elaborated results on all **4 Design Steps for Strategic Business Planning for the Business Scenarios BS2, BS3, BS4** – it is recommended for a future AVENUE entrepreneur to identify and analyze the concrete focus use case adapting these Design Steps as a systematic guide and identify, analyze and select the business scenarios, business opportunities, business strategies and business models suggested stepwise iteratively for relevance. On each Design Step level further iterative adaption, discussion and refinement processes have to be conducted and decisions have to be made before a final strategic business planning concept for the concrete use case can be compiled and implemented.

4 Business Case for focused Business Scenario 1 (AVENUE demonstrators and pilots)

4.1 Methodology

Inspired by the studies from Bösch et al. (2018), Henderson et al. (2017) and, Kalakuntla (2017) as well as by applying the Total Cost of Ownership (TCO) approach as done by Ongel et al. (2019), we developed a simulation tool for assessing the economic impact of services with Automated Shuttles for Collective Transport. The tool operates at 2 levels (local and global). The local level, presented here at section 4, integrates the internal costs (for designing and implementing the services with automated shuttles) while the global level – presented on section 5, integrates the macro external costs for the city.

The overall scope, methodology and previous results from this whole section 4 has already been approved and is going to be published in the book "The Robomobility Revolution of Urban Public Transport - A Social Sciences Perspective" , Mira-Bonnardel S., Antonialli F., Attias D., Springer Nature International Publishing 2021, (chapter 4: Antonialli, F., Mira-Bonnardel, S., Bulteau, J., Economic Assessment of Services with Intelligent Automated Vehicles: EASI-AV©)

During the past 12 months, a simulation tool with the aim of assessing the economic impact of services with automated shuttles was developed and validated by the Public Transport Operators (PTOs) from the demonstrator cities in the AVENUE project.

Our tool, kindly named as **EASI-AV©** proposes an **E**conomic **A**ssessment of **S**ervices with **I**ntelligent **A**utomated **V**ehicles by: providing the fleet dimensioning for the service, calculating the total cost of ownership (CAPEX and OPEX) and comparing those with a given baseline vehicle, and by calculating the local external costs for the communities where the shuttles are deployed (also in a comparative manner with a baseline vehicle).

EASI-AV© was designed with the objective of helping policy makers in cities, regions, Public Transport Operators (PTOs), and even others interested stakeholders that may wish to implement services with Automated Shuttles (e.g.: private corporate sites or university/hospital campuses).

This tool aims to evaluate the economic impact of different implementation scenarios - supply-pushed or demand-pulled strategy, fixed road or on-demand service – offering a comparison between an automated service and any other transport mode. Currently, EASI-AV© is being developed for four generic itinerary scenarios (Figure 58)

	Service 1: Demand-pull	**Service 2:** Supply-push
Option 1: Fixed-route	O1S1	O1S2
Option 2: On-demand service	O2S1	O2S2

Figure 58. Service scenarios encompassed by EASI-AV© (Antonialli, Mira-Bonnardel, Bulteau, 2021)

Each scenario induces algorithms to calculate costs both local and external. Also each scenario allows to think about different revenue models, not only based on ticketing or subsidies like the current public transport situation but we may think of specific tariff for on-demand with different customers like schools, hospitals, private companies with different on-board services integrated in the mobility app all that may conduct to new revenue generation and a different economic balance.

EASI-AV© helps to simulate the economic impact of those scenarios and to analyse the global economic balance. The AVENUE project demonstrators have been implemented on a supply-pushed strategy starting with fixed-road service and evolving to on-demand service as shown Figure 59.

	Service 1: Demand-pull	**Service 2:** Supply-push
Option 1: Fixed-route	- Copenhagen - Contern	- Groupama Stadium Lyon - Geneva 1st test - Pfaffenthal in Luxembourg
Option 2: On-demand service	- Next demonstration at Groupama stadium	- Belle-Idée Geneva

Figure 59. AVENUE's demonstrators operating sites scenarios.

4.2 EASI-AV©: Internal costs simulation tool

The present version of the EASI-AV© tool was designed using a spreadsheet software with manual data entry and automated calculation of results. As shown on Figure 60, the tool is divided into different tabs for each of the simulations proposed (fleet size, TCO comparison and, local impact). Over the next pages each analytical element of the EASI-AV© tool is precisely presented and exemplified with validated data from the AVENUE testing site in Pfaffenthal in Luxembourg. By the end of 2021, the excel file should be replaced by a web application in open access.

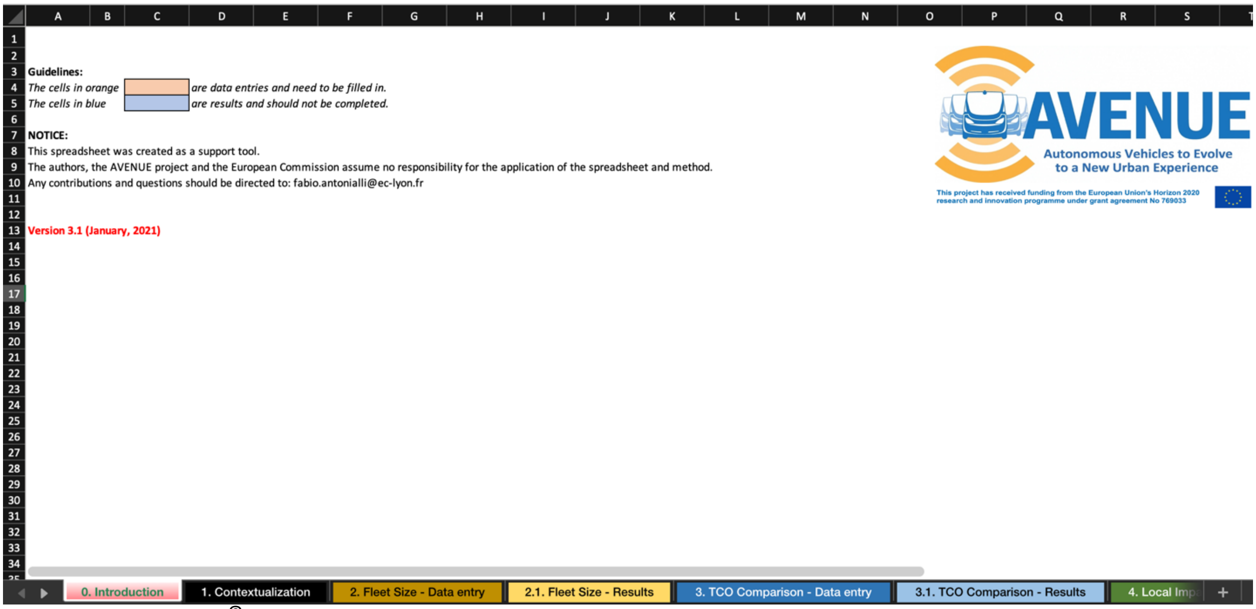


Figure 60. EASI-AV© calculation tabs (Antonialli, Mira-Bonnardel, Bulteau, 2021)

4.2.1 Service contextualization

As observed in Figure 60, the first tab to be completed (1. Contextualization) entails the generic contextualization of the envisioned service to be deployed. Contextualizing the service helps to build more accurate businesses scenarios, and allows decision makers to have a holistic view of the service to be implemented.

As depicted in Figure 61 (with exemplified data from Luxembourg's Pfaffenthal pilot site), EASI-AV© helps to properly frame the territorial typology (urban, peri-urban, rural environments), the zoning (residential, commercial, industrial or mixed areas), define the public transport supply (whether or

not public transport services are existent in the area) as well as the area's population density by asking the overall size (km^2) and the population in the area. The data entered here is automatically considered by the software for the subsequent analyses.
Framing the territory helps to design the service since population flows schedule differently in a residential area compared to a commercial one. Also, service supply strategies are different in urban or rural areas likewise business model innovations.

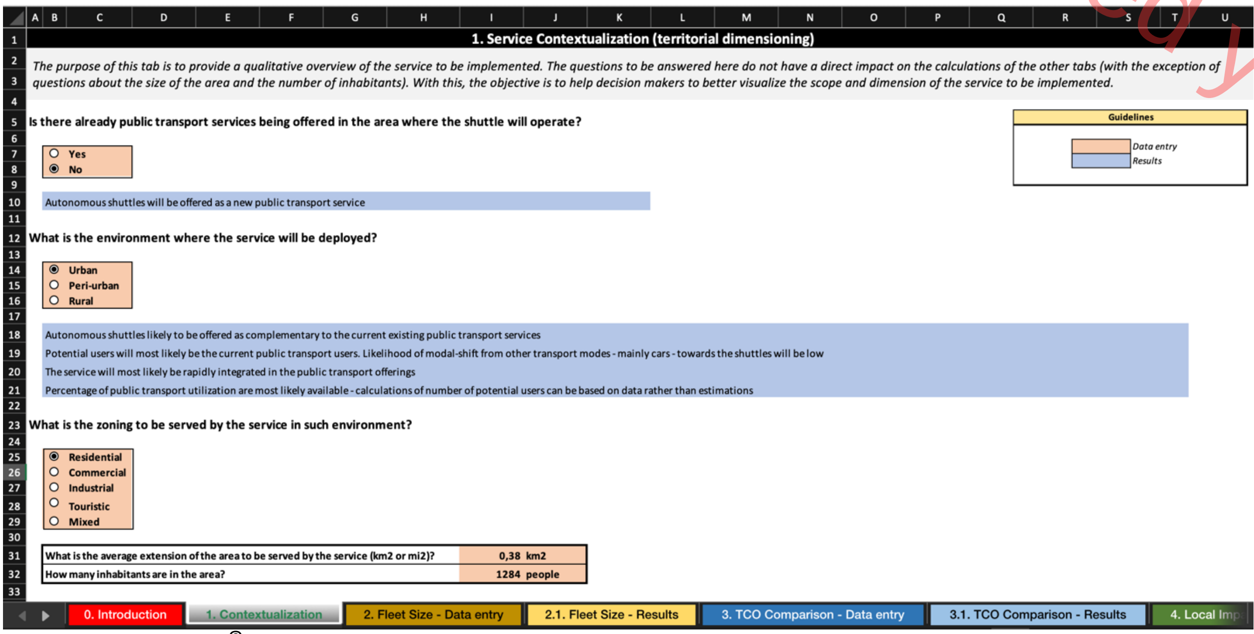


Figure 61. EASI-AV© service contextualization (Antonialli, Mira-Bonnardel, Bulteau, 2021)

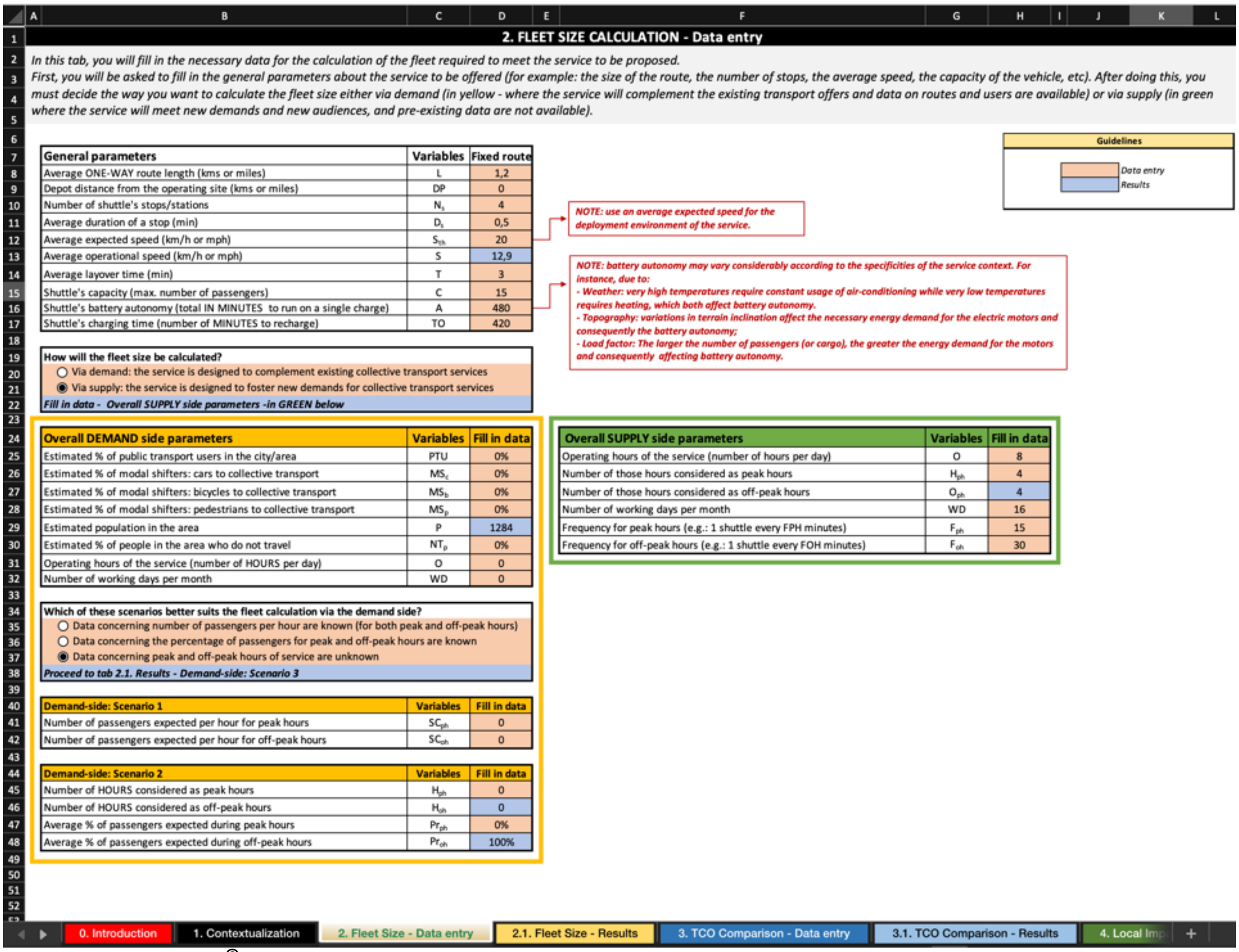
4.2.2 Fleet size dimensioning

Before calculating the investments and operating costs, it is paramount to dimension the fleet size of shuttles that are needed for the proper functioning of the service.
The overall goal of this analysis within EASI-AV© is to provide the fleet dimensioning for both fixed-route as well as for on-demand services with the option of estimating the fleet either via supply-push (where the service demand is unknown) or via demand-pull (where public transport in the area is already existent and demand is known) (as detailed on the scenarios proposed on Figure 58 in section 4.1). For the present version of EASI-AV© both supply-push and demand-pull calculation options for fixed-route were already tested and validated. The algorithms and calculations for on-demand fleet size are currently being developed and tested and will be presented on the next deliverable.
For option 1 (fixed-route) the dimensioning is based on traditional fleet size calculations. Besides the usual general parameters used for characterizing the service (e.g., route length, average operational speed, layover time, shuttle capacity, etc.) we considered some other specific elements that are particular for automated electric vehicles as a way of leading to a finer calculation (e.g., battery autonomy and its charging time) – which allows us to make a time differential to integrate in the calculation for how long a vehicle will be out of service to recharge. Simple algorithms compute these data and propose an optimum fleet size.
For option 2 (on-demand) more complex algorithms are needed to evaluate how many kilometres the vehicle may drive across the service area to meet user's demand for any direction at any time. Key elements for these calculations are the passenger waiting time (i.e. how long should a requester wait before a vehicle arrives), and the maximum distance between the requester and the vehicle at the time of the request. As previously stated, the present version of EASI-AV© only encompasses option 1, since the on-demand algorithms are currently being developed and tested.
For Service 1, EASI-AV© proposes the fleet-size dimension by demand-pull, that is: for when the demand for mobility in the service area is known. Three calculation scenarios are proposed depending on the degree of knowledge of data concerning the existing transport demand (e.g., the

exact number of passengers, the expected percentage of passengers during the peak and off-peak hours, etc.). The objective is to offer a flexible and modular tool depending on the transport demand and level of data available about it (see Figure 62).

For when data concerning the number of passengers per hour are known (both peak and off-peak hours), data for Scenario 1 must be filled in. For when data concerning the exact number of passengers are not available but rather an estimate percentage of passengers for peak and off-peak hours are known, Scenario 2 data must be filled in. At last, when no precise number nor estimate percentage of passengers for peak/off-peak hours are available, results will be present in Scenario 3.

For Service 2, the tool offers calculations via supply, that is: where demand on public transport is unknown or the service will be offered as a new transport offering in a supply-pushed strategy. Figure 6 presents the data-entry spreadsheet with the general parameters to be filled in (needed for both demand-pull and supply-push calculations) and also presents in yellow the data entry options for calculating the fleet by demand-pull and in green by supply-push. Data was filled in based on Luxembourg's Pfaffenthal pilot site (which fits the O1S2 model as previously depicted in Figure 58).


2. FLEET SIZE CALCULATION - Data entry

In this tab, you will fill in the necessary data for the calculation of the fleet required to meet the service to be proposed.
First, you will be asked to fill in the general parameters about the service to be offered (for example: the size of the route, the number of stops, the average speed, the capacity of the vehicle, etc). After doing this, you must decide the way you want to calculate the fleet size either via demand (in yellow - where the service will complement the existing transport offers and data on routes and users are available) or via supply (in green where the service will meet new demands and new audiences, and pre-existing data are not available).

General parameters	Variables	Fixed route
Average ONE-WAY route length (kms or miles)	L	1,2
Depot distance from the operating site (kms or miles)	DP	0
Number of shuttle's stops/stations	N_s	4
Average duration of a stop (min)	D_s	0,5
Average expected speed (km/h or mph)	S_{th}	20
Average operational speed (km/h or mph)	S	12,9
Average layover time (min)	T	3
Shuttle's capacity (max. number of passengers)	C	15
Shuttle's battery autonomy (total IN MINUTES to run on a single charge)	A	480
Shuttle's charging time (number of MINUTES to recharge)	TO	420

NOTE: use an average expected speed for the deployment environment of the service.

NOTE: battery autonomy may vary considerably according to the specificities of the service context. For instance, due to:
- Weather: very high temperatures require constant usage of air-conditioning while very low temperatures requires heating, which both affect battery autonomy.
- Topography: variations in terrain inclination affect the necessary energy demand for the electric motors and consequently the battery autonomy;
- Load factor: The larger the number of passengers (or cargo), the greater the energy demand for the motors and consequently affecting battery autonomy.

Guidelines: Data entry / Results

How will the fleet size be calculated?
- ○ Via demand: the service is designed to complement existing collective transport services
- ◉ Via supply: the service is designed to foster new demands for collective transport services

Fill in data - Overall SUPPLY side parameters -in GREEN below

Overall DEMAND side parameters	Variables	Fill in data
Estimated % of public transport users in the city/area	PTU	0%
Estimated % of modal shifters: cars to collective transport	MS_c	0%
Estimated % of modal shifters: bicycles to collective transport	MS_b	0%
Estimated % of modal shifters: pedestrians to collective transport	MS_p	0%
Estimated population in the area	P	1284
Estimated % of people in the area who do not travel	NT_p	0%
Operating hours of the service (number of HOURS per day)	O	0
Number of working days per month	WD	0

Overall SUPPLY side parameters	Variables	Fill in data
Operating hours of the service (number of hours per day)	O	8
Number of those hours considered as peak hours	H_{ph}	4
Number of those hours considered as off-peak hours	O_{ph}	4
Number of working days per month	WD	16
Frequency for peak hours (e.g.: 1 shuttle every FPH minutes)	F_{ph}	15
Frequency for off-peak hours (e.g.: 1 shuttle every FOH minutes)	F_{oh}	30

Which of these scenarios better suits the fleet calculation via the demand side?
- ○ Data concerning number of passengers per hour are known (for both peak and off-peak hours)
- ○ Data concerning the percentage of passengers for peak and off-peak hours are known
- ◉ Data concerning peak and off-peak hours of service are unknown

Proceed to tab 2.1. Results - Demand-side: Scenario 3

Demand-side: Scenario 1	Variables	Fill in data
Number of passengers expected per hour for peak hours	SC_{ph}	0
Number of passengers expected per hour for off-peak hours	SC_{oh}	0

Demand-side: Scenario 2	Variables	Fill in data
Number of HOURS considered as peak hours	H_{ph}	0
Number of HOURS considered as off-peak hours	H_{oh}	0
Average % of passengers expected during peak hours	Pr_{ph}	0%
Average % of passengers expected during off-peak hours	Pr_{oh}	100%

0. Introduction | 1. Contextualization | 2. Fleet Size - Data entry | 2.1. Fleet Size - Results | 3. TCO Comparison - Data entry | 3.1. TCO Comparison - Results

Figure 62. EASI-AV© fleet size calculation - data entry (Antonialli, Mira-Bonnardel, Bulteau, 2021)

Once all elements for the fleet size calculation data entry are completed, results will be automatically displayed on the next tab of tool (2.1. Fleet Size – Results). As observed on Figure 63, the results are color-coded to the service options (yellow: demand-pull, or green: supply-push). As aforementioned, for calculations via the demand-pull service option, results are displayed by one of three distinct scenarios (according to data availability on transport demand for the envisioned service area).

Besides the total fleet size estimation, some other relevant data and KPIs are available on Figure 63 results, such as: estimated frequency of the service (for both peak and off-peak hours); fleet size for both peak and off-peak hours, estimated number of daily users (for both peak and off-peak hours) as well as the estimated maximum kilometers to be completed by the shuttle (daily, monthly and yearly) – which can help estimating the costs with maintenance, energy consumption, etc.

Based on the data entry provided for the Pfaffenthal pilot site, EASI-AV© estimated a total fleet size of 2 shuttles. Which in fact is the exact number of shuttles used by Sales-Lentz in their trials in the site. Thus, the results presented by the tool are consistent with the reality of the project The tool was also validated with data from the Groupama Stadium testing site in Lyon (KEOLIS), the Nordhavn testing site in Copenhagen (Holo) and the Ormøya testing site in Oslo (Holo), yielding the same fleet size and the real number of shuttles used for the operators in these AVENUE testing sites.

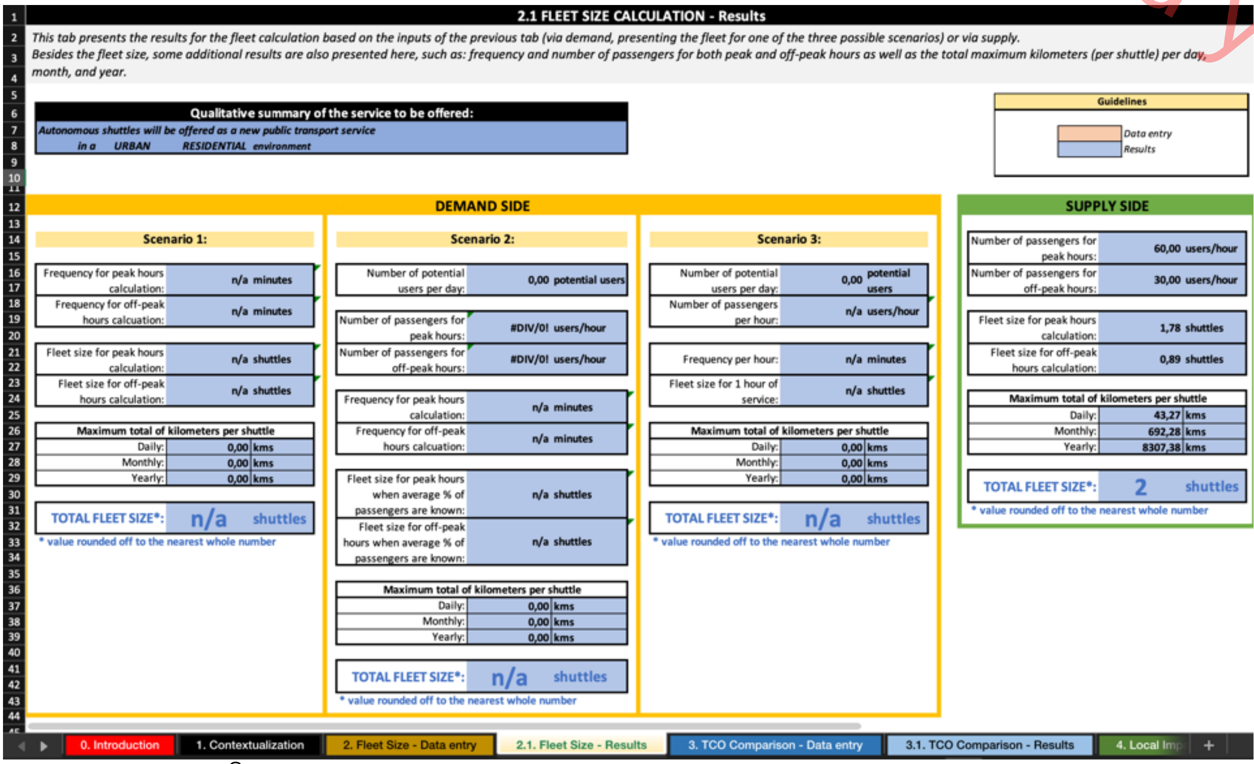


Figure 63. EASI-AV© fleet size calculation – results (Antonialli, Mira-Bonnardel, Bulteau, 2021)

4.2.3 TCO comparison analysis

Once estimated the fleet size to be used, the total costs for implementing the services can be calculated. Thereby, the TCO evaluation may be used as a follow up of part 2 (fleet size dimensioning), however, as shown on Figure 64, if the fleet size is already known, the tool also allows the possibility to carry out the TCO comparison by simply entering the fleet size that the users seek to evaluate.

Once the desired fleet size was calculated (or manually filled in) EASY-AV users are requested to fill in the expected lifetime for the shuttle (once this will impact on the depreciation costs). Next there are two questions about the staff needed for the service. Regarding the need of on-board safety drivers for the operations of the service (currently required by law in the four countries with the AVENUE trials) and the need/presence of off-board supervisors (for on-demand services and/or on-board safety drivers are no longer required). These staff numbers will directly impact the yearly operating expenses for the service (as further discussed on section 2.3).

The next data to be filled concern the base-line vehicle in which the shuttle service costs will be compared to. As described on Figure 64, the tool allows the user to choose the type of baseline vehicle that best suits its local reality; for instance, the comparison can be made between the automated shuttle and a 12 or 6 meters bus (combustion or electric); as well as with carsharing, private cars or even other transport mode available in the area. Thus, users are required to complete the capacity of the baseline vehicle, and going even further, for carsharing and private-car modalities, the tool even gives users the option to estimate the average percentage of occupation of these vehicles.

At last, similar to what was requested for the shuttle, users are also required to fill in the lifetime data for the baseline vehicle as well as the number of drivers needed for a full daily operation of the service.

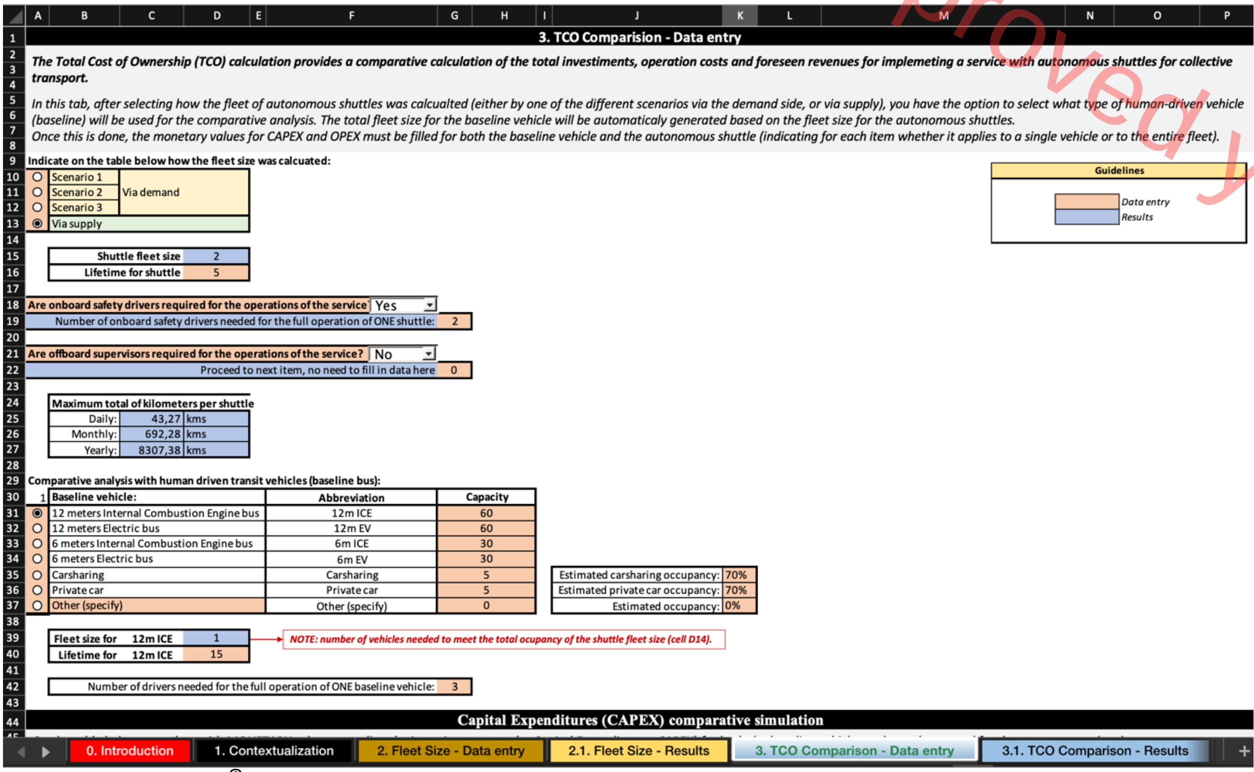


Figure 64. EASI-AV© TCO comparison - data entry (part 1) **(Antonialli, Mira-Bonnardel, Bulteau, 2021)**

Once this first part of the data entry for the TCO calculation has been completed, by scrolling down on the spreadsheet, users must then fill in the data for the Capital Expenditures (CAPEX), operation expenditures (OPEX) and revenue sources for the services (both for the automated shuttle and for the baseline vehicle of their choosing).

In order to select the cost sources to compose the structure of both CAPEX and OPEX, an extensive literature review was conducted (both in scientific articles as well as on management reports of transport operators available online). Once the costs list was created, validation sessions were held with the PTOs (Keolis and TPG) and also with the other project partners (HSPF and UniGE). A PDF manual with the complete qualitative description of the cost sources has been created and will be made available to users together with the EASI-AV© tool. Figure 65 depicts the CAPEX, OPEX and revenues data entry.

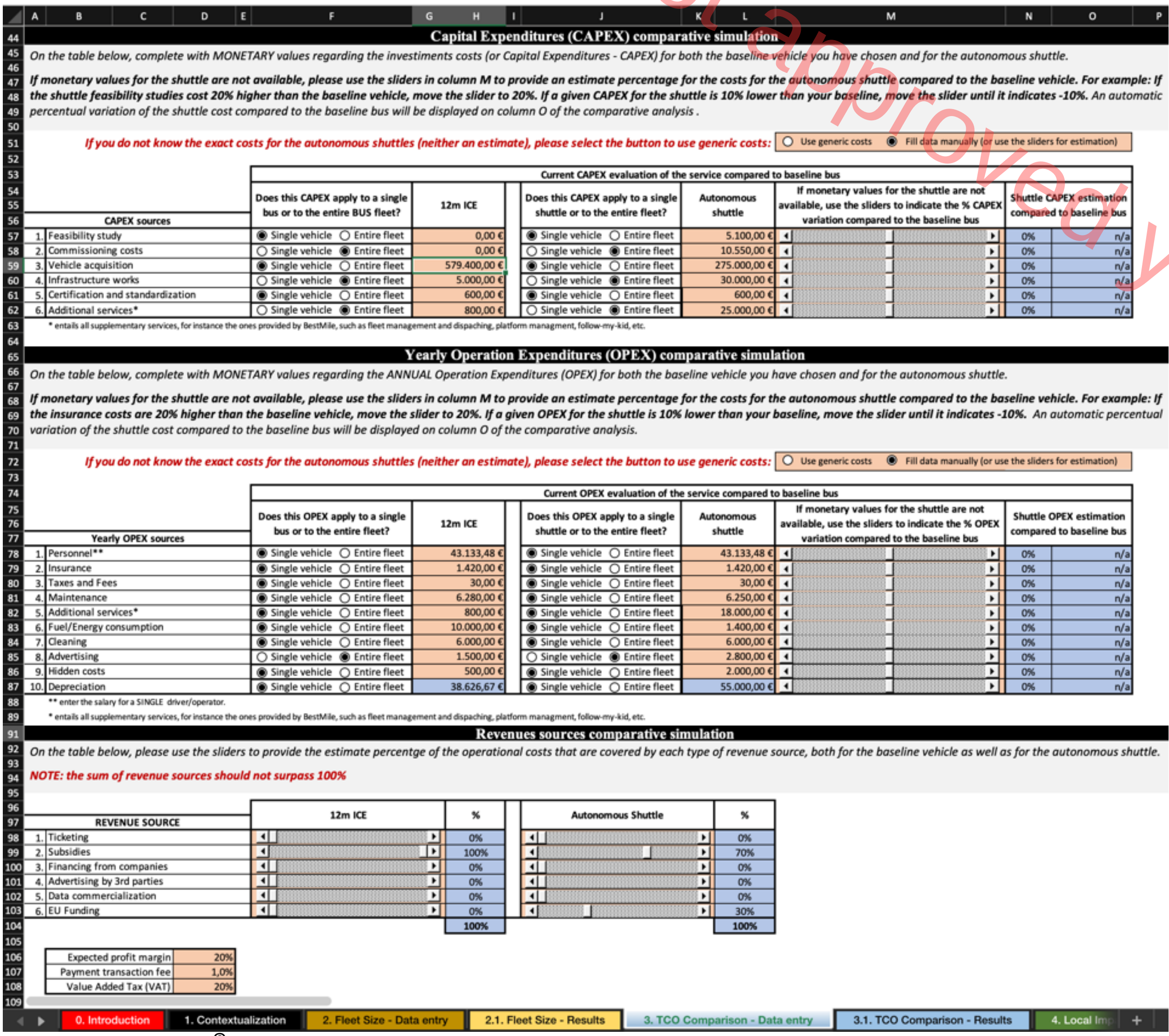


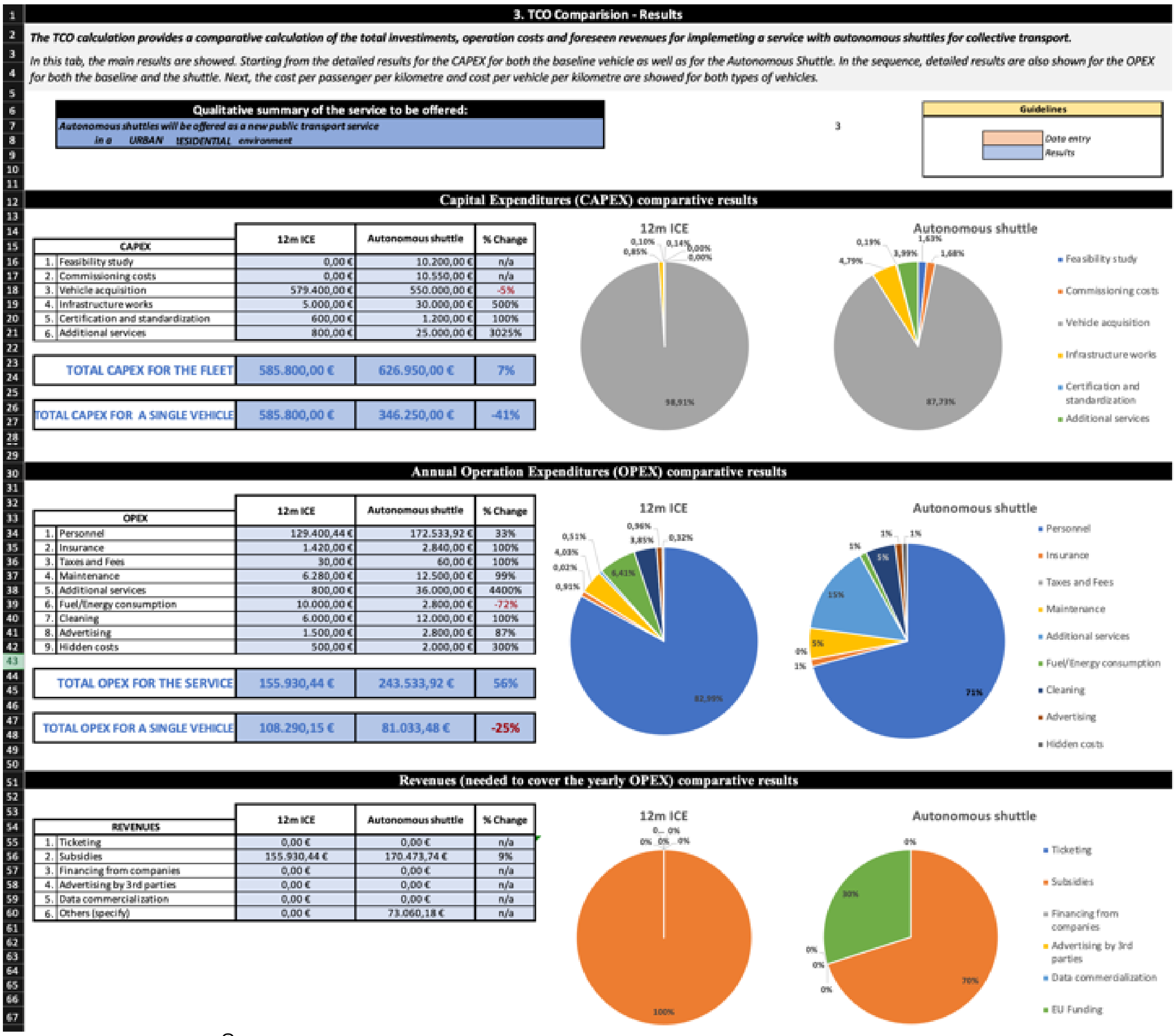
Figure 65. EASI-AV© TCO comparison - data entry (part 2) (Antonialli, Mira-Bonnardel, Bulteau, 2021)

For both CAPEX and OPEX, users are requested to fill in data with monetary values (in euros) for each of the cost sources for both the baseline vehicle as well as to the automated shuttle. As observed on Figure 8, the tool gives the possibility to select if the cost-source is applied to a single vehicle (e.g., fuel/energy consumption in the OPEX) or to the entire fleet (e.g., infrastructure works in the CAPEX). With automated shuttles being a new and not widely spread know technology, the decision makers completing the data may not know the precise monetary values for the listed cost sources. In this regard, EASI-AV© gives two flexible alternatives to complete the data:

1) After completing the values for the baseline vehicle of their choosing, the decision makers can use the provided sliders on column M to simulate (estimate) how much more (or less) each given cost would be for the automated shuttles compared to their baseline vehicle.
2) If given the circumstances the decision makers are not able to provide neither the precise monetary values or the estimate (by using the sliders) for the shuttle costs, they can simply click on the option of using generic costs (highlighted in red on Figure 65), and all CAPEX and OPEX will be automatically filled in with data. The generic costs were developed by considering inputs from literature review as well as by the average costs from the AVENUE operating sites. Although not as accurate, generic costs can be an appealing resource for decision makers who have little knowledge of the needed investment and operating costs for an automated shuttle service.

After completing the CAPEX and OPEX data entry, users are requested to provide the estimate percentage of the operational costs that are covered by the available revenue sources (both for the baseline vehicle as well as for the automated shuttle. The revenues sources may be ticketing, subsidies, financing from companies, third-party advertising, data commercialization and, EU funding. At last, for the sake of estimating the ticketing price (for those cases where the service will be paid), the user is asked to complete data for the expected profit margin, the payment transaction fee (if any) and the value added tax.

Once all these elements for the TCO comparison data entry are completed, results will be automatically displayed on the next tab of tool (3.1. Fleet Size – Results). As seen on Figure 66, the results for both CAPEX and OPEX as well as for the revenue sources are displayed both in a graphic manner (via pie charts) and in detailed tables, allowing the user to easily compare the results for the baseline vehicle and for the automated shuttle.



CAPEX	12m ICE	Autonomous shuttle	% Change
1. Feasibility study	0,00 €	10.200,00 €	n/a
2. Commissioning costs	0,00 €	10.550,00 €	n/a
3. Vehicle acquisition	579.400,00 €	550.000,00 €	-5%
4. Infrastructure works	5.000,00 €	30.000,00 €	500%
5. Certification and standardization	600,00 €	1.200,00 €	100%
6. Additional services	800,00 €	25.000,00 €	3025%
TOTAL CAPEX FOR THE FLEET	585.800,00 €	626.950,00 €	7%
TOTAL CAPEX FOR A SINGLE VEHICLE	585.800,00 €	346.250,00 €	-41%

OPEX	12m ICE	Autonomous shuttle	% Change
1. Personnel	129.400,44 €	172.533,92 €	33%
2. Insurance	1.420,00 €	2.840,00 €	100%
3. Taxes and Fees	30,00 €	60,00 €	100%
4. Maintenance	6.280,00 €	12.500,00 €	99%
5. Additional services	800,00 €	36.000,00 €	4400%
6. Fuel/Energy consumption	10.000,00 €	2.800,00 €	-72%
7. Cleaning	6.000,00 €	12.000,00 €	100%
8. Advertising	1.500,00 €	2.800,00 €	87%
9. Hidden costs	500,00 €	2.000,00 €	300%
TOTAL OPEX FOR THE SERVICE	155.930,44 €	243.533,92 €	56%
TOTAL OPEX FOR A SINGLE VEHICLE	108.290,15 €	81.033,48 €	-25%

REVENUES	12m ICE	Autonomous shuttle	% Change
1. Ticketing	0,00 €	0,00 €	n/a
2. Subsidies	155.930,44 €	170.473,74 €	9%
3. Financing from companies	0,00 €	0,00 €	n/a
4. Advertising by 3rd parties	0,00 €	0,00 €	n/a
5. Data commercialization	0,00 €	0,00 €	n/a
6. Others (specify)	0,00 €	73.060,18 €	n/a

Figure 66. EASI-AV© TCO comparison - results (part 1) **(Antonialli, Mira-Bonnardel, Bulteau, 2021)**

As exemplified with data for the Pfaffenthal pilot site in Figure 66, the most significant CAPEX source for both the baseline vehicle and for the automated shuttle is vehicle acquisition (98.91% and 87,73% respectively). However, for the automated shuttle, the costs with infrastructure works and other additional services are much higher than the baseline vehicle (500% and 3025% more), which is justified due to the need for several street and signs adaptations for the correct functioning of the service, as well as the several additional services to be offered in the shuttle (e.g.: follow-my-kid by MobileThinking).

In general, even with the high acquisition cost of the automated shuttles, it can be seen that for the case of Pfaffenthal, the total CAPEX for the fleet shuttle fleet would only be 7% higher than the baseline 12m ICE vehicle, and considering only a single shuttle (compared to a single 12m ICE) the

CAPEX would be 41% lower. This shows, even on an experimental basis, the potential for reducing the investment costs by using an automated shuttle fleet for collective transport services.
As for the annual Operation Expenditures (OPEX), the most relevant cost source for the baseline vehicle is costs with personnel (that is: drivers' salaries), representing more than half of the total OPEX (82.99%). For the current stage of deployments with the automated shuttles, costs with personnel are the most representative OPEX (71%).
In the current experimental stages of the service, the total OPEX for the shuttle is higher than the baseline (56% more), thereby, not currently cost-effective, as also found by Henderson et al. (2017). However, as stated by Ongel et al. (2019), Bösch et al. (2018), and Fagnant and Kockelman (2015) these figures are bound to change in favor of the shuttles once advances in legislation may no longer require on-board safety-drivers (reducing dramatically the personnel costs) and advances in technology shall extend the shuttle's life-cycle.
For the Luxembourg case depicted on Figure 66, as of March 1st 2020, the government made free all public transport in the country (Lo, 2020), thereby for traditional buses 100% of the transport is subsidized and there are no revenue from ticketing. While for the shuttles, by being a pilot site partially funded by the AVENUE project, part of the funding come from subsidies (around 70%) and part of it comes from the EC (around 30%).
By scrolling down the screen for the TCO comparison results, users will be able to see a range of indicators such as the cost per passenger/km, cost per vehicle/km, that are calculated taking into account the annual operating costs and the total early milage for a single shuttle in the route. These KPIs are important metrics for the decision making process, and allow an easy comparison with other transport modes and with other mobility services.

TCO Comparison - overall results

	12m ICE	Autonomous shuttle	% Change
COST per passenger/km	0,31 €	0,98 €	212%
COST per vehicle/km	18,77 €	14,66 €	-22%
ONE-WAY COST per passenger	0,38 €	1,17 €	212%
ONE-WAY COST per vehicle	22,52 €	17,59 €	-22%

NOTE: The 4 aforementioned KPIs are based on the annual OPEX for both the baseline vehicle and the autonomous shuttle.

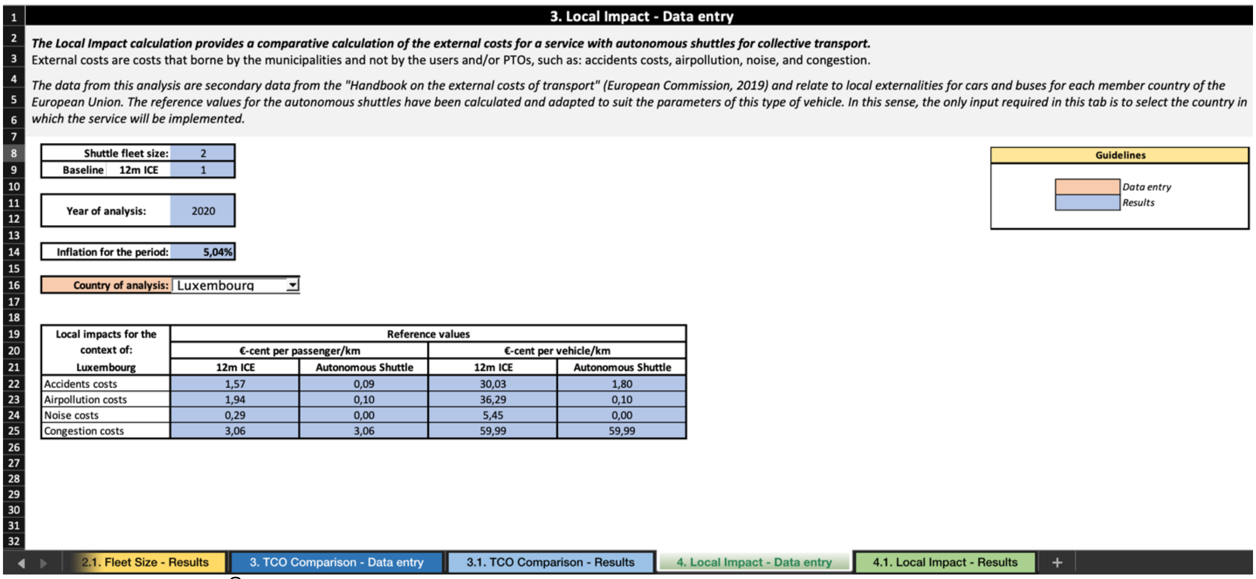
Figure 67. EASI-AV© TCO comparison - results (part 2) (Antonialli, Mira-Bonnardel, Bulteau, 2021)

Considering the indicators shown on Figure 67 for the Pfaffenthal pilot site, it is clear that the service with the shuttles is not yet as cost-effective as a traditional bus, being 212% higher – mainly due to the legal need of a safety-driver operator on-board the shuttles that considerably elevates the OPEX, thereby elevating the cost per passenger/km. However, even with all the current constraints, advances can already be seen in favor of the shuttles, with a cost vehicle/km being already 22% less than the baseline, which shows the promising potential of this technology on reducing the overall costs and prices of the service.
If we simulate on EASI-AV© a scenario where no safety drivers are needed for Pfaffental (only an off-board supervisor in charge of the two shuttles for the site), the estimates show the potential to reduce the cost per passenger/km to 0,46 euros. Furthermore, it is worth highlighting that the comparison shown on Figure 67 is based on the data given to us by the PTO and it is between a 12m ICE with a capacity for 60 passengers and an automated shuttle with a capacity of 15, thereby, if we further simulate on EASI-AV© that both vehicles had the same capacity (of 15 passengers) the cost per passenger/km for the baseline bus would be higher at 1,24 € versus the current 0,94 € for the shuttle.
After a second round of data collection and validation with the PTOs, for the next interaction of this deliverable, an extended comparative table of CAPEX, OPEX and KPIs between the shuttles and other vehicles (in particular small electric buses) will be proposed.

4.2.4 Local externalities costs simulation

The final analysis provided by the current version of EASI-AV© is a local impact analysis. The aim of this analysis is to provide decisions makers with an overview of the local external costs or gain of implementing a new mobility service with automated shuttles. A complete and in-depth analysis on external costs for the AVENUE services is provided by HSPF on their macro-analysis calculation (in the second part of this deliverable).

This analysis is based on secondary data the "Handbook on the external costs of transport" (European Commission, 2019) and relate to local externalities for cars and buses for each member country of the European Union. The reference values for the automated shuttles have been calculated and adapted to suit the parameters of this type of vehicle. In this sense, as shown by Figure 68, the only input required in this tab is to select the country in which the service will be implemented.



Local impacts for the context of: Luxembourg	Reference values			
	€-cent per passenger/km		€-cent per vehicle/km	
	12m ICE	Autonomous Shuttle	12m ICE	Autonomous Shuttle
Accidents costs	1,57	0,09	30,03	1,80
Airpollution costs	1,94	0,10	36,29	0,10
Noise costs	0,29	0,00	5,45	0,00
Congestion costs	3,06	3,06	59,99	59,99

Figure 68. EASI-AV© Local Impact analysis - data entry (Antonialli, Mira-Bonnardel, Bulteau, 2021)

Similarly to the TCO comparison analysis, the results here (Figure 69) are given both for the baseline vehicle and for the automated shuttle, allowing decision makers to compare the overall accidents, air pollution, noise and congestion costs for the service to be implemented. The results also provide relevant KPIs such as the local external cost per passenger and per vehicle/km for both the baseline vehicle and the shuttle as well as the daily, monthly and yearly local external costs for both types of vehicle.

For the Luxembourg Pfaffenthal site, results show a promising reduction on the local external costs, being 52% lower for the passengers and 53% lower when considering the cost per vehicle/km. Results corroborate the findings by Ongel et al. (2019) and show the positive environmental potential benefits of deploying fleets of electric automated shuttles for collective transport.

3. Local Impact - RESULTS

This tab brings the comparative cost results (between the shuttle and the baseline vehicle) regarding the externalities that impact the local service environment. Besides the detailed cost for each externality (accidents, air-pollution, noise and congestion), the tab also brings the total cost of the externalities per passenger/km and per vehicule/km as well as daily, monthly and yearly external costs per vehicle.

Guidelines
Data entry
Results

Qualitative summary of the service to be offered:

Autonomous shuttles will be offered as a new public transport service in a URBAN RESIDENTIAL environment

TOTAL LOCAL IMPACT COSTS FOR THE ENTIRE FLEET				
Luxembourg	Reference values			
	€ per passenger/km		€ per vehicle/km	
	12m ICE	Autonomous Shuttle	12m ICE	Autonomous Shuttle
Accidents costs	0,0157 €	0,0019 €	0,3003 €	0,0360 €
Airpollution costs	0,0194 €	0,0020 €	0,3629 €	0,0020 €
Noise costs	0,0029 €	0,0000 €	0,0545 €	0,0000 €
Congestion costs	0,0306 €	0,0612 €	0,5999 €	1,1999 €
TOTAL FOR THE FLEET €/km	0,07 €	0,07 €	1,32 €	1,24 €

	12m ICE	Autonomous Shuttle	% Change
COST per passenger/km	0,07 €	0,03 €	-52%
COST per vehicle/km	1,32 €	0,62 €	-53%

	12m ICE	Autonomous Shuttle	% Change
ONE WAY COST per passenger	0,08 €	0,04 €	-52%
ONE WAY COST per vehicle	1,58 €	0,74 €	-53%

	12m ICE	Autonomous Shuttle	% Change
Vehicle DAILY cost	57,01 €	26,78 €	-53%
Vehicle MONTHLY cost	912,15 €	428,50 €	-53%
Vehicle YEARLY cost	10.945,85 €	5.142,05 €	-53%

	12m ICE	Autonomous Shuttle	% Change
Fleet DAILY cost	57,01 €	53,56 €	-6%
Fleet MONTHLY cost	912,15 €	857,01 €	-6%
Fleet YEARLY cost	10.945,85 €	10.284,10 €	-6%

2.1. Fleet Size - Results | 3. TCO Comparison - Data entry | 3.1. TCO Comparison - Results | 4. Local Impact - Data entry | 4.1. Local Impact - Results

Figure 69. EASI-AV© Local Impact analysis – results (Antonialli, Mira-Bonnardel, Bulteau, 2021)

4.3 Preliminary results from AVENUE demonstrators

Besides the results for the Pfaffenthal site in Luxembourg (used to present and explain the EASI-AV© tool), we present below the preliminary results for the other AVENUE testing sites based on preliminary data made available to us by the PTOs. Figure 14 below summarizes the main CAPEX, OPEX and main KPIs for the testing sites of Pfaffenthal and Contern (Luxembourg), Meyrin (Geneva), Nordhavn (Copenhagen), Ormøya (Oslo), Décines (Lyon) and the average values for the AVENUE program. On appendix 2, the summary description of each AVENUE operating site are displayed (with details about, the operating hours, time tables, number of vehicles and stops, etc). These data were used for the fleet size calculation and consequently for the TCO calculation show on Figure 70.

	Luxembourg (Sales-Lentz)		Geneva* (TPG)	Copenhagen/Oslo (Holo)		Lyon (Keolis)	AVERAGE
	Pfaffenthal	Contern	Meyrin	Nordhavn	Ormøya	Décines	Avenue
CAPEX							
Single shuttle	346.250,00 €	346.250,00 €	333.000,00 €	472.000,00 €	472.000,00 €	1.070.000,00 €	506.583,33 €
Fleet total	626.950,00 €	346.250,00 €	333.000,00 €	472.000,00 €	772.000,00 €	1.420.000,00 €	661.700,00 €
OPEX							
Single shuttle	81.033,48 €	81.033,48 €	184.860,00 €	191.000,00 €	189.975,97 €	166.622,00 €	149.087,49 €
Fleet total	243.533,92 €	81.033,48 €	274.860,00 €	335.000,00 €	676.951,94 €	488.572,00 €	349.991,89 €
KPIs**							
Cost passenger/km	1,01 €	0,43 €	2,20 €	1,19 €	0,82 €	0,74 €	1,07 €
Cost shuttle/km	15,28 €	6,65 €	33,15 €	17,87 €	12,41 €	11,23 €	16,10 €

Figure 70. Total Cost of Ownership of the AVENUE service

* By being an on-demand site, values for the Belle Idée (Geneva) were not calculated yet.

** Values comprise the Total Cost of Ownership considering the CAPEX, OPEX and Local externalities.

The variations on the CAPEX values among the operating sites shown on Figure 70 are due the different prices and levels of investments needed mainly on feasibility studies, commissioning costs, infrastructure works, and certification and standardization for each country. Those values vary according to the specificity of each site as well as based on local legislation. For Lyon for example, the feasibility studies and infrastructure works needed (70.000,00 euros and 500.000,00 euros respectively) were much higher than the other AVENUE operating sites where their average values were 5.940,00 euros for feasibility studies and 25.800,00 euros for infrastructure works. That is the reason why the CAPEX values for Lyon are an outlier when compared to the other sites.
The variations seen on the OPEX values are mainly due to the costs with personnel. That is the average salary paid for the operators and supervisors on each country are varied as well as the number of operators needed for the daily operation of a single shuttle. For Lyon and Switzerland the reported average annual salary for the safety drivers range about 90.000,00 euros while for Luxembourg the values are around 43.133,48 euros, for Denmark around 48.000,00 euros and for Sweden 55.700,00 euros.
Also worth noting that the KPIs calculations are based on the maximum daily milage that a shuttle can run, and such variable is dependent on the route length, operating hours and frequency of the service), in this regard the KPIs (cost passenger/km and cost shuttle/km) vary accordingly. For instance in the Meyrin site, and in Pfaffenthal the shuttles run much less than on the other sites (31.66 kms and 43,27 kms respectively versus the average of 72.73 kms for the other 4 testing sites).

At last, it is worth highlighting that the results in Figure 70 are still preliminary, and based on a first round of data collection with the PTOs and thereby need to be further refined and validated. However, these results already show us that the cost per passenger/km for the current demonstrators are still higher than other traditional public transport offerings (AVENUE average: 1,07 euros per passenger/km), corroborating the findings by Henderson et al. (2017) in their feasibly study for a shuttle-service trial in Ohio State University Campus where the authors also concluded that the automated shuttle is indeed currently not cost-effective relative to traditional buses.
However, as technology and legislation evolves, it is expected that in the coming years an onboard safety driver will no longer be needed (thereby drastically reducing the costs with personnel), which assures that our tool is also aligned with the results of the prospective studies carried out by Fagnant and Kockelman (2015), Bösch et al. (2018) and, Ongel et al. (2019).

4.4 Conclusion research agenda on micro level

The task 8.2 aims to analyse the economic impact of the used automated electric vehicles focusing on first economic balance and business viability. Therefore, a comparison of the demonstrators has been conducted via a Total-Cost-of-Ownership (TCO) calculation. To conduct this analysis we designed the EASI-AV© tool.
With the use of the EASI-AV© tool, direct and indirect costs and savings as well as cost drivers, hidden costs (e.g. cleaning costs or vandalism in vehicles without drivers) and externalities are clearly identified and evaluated as a basis to evaluate the economic viability of automated vehicles as a part of an integrated public transport system. The tool helps to calculate a global cost per kilometre or cost per passenger for a site. It allows comparison with any other transport mode. It offers the valuation of scenarios. In a nutshell the EASI-AV© has been designed as a decision support tool.
EASI-AV© is still a work in progress, we are currently working on a web application for the EASY-AV tool, to make it widely accessible and easier to use than the current version. EASI-AV© application is due to be on open access on the AVENUE project website. The aim of our current work is to include automated data collection (extraction of geolocation data, traffic data mining, population, square meter, …).
We are also currently developing the algorithms for the on-demand fleet size calculation as well as a global rentability and business model analysis (comprising the costs and revenues to better understand and formulate future business models) which will propose a wider range of revenue model than those existing currently for public transport in order to simulate the global economic balance of an automated service.

1. Expected externalities for cities

AVs are poised to cause a modal shift, but their deployment in cities could be a double-edged sword. If AVs are used as a private transport mode, they could reinforce further car-centric mobility; Consequently, cities will have to bear increasing external costs. On the other hand, if they are integrated within the public transport network in the form of a shared, on-demand, door-to-door and efficient means of transport, they could mitigate externalities such as pollution, congestion, and air pollution. In the form of shared automated electric mini-buses, AVs could accelerate the modal shift towards sustainable urban public transport through the customer-centric offer, better use of different means of transport and intermodality (UITP 2020; Ceccato and Diana 2018). Public transport similar to AVENUE transport solutions could thus increase the attractiveness for citizens and thus enable an attractive alternative to ICE cars in cities. Due to the impacts of different modes of transport on the environment and the society, the research relies on the economic assessment and comparison of the externalities of shared automated minibuses with other transportations schemes (Jochem et al., 2016). The further integration of private transport providers with an open data platform like described before could further raise positive externalities and diminish negative externalities. For now, they are not included in this chapter. This should be a focus of further research.

To assess the economic impact of automated minibuses of AVENUE in cities, we will first describe potential key scenario parameters to test the external cost of introducing the automated minibus in cities (5.1). Then, we develop a methodology to calculate the externalities (5.2) and afterwards describe the fleet calculator (5.3). In later steps, we will use the fleet calculator to support the different scenarios planning to assess the impact of on-demand AV integrated into public transport in cities. Figure x below describes the structure of this part. The key parts of the analysis, rebound effects and the selected scenarios will be addressed in the next deliverable. See Figure 71 for further details.

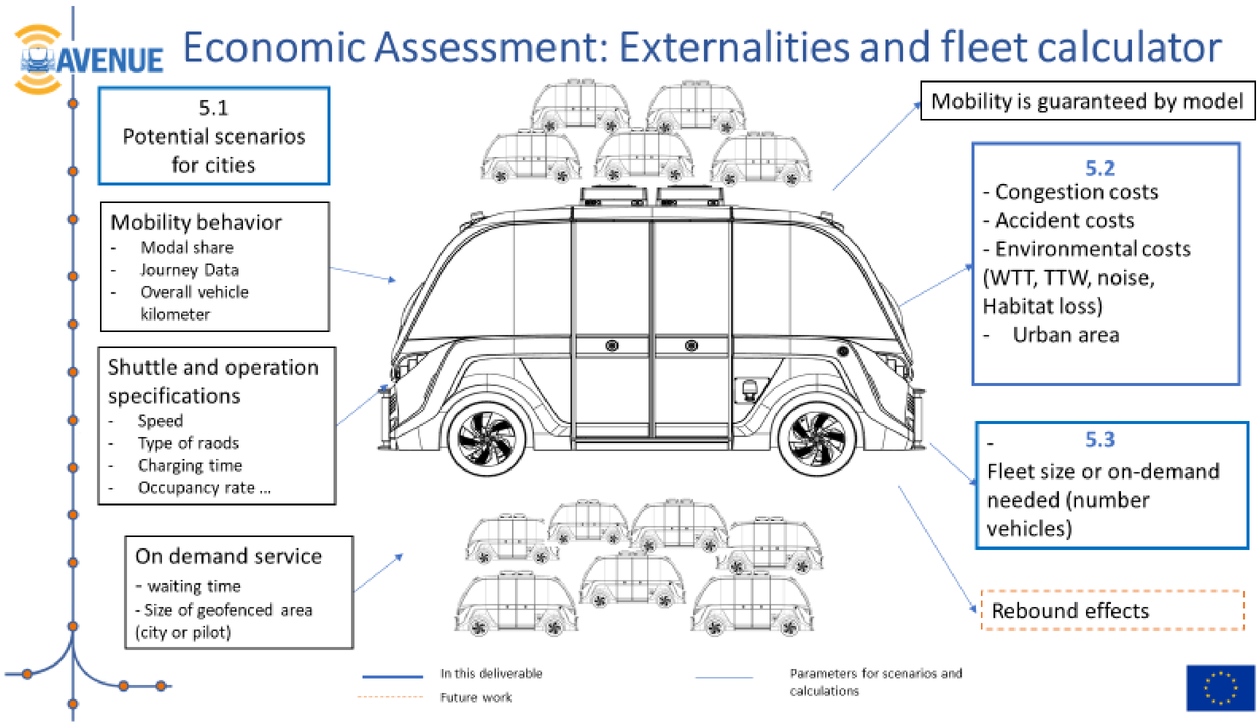


Figure 71: econmic assessment and fleet calculator

5.1 Parameters for Potential scenarios for cities

This part aims to describe the variables that help in building potential scenarios for the assessment. As mentioned previously, the assessment focuses on the impacts of introducing Automated minibus in urban areas. These potential scenarios will help to select an ideal scenario that will align best with the guidelines of SUMP described in 2.1 and the Sustainable Development Goals (SDGs) of the United Nations, precisely goal 11 for sustainable cities and communities. A range of potential scenarios and their effects on the city of the future can thus be reflected to provide a comparative analysis of externalities for a defined geographical area between conventional transport such as public transport, private cars, non-motorised transport NMT and smart mobility such as automated vehicles. Thus, a solution that promotes sustainable urban mobility and sustainable urban cities can be determined. The following set of parameters could be grouped as follows:

Vehicle specifications
- occupancy rates,
- speed

Traffic situation
- type of roads
- speed limit
- dense or thin traffic

Mobility behaviour
- modal shares and
- the overall travelled kilometres.

The parameters from vehicle specifications and the traffic situation, such as occupancy rates, type of roads, and average speed, were determined from the results of WP7 and interviews with the PTOs. The parameters of mobility behaviour, such as the modal shares and the overall travelled kilometres, are determined based on national mobility surveys as well as representative surveys of the pilot cities (see social impact assessment WP8). They are important for defining the different scenarios, and they play a role in the decision of the externalities factors in 5.2.

5.1.1 Vehicle specifications

The **occupancy rates** are classified as follows: low for 2 or fewer passengers in the AV on average, moderate for up to 6 passengers, and high for more than 6 passengers. The values are based on interviews with the PTOs. The occupancy rate is used in the calculations for the space externality and is considered for the congestion as well.

The **speed** is also used in the externality of dynamic urban space. Also, it helps determine if the automated minibus will drive for long distances or short distances. This is a key factor for transport and urban planning and helps build the scenarios (Knoflacher 2007). Currently, in the pilots, it has on average 4-6 passengers on average per trip and an average speed ranging between 12-30 km/h.

5.1.2 Traffic situation

Based on the current AVENUE trials, it is important to note that the Automated minibus circulate in urban areas and on urban roads described as trunk roads (main roads) and other urban roads. This is based on the deliverables of WP7 "Autonomous vehicles demonstrators". Other variables such as the congestion situation (near congested, congested, overcapacity) and the time of circulation (day or night) are kept variable because they are too specific and could be altered based on the scenario. They are also kept variable in the externalities calculation in 5.2.

5.1.3 Mobility Behaviour

It is furthermore considered that the deployment of Automated minibus could affect: individual mobility (cars, taxis), collective mobility (buses), and non-motorised transport like walking and biking (Janasz 2018). Thus, it is crucial to consider the effect of their introduction on the **different modal**

shares. The automated minibuses are poised to be a first/last mile solution, impacting intermodal journeys. The reason is to provide an individual combination of several means of transport in one trip (see social impact assessment), which is attractive for citizens (see social impact assessment). The assumption is that the automated minibuses deployment for public transport in the cities will lead to a **modal shift.** So far, only data of Lyon have been collected before the COVID-19. Other representative surveys are planned.

Nevertheless, it is essential to acknowledge that this technology, in case of a large scale deployment, might cause an increase in travel demand and consequently cause a rebound effect. The induced demand is estimated based on Fagnant and Kockelman (2015) research. They assume that for a penetration rate of 10% of automated vehicles, the **vehicle kilometres travelled (Vkm)** will increase by 20% (for 90% rate, Vkm will increase by 10%). Similarly, a study from the Technical University of Munich anticipates an increase of 8% in Vkm caused by shared automated vehicles (Moreno et al., 2018). Finally, for on-demand shared rides as in the case for AVENUE vehicles, Fagnant and Kockelman (2018) anticipate an increase of 4.5%. In our iteration, the assumption used in a first stage (also for the calculations for the test case in Geneva in 5.2.4) is that the deployment of the automated minibuses will not lead to an increase in the overall kilometres travelled. This is supported by Transportation Demand management TDM[10] (Ferguson 1990). First, the technology provides better connectivity and coordination with other modes of transportation within a MaaS platform. Thus, the mobility gap will be fulfilled by Automated minibuses and replace other individual means of transport. Second, policies and incentives will be used to support walking, biking, and ridesharing (Shared mobility principales 2017).

Finally, by varying the different parameters like modal shares, speed, and VKm,... we can build different deployment scenarios. These scenarios are used to calculate the different externalities and some of them also rely on the fleet size for on-demand service. Scenario planning will be elaborated in future work.

5.2 Methodology for the externalities

The methodology to calculate the externalities implementing Automated minibuses is very important as it can impact the results and the recommendations accordingly. The assessment will combine deployment scenarios of the automated vehicles for public transport and the related calculation of externalities. For each scenario, there is an estimation of the costs of transport externalities. The goal is to produce externalities values for different scenarios to find the most sustainable urban development scenario.

Thus, we will first define the categories (5.2.1). It specifies the considered impacts considered for the calculations (5.2.2). Finally, it provides the methods to calculate each externality category and the values of externalities (factors in €-cent/pkm) per the mode of transport (bus, car, and the automated minibus) for the four cities of AVENUE (5.2.3). Moreover, a test case (5.2.4) is included based on one scenario to replace 18% of the projected increase in ICEV in 2040 in Geneva using the assumptions from 5.1.

The categories, impacts and externalities values are based on the 2019 study from CE Delft which comprises the most exhaustive research on external costs of different transport modes, specifically, of different passenger road transport vehicles in the EU (van Essen et al. 2019).

See more details in Figure 96.

[10] Transportation demand management (TDM) is the art of modifying travel behavior, usually to avoid more costly expansion of the transportation system (Ferguson 1990).

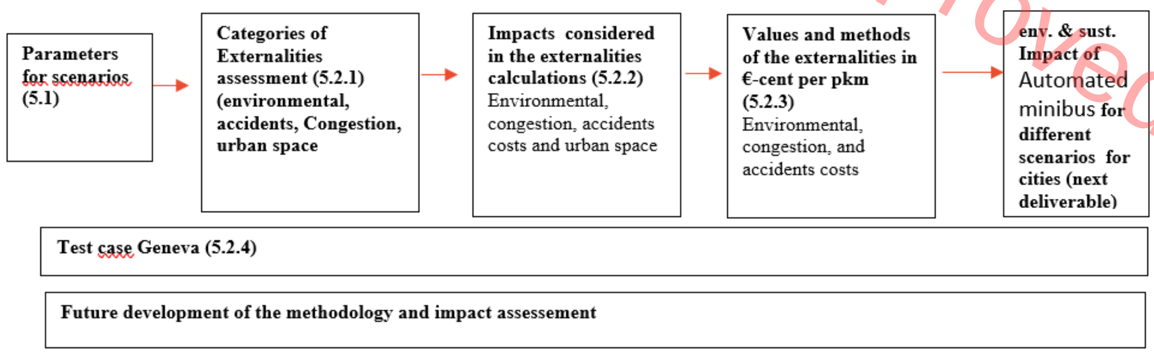


Figure 72: The structure for the methodology

5.2.1 The categories of Externalities assessment

Transport Externalities are at the core of this part of the economic assessment. First, a definition of external costs and external transport costs are provided. Then, the categories based on the CE Delft (2019) are presented.

The CE Delft report focuses on air, maritime, and road transportation. AVENUE focuses only on-road passenger transport externalities, specifically passengers' cars and buses externalities.

Moreover, it is important to note that this model results are total external costs. Total external costs are incurred in a predefined geographical area and caused by one mode of transport. They represent the result of combining the short-run marginal costs (correlation with the current infrastructure capacity and the traffic flow) from the report in (€-cent/pkm) with the modal share (in pkm). Long-run marginal costs take into account future infrastructure expansions to meet the rise in traffic demands (Miola et al. 2008), and they are not part of this assessment.

The categories of the externalities adopted from (van Essen et al. 2019) study are:

1-Environmental externalities

a-aggregated Well-to tank emissions (air pollution and climate change)

b-Wheel-to-tank emissions

- Air pollution
- Climate change

c- Noise

d- Habitat damage

2- Accidents

3-Congestion

And to further strengthen this model, our AVENUE Assessment will include the externalities classes that were not addressed in the CE delft report like

- Urban space,
- Production and disposal emissions (not in this iteration).

To calculate the externalities, the categories will refer to vehicles externalities induced by cars, buses, and automated vehicles for public transport. Active mobility externalities like walking, biking etc., are considered negligible (Keall et al., 2018).

As a result, the marginal costs adopted from the handbook are presented on a national level for Luxembourg, France, Denmark, and Switzerland and are used for the cities level. The distinction between rural and urban areas will be made through a sensitivity analysis using European level values.

5.2.2 The Impacts and methods considered in the externalities calculations

The following describes the impacts to be considered later on for the calculations.

- **Environmental externalities**

Environmental externalities include well-to-wheel emissions, noise, and habitat damage.
The assessment of the environmental externalities follows the LCA well-to-wheel. The LCA is used because it aims at analysing the composition of materials and their environmental damage potential Jochem et al., 2016).

Well-to wheel assessment

The LCA focuses on the environmental assessment during the life cycle of a product: primary material extraction, production, use, and disposal or recycling. Ramachandran and Stimming (2015) explain that "Well-to-wheel (WTW) analysis is an application of LCA which is used to compare drivetrains/vehicles from a global perspective". The Well-to-wheel represents the energy flow and the associated emissions. It starts from the mining phase or the raw materials extraction phase: "the well" until the use phase " the wheel".

The well-to-wheel (WTW) is composed of 2 parts: well-to-tank (WTT) and tank-to-wheel (TTW). The WTT has 5 steps: extraction of primary materials- well, the primary fuel production, transport of the fuel, production of vehicles fuel, distribution of road fuel, and fuelling the vehicle. The TTW represents the driving of the vehicle: the burning of the fuel in the vehicle and the wheel phase (JCR, 2016; Woo et al., 2017). See Figure 73

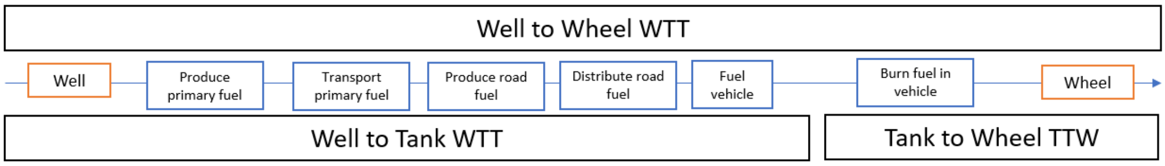


Figure 73: Well-to-wheel analysis

Air pollution

Air pollution leads to harmful health effects. Up to 30% of strokes, lung and heart disease are caused or aggravated by air pollution (Jochem et al., 2016; WHO, 2016, 2018). The pollutants to be considered are PM2.5, PM10, NOx, SO2, and non-methane volatile organic compound NMVOC. The analysis is built on 4 types of impacts caused by air pollution:

- Health effects (medical costs, loss of work productivity due to sickness),
- Crop losses (lower crop production),
- building damage (damage to building surfaces and building façades and materials - corrosion due to NOx),
- and biodiversity loss (soil and water acidification, eutrophication of ecosystems).

Climate change

Transportation sector contributes with around 25% of GHG emissions in the EU. Road transportation emissions account for 70% of that share in 2017 (European Commission, 2016). The calculations for climate change costs, in line with the CE Delft report, accounts for costs related to global warming:

- sea-level rise,
- biodiversity loss,
- water management difficulties,
- extreme weather conditions,
- and crop failures.

The emissions of CO2, N2O, and CH4 are leading factors of global warming.

Noise

van Essen (2019) defines noise is as "unwanted sounds of varying duration, intensity or other quality that causes physical or psychological harm to humans". According to the European Environment Agency, around 72,000 people are admitted to hospitals, while 16,600 fatalities could be attributed to noise pollution. Road transportation remains the leading cause. It is even considered as the second most environmental stressor in the EU (EEA, 2014).

The model accounts for:

- the annoyance
- and health effects caused by road traffic noise.

The WHO (2011) describes annoyance as a leading burden of road transport environmental noise. It causes irritation and stress, which could disturb daily activities. Noise pollution is a culprit in cardiovascular diseases and sleep deprivations (van Essen et al., 2019).

Habitat damage

Habitat loss is caused by:

- the construction of infrastructure
- and the damage to the natural wildlife.

Specifically, habitat fragmentation affects biodiversity. Moreover, transport emissions aggravate the effects on natural species. The estimation for habitat damage account for the following impacts:

- habitat loss: the loss of natural ecosystems. The land use of transport leads to
- negative effects on biodiversity. Habitat loss is caused during the building phase of transport infrastructure, but its effects are continuing during the lifetime of the road.

habitat fragmentation: fragmentation has a bad influence on animals and on biodiversity. Habitat fragmentation is the result of the transport infrastructure and the transport demand on the infrastructure.

- Accidents

Around 1.2 million fatality is caused by road transport, and up to 90% of these accidents are due to human error. Automated vehicles could lead to a significant reduction in these rates (UITP 2017).
Road accidents costs are incurred because of injuries and fatalities.
They constitute:

- material damage,
- production losses,
- and administrative, medical, and human costs

van Essen et al. (2019) define the external accident costs as: "*the social costs of traffic accidents that are not covered by risk-oriented insurance*". Human costs are a way to represent the pain and suffering caused by traffic accidents. The external costs depend significantly on the severity of the accident (Jochem et al., 2016).

- Congestion

Congestion remains a significant nuisance for cities. Banister (2008) states that it is unrealistic to opt for a transportation system without congestion. Thus, policymakers should seek to establish reasonable travel times rather than minimising them. The deployment of AV as an on-demand service complementary to public transport could be a solution to achieve optimised travel durations. The technology could enhance the transport network performance and reduce delays. In contrast, if AV were to be introduced as personal transportation, it will cause an increase in trips distance as it gets more efficient and accessible, which is described as induced demand. Consequently, congestion will worsen (Simoni et al., 2019; UITP, 2017).
According to van Essen et al. (2019), external costs of congestion result from not meeting passengers' mobility demand due to the temporary scarcity of infrastructure. In other words, this cost occurs

when an additional vehicle enters the traffic flow; it reduces the speed and increases the travel time. Hence, it causes traffic flow to reach its capacity.

- **The potential impact of Urban space**

Space plays an important role in the externalities calculations for the habitat damage. Also, it provides an indicator that will be used in determining the scenarios for sustainable urban development. For instance, if the automated minibuses are replacing individual transportation, one minibus could replace numerous vehicles, and there will be no need for a lot of road space nor parking spaces. This means more urban space that could be designated for more sustainable and liveable cities.

Currently, cities are designed to reserves up to 80% of the urban space for cars (Cugurullo et al. 2020; González-Guzmán and Robusté, 2011). According to the European Parking Association (2013), there is around 47 million parking space in the EU (17 million on the street and 30 million off-street). This is further aggravated because a car is used around 5% of the day (Janasz 2018).

The introduction of automated vehicles is destined to trigger a transition in urban design. Transport systems affect the built environment, and the switch from private transport to more shared, sustainable, and automated mobility would reduce the needed space to accommodate cars. This switch hinges on introducing automated vehicles as a MaaS rather than a private transport option. The saved urban space could be reclaimed for green parks and housing. This supports mixed land use development (residential, commercial, and workplaces are mixed within urban areas) in smart cities (Plumer 2016; UITP 2017).

5.2.3 The methods and values of the externalities in €-cent per pkm

The methods used to calculate them are described briefly; a detailed description is in the second iteration of the environmental deliverable. This analysis follows the work of van Essen et al. (2019). Then we present the different values for the external costs per category and per mode of transport to be adopted for Geneva, Lyon, Luxembourg, and Copenhagen based on the impacts in 5.2.2. It follows the same order: environmental externalities, accidents and congestion.

- Externalities of environmental impacts

The following cites the costs and methods to calculate the environmental impacts of 5.2.2. It also represents tank-to-wheel aggregated costs.

Air pollution costs

The methodology used to estimate the external costs of the impacts of air pollution described previously is a damage cost estimation. A damage cost estimation estimates all damage borne by individuals as a result of the existence of an externality. It relies on cost factors from an adapted version of NEEDS approach, the emission factors from COPERT data, and transport performance data from Eurostat.

The marginal costs are taken on a national level for the values for the passenger cars and the standard buses. They are presented in Table 1.

Table 1: Marginal costs for air pollution in €-cent/pkm

	Average costs in €-cent per pkm			
	Pass car - petrol	Pass car – diesel	Pass car - total	Bus
Denmark	0.292	0.809	0.483	0.513
France	0.387	1.260	1.001	1.010
Luxembourg	0.429	2.630	1.880	1.846
Switzerland	0.311	1.461	0.626	0.755

Using national values for the city-level assessment could affect the calculations because of the PM emissions differe between rural and urban areas. However, this could be adressed using the European values for urban and rural parts in a sensitivity analysis in Table **2**.

Table 2: EU level average costs for air pollution in €-cent per pkm

Vehicle	Urban areas- urban roads
Petrol passenger car	0.11
Diesel passenger car	0.99
Standard bus	1.07

As for the Automated minibus, the values follow the analysis on the potential competitors from the environmental deliverable. The emissions of an electric automated minibus are comparable to those of an automated one. Thus, the values used are those of urban electric mini-bus. For now, we use the values on a European level because the limited deployment of Automated minibuses will not vary immensely from one European country to another. All the values for the well to wheel emissions are also presented in Table **5**

Climate change costs

The methodology to estimate the marginal external costs of climate change follows the avoidance cost approach. It accounts the costs needed to meet the EU CO2 reduction targets. This presents an indication of the willingness to pay (WTP) to avoid the damage of climate change. According to (Miola et al., 2008) The avoidance costs are defined as "the least-cost option to achieve a required level of GHG reduction."

First, the study uses the emission factors from COPERT data of CO_2, CH_4, N_2O, and transport performance data from Eurostat. Then, it applies the Global Warming Potential GWP to sum up the total emissions of the GHG in a tonne of CO_2 equivalent. Finally, the cost factors from the NEEDS approach provides the total costs of climate change per vehicle per country.

The values are in Table 3; they present the average costs for climate change.

Table 3: Average costs for climate change in €-cent per pkm

	Average costs (€-cent per pkm)			
	Pass car - petrol	Pass car – diesel	Pass car - total	Bus
Denmark	1.168	1.054	1.126	0.418
Finland	1.503	1.398	1.478	0.418
France	1.122	1.096	1.104	0.519
Luxembourg	1.385	1.206	1.267	0.477
Switzerland	1.358	1.174	1.308	0.438

Following the same comparison with the small electric urban bus from the air pollution costs, the average costs for Automated minibus for climate change are negligible van Essen et al., (2019).

Aggregated emission of well-to-tank

The well-to-tank phase represents the energy provision for driving. It accounts for the aggregated emissions of fossil fuel as well as electricity extraction, processing, transport, and transmissions (Hagedorn and Sieg, 2019).

The methodology to estimate the costs is similar to that of air pollution and climate change during the tank-to-wheel assessment (using damage cost for air pollution and avoidance costs for GHG emissions). The marginal costs of well-to-tank emissions are in Table 4.

Table 4: Average costs of WTT in €-cent/pkm

	Average costs (€-cent per pkm)			
	Pass car - petrol	Pass car - diesel	Pass car - total	Bus
Denmark	0.374	0.340	0.361	0.158
France	0.425	0.393	0.403	0.191

Luxembourg	0.653	0.603	0.620	0.296
Switzerland	0.430	0.397	0.421	0.190

Similarly to the previous analysis, the marginal cost of WTT for the automated minibus is 0.54 – 0.63 €-cent per pkm.
Finally, the summed average costs of the emissions for the well-to-wheel assessment (aggregated well to tank, air pollution and climate change for tank-to-wheel) for the buses, cars, and Automated minibuses are presented in Table **5**.

Table 5: The average external cost per the mode of transport in €-cent per pkm for the WTW emissions

	Average costs – WTW emissions in €-cent per pkm				
	Passenger car			Bus	Automated minibus
	petrol	diesel	total		
Denmark	1.83	2.20	1.97	0.67	0.59
France	1.93	2.75	2.51	1.20	0.59
Luxembourg	2.47	4.44	3.77	2.14	0.59
Switzerland	2.10	3.03	2.35	0.94	0.59

Noise

The estimation of the noise impact relies mainly on noise maps. It depends on the number of people exposed to noise based on 5dB thresholds from noise maps from EEA (2014).
Following the analysis of the Delft report, the annoyance cost is calculated based on willingness-to-pay (WTP). WTP is the price (or below) a person is willing to pay to avoid the nuisance of noise. It estimates a € 14/dB per person as an annoyance cost for people exposed to a range of 50-55 dB. The health values are estimated based on a burden of disease approach from the Defra (2014) report. It accounts for €40,300 for Value-of-statistical life (VOLY).
Notably, the noise effects depend on the population density, traffic status, and time of day. Thus, the marginal costs differ from the average costs. However, the data on a country level for theses specific contexts is limited. Thus, the model at hand uses average costs (Table 6) to reflect more the specifics on the deployment location. The marginal costs for the UE28 (Table 7) level will be used in the sensitivity analysis.

Table 6: Average costs per country for noise per the mode of transport in €-cent/pkm

	Average costs (€-cent per pkm)			
	Pass car - petrol	Pass car - diesel	Pass car - total	Bus
Denmark	0.60	0.64	0.62	0.34
France	0.36	0.38	0.38	0.28
Luxembourg	0.52	0.54	0.53	0.28
Switzerland	1.89	2.00	1.92	0.84

Table 7: Marginal costs for noise per €-cent per pkm

Marginal costs in €-cent per pkm for EU level			
Mode of transport	Time of the day	Traffic situation	Cost
Passenger car	Day time	Dense	0.5
		Thin	1.1
	Night time	Dense	0.9
		Thin	2.1
Bus	Day time	Dense	0.5
		Thin	1.3
	Nighttime	dense	1

		Thin	2.4

For the Automated minibus, the costs depend on the traffic status on the operation time of the day, similarly to an Internal combustion engine vehicle. At higher speeds (higher than 40km/h), there is no significant difference between an electric vehicle and an ICEV. For constant low speed, electric vehicles are quieter (Pallas et al., 2015)

The noise from the electric engine in the vehicle is negligible for speeds between 30-50 km/h. The lion's share of the noise goes to the tires and the aerodynamic components. The Automated minibus circulates in a speed between 12 and 30 km/h in urban areas where maximum speed limits are around 50km/h.

There are potential savings in external costs when replacing Automated minibuses and ICEV (or standard buses). The automated components do not emit significant noise. Thus, the Automated minibus is comparable to an electric vehicle in term of noise pollution.

of Jochem et al. (2016) study for the external costs of electric vehicles is followed to estimate the average costs. His research considers the traffic situation in estimating the cost; the operation time during the night leads to higher costs.

The final result for the EU level costs for Automated minibus for noise in €-cent/pkm are in Table **8**. Further analysis is required to distinguish the effect of different traffic situation (dense/thin).

Table 8: The average costs for the **Automated minibus** for noise in €-cent/pkm

	Day time	Nighttime
EU level for Automated minibus	0.2	0.4

Habitat damage

Simalarly to the marginal costs of air pollution, cost factors from NEEDS are combined with the extent of the road infrastructure. The marginal costs for damage habitat depend on the infrastructure.

The automated minibuses are circulating on the same road network, thus using the same existing roads. However, they contribute to a reduction in the road space needed because of less vehicles circulating in general. Thus, we estimate the potential urban road space saved by reducing the number of vehicles circulating. The urban space calculation is explained later on.

The space saved is then multiplied by the cost factors €/km^2 from Table 9 to produce the overall saved externality). This represents the potential savings from different deployment (or replacement) scenarios

Table 9: Cost factors for Habitat damage for urban roads in €/km^2

	Road €/km^2
EU-28	4,100
Denmark	5,500
France	4,900
Luxembourg	4,300
Switzerland	6,800

If the fleet size is reduced due to the use of automated minibuses. The road space called dynamic space will also be reduced. Thus, it is expected to have significant savings in term of space and external costs. Indeed, one on-demand shared automated minibus could replace between 8 to 10 vehicles (Fagnant and Kockelman 2015; ITF 2020)

- **Urban Space**

The total urban space is expressed in km^2 (or m^2). The modal shares are a key component to obtain the potential saved overall space since it helps determine how many road space and parking spots we can save when we know how many vehicles could be replaced. Occupancy factors (passenger/vehicle) for different vehicles are also used to convert from vkm to pkm, which is important to calculate the habitat loss externality as well and determine the space needed per the mode of transportation. The values are from Héran and Ravalet (2008) study. They are presented in Table 10.

Table 10: Occupancy rates of different modes of transportation

	Passenger car	bus	Automated minibus	bike
Occupancy rates	1.7*	20 *	6	1

*Value adjusted according to the average occupancy factors from Delft report

Road transportation occupies plenty of valuable and scarce space in cities (Gössling 2020). This space can be divided into dynamic space and static space.

Dynamic space

The calculations of the urban space account for the potential saved road space (dynamic space) if fewer cars are used because of the modal shift caused by the introduction of the automated transport system. The preliminary estimation relies on the safe separation distance; It is the space needed between the vehicles in full traffic based on the speed to ensure the safety of drivers. The assessment utilises Héran and Ravalet (2008) report as part of the program for Research & Development in road transport in France. Based on the number of passengers. The dynamic space dedicated to a vehicle is computed as follows:

$$DS = (L + SSD) \times W$$

DS: dynamic space of circulation
L: Length of the vehicle
SSD: safe separation distance in the function of speed
W: average width of roadway
Based on the same report, Shalkamy et al. (2015), and the Navya vehicle dimensions, the vehicle dimensions are in Table 11. They are needed for the calculations of dynamic space using the formula above.

Table 11: Vehicle dimensions in m

	Length of the vehicle (m)
Car	4
Standard bus	12
Bike	1,8
Automated vehicle for public transport	4.75[11]

The dynamic space depends on the speed of circulation due to the Safe Separation Distance and Width of the roadway values.

$$SSD = V + 0{,}01371\, V^2$$
$$W = 2{,}2 + 0{,}0052\, V^2$$

Thus, the dynamic space for one car is

$$DS = 8{,}8 + 2{,}2\, V + 0{,}050962\, V^2 + 0{,}0052\, V^3 + 0{,}000071292\, V^4$$

In the AVENUE case, the automated vehicles' speed for public transport is between 12-30 km/h. As explained in 5.1, the modal shift will occur in urban areas; thus, the speed circulation limit is 50 km/h (Shalkamy et al., 2015). The values for dynamic space needed per the mode of transport are in Table 12.

Table 12: Dynamic space needed based on speed in m^2

Speed km/h	10	30	50
DS per car	15	34	66
DS per standard bus	46	78	135
shuttle	36	75	113

For the replacement of buses by the shuttles, additional development is needed in term of dedicated bus lanes. According to Héran and Ravalet (2008), bus lanes width measure 3,5 m. Notably, the lanes

[11] Navya autonomous shuttle brochure - https://navya.tech/wp-content/uploads/documents/Brochure_Shuttle_EN.pdf

are used more and more as bike lanes as well. This leads to a potential width that ranges from 7,7 m to 8 m. The AVENUE vehicles circulate in mixed traffic and do not use the dedicated lanes, which means more urban space savings. This is due to these lanes not being used as the automated minibuses circulate in mixed traffic and replace a percentage of buses modal share.

However, we should also account for the possibility of utilising these lanes by the automated shuttles during night shifts. For now, this space is not considered in the assessment and will need further research

Static space

The parking space is composed of on-the-road (public) parking. The dimensions are based on the average size of a European car. These values vary based on vehicle usage trends; for instance, vehicles are usually larger in the USA, requiring more parking space. The estimations are based on (Héran and Ravalet 2008). The values needed for parking spaces are in Table 13.

Table 13: Space for parking per the mode of transport in m2

	Space for parking per vehicle	Space for parking per person
Cars	10	19,2
Bikes	1	1,5
Standard bus	42	2,3
Automated minibus	~10	~1.6

- Accidents

For this cost category, the damage cost approach is used. Furthermore, costs related to the prevention or avoidance of accidents are not considered. The Delft report (2019) considers that some of the social costs are internalised by the road user. The computed costs characterise the impact of an extra vehicle entering the traffic flow.

The delft report relies on accidents statistics from the Road Accident Database CARE, and the costs per causality are adopted from SafetyCube. It is supported by human costs based on the value of statistical life VSL without considering the potential of consumption loss potential. For instance, the EU28 VSL is 3,6 million euros, and the value used for the calculations is 2,9 million euros. The VSL is determined through the stated preference method, which indicates the willingness to pay for safety.

The values adopted for the passenger cars and the buses from van Essen et al. (2019) analysis are in the following table. These values account for the underreporting of accidents in the form of correction factors.

Table 14: Marginal costs for accidents in €-cent/euro

	Marginal costs (€-cent/pkm)	
	Pass Car	Bus
Denmark	0.49	0.23
France	0.76	0.23
Luxembourg	2.31	0.33
Switzerland	1.35	1.62

For the AVENUE vehicles, the calculations for marginal costs were computed based on the inputs of accident risk per vehicle, costs per causality, and the risk elasticity. The formula to calculate the accidents from van Essen et al. (2019)

Is used to calculate the accidents marginal cost for the automated minibus.

$MC = r\ (a+b+c)(1+E) - \theta r(a+b)$

MC = marginal cost

r = risk of the vehicle causing an accident or being in one

a = The costs due to an accident for the person exposed to the risk

b= The costs for the relatives and friends of the person exposed to the risk

c = The costs of the accident to the rest of society (production loss, material damages, administrative costs, medical costs)

θ =The share of the accident costs that is internal for each vehicle category
E = risk elasticity which reflects how much a 1% increase in traffic (measured in vkm) increases the accident risk

The risk of being in an accident in the automated vehicle for public transport is the ratio of the number of injuries (or fatalities) and the number of vkm driven. Based on the number of incidents reported from the pilot sites of AVENUE compared to the total km driven, we assume that the risk values are negligible. Furthermore, data found regarding the number of incidents related to different AVs from the literature review supports this assumption (Dixit et al., 2016; Filiz 2020; Petrović et al. 2020). In conclusion, with a negligible risk value, the marginal cost for accidents per automated vehicle for public transport is **0 €-cent/pkm**.

- Congestion

Similarly to previous categories, the model relies on Delft report externalities values. The costs are computed thanks to delay cost and deadweight loss approaches. The delay cost approach defines the road congestion cost as the value of the travel time lost relative to a free-flow situation, while the deadweight loss DWL approach determines the economically optimal solution for transport pricing. However, the process of monetising congestion is complicated as it depends on an EU-level study to reach national marginal costs (Jochem et al., 2016). The meta-analysis requires inputs of speed-flow functions, demand curves, and value of time (VOT). The VOT differs based on the travel purpose
Costs carried by the driver, such as fuel and travel time, are considered internal costs and are not included in the externalities. This is called marginal private costs (Janasz, 2018). The focus of this modelling is the social marginal costs.
The calculations also neglect network effects. They account for delays, unreliable travel times, extra operation costs, and loss in economic activity. The costs hinge on circulation circumstances and local conditions, such as the type of road addressed in 5.1 and the level of traffic. The Delft study accounts for the traffic intensity estimated based on the volume and capacity of traffic flow; thus, there is a distinction between the cost for overcapacity, congested, near capacity, and well below capacity traffic. Notably, the bus estimations are based on simplified assumptions using the Passenger Car Unit PCU (PCU for a car is 1 and for a bus is 2) (Smith and Belwit 2010; van Essen et al. 2019).
The values for marginal costs for congestion per country for cars and buses based on the urban road type and the traffic situation are presented in Table 15.

Table 15: Marginal costs for congestion per mode of transport in €-cent/pkm

	Car						bus					
	Trunk Road			Other urban roads			Trunk Road			Other urban roads		
	Overcapacity	Congested	Near capacity	Overcapacity	Congested	Near capacity	Overcapacity	Congested	Near capacity	Overcapacity	Congested	Near capacity
EU-28	19.9	15.4	10.8	41.2	36.1	29.3	3.3	2.5	1.8	6.8	5.9	4.8
Denmark	20.8	16.0	11.3	43.0	37.7	30.6	3.4	2.6	1.8	7.0	6.2	5.0
France	18.7	14.4	10.2	38.6	33.9	27.5	3.1	2.4	1.7	6.4	5.7	4.6
Luxembourg	43.8	33.8	23.8	90.5	79.5	64.4	7.1	5.5	3.9	14.8	13.0	10.5
Switzerland	26.7	20.6	14.5	55.2	48.5	39.3	4.4	3.4	2.4	9.1	8.0	6.5

First, it is notable that the values are high; for example, the passenger car marginal cost is 43.8 €-cent per pkm for overcapacity trunk roads in Luxembourg which is a significant value compared to the other values for the other categories of marginal costs. Moreover, it could skew the overall results. This is explained by the dependence on a meta-analysis that requires inputs of speed-flow functions, demand curves, and value of time VOT. The data sets are broad and detailed enough (van Essen et al., 2019). Also, the calculations combine methods of deadweight loss and delay cost, which could overestimate the costs.
Second, for automated vehicles, some researchers attest to the positive effects on congestion due to cooperative technologies (tighter separation distances between vehicles, better intersection

manoeuvering; faster reaction times). At the same time, (Martínez-Díaz et al. 2018) argue that driverless technology's current development is conservative and cautious because it focuses on safety. Thus driving manoeuvres such as changing lanes and bypassing vehicles will be limited. Consequently, the AV deployment will increase traffic jams due to cautious driving (Medina-Tapia and Robusté 2019). The cautious driving could be accounted as a rebound effect. For the sake of the calculations, automated vehicles are considered capable of reducing congestion and competently predicting driving decisions (Fagnant and Kockelman 2015). Based on Fagnant and Kockelman (2015), the congestion is reduced by 5% in urban areas with a 10% penetration rates of automated driving. The different values are present in Table 16. The penetration rates of AV, as well as their effect on modal shares, could be tested in the different scenarios in future steps.

Table 16: congestion reduction based on AV penetration rates

The penetration rate of AV	10	50	90
Reduction of congestion	5	10	15

To better incorporate the fact that the automated vehicle is used as a public transport solution, the automated minibus's marginal cost is comparable to a mini-bus as they both have similar dimensions and occupancy rates. The Potential Capacity Unit for a mini-bus from Pajecki et al. (2019) and Shalkamy et al. (2015) study is between 1,25 and 1,5. Finally, the marginal social cost for congestion for a mini-bus in €-cent per pkm for a PCU of 1.25 is presented in Table 17.

Table 17: Marginal social costs of congestion for a mini-bus in €-cent/pkm

	Automated minibus					
	Trunk Road			Other urban roads		
	Overcapacity	Congested	Near capacity	Overcapacity	Congested	Near capacity
EU-28	1.8	3.9	3.6	13.8	12.1	9.8
Denmark	6.9	5.3	3.8	14.3	12.6	10.2
France	6.4	4.9	3.5	13.1	11.5	9.4
Luxembourg	14.6	11.3	7.9	30.1	26.4	21.4
Switzerland	9.0	6.9	4.9	18.5	16.2	13.2

Finally, the combination of the values in table x and table xx leads to an estimation of the marginal social costs for an automated minibus based on AV's estimated penetration rates. Thus, the study of modal shares is crucial for estimating total external costs for different scenarios.
The following part tests the externalities on a selected scenario to assess the estimations and calculations from 5.2.2 and 5.2.3. It accounts for a mobility survey of 2015 in Geneva as well as one scenario of mobility from a study of the spatial development office in Switzerland.

5.2.4 Test application of the city of Geneva – externalities calculations

A test case is a good method to test the validity of the values from 5.2.3 and insight into how the calculations will be for a specific scenario based on 5.1.
First, mobility behaviour data from the transportation survey is presented. Then, the savings in externalities for the described scenario are calculated.
The data from "The mobility of the residents of Geneva, results from the microcensus of mobility and transportation 2000-2015 "[12] delivers input on daily distances, number of annual trips and modal shares. Further development was needed to estimate the overall annual pkm by determining the average annual distance travelled per person per transport mode. The values of the average daily distance and the modal shares of the annual trips per person and the Geneva population were used from the microcensu for 2015 see Table 18.
It estimates an average of individual trips per day as 3.6 and an average distance of 30.3 km per day.

[12] N° 59 – MAI 2019 – COMMUNICATIONS STATISTIQUES

The mobility survey is a residential based survey; hence it accounts for only the trips conducted by Geneva residents. The population of Geneva in 2015 was 484 736 residents, and the number of private cars was 221 143 (FSO, 2016).

Table 18: Mobility behaviour – Geneva 2015

Mode of transport	Percentage of annual trips	Average daily distance per person	person mobility distance pkm
public transport	16.6	7	2555
private cars	33.9	19.2	7008
cycling	5.6	0.9	328.5
walking	39	2.3	839.5

The scenario in consideration relies on estimation from the federal office for spatial development ARE of Switzerland [13]. The report predicts an increase of 18% in the modal share of private vehicles. In this scenario, the automated vehicles for public transport will absorb this increase but will not increase total VKm as the deployment is part of a TDM; this was explained in 5.1.

Table 19: The externalities calculation for Geneva scenario

	externalities in million€ 18% share of private cars	externalities in million€ 18% replaced by automated minibuses	externalities in million€ Savings
Air pollution	3.83	0.306	3.52
Climate change	7.995	0	8
WTT	2.572	3.302	-0.73
Noise	11.747	1.223	10.52
Accidents	826.7	0	331.83
Congestion	8875.4	2973	5607

The calculations consider automated minibuses deployed to compensate the pkm travelled on near capacity trunk roads during the day using the scenario parameters' assumptions from 5.1. For this scenario in 2040 in Geneva, the total savings from replacing 18% of the current modal share of private vehicles (the expected increase in private vehicles modal share in 2040) with the automated minibuses is around 6455 million euros. The values of the congestion could be overestimated and should be validated at a later stage. The values for congestion depend on metadata which could skew the savings. Moreover, the noise values depend on the country; Switzerland had the highest estimation for 1.92 €-cent per pkm compared to 0.38 €-cent per pkm for France, which proves the importance of using national values for external costs instead of an EU average.

However, these monetary values show promising results for the potential of these vehicles if deployed under adequate conditions (for example: urban/suburban, time of operation, connections to train stations and mobility hubs, complementarity with public transport and active mobility, Transport demand strategy, and part of a MaaS service) to benefit cities. The next steps should focus on describing different potential scenarios based on the parameters from 5.1. Then, we should calculate the different externalities for these scenarios and further support them with sensitivity analysis. The scenarios with the most savings of externalities will be the ones to recommend and support the guidelines of the SUMP and SDG as described in 5.1.

5.3 Input for On-Demand Services: Fleet Calculator – Description, User Manual, XLS tool

The fleet calculator aims to calculate the number of on-demand AV needed to satisfy mobility needs and replace a mean of transport like ICE vehicles. This will be an input for scenarios to calculate the externalities described above in later steps. The on-demand service could fil mobility gaps and

[13] Transport outlook 2040, 2016

support travel demand management. This means that the on-demand fleet could help reduce the number of travelled kilometres and support public transport rather than compete with it.
To take mobility-on-demand and door-to-door services into account, the current calculators are unfortunately not sufficient anymore as timetables become obsolete and routes are not fixed anymore. This means that complex algorithms had to be developed to know how many vehicles are needed to satisfy citizens' mobility needs in a certain area. Furthermore, the factor of time was considered to calculate how many vehicles are needed depending on the waiting time (see figure 7): the longer a passenger is waiting, the fewer vehicles are needed in the fleet. This has an impact on costs for the PTO and external costs.
In this part, we describe the development of the model that the calculator is based on, the inputs needed by the user, and then use a test case in Lyon to estimate the number of vehicles needed. Finally, it includes conclusions and future development of this tool.

5.3.1 The model used

The model is designed based on the Fournier et al. (2020) model for robotaxis. It is further developed to focus on automated minibuses rather than carsharing schemes. The core of the calculations is summed up in Figure **74**. It depends on a vehicle's waiting time to pick up a passenger after they ask for a ride.

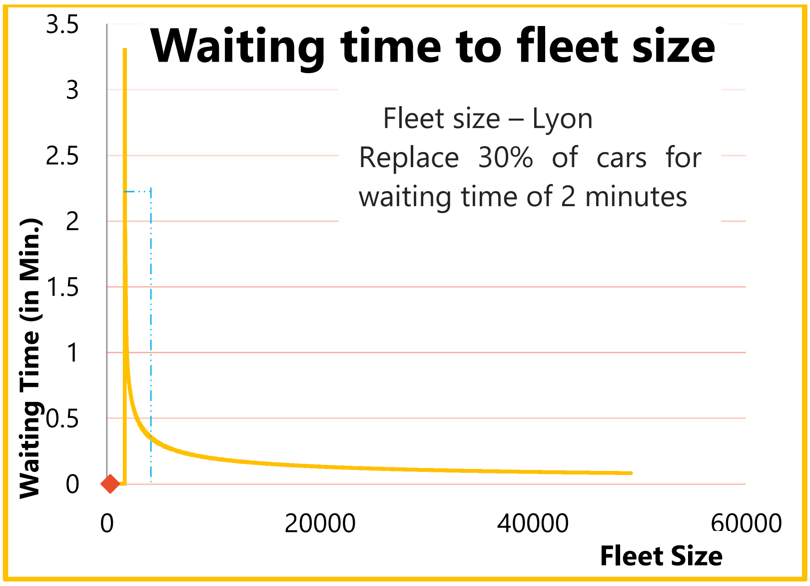


Figure 74: fleet size based on waiting time

Based on this model, a geographical area of the service and a daily trip rate are determined. Similarly, the AVENUE fleet calculator depends on trip data for the operation cities: average number of trips of the mobile population and average duration and distance per trip per car.

Furthermore, the calculation assumes a period for processing passengers' request. Finally, the automated minibuses supply starts with a request and follows a strict scheme that must be digitally executed and supported by the provider's staff. The procedure is: a customer's trip request is submitted at a random time within the defined area through a smartphone app. Infrastructure with continuous GPS-signal and mobile internet is needed to guarantee real-time information. Then, the system looks for all available vehicles and then deploys the fastest to reach the passenger. After the trip, it directly fulfils the next trip request assigned by central control or switches into an inactive condition and waits for a new order. However, the AVENUE version also includes the charging time needed as part of the estimations (Fournier et al., 2020).

5.3.2 The inputs needed from the user

The model is also repurposed to be user friendly. The calculator relies accordingly on key parameters that a user can alter based on different use cases. These variables are summed up in **Table** 20.

Table 20: Inputs from the XLS user

Vehicle specification	On-demand service	Mobility behaviour inputs
- speed - occupancy rate	Waiting time Time for ordering the service	- The city - The mode of transport to be replaced and its average occupancy rate - How much of the modal share of the selected mode is to be replaced by automated minibuses

The XLS user's inputs help predict the fleet needed to replace one mode of transport by the automated minibuses. It also considers the variables of time of day, desired waiting time, the replacement rate, and the occupancy rates.

5.3.3 Test Case for Lyon

For instance, to determine the fleet needed to replace a part of the modal share of ICEV in Lyon, the XLS user selects an average capacity of 6 passengers for the automated minibus, a waiting time of 2 minutes, and a speed of 25km/h. The replacement rate is 30% of ICEV passenger cars. The operation of these vehicles is during peak time. The occupancy of the IECV to be replaced is 1 passenger per vehicle. Then, the fleet calculator estimates the number of vehicles needed to deliver the use case. In this example, the fleet is composed of 2130 vehicles. This is shown in Figure **75**, the green part is the input part, and the grey is the final results generated by the calculator

Fleet calculator:		
Input:		
Please choose the city:	Lyon	
Please choose the type of roads:	urban road	
Expected Waiting time for the shuttle [in minutes]:	2	
Average speed of the shuttle (MAX [25 km/h]:)	25	
Please choose the time of departure/ Peak time/ average time:	Peak Time	
Which means of transport is replaced by electric automated minibus?	Cars	
How much percentage of the Cars do you want to replace with the shuttles to extend the service area?	Replace	30%
The occupancy rate of Cars to be replaced are …? [High=75%; Moderate = 50%; Low =25%]	Low	
The occupancy rate of the electric shuttle is? [Low = 2 passenger; Moderate = 7 passenger ; High = 13 passenger]	Moderate	

Results:	
Needed Vehicles:	2,130
Saved road space [km]:	852.000
Saved parking space [in km²]:	0.2045
Reduced parking costs (direct) [in €/ hour]:	46,235.20
Reduced parking costs (indirect [in hours]):	1,420.000
Vehicle kilometre (electric Bus) [vkm]:	11,494.919
Vehicle kilometre (without electric Bus) [vkm]:	91,959.353
Δ vehicle kilometre (saved vkm) [vkm]:	80,464.43
Passenger kilometres [pkm]:	721,978.06
Created Scenario:	Replace 30% of Cars in Lyon

Figure 75: The user interface

Inputs of waiting time and time of the trip help determine the number of automated minibus needed for this shift, while the speed limit influences the urban space's externality. The result is mobility guaranteed by the model.

5.4 Conclusion research agenda on the city-level externalities

The external costs factors are fixes based on operation assumption and data availability. The next steps should focus on the potential modal shifts caused by the introduction of automated minibus. The modal share distributions, as well as the initial assumptions of the external costs such as (limited speed, urban roads, near congested roads, the introduction of travel demand strategy, passenger's acceptability, open mobility platforms….), will help define the scenarios. The calculations for the externalities of different scenarios should help determine the optimal scenario for sustainable urban development.

Furthermore, the definition of the potential rebound effects such as social exclusion due to technology illiteracy, induced demand, overcapacity infrastructure should be addressed. Finally, the role of carsharing (robotaxis), new mobility (e-scooters) and the impact on active mobility will be the focus of future studies.

The assessment will be further strengthened with the categories for production and end of life externalities. The scenarios also will account for extrapolation for current values of externalities for the private vehicle due to technological progress in the ICEV energy use (Jochem et al. 2016). It will also consider the induced demand and network effects on the deployment of the automated minibus and the future cities.

The fleet calculator supports the development of scenarios to calculate the externalities of deployment of on-demand automated. The fleet size is also important to support the calculations of the urban space externality. It can also compensate for the uncertainty of predicting future modal shares.

Finally, it is important to note that the calculator is also adaptable to include other operation locations. It requires the submission of trip data, mobility behaviour, and modal shares of the calculations' desired area.

5 General Conclusion

The deliverable D8.4 presents current state of work of WP8 T8.3. The deliverable D8.4 presents the economic impact evaluation at two levels: the micro-level analysis considers a local context with its specification, the macro-level analysis considers a larger perspective at least like a city.
The remarks and recommendations of the external reviewer concerning D8.3 have been addressed along the document. The principal answers are listed hereafter.

At the service-level, the working team takes into account current situation that is call base scenario and proposes a simulation tool (EASI-AV©) as a decision support tool. The tool helps to analyze the economic impact by adjusting different cost variables like the cost of staff (operator on boar, remote center, no staff…), the cost of infrastructure investment (required or not), the cost of energy etc. The urban dimension is addressed by taking the externalities evaluation into the total evaluation.

Variables linked to the vehicle, like speed limit, charging time, vehicle capacity, loading factor etc., are taken into account to calculate the fleet size. As a simulation tool, EASI-AV can investigate any realistic conditions to evaluate the economic impact of an automated fleet. The D8.4 presents the operational case of Luxembourg demonstrator. By providing a comparative approach with any other transport mode, the tool enlightens in which way AV can allow cost savings concerning TCO as well as externalities. The final calculation of cost per km or cost per passenger is provided as comparative ratio.
Business model with analysis of ticketing strategies and new revenue models will be analysed in the forthcoming months while a web-application is under development.

At the the city-level the analysis relates more to SUMPs with a critical review of the role of shuttles/mini-bus services in the wider SUMP context, in intermodal chains and multimodal car independent lifestyle. Several scenarios have been presented in details showing how AVENUE can enhance the innovation potential in various fields, analyzing stakeholders and users behaviors as well as business opportunities.
The urban dimension is largely addressed with externalities analysis at all levels: pollution, noises, accidents as well as urban space. The macro calculator helps to evaluate all externalities with a cost per km.

Both micro and macro analysis (service and city-levels) help to simulate in which conditions an automated fleet service will create benefit for the community.

The next steps for WP8 T8.3 will allow to present:

1. A deepening of the identified 4 business opportunities presented in section 3 and analyse under which circumstances the business models are viable for the stakeholders. A particular attention will be paid to PTO and the users.
2. An operational version of the web application for EASI-AV© simulation tool including a total cost calculation in comparison with other transport modes and a complete profitability economic balance with revenue scenarios.

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APPENDIX 1

WP8 – Task 8.2
Economic Impact Assessment

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Glossary of CAPEX, OPEX and REVENUE sources

This document is a glossary to assist on the second part of the overall economic assessment and it aims to present the main sources of internal costs and gains for the implementation of a service with Automated Shuttles for Collective Transport (ASCTs).
The glossary is divided in three main parts: 1) the initial investment costs, as known as Capital Expenditures (CaPex), 2) the annual exploitation costs, as known as Operation Expenditures (OpEx), and 3) the main revenue sources.
It is important to note that not all the sources of costs and revenues listed here need to be considered. The implementation of services with ASCTs is context-based, therefore for each given context, the city, PTO or firm shall select what are the costs and revenues for their own context.
Moreover, it should be noted that this proposition is meant to serve as an initial guideline. In this sense, it is at the discretion of each PTO, city and other involved stakeholders to apply the calculation methods and formulas that better suit their needs. In addition, this glossary does not identify who should be the bearer of each source of cost or benefit. However, for the calculation sheet a column indicating the bearer should be added.
With an overall calculation of the internal costs and revenues the aim is to assist the calculation of metrics such as: cost per passenger/km, which would allow the comparison with other transport modes within the modal split and better identify the economic assessment of the deployments

Capital expenditures (CaPex)

Feasibility study

Comprehensive report that examines the practicality of the proposed project. It aims to objectively and rationally uncover the strengths and weaknesses of the proposed venture, the opportunities and threats present in the environment of the deployment, as well as the resources required to carry through.
It should provide a historical background of the project, a description of the product/service, accounting statements, details of the operations and management, marketing research and policies, financial data, legal requirements and tax obligations.
The common assessment factors to be included in the report are:

- Cost of Technical feasibility assessment;
- Economic feasibility assessment;
- Environmental impact assessment;
- Legal feasibility assessment;
- Operational feasibility assessment;
- Scheduling feasibility assessment.
- Other R&D costs.

It can be carried out by a designated team within the PTO's staff or even by a third-party hired consulting firm (or by a combination of both).
** It is worth highlighting that some additional reports, documents and data to assist in the feasibility study may need to be acquired from third-party entities or institutions.*

Commissioning costs

Entails all expenditures needed before the implementation of the project, it is mainly divided into: 1) vehicle homologation, and 2) test site homologation.

Vehicle homologation
It requires a technical inspection by the designated transport authority. The inspection is comprised of a series of tests (e.g., brake-test and test of electrical components) which are normally carried out by an specialized firm. In addition, a full technical documentation of the shuttle should be provided to the designated transport authority.
** vehicle homologation is normally done only once – not requiring periodical renewals.*

Operating site homologation
It mainly requires a technical inspection and authorization by the designated transport authority (and other select stakeholders whenever needed) of the selected track (in the case of fixed traffic routes) or selected driving area (in the case of on-demand geofenced routes). It is mainly sub-divided into concessions, and application.

Concessions:
Telecommunications concessions: transmission of radio and 3/4/5G signals – normally granted by the country's Federal Communications Office.
Passenger transport concessions: transport of people – normally granted by the country's Federal Transport Office.

Application:
Complete written document (normally divided by chapters) containing detailed information on:

- Project (description; official waiver request; objectives);
- Authorities (PTOs service agreement);
- Concessions (telecom and passenger transport);
- Routes (in-depth description);
- Bus stops (description and identification);
- Vehicle (description; technical information; documents);
- Safety (operational measures, legal bases, traffic rules);
- Operations (timetables, supervision, procedures);
- Positions (experts, trainers, operator);
- Operators (commitment, instructions, accident procedures);
- Training (theoretical, practical, assessment, certification);
- IT (data security, software, embedded systems);
- Reporting;
- Communication (internal, external, clients).

Depending on the complexity of the project (road environment where the shuttles will be deployed), the PTO could opt to carry out tests and simulations on designated test-tracks (e.g.: Transpolis in France) to reduce uncertainties and errors in the test site.
The working hours of the PTO's employees involved in writing the application document may also be considered in the cost structure.
Furthermore, steps and bureaucracy may vary according to different countries and cities. As well as it may require periodic renewals of such homologation.

Vehicles acquisition
It entails the purchase of the Automated Shuttles fleet from selected OEMs. Prices may vary according to each OEM as well as according to the shuttle's specifications (e.g.: added seatbelts, air-conditioning, ramps for persons with reduced mobility, etc.). Paint-jobs for the vehicle exterior may also incur in additional costs. Another alternative for the acquisition of the fleet is a leasing contract. If the PTO or the city chooses this alternative, there will be no initial purchasing costs, but recurring expenses (OpEx) for the lease payment.

Observation: according to Bösch et al. (2018), in comparison to traditional vehicles, the cost of automation would increase vehicle price by an average of 20%. For instance, the Olli shuttle has an initial price of $275,000 ($59,500 when annualized for a 5-year lifespan) (Henderson et al., 2017). According to a comparative

cost/benefit study carried out by the authors: "Olli outperforms traditional fleet vehicles and CABS shuttles in annual carbon emissions, maintenance costs, and fuel costs… The variable that it differed significantly from the other vehicles was initial purchase price, which was over $100,000 more expensive than a traditional minivan."
** costs with insurances as well as annual inspections and taxes are listed in the OpEx.*

Infrastructure works

Costs here may be divided among the PTO and the municipality depending on each city's agreements among the transport authorities and the PTOs. The main recurrent expenditures are described below.

Road work infrastructure

According to Nacto (2012), many city streets were created in a different era and need to be reconfigured to meet new mobility needs. With that, transportation engineers can work flexibly within the building envelope of a street, which includes moving curbs, changing alignments, daylighting corners and redirecting traffic where necessary. Therefore, Automated Shuttles will require infrastructure adaptations and constructions, therefore public spaces of the city will have to be reallocated to properly accommodate the shuttle service.

It should include works on infrastructure adaptation and construction, such as:

- road-marking paintings;
- traffic signs;
- traffic lights (with V2I; V2X technology);
- asphalt pavement;
- roundabouts (construction and/or adaptation);
- stops for the shuttles (station and platforms);
- GNSS/GPS base station (stationary station for shuttle's location correction);
- and so on.

** these costs are paid by either the city or by the PTO, and in some cases the costs can be spread and divided among the two.*

Mapping of operating site

Entails the costs for creating a compressive 3D mapping of the operating site (or testing route) and embedding it into the shuttle's driving software. It is normally carried out by the OEM (but in some cases it could also be done by a third-party firm or even the PTO).
** if the operating site changes and/or expand, further mapping should be done, which will incur is additional expenses for.*

Depot & Maintenance

Includes costs with building a space for the shuttles' depot and maintenance site. Normally both are in the same physical space (depot and maintenance) however, this could vary according to the city and available area for construction.
Costs with charging stations must also be considered for the depot (since most shuttles charge overnight or in idle hours).
Depending on the nature of the operation (e.g.: on-demand routing) a mobile office may also need to be put in place (it can be installed in the same physical space and the depot, or somewhere nearby the operating site).
** in some cases, the PTO and the city may opt to rent a place for the depot and maintenance site instead of building it. In that case, there will be no constructions costs, but instead recurring operating costs (OPex) with rent, electricity and others.*

Surveillance systems

Investments with surveillance systems to assure safety, those may include: cameras; storage units (in-vehicle and on-the-cloud) as well as costs related to software security against possible cyber- attacks (e.g.: hackers aiming to take control of the vehicle).
** such services may be carried out by the PTO or by hiring a third-party company or even by the OEM.*

Certification & Standardization

Includes the costs with implementation and certification of international standards for automated vehicles road safety, being the most relevant:
ISO 26262 "Road Vehicles – Functional safety";
SOTIF (ISO/PAS 21448) "Road Vehicles – Safety of the intended functionality"

** these certifications are not yet mandatory for the PTO to deploy the service. Their costs may be borne by the OEM and not necessarily the PTO.*
*** once certified, there may be periodical OPex costs regarding the certification.*

Additional services

Include investments costs for supplementary services, such as software development and/or acquisition, which can be divided into different categories of applications (those can be provided by different firms):

- Traveler interaction (mobile app for users);
- Vehicle management (mobile app for vehicle operator);
- Fleet orchestration (as provided by BestMile);
- Operations and customer management.
- Ticketing infrastructure (networks and integration with the PTO's ticketing service)
- Others.

** recurrent operational expenses are specified in the OpEx table.*

Depreciation

Depreciation of tangible assets

For each group of tangible assets the depreciation taxes and life-span may vary, for instance:

- *Buildings:* annual depreciation rate of 4% and life-span of 25 years;
- *Installations:* annual depreciation rate of 10% and life-span of 10 years;
- *Machinery and equipment:* annual depreciation rate of 10% and life-span of 10 years;
- *Furniture and utensils:* annual depreciation rate of 10% and life-span of 10 years;
- *Vehicles:* annual depreciation rate of 20% and life-span of 5 years;
- *Computer equipment:* annual depreciation rate of 20% and life-span of 5 years;

** As stated by Ongel et al. (2019), public transportation buses are scrapped at the end of their lifetime. In the EOL cost calculations, it was assumed that the revenue of selling vehicle scrap material would be equal to the costs of scrapping. Therefore, no EOL value are normally assigned to diesel buses. However, for automated shuttles (which the life-span is about 5-years), their batteries are replaced when the remaining maximum battery capacity reaches 70–80% of its original value. Therefore, remaining battery value is added as a negative cost to the operational costs for the years when the battery is replaced. The authors assume that the price for the second-life batteries with 70–80% of its original capacity would be 50% of the new battery.*

Annual Operation expenditures (OpEx)

Personnel expenses

It comprises the total remuneration, in cash or in kind, payable to employees in return for work done during the reference period. It also entails the costs with capacity building and training.

Salaries

Remuneration, in cash or in kind, payable by the TPO to the designated staff involved in the project, such as:

- Steward/Operator (Safety driver - for now, requested by law); - For the Olli shuttle, the average salary is $22.50/hour (Henderson et al. 2017).
- Supervisor;
- Interns;
- Engineers;
- Mechanics.
- and so on…

** Some PTOs are opting to hire students and interns to be their in-vehicle operators (in some countries and areas the law states that for vehicles that runs on less than 25km/h a simple tractor driver's license is sufficient). Therefore, by hiring students for those posts it reduces the costs of hiring a professional bus-driver as operator and also does not imply in training such regular drivers for a job that is likely to be temporary.*
*** salaries may normally include all payroll taxes and healthcare benefits.*
**** the aforementioned positions are non-exhaustive and may vary from PTO to PTO.*

Training and capacity building

Expenditures on training, qualification and certification of personnel for the correct implementation and execution of the project.
** it may need specific training sessions and courses (in person or at a distance) which may result in added expenses with travel missions and other costs and fees.*

Insurances

It entails the total insurance annual costs per shuttle. It is worth noting that commercial buses insurances can be broken up into several types of coverage, however, a typical insurance policy will likely include:

- Liability insurance (public liability insurance);
- Property damage (automobile liability insurance);
- Collision coverage;
- Medical payments coverage;
- Uninsured/underinsured drivers coverage;

Depending on the hired insurance policy it could also include:

- Comprehensive coverage (which entails comprehensive, or "other than collision" coverage, compensating the PTO for loss due to things like vandalism fire, theft or damage.

However, depending on the price to be paid for the insurance deductible, damage caused by vandalism for instance, may not justify triggering the insurance company. Therefore, such costs can be borne directly by the PTO (these are listed on the hidden costs category).

It is worth noting that rates for commercial bus insurance vary considerably, depending upon the fleet size, the use of the buses, how far they drive and other factors. Some of the factors that go into the cost of the insurance policy include:

- Fleet size;
- Number of seats in the shuttle;
- Driving records;
- Number of kilometers/year expected;
- Type of business (purpose of the service);
- Insurance company to be chosen and available discounts.

As pointed out by Bösch et al. (2018) and Ongel et al. (2019) based on earlier research, it was assumed that safer driving would lower insurance rates by 50%. This is regarded as conservative, as today's Tesla Autopilot is reported to have already decreased accident rates by 40%. However, premiums may not decline immediately after the deployment of AVs, since the AVs should prove to be safer over the human operated vehicles for the insurance premiums to adjust accordingly.

Taxes and fees

Licensing fees, taxes and tolls for the permission of vehicle circulation in the public roads.
Those fees may vary from country to country but wherever they are mandatory, they are mainly divided into:

- Road taxes (normally charged annually per vehicle);
- Vehicle registration taxes (normally paid only once – on the act of purchase);
- Vehicle emission taxes (normally charged annually per vehicle);
- Tolls.

Maintenance costs

Comprises all expenses directly related to the annual maintenance of the service, those being:

Shuttle maintenance

Due to their electric powertrain, Automated Shuttles benefit from regenerative braking, fewer moving parts and less fluids than a traditional ICE bus. Which means that generally they come with lower maintenance costs. However, maintenance is still needed and, it can be divided into 1) hardware and 2) software:

Hardware (mechanical) maintenance:

- Powertrain (electric engine; inverter; on-board charger; battery);
- Brakes and brake pads;
- Windscreen wipers;
- Tires;
- Lights (headlights, brake lights and blinkers);
- Sensors (odometer, lidars);
- Cameras;
- Antennas (GNSS);
- Computers.

Software maintenance:

- Updates & optimization;
- Errors corrections.

** PTOs are today heavily dependent on the OEMs to oversee the vehicles and perform maintenance (following SAE's automation levels, if the required maintenance is between levels 1-3 it can be done in house by the PTO, however if its higher, it requires intervention of the OEM). However, such business model is not well suited for larger fleets as well as it is not sustainable in the long-run. A better and more fluid arrangement will have to be achieved between PTOs and OEMs regarding the overall aspects of shuttles' maintenance.*

According to Bösch et al. (2018), due to more considerate automatic driving, it is expected that automated vehicles will need less maintenance for traditional car components. However, since it can be expected that the new sensors themselves need periodic maintenance different cost figures for the total maintenance costs are not assumed. According to Henderson et al. (2017) the average annual maintenance costs for the Olli shuttle – from Local Motors, is 600 dollars/year. Furthermore, according to Ongel et al. (2019), maintenance costs for ASCTs consist mainly of the battery replacement and service costs.

Transfer

It entails the annual costs for transporting the shuttles to and from the operating site. Such transfers may be divided into two categories: 1) initial transfer – which is the cost to be payed to get the shuttles from the OEM to the operating site and, 2) recurrent transfers – in some rate cases, the shuttle's depot may not be located close to the operating site, which may require daily transfers to take the shuttle to and from the site (this of course it is not the ideal situation, given that such costs may be avoided by having the depot close to the operating site).

** Such costs may be higher or lower depending on the fleet's size as well as on how far the operating site is located from the depot.*

Inspection

Depending on the country and/or city, yearly inspections of the shuttles may be required by the transport authority.

** The inspection is comprised of a series of tests (e.g., brake-test, test of electrical components and software) which are normally carried out by an specialized firm.*

Safety and security

Yearly costs with in-vehicle surveillance to assure safety, those may include: cameras; storage units (in-vehicle and on-the-cloud) as well as costs related to software security against possible cyber- attacks (e.g.: hackers aiming to take control of the vehicle).

** such services may be carried out by the PTO or by hiring a third-party company or even by the OEM.*

Vandalism

It entails all repair costs derived from vandalism which are not representative enough to pay for the insurance deductible, and thereby trigger the insurance company. Some PTOs make only minor repairs in-house, while others run their own upholstery shops and other repair facilities and take care of their buses' needs from top to bottom.

** It is worth noting that repairs caused by vandalism should be done the right way, since damaged equipment invites further damage, because it sends the message to passengers that bus property is not respected or protected. In this sense, it's helpful to keep replacement parts in stock so that damaged equipment, such as broken windows, can be replaced immediately.*

*** A well-placed and well-advertised surveillance system as well as good cleaning and property of the shuttles are likely to reduce and inhibit acts of vandalism.*

Operating site maintenance

Similarly to the shuttles, the operating site itself may need some regular maintenance, such as repairs and replacements of traffic signs and lights, asphalt pavement, road-mark paintings, V2I infrastructure, shuttle stops and platforms, depot and maintenance site, and so on.

** depending on the city these costs are paid by either the PTO or by the municipality itself, and in some cases the costs can be spread and divided among the two.*

*** regarding the depot and maintenance site, energy costs and other overhead costs should also be considered.*

Depot and Maintenance

PTOs may opt to rent the physical spaces for the depot and maintenance sites rather than building them. In this sense, PTOs will not have investment expenses on these assets, but recurring rental ones.

Inspection

Similarly to the shuttles, yearly inspections of the operating site may be required by the transport authority (and other selected stakeholders), regarding the renewal of the concessions fees and application forms.

** such early inspection of the operating site are context-base and may not be mandatory for all cities and countries.*

Vandalism

Acts of vandalism may occur not only with shuttles, but also in the operating site infrastructure. If the infrastructure is damaged, PTOs run the risk of a service malfunction or even interruption.

** Similarly to the shuttles, repairs caused by vandalism should be done the right way, since damaged equipment invites further damage.*

*** The costs of repairing damaged infrastructure may be paid by either the PTO or municipality (or both), depending on the contracts, agreements and arrangements made between the two parties.*

Software's and mobile applications

Yearly costs related to the running and maintenance of the IT applications necessary for the proper functioning of the Automated Shuttle service. It may be divided into the different types of applications needed to run the service:

- Fleet management system;
- End-user application (routing, scheduling, booking platform);
- Free in-vehicle wi-fi for the users.
- *Such applications can be provided by different firms and shall be integrated according to the PTO's needs.*

Additional services

Include the recurrent costs for supplementary services, such as software development and/or acquisition, which can be divided into different categories of applications (those can be provided by different firms):

- Traveler interaction (mobile app for users);
- Vehicle management (mobile app for vehicle operator);
- Fleet orchestration (as provided by BestMile);
- Operations and customer management.
- Ticketing infrastructure (networks and integration with the PTO's ticketing service)
- Others.

Fuel/Energy consumption

It entails the annual costs with energy (kWh) for recharging the batteries of the shuttles. Due to more balanced driving, it is further assumed that automation lowers fuel costs by 10% (Stephens et al. apud Bösch et al. (2018). According to Ongel et al. (2019), the annual electricity costs for ASCTs can be calculated as a function of the daily hours of operation, electricity consumption of the vehicle, efficiency of the charging station, and electricity prices. Comparatively, for a diesel vehicle, costs can be calculated as a function of the daily distances travelled, diesel prices, and diesel consumption per vehicle.

** As exemplified by Ongel et al. (2019) and Kalakuntla (2017), it is possible that the powertrain of the automated shuttle in an Internal Combustion Engine (ICE) rather than an electric one. In this case, the purchasing price of the fleet may be lower, but the environmental effects are negative and not desired by the regulatory bodies (especially in Europe and North America where many policies are being put in place to replace ICEs to more sustainable sources).*

Cleaning

It entails the annual costs with cleaning and organization of the shuttles both regarding the internal space and the fuselage.

** Data suggests that PTOs that keep their buses clean will generally have fewer incidences of graffiti and property damage.*

According to the economic assessment of ASCTs proposed by Ongel et al. (2019) for the city of Singapore, the average service line time for cleaning is generally around 15 minutes per bus and buses are usually cleaned once a day on days of operation. The Ministry of Manpower (MOM) of Singapore recommends a minimum monthly salary of S$1,200 for cleaners starting from 2019.

Advertising

Yearly costs related to advertising and marketing of the shuttle service. It can be done virtually (on the PTO and municipality's websites and social medias) as well as physically on newspapers, billboards, and so on. A third-party advertising company could be hired to promote the new shuttle services' or it could be done internally with the advertising and marketing department of the PTO.

Hidden costs

Comprises the expenses not normally detectable in the OpEx of the service. Among many others, they might include:

- Costs with unexpected fleet relocation;
- Costs of road incidents;
- Costs of absent passengers (when there is a booking but the passenger does not show up);
- and so on…

** hidden costs are context-based and may vary according to each city and service. They are not easily calculable either, however they may not vary much from the hidden costs currently present in normal urban transport services, thereby adaptions to the automated shuttles may be feasible (both for the regular-line as well as on-demand routes).*

Revenues

Ticketing

Entails the recurrent revenue of transport tickets paid by passengers, they can be:

- **Individually purchased:** valid for a single one-way trip (or for a pre-determined time-period allowing connections with other buses, trains, metros, etc).
- **Periodically recharged** on cards, being those:
- ***Flat rate model***: daily, weekly or monthly package in which passengers charge their transport card (e.g., Navigo card in Paris) and are able to use the multimodal public transport network during the validity-period of the package.
- ***Top up model*** (pay as you go): cards are recharged according to the user's needs and may be "topped-up" at any moment in time (e.g., Oyster card in London).

It is worth noting that is some cities and countries (e.g., Luxembourg city; Tallinn – Estonia; Chengdu – China), public transport is free of charge for users. Therefore, revenues from ticketing are not a source of gains for PTOs/Municipalities in those places.

Fare revenues are a significant source of income for large cities. In Paris, ticket and travel card sales account for 33% of the transport budget. The rest is funded by local communities and private sector employers, via a special transport tax. If zero-fare public transit were extended to all holders of a Navigo transport pass, and not just Parisians, the gap would amount to €3.5 billion a year (Insight, 2018).

Subsidies

Transport subsidies, as defined by Nash (2002) apud EEA (2007, p.13), includes all transport costs that are not covered by users, including all kinds of externalities, infrastructure costs or different regulation.

They are mainly paid to PTOs mainly via Public Service Obligations (PSO), which are public-funded payments made from municipalities (or states) to PTOs to guarantee a sufficient quality of public transport services – e.g.: train services to remote regions or bus services at late hours (EEA, 2007). The overarching goal of PSO of public transport is to realize the positive effects of public transport beyond the level which would be permitted though solely market based allocation, that is, funding with the objective of ensuring that services which are financially unviable but socially beneficial may be provided (IGEES, 2018). These benefits may be broken down into 3 groups:
Reducing the negative externalities of private car use, such as congestion and pollution;
Availing of system economies of scale which come from having high rates of usage; and
Promoting social inclusion and equity goals, in particular to marginalized and disadvantaged groups.

Without PSO these services are not profitable and would probably not be provided. Payments for PSO are supposed to provide a minimum quality of mobility and access without private cars, e.g. for under-aged, elderly, handicapped or people on low income. As such PSO could be considered a sort of 'social subsidy'.
Road transport receives an average of EUR 7 billion/year on PSO (while rail receive over EUR 40 billion).

Advertising by 3rd parties

PTOs and municipalities may also gain revenue by allowing third-party advertisement on their vehicles, stations and stops. Advertising contracts can vary according to the time-span of the publicity campaign, according to the location (in-vehicle, on bus-stops, stations…), and so on. Alongside ticketing, they can constitute an important source of revenue for the PTO and the municipality.
** Such kind of contracts are normally made between the PTO and an advertising company, such as JCDecaux, Times OOH, ExterionMedia and so on.*

Data commercialization

Entails the revenue that could be earned by the alternative use of a given product or service. In the case of automated shuttles there are a wide array of data which could be capitalized, such as:

- Vehicle's data
- Passenger's flow data
- Traffic data

** It is worth highlighting that the commercialization of data must be in accordance and must respect the governing legislation regarding its transparency, privacy and ownership.*

Others

Fixed-term contracts

Besides providing services to the municipality, PTOs may also enter into fixed-term contracts with other institutions (e.g., Hospitals, Airports, Universities, as well as with Cargo and Delivery companies) to provide mobility services with Automated Shuttles for Collective transport.
Some recurrent examples on both academic literature and news websites are transport operators like Keolis and Transdev providing trials in private sites worldwide such as in fairs and exhibitions, powerplants, university campus, airports and so on. Antonialli (2019), carried out a comprehensive worldwide benchmark study with ASCTs listing 92 experimentations, in where most of them were carried out via fixed-term contracts.
Those fixed-term contracts are important way for PTOs and OEMs to test the shuttles, improve the quality of the service and overall performance as well as to get the general public acquainted with automated driving technology.

In-vehicle services

Vehicular automation is opening a wide range of possibilities for in-vehicle services. By being highly connected, AVs can provide "infotainment" options to users. PTOs may take advantage of those features and offer in-vehicle services to users via the multiple screens and other man-machine interfaces imbedded in the shuttles.
** such type of services are likely going to be provided by third-party companies in partnership with the PTO. As a result, PTOs may assign the right to use such in-vehicle devices to these companies and charge a percentage of their revenues.*

Intellectual property

The initial implementation of a service with automated shuttles can be very costly and time-consuming, however, good knowledge management of the project may lead to significant savings in future deployments. That is, the learning curve leads to greater agility and cost reduction in future projects by the PTO. In parallel, PTOs may also opt to sell their know-how to other companies as a form of consultancy, which in turn may be characterized as additional sources of revenues (benefits).

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APPENDIX 2

	Summary of AVENUE operating sites Demonstrators						
	TPG		Holo		Keolis	Sales-Lentz	
	Geneva		Copenhagen	Olso	Lyon	Luxembourg	
Site	Meyrin	Belle-Idée	Nordhavn	Ormøya	ParcOL	Pfaffental	Contern
Funding	TPG	EU + TPG	EU + Holo	EU + Holo	EU + Keolis	EU + SLA	EU + SLA
Start date of project	August 2017	May 2018	May 2017	August 2019	May 2017	June 2018	June 2018
Start date of trial	July 2018	June 2020	September 2020	December 2019	November 2019	September 2018	September 2018
Type of route	Fixed circular line	Area	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
Route length	2,1 km	38 hectares	1,3 km	1,6 km	1,3 km	1,2 Km	2,3 Km
Road environment	Open road	Semi-private	Open road	Open road	Open road	Public road	Public road
Type of traffic	Mixed	Mixed	Mixed	Mixed	Mixed	Mixed	Mixed
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
Roundabouts	Yes	Yes	No	No	Yes	No	No
Traffic lights	No	No	No	No	Yes	Yes	Yes
Type of service	Fixed line	On demand	Fixed line	Fixed line	Fixed line	Fixed line	Fixed line
Concession	Line (circular)	Area	Line (circular)	Line (circular)	Line (circular)	Line (circular)	Line (circular)
Number of stops	4	> 35	6	6	2	4	2
Type of bus stop	Fixed	Fixed	Fixed	Fixed	Fixed	Fixed	Fixed
Bus stop infrastructure	Yes	Sometimes, mostly not	Yes	Yes	Yes	Yes	Yes
Number of vehicles	1	3-4	1	2	2	2	1
Timetable	Fixed	On demand	Fixed	Fixed	Fixed	Fixed	Fixed
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
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
Timeframe weekends	No service	07:00 – 19:00	No service	9:00-18:00	08:30-19:30	10:00-21:00	No Service
Depot	400 meters distance	On site	800 meters distance	200 meters distance	On site	On site	On site
Driverless service	No	2021	No	No	No	No	No