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Autonomous Vehicles to Evolve to a New Urban Experience

DELIVERABLE

D4.4 First iteration in-vehicle services

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Acronyms

ADS	Automated Driving Systems
AI	Artificial Intelligence
API	Application Protocol Interface
AV	Autonomous Vehicle
BMM	Business Modelling Manager
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
DSES	Department of Security and Economy Traffic Police
DTU test track	Technical University of Denmark test track
EAB	External Advisory Board
EC	European Commission
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
GIMS	Geneva International Motor Show
GNSS	Global Navigation Satellite System
HARA	Hazard Analysis and Risk Assessment
IPR	Intellectual Property Rights
IT	Information Technology
ITU	International Telecommunications Union
LA	Leading Author
LIDAR	Light Detection And Ranging
MEM	Monitoring and Evaluation Manager
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
PC	Project Coordinator
PEB	Project Executive Board
PGA	Project General Assembly
PRM	Persons with Reduced Mobility
PSA	Group PSA (PSA Peugeot Citroën)
PTO	Public Transportation Operator
PTO	Public Transport Operator
PTS	Public Transportation Services
QRM	Quality and Risk Manager
QRMB	Quality and Risk Management Board
RN	Risk Number
SA	Scientific Advisor
SAE Level	Society of Automotive Engineers Level (Vehicle Autonomy Level)
SAN	Cantonal Vehicle Service
SDK	Software Development Kit
SMB	Site Management Board
SoA	State of the Art
SOTIF	Safety Of The Intended Functionality
SWOT	Strengths, Weaknesses, Opportunities, and Threats.
TM	Technical Manager
UITP	*Union Internationale des Transports Publics*
V2I	Vehicle to Infrastructure communication
WP	Work Package
WPL	Work Package Leader

Executive Summary

The overall purpose of this deliverable is to provide the basis for improvements of these services as well as to introduce new and more advanced personalised in-vehicle services - using technology like sensors, interactive screens, communications means, AI and so forth.

The new and innovative in-vehicle services will be developed, tested and improved with the purpose of increasing accessibility, comfort, safety and passenger experience during the transportation. To do so, passenger needs and behaviour have to be taken into account. The goal is to deliver a high standard and personal services for the travellers.

This deliverable provides an overview and status of the various in-vehicle services initially identified in the project. The services originate from three different aspects and include:

- Current in-vehicle functions that provide several services towards the passengers.
- Which services the safety driver provides today and that must be fulfilled by in-vehicle services once the driver is taken out of the bus.
- The initial services drafted in the AVENUE 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 autonomous 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 autonomous 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 autonomous 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 autonomous vehicles will become the future solution for public transport. The AVENUE project will demonstrate the economic, environmental and social potential of autonomous vehicles for both companies and public commuters while assessing the vehicle road behaviour safety.

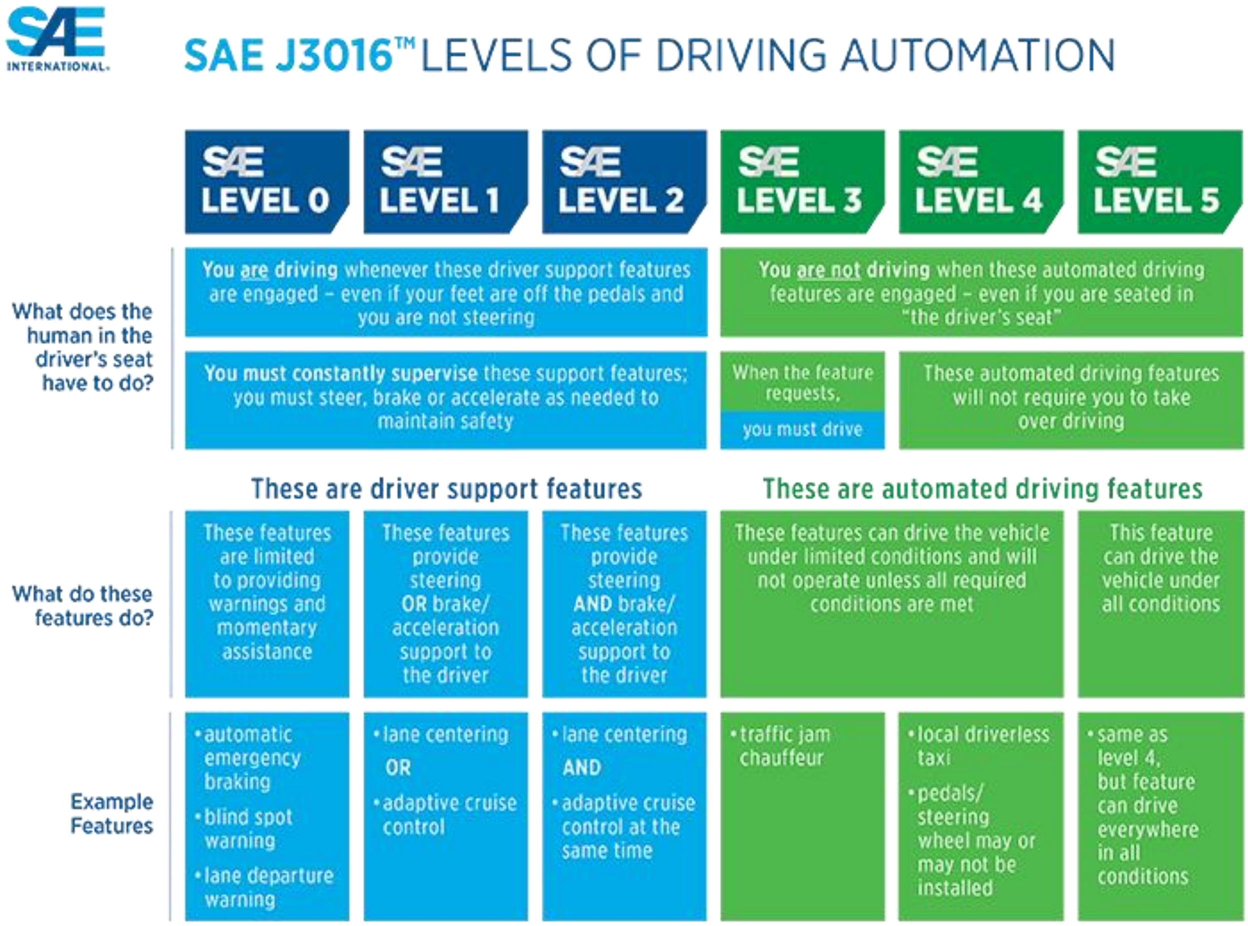
1.1 On-demand Mobility

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 autonomous 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 Autonomous Vehicles

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



1.2.1 Autonomous vehicle operation overview

We distinguish in AVENUE two levels of control of the AV: micro-navigation and macro-navigation. Micro navigation is fully integrated in the vehicle and implements the road 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 Autonomous 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 Autonomous 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 Autonomous vehicle capabilities in AVENUE

The autonomous vehicles employed in AVENUE fully and autonomously manage the above defined, micro-navigation and road behaviour, in an open street environment. The vehicles are autonomously capable to recognise obstacles (and identify some of them), identify moving and stationary objects, and autonomously 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

1.3 Preamble

Work package WP4 aims to design, develop, adapt and integrate services to support users of autonomous vehicles before the trip, during the trip, and at the end of the trip. The main objective of WP4 is to provide services in order to demonstrate that the user experience can be seamless and secure, and that people embrace this new technology. Hence, we have to include the following services:

- Adapt and integrate existing transport services
- Develop autonomous vehicle specific services
- Provide services that foster the acceptance of driverless vehicles by both passengers and people interacting with the shuttles
- Introduce safety related services

The target of task T4.2 is to develop, teste and integrate innovative in-vehicles services, in collaboration with the four operators in Lyon, Luxembourg, Geneva and Copenhagen, respectively. The in-vehicle services should in combination with the out-of-vehicle services support a holistic service for travellers commuting with the e-minibus.

In-vehicle services are services developed to improve the user experience when traveling with autonomous vehicles. The services are user-centric and focus on supporting travellers (including PRM) with smart solutions while sitting inside the vehicle - in this case the Navya autonomous vehicle.

The development of the in-vehicle services is iterative and user insights and feedback will be gathered in several rounds, contributing to the specifications of the in-vehicle services during the AVENUE project. This iterative process is important with the purpose of ensuring that the services actually meet real user needs and provide real value for the passenger when traveling with the autonomous vehicles. This process is further elaborated in section 5: Testing of in-vehicle services.

During the development of the in-vehicle services, the different target groups - including their characteristics and traits - will be considered, ensuring a broad acceptance of the in-vehicle services introduced in the autonomous vehicle.

As opposed to public transport today, there is no driver (or there will be no driver) inside the autonomous vehicle. This means that the services a driver normally provides to travellers, must be translated into in-vehicle services, solving the needs of the passengers. Furthermore, the autonomous vehicle enables new kinds of transport solutions, hence also a potential for new services - both in-and-out-of-vehicle.

2 Existing in-vehicle technical facilities

As of today, the Navya autonomous vehicle is equipped with some functions which will be integrated in the provision of services, targeted at the passengers. Therefore, the functions are highlighted with the purpose of including them in the further service development process.

The in-vehicle technical functions are as follows:

- ***Open/close doors button***
  Manual buttons inside the vehicle, allowing the passengers to press them. The doors do also open automatically at each stop.
- ***Wheelchair ramp button***
  Manual button inside the vehicle. Passenger or safety driver can use the button to activate the automatic wheelchair ramp. This function is not installed in all Navya autonomous vehicles as a standard. It must be installed on the shuttle by Navya.
- ***Real time visualisation of route and stops (service screen)***
  There is a screen inside the vehicle showing a map of the route, including the stops. The screen is also used by the safety driver to restart the vehicle or detect issues during operation. The screen is currently not designed for passengers, but for the safety driver. In the future, once the safety driver is removed from the vehicles, the screen will function as the main interaction point between the travellers and the service.
- ***Speaker system***
  Speakers located inside the vehicle, enabling contact from Navya supervision to passengers during emergencies. Potentially in the future, the PTO's could use the system for service

announcements, safety protocols or regular communication - especially once the safety driver is removed from the autonomous vehicles.

- ***Emergency call button***
  A manual button located under the service screen allows the passengers to get in contact with Navya supervision. The button could potentially in the future be used to link the travellers with the operators' own supervision - leaving the contact to Navya to the operators instead.
- ***Emergency stop button***
  Manual button located on each side of the large window in the middle. Manually brakes the vehicle.
- ***Emergency door opening handle***
  Manual handle located on each side of the doors. Manually forces the doors to open.
- ***Emergency Glass breaking hammer***
  A hammer clearly located inside the vehicle is available to be used in case passengers are blocked and need to exit from the window of the e-minibus
- ***Emergency First Aid Kit***
  A First Aid kit is located inside the e-minibus and is easily accessible in case of need.
- ***Fire extinguisher***
  Inside the e-minibus a fire extinguisher is installed for use in case of any emergency.

3 Safety driver

Currently there are safety drivers present in the vehicles at all four demonstration sites. The safety driver currently covers/offers a wide range of services to the travellers - both via his/her presence inside the vehicle and by taking certain actions. The safety driver can therefore currently be seen as providing additional in-vehicle services.

This presence of the safety driver enables the operators to gather valuable insight and observation about the users' behaviour and interaction with initial in-vehicle services, and thereby gather a solid foundation for further development and refinement of existing and new in-vehicle services.

The purpose of identifying these services is to define some requirements for replaceable in-vehicle services, with emphasis on the fact that the safety driver will be removed from the vehicle at some point. These requirements will be defined during an ideation process in collaboration with Bestmile and MobileThinking of the AVENUE project - with the purpose of delivering in-vehicle services providing the same or even more streamlined user experiences in the future. This will be done during the next couple of months and will be included in the next deliverable D4.5.

The analysis of the in-vehicle services provided by the safety driver is mainly based on the initial insights from the State of the Art analysis and the experience of Autonomous Mobility. Once all operators are in operation, the safety driver inside the vehicles will be further analysed and compared across the operation sites - contributing to a more refined and exhaustive definition of the in-vehicle services that needs to be designed in the future.

The following table 1 shows the current in-vehicle services provided by the safety driver. Each service is shortly described, with the purpose of initiating a thorough investigation of what is necessary once the safety driver is removed from the vehicle.

Safety driver Current in-vehicle services provided by the safety driver			
#	In-vehicle service	Description	Replacement requirements
1	Operational information	Providing information about the project, route, vehicle, laws etc.	Ideation process, will be included in D4.5
2	Safety + risk mitigation	Safety driver presence and authority establishes a safe environment for the passengers. + Active risk control (joystick, eyes etc.)	Ideation process, will be included in D4.5
3	Entertainment	The safety driver can interact with the passengers and start conversations about anything + tell stories about the technology etc.	Ideation process, will be included in D4.5
4	Travel assistance	The safety driver can assist passengers in boarding and exiting the vehicle + ensure that the bus stops where the passengers wants to get on/off.	Ideation process, will be included in D4.5
5	Area guidance	The safety driver can assist passengers in finding restaurants, shops etc. in the local area of the route.	Ideation process, will be included in D4.5
6	Branding	Branding of operating company, logo, name, etc. Can be used to assure users that the operation is safe and offered by a trusted company. Things are under control.	Ideation process, will be included in D4.5
7	Provides data on various areas	User behaviour/insights + counting passenger + road user behaviour	Ideation process, will be included in D4.5

Table 1 - Safety driver (in-vehicle services)

4 Initial AVENUE in-vehicle services

In the AVENUE project we wish to demonstrate in-vehicle services and as a foundation of the project several potential services were identified for further development. These services were introduced in WP2, where they were categorised and prioritised by the operators and developers.

The initial in-vehicle services were identified in the proposal, based on the grounds that they would boost the acceptability and adoption of autonomous vehicles as a public transport mean. Each in-vehicle service will be discussed and assessed in terms of maturity and development status. The following table 2, will introduce the in-vehicle services presented in the proposal. Some of the in-vehicle services can also be seen as out-of-vehicle services and will be described below. The list of services was originally based on the fact that there would be no safety driver inside the vehicle. Since there currently is a safety driver inside the vehicle, some of the following services overlap with the current functionality of the safety driver.

In-vehicle services *In-vehicle services presented in the proposal*				
#	In-vehicle service	Description	Value	Status
1	Intelligent ticket control when entering the vehicle (In-vehicle service)	This service eases the process of purchasing tickets by integrated smart and wireless payment systems. No need to do anything but to go in - and out of the vehicle. Can also be used to see if tickets bought are actual used.	Value for user when going inside the vehicle without worrying about payment or fines. Potential driver for using the system instead of another.	Service requirements will be further investigated in the next phase of WP2.
2	Visualisation in real time of the path/destination (In-and-out-of-vehicle service)	This service provides a real time location of the bus at all times on the route. Expected arrivals and end destination times can be provided based on the location of the bus. This service provides a transparent picture of the autonomous vehicle service. If the bus is not operational, users can see the lack of movement.	Value for user inside the vehicle. Real time visualisation allows the user to see exactly where they are on the route as well as provide time of destination. Value in terms of reliability and trust of the system. Can also inform users about the journey. For example, when picking up other travellers on the way - be informative. Value for user outside the vehicle - real time visualisation allows the user to see where the bus is located, how far away etc. Knowledge about the trip ensures a reliable experience. Value for the user in terms of transparency and trustworthiness. Both in terms of a reserved bus, that the user is waiting for, and for users waiting at a bus stop.	The first wireframe has been developed and tested as an out-of-vehicle service. Details are to be found in D4.7. The test results are being implemented and the next development phase is under its way.
3	In vehicle entertainment (In-vehicle service)	This service provides in-vehicle entertainment for the travellers. This can range from digital storyboards and commercials, to videos, games, interaction apps and so forth. This function can also provide the travellers with information about the area, monumental building, museums etc. This service shall show the travellers the opportunities existing when not driving the	Value for user inside the vehicle in terms of entertainment, education, social interactions etc. A new image for public transport should be gained. “It's fun and interesting”!	Service requirements will be further investigated in the next phase of WP2.

		vehicle on your own - hence help to create a positive image of self-driving vehicles.		
4	Emergency automatic call system (In-vehicle service)	This service allows users (and safety drivers) to get in contact with appropriate institutions when emergencies occur. This service can be seen as a function inside the vehicle, like a button or similar. This function can also be developed to recognise any odd behaviour, like people falling, being sick. Facial recognition or human behaviour analysis - in case people cannot press a button.	Value for user/safety driver inside the vehicle by ensuring safe procedures surrounding the operations. User feel safer, when safety systems are in place. Next of kind and relatives also feel safer knowing that the vehicles are equipped with required and necessary safety systems.	Service requirements will be further investigated in the next phase of WP2.
5	Enhancing the sense of security and trust' (In-vehicle service)	This service consists of multiple layers of services, actions, policies etc. The purpose is to enhance security and trust inside the vehicle, by implementing necessary procedures and functions.	Value for user inside the vehicle, knowing that functions like cameras, cyber security, petty crime automatic detection, safe payment systems etc. is in order. Positive brand outside the vehicle → potential value for user outside the vehicle	Service requirements will be further investigated in the next phase of WP2.
6	Prevention of night aggressions	This service has the purpose of securing the passengers of the bus, when the safety driver is no longer inside the vehicle. This service can be cameras, microphones and other devices, that can record/prevent or document aggression inside the bus.	Value for users inside the vehicle in terms of safety caused by knowing that the bus is surveyed. Positive brand outside the vehicle → potential value for user	Service requirements will be further investigated in the next phase of WP2.
7	Virtual personality interaction	This service should provide an AI based help desk experience, where users can interact with the vehicle and the services inside the vehicle. This service should be developed in many languages and for people with disabilities.	Value inside the vehicle (AI version of the safety driver). User can be assisted in multiple subject and services.	Service requirements will be further investigated in the next phase of WP2.
8	Follow my kid / grandmother / father (In-and-out-of-vehicle service)	The service allows next of kin to follow their relatives in real time, seeing that they reach their destinations safely.	Value for user inside the vehicle, by feeling safe and monitored. Help is nearby. Value for next of kin outside the vehicle, by knowing that relatives travel safely. Less worries.	Service requirements will be further investigated in the next phase of WP2.
9	Mutual help	This service allows users to	Value for user inside the	Service requirements will

	facilitation	assist other passengers or be assisted when needed. The service should enable passengers to interact and help each other.	vehicle by knowing that there is focus on help facilitation. Help or be helped. Value for next of kin outside the vehicle by feeling safe about relatives traveling with the autonomous vehicle.	be further investigated in the next phase of WP2.

Table 2 - In-vehicle services

Based on the list of in-and-out-of-vehicle services, the operators ranked each service in collaboration with Bestmile and MobileThinking during WP2. This list of services was defined in three development phases indicating when each in and out of vehicle services shall be developed, adapted, tested and integrated with the four operators and their local travellers.

Based on the knowledge that we had at the time, the operators chose the following services: From deliverable D2.13 in WP2, the following in and out of vehicle services were chosen for phase 1 - running from M6 to M18:

1. Passenger counting (Out-of-vehicle service)
2. On demand stop (In-and-out-of-vehicle service)
3. Visualisation in real time of the path/destination (In-and-out-of-vehicle service)

As can be seen, on demand stops and visualisation in real time of the path are both services that overlap between in - and out of vehicle services. Since both services are mostly out-of-vehicle service, they will be further developed and tested by MobileThinking in D4.7 to begin with.

Once the first prototype has been developed, both services will be further tested, and deployed as in-vehicle services. This process will be included in the second version of this deliverable, D4.5. The reason for this is that the current maturity of the operations is at a point where the operators focuses mainly on getting the vehicles in operation on route, and not so much on services inside the vehicle.

Once the operators have steady operations, the in-vehicle services will become more relevant. Furthermore, the in-vehicle services have to be ideated on with the operators, emphasising more in detail what each service really has to offer for the passengers inside the vehicle. This will be done with the operators during the next couple of months and will be included in D4.5.

5 Testing of in-vehicle services

As a part of the iterative development of the in-vehicle services, each service will be tested based on a testing framework developed for the AVENUE project. The purpose of the testing framework is to ensure that user insights and feedback are analysed, consolidated and implemented the same way across the four operation sites. The testing of in-vehicle services will be conducted in three rounds corresponding to the three phases of WP2, ending at M10, M25 and M40. The chosen services for each round will go through an iterative feedback loop, as visualised in figure 1 below.

Figure 1 shows the process of testing a service in an iterative feedback loop, indicating some of the major steps. The idea of the figure is to highlight that the process is iterative - and in that sense also to highlight that the process is happening many times during the project, but that there are deliverables consolidating the process in M10, M25 and M40. The feedback loop emphasises that the users are involved in both the development and the testing of the services, indirectly by being a part of the process over and over. Hence the testing framework ensures a user-centric approach.

Since the in-vehicle services have not yet been finalised, the testing of the services will run in the next round - hence results will be presented in M25 and M40. The development of the in-vehicle services will start earlier, once the ideation process with the operators has been done. Therefore, testing of in-vehicle service will also be conducted earlier, but not presented before M25.

6 Conclusions

Since the in-vehicle services have not yet been finalised, the testing of the services will run in the next round - hence results will be presented in M25 and M40. The development of the in-vehicle services will start earlier, once the ideation process with the operators has been done. Therefore, testing of in-vehicle service will also be conducted earlier, but not presented before M25.

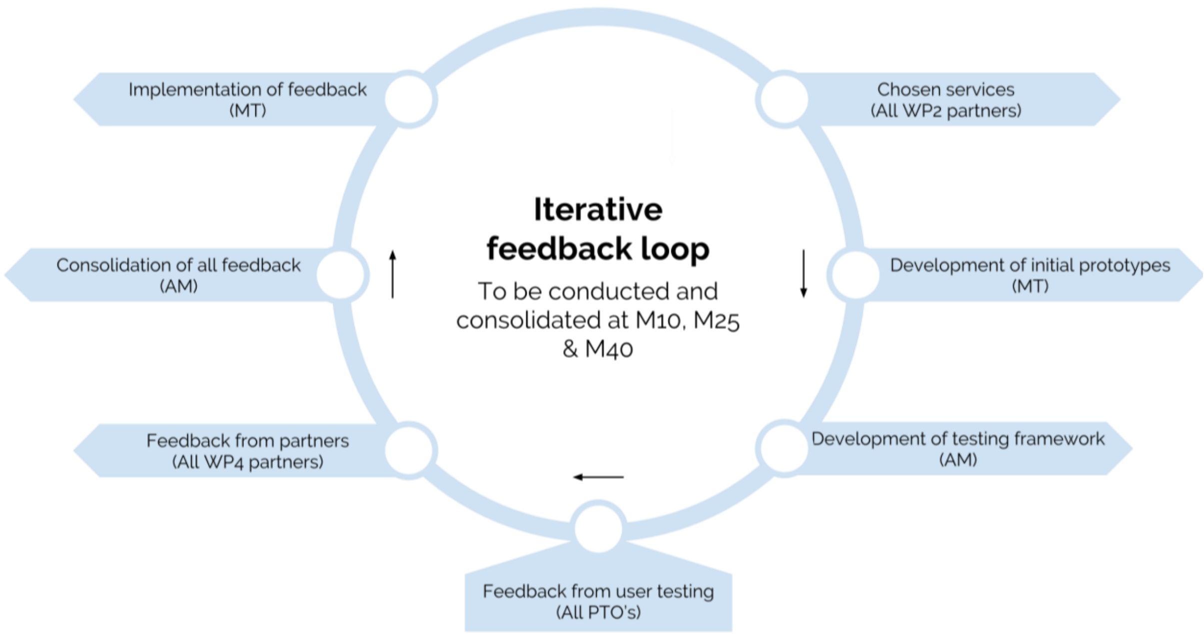


Figure 1 - Iterative feedback loop

As seen in figure 1, the overview provides a general picture of the testing process. Included on some of the steps are interactions with the operators, safety drivers, users etc. ensuring a thorough collection of insights - enhancing the credibility of the developed services. Feedback on acceptability and user experience of the services, will be tested in collaboration with Siemens in WP8 - specifically with focus on people with disabilities.