AVENUE

Autonomous Vehicles to Evolve to a New Urban Experience

DELIVERABLE

D2.5 Second Passenger needs analysis and specifications

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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
	General Transport
OCT	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

User experience and accessibility, e.g. for Persons with Reduced Mobility (PRM), play a major role when trying to develop and establish innovative and disruptive urban public transport services. Moreover, access of PRMs to public transport is a human right and mandatory in Europe (and member states). To ensure that the AVENUE Vehicles and the services around them are not only usable but also well accepted by all users including PRM (elderly, people with disabilities and in general potentially vulnerable users) we are following the human centred design process for interactive systems (ISO 9241-210). Following this standard, we ensure that all relevant stakeholders play an important role in the requirement phase and throughout the project.

This is the second version of the AVENUE Passenger needs and analysis document which is due one year after the first version. While the D2.4 had main focus on requirements of general public transport this version has its focus mainly on users that have already used or are even familiar with autonomous vehicles in public transport.

All passenger needs are derived from the evaluation as well as the interviews and are grouped in minimum, baseline and ambitious expectations. These results will be communicated to the designer and developer of the AVENUE partners and contributes to the other WPs and Deliverables.

To ensure an actual, positive user experience for all, users will be involved in all relevant phases of the project (conception of services (WP4), security options (WP6), operation validation (WP7) etc.) to guarantee that the users opinion and needs are taken into account as early and thoroughly as possible. D2.6 will therefore update this deliverable and summarize the results, collected in the progress of the project at the respective time.

Chapter 2 gives an overview on the second user studies and the different strategies to gather information and summarizes already some main results from the different interview sites.

Chapter 3 is about the analysis of the gathered answers.

Chapter 4 summarizes the requirements derived from the user study.

Chapter 5 gives the conclusions.

Chapter 6 includes personas developed based on the second user study and use cases based on these personas.

Annex A gives an overview of the most important and related legal requirements.

Annex B contains the used interview and observation guidelines.

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.

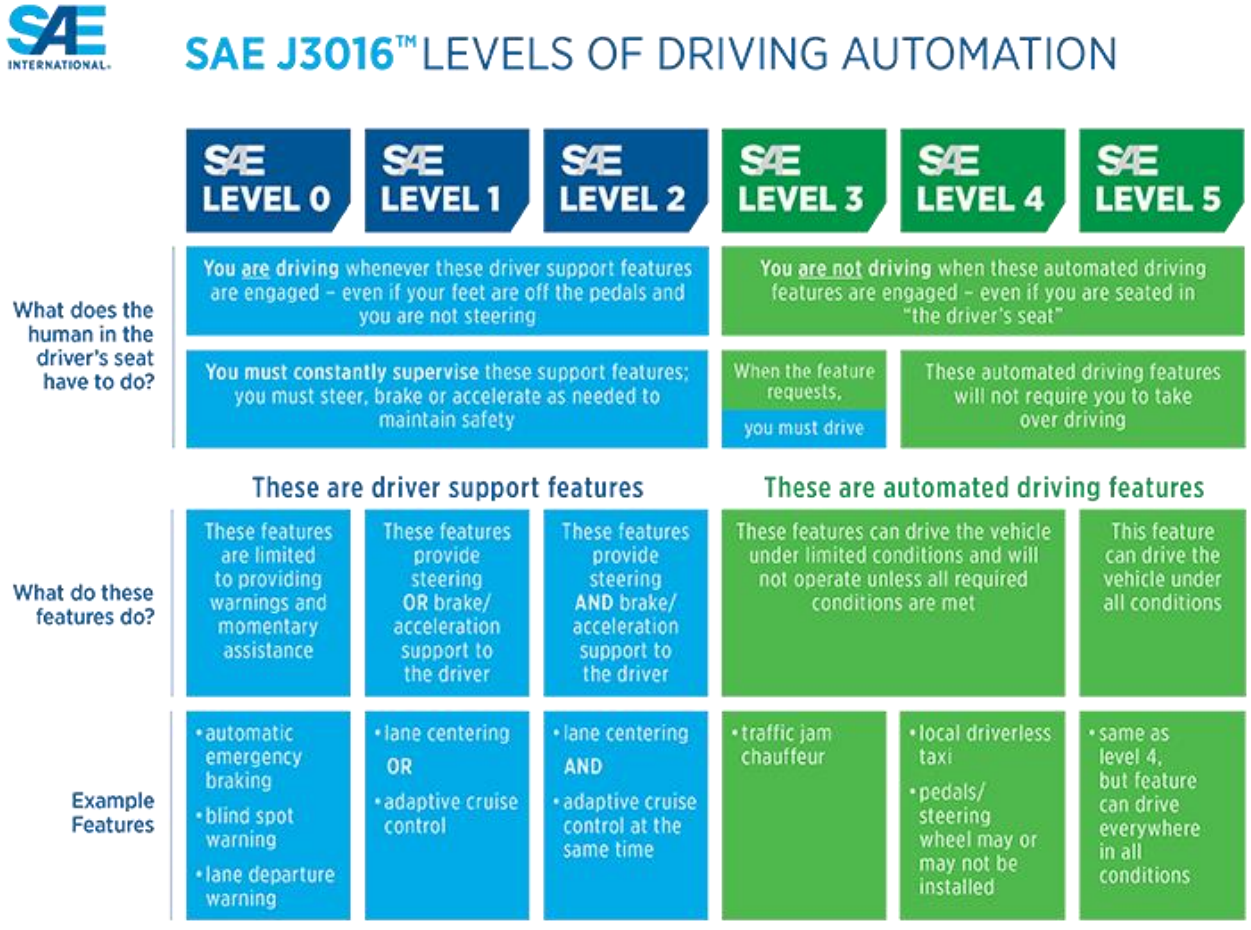
1.1 On-demand Mobility

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 2 *Requirements and Use Cases* paves the foundation for developing and establishing innovative and disruptive urban public transport services.

Task 2.2 *Passenger needs (including PRM) and requirements specification* takes care of all users and their needs. To ensure that all needs are considered, AVENUE aims to continuously involve users throughout the project.

This Deliverable is the update of “D2.4 - *First Passenger needs analysis and specifications”* and is the 2nd version of a series of three deliverables. It provides an overview of the 2nd user and 1st safety operator consultations and observations made in and out of autonomous vehicles carried out in the

different partner countries, as well as the resulting analysis and the definition of the user requirements. These requirements have been derived from the conducted observations and interviews with users and user organizations and from relevant normative and legal documents.

1.4 Motivation and context

Public transport has changed a lot in the last 30 years. In many cases the whole infrastructure provides tailor-made services like e.g. mobile tickets or mobility services for the wide range of people who frequently use the different transport systems. In particular the requirements of people with disabilities and older persons are now considered during all development stages of new vehicles, bus stops or ticket machines to really fit the special needs of the different target groups. New service solutions include the support of smart devices like e.g. mobile phones to allow people to use their preferred method to purchase tickets, to schedule their transport as well as to get a lot of useful information while they are on the go. Upcoming services[1] even realize a Bluetooth connection to the board computers of buses and trams allowing users to get additional information on the route or allow passengers to remotely control the vehicle by transmitting signals to trigger stop and other service requests using their Smartphone. Being used to these services the expectations of future mobility services is rather high.

Therefore, to set up a new model of public transportation targeting also elderly people, people with disabilities and vulnerable users, a user centred design approach is essential. Such an innovative model will only be successful when the needs of the users (passengers) are considered sincerely in the specifications and functionalities. Consequently, AVENUE aims to include and consult users-right from the beginning of the project and throughout the project. It is important to identify these requirements as a first step of the project. For that reason, a survey acquiring these needs has been conducted right at the beginning. The goal of these interviews was to gather all requirements, problems and identify strategies that passengers have developed to overcome barriers. As problems and solutions might vary between local areas and between nationalities, interviews have been conducted by all involved partners and in all participating countries.

Besides users, also regulations in Europe and in the different countries play a major role. The following directives and laws have direct influence on our developments (an extract of the most important ones can be found in Annex A: Legal Overview

- Bus & Coach Directive 2001/85 ECE (Repealed 2014): Accessibility of the vehicle (ramps, kneeling systems, lifts) & wheelchair & occupant restraint systems (WTORS) for wheelchair occupant & bus passenger safety
- REGULATION (EC) No 661/2009 [1] *(successor of Bus & Coach directive) Article 7* 4. Vehicles of Class I shall be accessible for people with reduced mobility, including wheelchair users
- Regulation No 107 [2] of the Economic Commission for Europe of the United Nations (UNECE) — Uniform provisions concerning the approval of category M2 or M3 vehicles with regard to their general construction

[1] ivantoCore https://www.ivanto.de/home_en/

- In Switzerland Section 3 of the Directive on the technical requirements for the accessibility of public transport defines the Special requirements for bus and trolleybus services.

Indirect influence:

- COMMISSION REGULATION (EU) No 1300/2014 [3]

When applying today's regulation to our project, there are many things that need to be clarified.

E.g.: Regulation No 107 Annex A 3.3.4: *If a vehicle is fitted with a ramp or lift, a means of communication with the driver shall be fitted outside, adjacent to the door, and at a height between 850 mm and 1 300 mm from the ground. This requirement shall not apply to a door situated in the direct field of vision of the driver*.

How can operators follow this rule in a driverless vehicle?

2 Evaluations and second user studies

The aim of the first user studies in 2018 was to fully understand the needs, the issues and the problems of public transport users and the personal tricks and strategies they have developed for themselves. Therefore Task 2.2 developed an interview guideline which was used in all participating countries to interview users of public transportation. At the very least, the status quo must be achieved in all future public transport solutions. In deliverable "D2.4 - *First Passenger needs analysis and specifications"*, we have documented the user requirements for today's public transport as well as anticipated advantages and disadvantages of autonomous public transport.

The aim of this deliverable is to go beyond anticipated experiences and to figure out the issues, the problems and the missing services in autonomous vehicles. Therefore, all participants of the studies have experience with the use of autonomous e-minibuses. To get a broader understanding we also included non-AVENUE sites and sites with other autonomous busses than Navya. To get a broad range of information we decided to follow three different approaches to gather information: interviews with safety operators, interviews with (disabled) passengers and observation studies.

2.1 Interviews with safety operators

Currently every autonomous vehicle in the AVENUE test sites has a safety operator on board. These persons are responsible for the safety on board and can control the bus manually if necessary. Furthermore, they are contact persons for the passengers. The safety operators are a valuable source of information as they have direct contact to passengers and experience their reactions, open questions, requirements and problems every day. There is probably no other person who has had more user contact and knows the questions and problems of the users better.

In order to obtain the most information from this valuable source, we have decided to give questionnaires to the safety operators of all participating PT providers and additionally conducted some interviews with safety operators in non-AVENUE sites like Berlin and Vienna [4]. The questionnaire filled in by the safety operators can be found in Annex B: Interview guideline safety operator.

2.2 Interviews with (disabled) users

Passengers are the most important source when gathering user requirements for autonomous public transport. To get as many users as possible we conducted interviews on several days in Berlin with kind support of the ABSVBerlin [5] and in Vienna (auto.Bus - Seestadt [6]) with kind support of the Wirtschaftsuniversität Wien [7] Mr Angelo Spörk.

Due to the fact that people with disabilities have special requirements they play an important role when gathering user requirements. Taking into account that every human will have some type of disability in his/her life or can be situational induced disabled (e.g. wearing a headset), the requirements derived from people with disabilities will be useful for all.

The AVENUE project member Siemens was invited to join several practical user tests with autonomous vehicles in Berlin. These tests were hosted by the BVG [8], as coordinator of the Stimulate [9] and the See-Meile [10] project. The BVG aims to introduce autonomous vehicles into the public transport of the capital city of Germany.

The Stimulate project offers two different test locations in Berlin, both close to the University clinical environment of the Charité [11], who represents another project member of Stimulate. The manufacturer of the autonomous vehicles that were provided for the practical tests is Easymile.

The tests were conducted to gather important information in terms of user requirements as well as user acceptance. In particular, the tests were organised in a manner which also fits the needs of persons with specific disabilities, who often have to overcome the highest level of difficulty when coping with the public transport in their real life.

Siemens took the opportunity to observe the practical user tests and to perform interviews with the different user groups, represented by passengers with or without disabilities, and as well as with the safety operators who accompanied the autonomous vehicles in terms of traffic or other problems, which sometimes require individual assistance.

The group of disabled persons was represented by the ABSV, the Allgemeiner Blinden- und Sehbehindertenverein Berlin, which is the oldest association of blind and visually impaired users in Germany, founded in the year 1874. To ease the tests for this specific user group, a team of the Accessibility Competence Center from Siemens provided individual assistance according to the personal demands of the users.

A common questionnaire was developed and used in these face-to-face interviews to collect data from the users that could be effectively analysed and provide a dependable and consistent set of user requirements which could be used in AVENUE. We utilised a mixture of closed and open questions. While the closed questions can easily be analysed, the open questions give users the opportunity to explain their way of handling things, but also to raise issues, which had not been thought of by the experts. For privacy reasons, and because of the fact that the requirements are similar, we did not distinguish between blind and different levels of low vision/partial sight. To ensure the best phraseology the questionnaire was developed together with Physiologists, disability experts and colleagues with disabilities. The guideline was prepared in German and English.

Participation in the interviews was voluntary and anonymous. Medical data was neither asked nor recorded. To enhance privacy the interview does only distinguish between four different age groups, gender and three kinds of disability: visually, hearing or mobility impaired. Persons with reduced cognitive abilities, e.g. reading, understanding, were not considered explicitly and will maybe analysed in more detail in the follow-up evaluation.

2.3 Observation study

Besides interviews with safety operators and users, we decided to conduct personal observations as a third source. These observations took place during a regular usage of the bus. While riding the bus, the evaluator observed all persons in the bus following an observation guideline including the most important tasks during a bus ride:

- Behaviour at the stop...
  - What do the passengers do
  - If there is a timetable, the timetable is respected by the passengers
  - How does boarding work?
  - How many passengers are boarding?
  - How does boarding / disembarking with luggage/stroller/rollator work?
- Passengers
  - How do the passengers react to the strong braking?
  - Do the passengers try to talk with the driver? Why?
  - Do they ask questions? On what topics?
  - Does the driver talk with the passengers? What for? Does he help?
  - What are they talking about?
  - What is the mood like?
  - Which seats are occupied first: in/against/transversely to the direction of travel?
  - What do the passengers do during the journey?
  - Are the passengers looking out? Forwards/to the side?
  - Is the monitor observed?
  - Do the passengers drive the whole tour or do they have a destination?
  - How does getting off work?

3 Analysis of the results

3.1 Analysis of answers of safety operators

Currently, all AVs have a safety operator on board who monitors the system, who is able to intervene in case of any doubts and who acts as contact person for the passengers. Safety operators enjoy talking with the passengers, as they (in a regular bus) are not allowed to talk with them. During their duty hours they talk with and observe lots of passengers. Therefore, they are a valuable source for getting a wide spectrum of impressions and information.

For this deliverable, 27 safety operators (five from non-AVENUE sides) have been interviewed and asked about their impression and experiences made with passengers on board of the vehicle. All of them mentioned a positive acceptance of the vehicles by nearly all passengers. Many users (especially the anxious ones) talked with the safety operators about the technique. The better understanding helped them to relax and enjoy the ride. One driver mentioned that even those users having a negative view changed their mind while driving with the vehicle. For passengers who drive the vehicle for the first time, as well as for people with an affinity for technics, technology is of course the first topic of conversation. Questions like how the bus knows where it is and how it works are dominating here. With people who have already driven several times it is mostly small talk. The presence of the safety operators has also a great influence on the reaction of passengers to technical problems. Most of them stay calm because they know that there is a professional on board. Some even waited 20 min when the vehicle had to be completely restarted.

There is no clear answer to when most users take the shuttle, because it strongly depends on the test area. For example, in Oslo the number of passengers rises significantly when cruise ships dock in the harbour. What all test areas seem to have in common - and what is very surprising - is that the number of passengers increases in good and decreases in bad weather conditions.

The number of passengers using the shuttle to reach a specific destination varies depending on the test area, even in the same city, and also depends on how long the test track has been in operation (in the beginning the majority just wants to try it out): On the XA line in Geneva, around 90% of passengers have a particular destination, when the vehicle was introduced it was exactly the other way round. In Vienna where the line was recently opened only 20% have a particular destination while 80% want to try it out.

Nearly all passengers like the vehicle, and also the arrangement of the seats is welcomed because it encourages communication. However, all are complaining about the hard and unforeseeable braking. So, it is clear that smoother braking is one of the most wanted features, besides more speed.

Typical situations in which the drivers help the passengers are getting in and out (including opening and closing the doors) and buckling up. Some drivers report that they have to calm passengers after one of the above-mentioned hard brakes.

The question about the drivers needs and wishes resulted in interesting answers and ideas, the most popular answers and suggestions are:

- Based on the mentioned problems with the seatbelts the idea of a color coding of the belts was mentioned several times.
- Improvement of the hard braking issue
    - generally a smoother braking behaviour
    - by allowing the driver to slow down the shuttle without switching to manual mode
    - improvement of the detection when (overtaking) objects move away and it is not necessary for the vehicle to slow down
- Better seats for passengers and stand or seat with seatbelt for the safety operator, because backpain is already an issue for some drivers.

In general, one can say that based on the observations of the safety operators the acceptance is very high at all test sites and even in case of issues passengers stay relaxed and rely on the safety operators. Although the service is still in test phase it has already passengers that use it even regularly as a real public transport service. However, hard braking, unclearly marked seat belts and the high entry level are real disadvantages and frequently require the support of the safety operator.

Based on the feedback from Vienna it looks like the hard-braking issue has been solved with the latest Software Update: Drivers in Vienna mentioned that the NAVYA vehicles now have a more gentle braking strategy after the software update.

The complete questionnaire can be found in Annex B.

3.2 Analysis of the answers of (disabled) users

For the creation of real user requirements passengers of the AV were asked to answer a small questionnaire. The goal of the questionnaire was to find out their problems, missing information and their attitude towards AVs.

To make sure that the answers of the passengers are not vehicle dependent or dependent on the PTO or the city, also users in non-AVENUE-Cities like Vienna and Berlin were interviewed.

3.2.1 On-site visit Berlin

The practical user tests with autonomous vehicles in Berlin were conducted on Sept 18th, 2019 in Berlin Campus Mitte, Charité.

Ten passengers tried the autonomous shuttle, seven of whom are visually impaired.

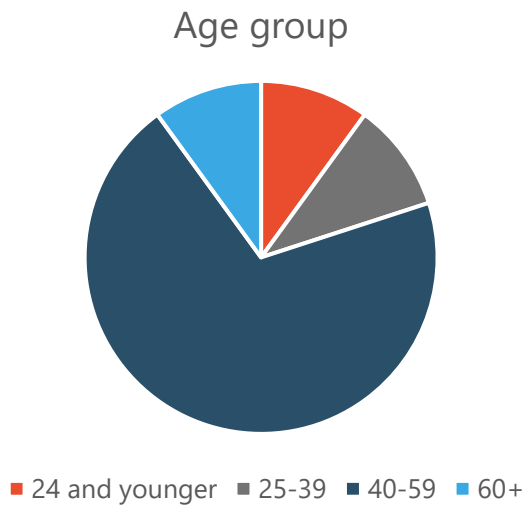


Figure 1: Age groups (Berlin)

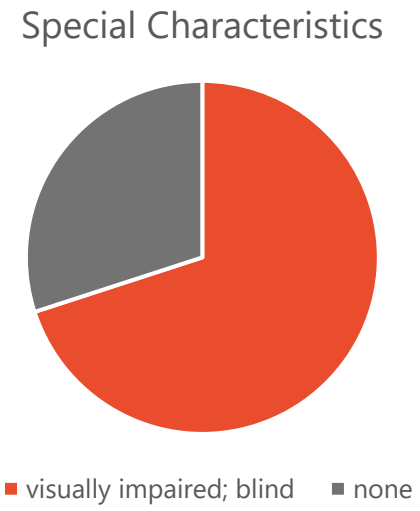


Figure 2: Special characteristics of passengers (Berlin)

All interviewed passengers use their smartphones in the context of using public transport, mainly to get information on timetables and connections. Other popular services are notification of delays, ticket purchase and use of WiFi.

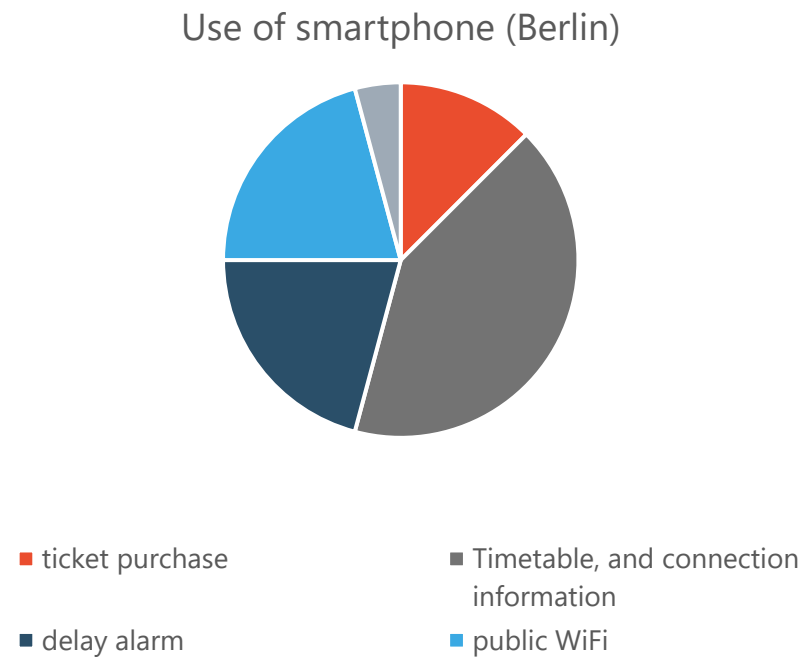


Figure 3: Use of smartphone (Berlin)

The interviewed passengers especially appreciate the smooth and quiet driving behaviour of the shuttles. However, some do consider the bus to be too slow. The braking behaviour is unpleasant.

Many complain about the missing announcements in the shuttle as well as at the bus stop. They want to have the information about the next stop or – when the shuttle stops – the name of the current stop. At the station, passengers would like an announcement of the bus line and its direction.

The interviewees express wishes regarding the vehicle itself: they wish for buttons to request a stop, preferring a haptic button over a touch button. The buttons shall be on both sides of the door. The step at the entrance of the shuttle is considered to be too high. It is difficult for visually impaired persons to find the position of the door from the outside. The interior of the shuttle is rather cramped and narrow. The handles could use more contrast. It is very useful that the vehicle has a ramp and it has been explicitly mentioned that it is a perfect solution that the door closes while the ramp is moving out.

The acoustic signals, e.g. the ringing when driving off or the signal when doors open, are considered too loud and annoying. However, they miss an Acoustic Vehicle Alerting System (AVAS). For passengers with a visual impairment as well as distracted passengers a quiet vehicle can pose a danger.

When asked explicitly about the boarding of the shuttle, the visually impaired passengers say that the step at the entrance of the shuttle is too high. That makes boarding challenging. It is difficult to find the door, passengers would like it marked better. The buttons are also hard to find, especially since they are only on one side of the door. The Buttons should not be accidently operated when exploring and finding them with fingers. If the bus does not open the door automatically at every bus stop (not in tram mode) the user must recognize whether the bus has reached a bus stop and press the Door button for descending within a certain time frame. Therefore user must be able to recognize the functionality of the door by means of visual and acoustics. Alternatively the door open request should be possible by previously pressing the button for automatic opening of the door at the next bus stop. This request should be confirmed visually and audible.

Figure 4: Buttons on the AV

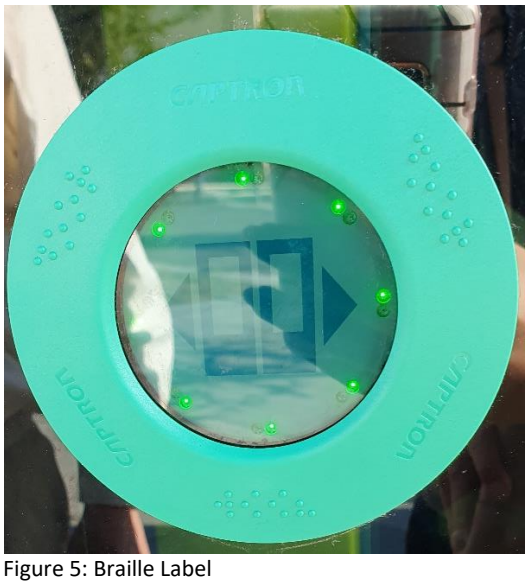


Figure 5: Braille Label

The passengers with visual impairment emphasize that braille text should not be diagonal or upside down (see Figure 5).

Finding a seat and sitting down might seem a simple task, for users that are visually impaired it can be quite a challenge: “When you’re completely blind, you have to feel each and everything first”. Passengers would like to have storage space under the seat (for shopping bags or maybe a guide dog) and a place to put an umbrella or a white stick. A headrest (because of the braking manoeuvres) would also be appreciated.

The shuttle in Berlin is running in tram mode (meaning that it stops at every station). When in regular mode passengers require buttons to request the shuttle to stop. One such button is not sufficient in the shuttle. The existing button(s) in Berlin is reported to be very sensitive. One passenger has accidentally triggered SOS while looking for it. The users want announcements when the shuttle stops to know whether a bus stop has been reached (and which one it is) or whether the shuttle has stopped unscheduled.

Passengers consider the opportunities to hold on to be sufficient. Maybe more handles could be provided at the top.

Getting off the bus works well for the passengers. A highly reliable anti-trap protection of the automatic door of autonomous vehicles is a prerequisite because no intervention of a driver or passenger is possible. The anti-trap protection is also needed when the opening door slides along the chassis of the bus. The values given in the TSI PRM for obstacle detection (cane, dog leash etc.) (see 4.1.2) should be the minimum requirement for doors of autonomous vehicles.

Not all passengers pay any attention to the monitor in the shuttle. Those who do often complain that information on the monitor is displayed too small and that there is not sufficient contrast. The monitor is difficult to look at from the seats and seems to be for the safety operator only. Information should generally be communicated using the 2-channel principle, e.g. all information on the monitor shall also be announced.

Figure 6: Monitor in Berlin

Only one passenger likes the info displayed on the monitor and finds the information displayed well-structured and clear.

When asked about the information they require on the shuttle, users mention:

- Announcement of stops (next stop/current stop) → most frequently mentioned wish!
- Sound as confirmation that stop was requested and that shuttle will stop
- Sound/Signal to find door
- Information at the bus stop that the right shuttle has arrived (line no. and direction)
- Speed of the shuttle
- Current Time

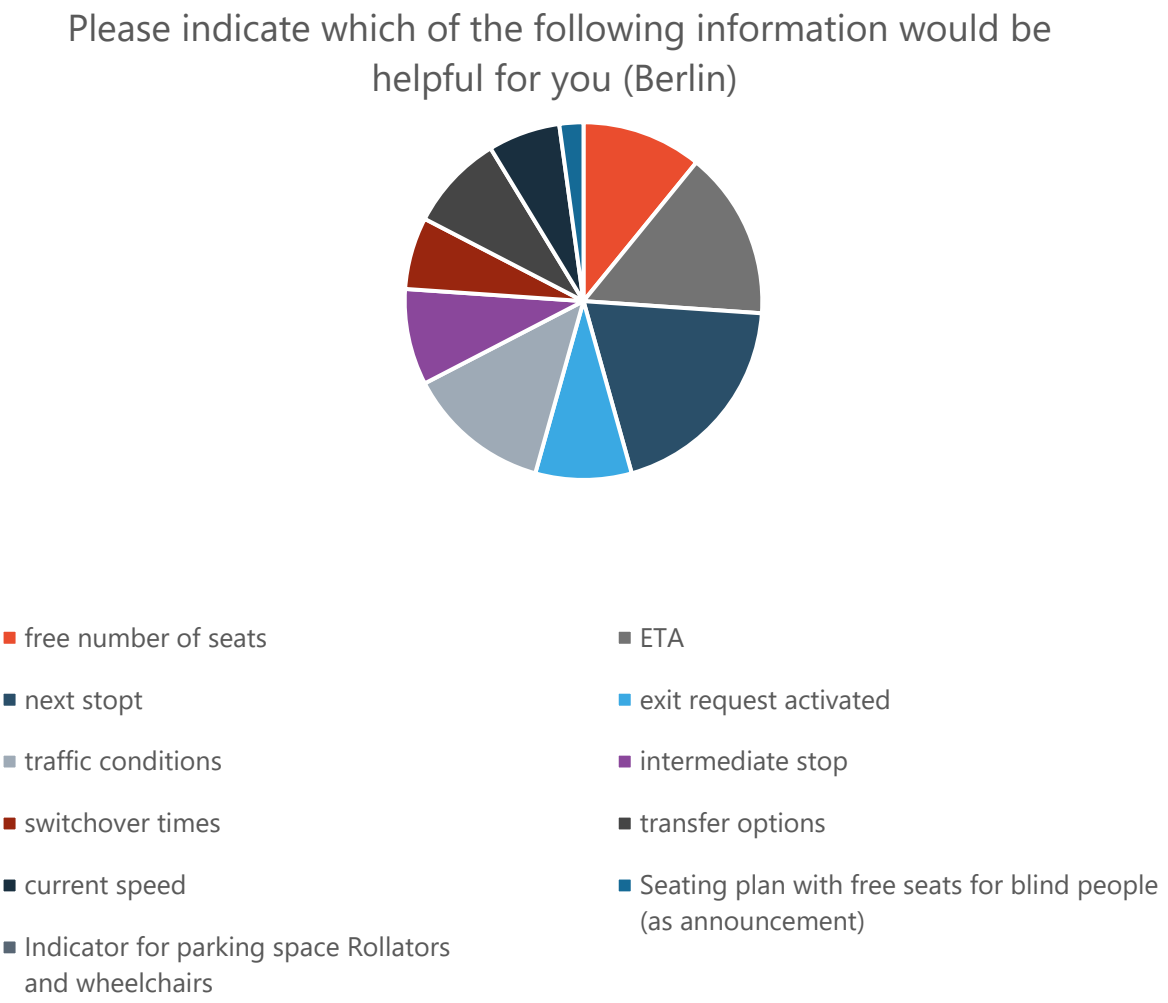


Figure 7: Information considered helpful (Berlin)

As all interviewed passengers are not regular users of the autonomous shuttle we want to know if they would use the shuttle if it would drive in their neighborhood.

Most passengers say that they would definitely use the shuttle as they rely on public transport and are willing to take advantage of everything that makes life easier. Some say, however, that the routes are too short and the shuttle is too slow to be of real use. Passengers would take the shuttle for everyday things, like shopping.

The interview partners would consider using the autonomous shuttle on a regular basis if

- The shuttle went faster
- The routes were longer
- The shuttle could deal with everyday traffic situations

- There was a regular service with frequent departure times
- There was an on-demand service with flexible routes (incl. bus stop in the immediate vicinity of the place of residence)

The users like the idea of a shuttle service that does not depend on fixed bus stops. However, they raise the topic that the shuttle may stop only at secure places. It is not clear how the passenger could communicate these places to the shuttle and how the shuttle could confirm this.

Most passengers would recommend the shuttle.

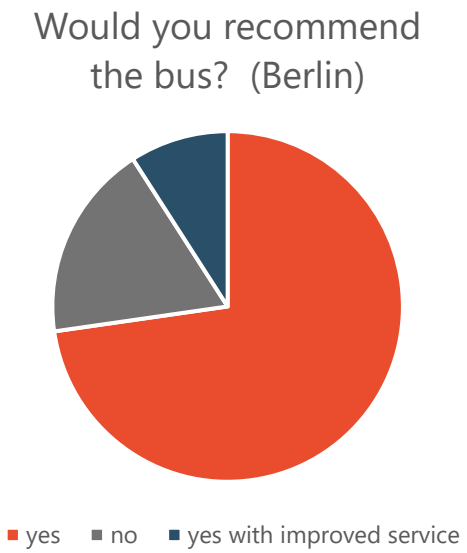


Figure 8: Recommendations of autonomous shuttle (Berlin)

While five of the ten interviewed passengers instantly say they would drive with the autonomous shuttle even if there wasn't a safety operator on board, two others hesitate and would do so only if the shuttle was reliable and didn’t constantly stop whenever there is an unexpected situation like an illegally parked car. One user is undecided, and two are firmly convinced that the shuttle without an operator is not possible at the present time as this was too dangerous in road traffic.

3.2.2 On-site visit Vienna

The passenger interviews in Vienna were conducted during week 38 (Sept 16th through 19th).

Eight passengers (or groups of passengers like couples or families) took the time to answer our questions about their experience with the autonomous shuttle.

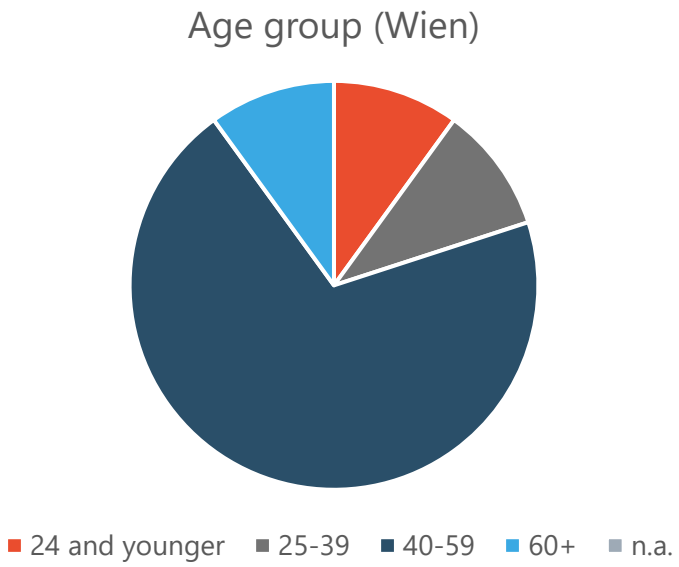


Figure 9: Age groups (Vienna)

All interviewed passengers use their smartphones in the context of using public transport, mainly to get information on timetables and connections. Other popular services are ticket purchase, use of Wi-Fi and notification of delays.

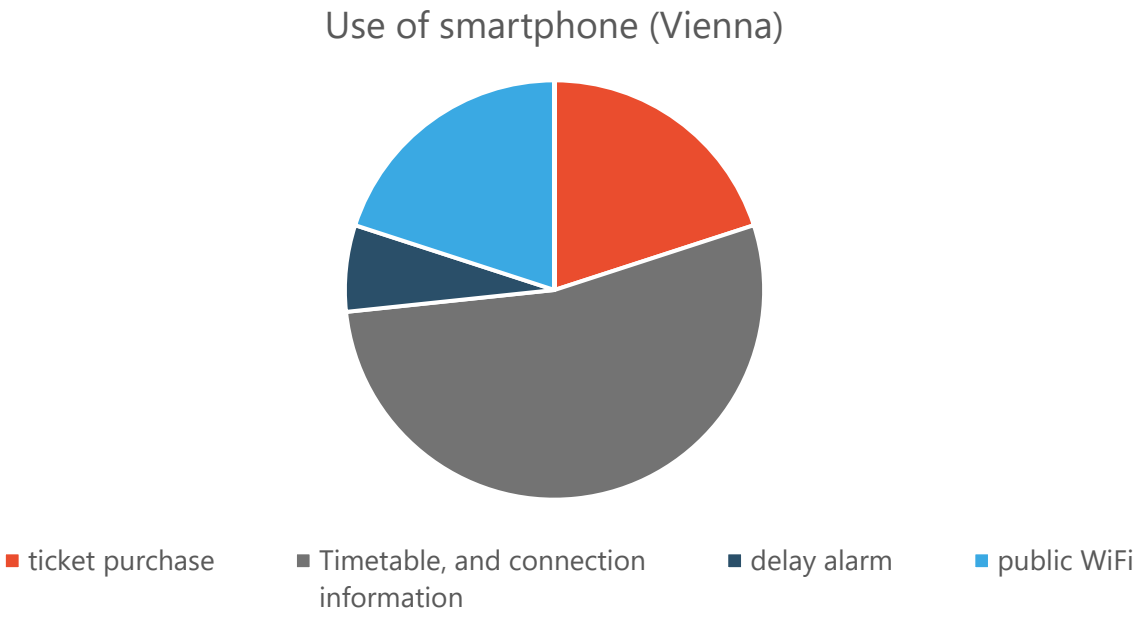


Figure 10: Use of smartphone (Vienna)

None of the interviewees use the shuttle to reach a destination, they just want to try it out. For all but one person, it is the first time they take the autonomous shuttle.

The interviewed passengers mention the driving behaviour as pleasant and something they enjoy. However, one couple complains about the jerky driving style. The fact, that the vehicle can only drive in its set course is another point is something passengers don't like. The braking of the shuttle is considered normal braking behaviour (As we have been told by the operator, an update regarding the braking behaviour was installed shortly before the survey.

Many passengers complain about the speed ("I would have been faster walking") and the fact that the shuttle often comes to a stop. With this travelling speed, it is not suitable as a means of transport. Only one passenger sees something positive in it: with everything getting higher, faster and bigger, it is enjoyable that this vehicle only goes with 10 km/h.

The passengers like the interior of the shuttle and find it surprisingly spacious so that there is room for a stroller etc. They appreciate that the vehicle has air conditioning. What's missing is a button to request a stop. The position of the monitor is considered to be not ideal: It would be better if it were mounted in the direction of travel. Announcements of the next station would be appreciated. The acoustic signal in the shuttle is considered annoying.

The interviewees in Vienna are impressed by the technology. It's amazing that autonomous driving is possible, especially that the shuttle detects obstacles and bus stops.

However, they value that there is an safety operator on board: it is good to have someone in the shuttle who can intervene in an emergency and who helps when you get on the bus with a stroller etc.

The passengers generally rate the overall atmosphere as very positive. They enjoy the experience, they trust the technology and they would use the shuttle again with confidence at any time.

Most interviewees noticed the monitor in the shuttle. Those who do appreciate to be able to understand the range of the shuttle's sensors and the safety clearance. They can observe that the clearance is kept. Some also like that they can see the surroundings of the bus and its route while others don't consider this information helpful because they are familiar with the neighbourhood.

When asked about the information they require on the shuttle, users mention:

- Announcement of stops (next stop/current stop)
- Information on how to request a stop
- A warning that the vehicle is about to brake (this is currently done by the operator) because passengers would not expect a sudden braking
- Info on the battery of the shuttle: battery status and required charging time
- Information at the bus stop when the next shuttle will arrive

When asked explicitly which of the following information is useful to the passengers, the most frequent answers are

- Next stop
- Number of free seats in the bus
- Transfer options
- Time to transfer

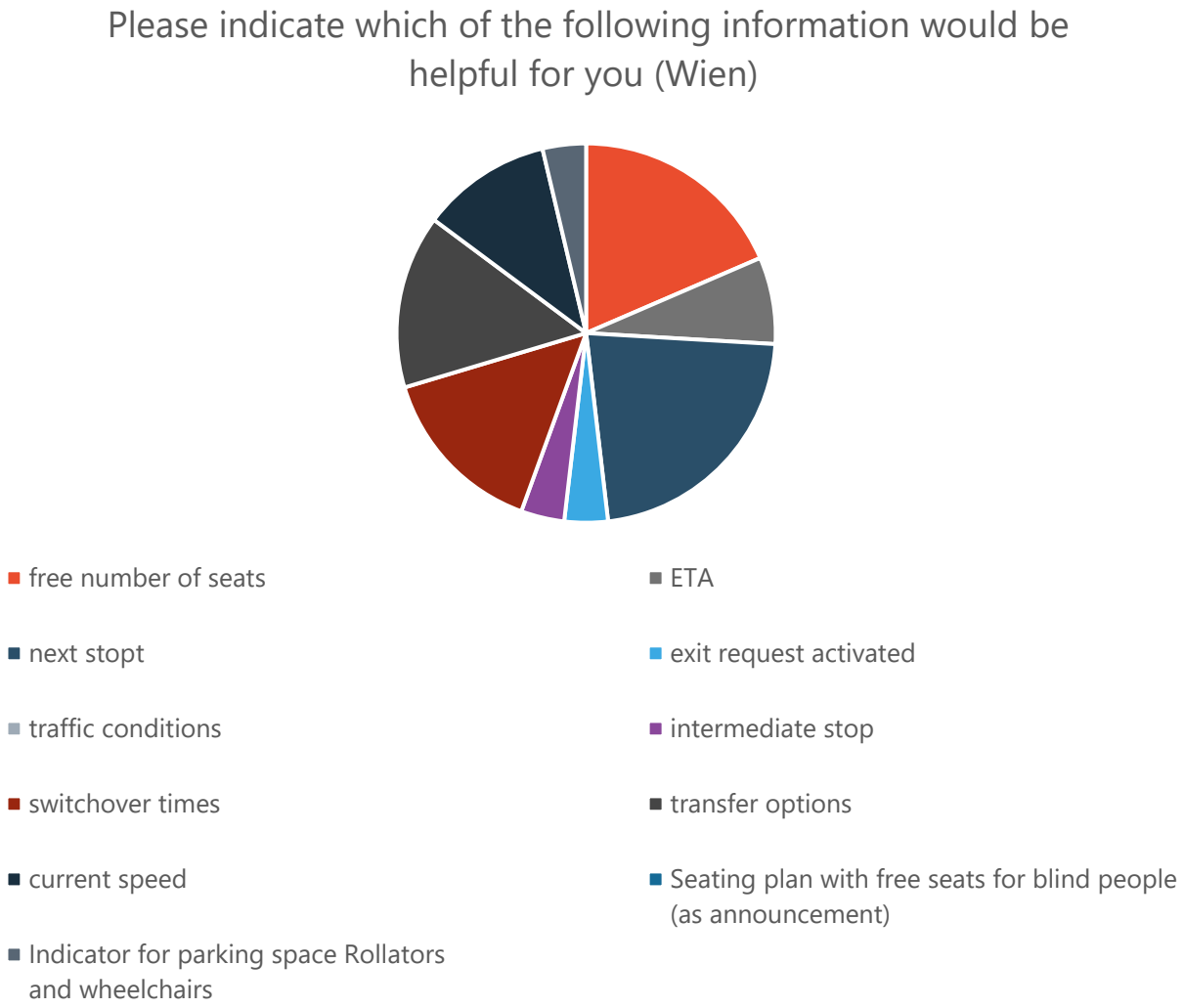


Figure 11: Information considered helpful (Vienna)

As the interviewed passengers are not regular users of the autonomous shuttle we want to know if they would use the shuttle if it drove in their neighbourhood.

Most interviewees say that they would use the shuttle. They would use it for everyday things, like going to work or shopping. One couple generally doesn't use public transport and they wouldn't make an exception for this shuttle. Another couple thinks the shuttle is too slow to be of any use. Only in the summer when it is really hot, they would consider a ride in the air-conditioned shuttle.

The interview partners would consider using the autonomous shuttle on a regular basis if

- There were more shuttles (a regular service with frequent departure times)
- Timetables were available at bus stops
- Information was available at bus stop when next shuttle will arrive
- Infrastructure was improved: Coordination with other means of transport like subway
- There was more space for strollers (currently only space for one stroller, buggy, etc.)

Some users can even imagine to give up their own car but only if there was a regular service with frequent departure times, coordinated with other means of public transport so that there is a public transport network that covers the complete city. Others think that there are occasions when a car is better , e.g. when transporting heavy or bulky things or when needing to reach several destinations.

Six out of eight passengers say they would drive with the autonomous shuttle even if there wasn't a safety operator on board. A hotline shall be available in the shuttle so that passengers can call if they feel the need to do so.

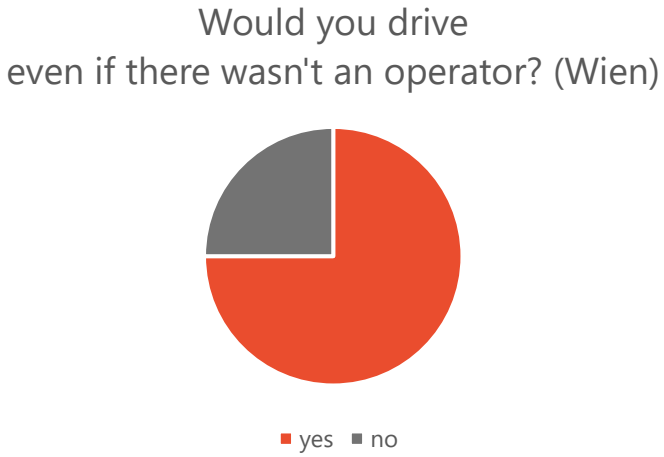


Figure 12: Using the shuttle without safety operator (Vienna)

The other two interviewees think that the system is not yet mature enough and that a human attendant will always be required in the shuttle. What if the bus suddenly stops and doesn't drive on? What if someone gets stuck in the door? What if there is an accident?

Most users don't like the idea of a shuttle service that does not depend on fixed bus stops. They are concerned that the bus couldn't keep to the schedule without fixed stops. Some people could make the bus stop all the time just for fun.

All passengers would recommend the shuttle.

3.3 Analysis of the observation study

Besides interviews with safety operators and users, we decided to conduct personal observations as a third source. These observations took place during a regular usage of the bus. While riding the bus, the evaluator observed all persons in the bus following an observation guideline including the most important tasks during a bus ride.

3.3.1 Detailed walk-through with blind users

The AVENUE project member Siemens was invited to join several practical user tests with autonomous vehicles in Berlin. These tests were hosted by the PTO of Berlin (BVG). The BVG aims to introduce autonomous vehicles into the public transport of the capital city of Germany.

Siemens took the opportunity to observe the practical user tests and to perform interviews with the different user groups, represented by passengers with or without disabilities, and as well as with the safety operators who accompanied the autonomous vehicles in terms of traffic or other problems, which sometimes require individual assistance of this non AVENUE Site.

Three of these seven user where expert users, that have been involved in tests with new public transport vehicles and who are active in different association working together with PTOs.

3.3.1.1 Concerns from blind users perspective

The usage of autonomous vehicles in German public transport is currently a real challenge for the passenger group of blind and visually impaired users. To outline the problems of this specific user group, the following report describes the first impressions of a blind person who performed a practical test in a safe environment. This 59-year-old male user has good experiences in terms of mobility. In his hometown, a medium-sized city in Germany, the person uses public transport daily and completely on his own, from home to work and vice versa.

The described practical test took part on 30.08.2019 in Berlin, the autonomous bus was provided by the Stimulate [9] project. The operator and manufacturer of the corresponding vehicle was the company EasyMile [12]. The bus provides 6 seats to its passengers and all passengers are advised to take a seat during the test course. This should avoid dangerous situations which can be caused by abrupt braking actions within real traffic situations.

3.3.1.2 Bus stops on the course

The scheduled course of the autonomous bus and the bus stops were planned and provided by the project member BVG, the operator of the public transport in Berlin, Germany. The autonomous bus runs in a kind of circular course and provides 9 different bus stops where the vehicle automatically stops to allow the passengers to get in and out.

The test environment was completely unknown for the tester, and therefore he wasn’t able to find a bus stop on his own without assistance, even though the address of the corresponding bus stop was given to the user in the lead-up to his test. All bus stops are represented by normal traffic signs with additionally installed timetables, directly mounted at eye-level on the pillars of the traffic signs. The bus stops are neither equipped with audio signals (like e.g. attention signals on traffic lights) nor with tactile markers on the walkway, which could help

blind users to find and quickly locate specific places on their own. The next difficulty occurred while trying to read arrival and departure times from the timetable. The timetable is not provided in braille and an audio based passenger info system, like e.g. a standard loudspeaker, is not available. Timetables provided online as well as the usage of personal mobile phones together with appropriate optical character recognition (OCR) apps could solve such kind of problems in the future. The autonomous bus is not equipped with Acoustic Vehicle Alerting System (AVAS), therefore the arrival of the bus was difficult to detect for the user, who wasn't able to perceive road noise from the bus due to environmental sounds.

3.3.1.3 Boarding process

The bus stops directly at the bus stop sign but without any attention signal. The door does not open automatically, the user has to locate the corresponding sensor button that is mounted on one site of the double door of the bus, but without any kind of tactile markers. Moreover, there are two different sensor buttons available, the second one is for wheelchair users who can request a special ramp for boarding. Which button is the right one, there is neither braille nor tactile markers available to answer this question in an accessible way. Audio signals which could help blind users to quickly locate the door as well as to find the appropriate sensor button are also absent. The entrance level of about 32 centimeters above the street level is very high for a wide range of users, nevertheless, the bus can be lowered up to 25 centimeters to ease the boarding. In reality the level is highly depending on the curb height at the bus stop. For example with a curb height of 16cm and the bus tilted the step height is at least 9 cm. Such a change of level may be bridged by an onboard ramp. There is no audio-based passenger information system installed at the bus stop which could enable the blind user to identify the arriving bus as his correct line. Moreover, the tester finds the entry area of the bus to be not slip-resistant enough, in particular in case of rainy weather.

Figure 13: Ramp

3.3.1.4 Interior situation and bus ride

The autonomous bus is equipped with 6 seats, a row of three in the front and another row of three in the back of the vehicle, both rows are oriented to point to the middle of the bus, so that three passengers look into the motion direction of the bus and the other passengers vice versa. All passengers are asked to take their seats during the bus ride to reduce any potential transport risks. Standing passengers are not allowed. There is no additional storage space for hand luggage or shopping bags. The user assessed the number of grips, handles and handrails to be too low to ensure a safe movement or orientation within the interior of the bus. He also had problems to quickly find his seat without assistance. The riding process was comfortable, there were no abrupt braking actions at all, all speedup or slowdown actions led the user to a good driving experience in terms of security requirements. The autonomous bus is configured to operate in Metro-mode, this means, that the bus automatically stops at all available bus stops at the circular course. There is no audio-based passenger information system installed which could tell blind users the next bus stop in an accessible manner. Therefore, the user has to know the stops at the circular course and has to count the already visited bus stops to identify the

right one. The safety operator explained to the test person that there are no complex traffic situations within the bus course, like e.g. complex set of traffic lights or difficult crossings. Potential stops of the autonomous bus are only caused by two situations: the vehicle reaches the bus stop or the vehicle detects obstacles on the course. In both cases the bus indicates the stop by a clear and good perceivable audio signal, but without any audio information of the corresponding reason. Arrival points are not announced by speech. Moreover, it is the same signal for both situations and blind passengers are not able to differentiate between the above mentioned triggering events. As a result, the test person tried several times to get off the bus on the course without success.

3.3.1.5 Getting out of the bus

The bus currently operates in Metro-Mode and halts automatically at each bus stop; therefore, passengers do not need to initiate an extra halt-request. Nevertheless, the double-door does not open automatically at the bus stop and passengers need to open the door by triggering the correct sensor button. At this point, blind users have to cope with several issues in terms of accessibility. There is no audio announcement available that indicates the current arrival point, this information is only presented on an info display, blind passengers therefore cannot be sure to reach their destination. The test user remarked that the placement of the different sensor buttons, each one equipped with a specific function, will lead blind persons to operating errors. These difficulties are caused by the sensitivity of the sensor buttons that instantaneously trigger in case of any finger contact, but finger contact is required for this user group to read braille as well as to identify other tactile markings. Due to these problems, the test person was unable to distinguish between the three halt-functions, provided by the different sensor buttons: SOS, halt-request for wheelchair users (which automatically activates a ramp) and the default exit button that opens the door. In particular the exit button raised additional problems because the door must be released by the autonomous bus security-system, before passengers are able to successfully trigger the exit button to leave the bus. And exactly this release feedback was not perceivable by the test person who was only able to get out of the bus after pressing several times the exit buttons to open the door.

3.3.1.6 Summary

Some of the above mentioned accessibility issues can be resolved by using the capabilities of a modern mobile phone. For example GPS localisation and online timetables could help users to successfully deal with these specific problems. But in most cases, there are a lot of additional improvements required to answer the needs of this user group and to ensure a comfortable public transport with autonomous vehicles.

3.4 Acceptance of autonomous vehicles – obstacles and motivators

3.4.1 Obstacles

- People prefer to drive their own car
- Passengers want to talk with a driver
- Passengers rely on a driver to help them
- Doubts that the technology is mature enough to be trusted up to the absolute refusal to trust in this technology
- Stories about accidents with autonomous vehicles
  → Passengers need to be convinced that the vehicles are absolutely safe
  → possible indicator: the amount of time or km a vehicle has been running without accidents
  → Even little incidents or accidents are likely to destroy any trust passengers have developed
- Worries that other road users will not be able to anticipate the behavior of autonomous vehicles
- Autonomous busses in the field will lead to more delays and failures and more traffic jams for other road users
- Traffic situation is very complex:
  - too complex to be handled by technology in general
  - a driver can flexibly react to all unforeseen situations and interfere if necessary
  - the autonomous bus will have accidents without a driver
- Risk of cyber attacks: hackers could make the bus go faster or drive off a bridge or into oncoming traffic
- Passengers do not like the idea that there could be no supervisor in the shuttle:
  - No one in the bus to perform first aid if required
  - Feeling uncomfortable all alone in the bus at night, especially in certain neighbourhoods
  - Even robberies or assaults
  - No authority figure present to keep passengers calm (-> school kids)
  - Vandalism
  - No information if there are any problems
  - No communication (chatting with the driver is quite common in some areas)
  - No support during the trip/on board and especially no support to get on and off (passengers are worried that they might not have enough time to get on and off the shuttle and the doors could close too soon)
  - No support to reach a connection

3.4.2 Motivators

- Presence of a supervisor in the bus
    - someone who can interfere or take over (if the technology fails)
    - someone to act as an authority figure
    - someone who can answer questions, provide information and help with getting on or off the bus when necessary
- Better coverage of an area with public transport; bus connections where there are none today (because it is not profitable today)
- More destinations
- Higher frequency of service
- Public transport anytime of the day/night
- Bus on demand: no rigid timetable but being able to call the bus whenever needed
- More flexibility regarding the stops / door-to-door Service
- Reliable service that is on time
- Cheaper tickets
- Clean vehicles
- Sufficient seating, maybe “even guaranteed seats for people with special needs"
- Better information than today: more, accurate, accessible
    - e.g. acoustically understandable announcements, correct announcement of the upcoming stop, information when the bus will actually arrive, information where the bus is at every moment and where it is going (considering flexible routes)

- Expected advantages if the bus is not operated by human driver:
    - a smooth driving style as there is no impatient driver
    - gentle braking, no more sudden braking manoeuvres
    - clear announcements, no more mumbling, no cursing

4 Use cases and requirements

The use cases and requirements gathered in D2.2 are general and some of them regulatory requirements for public transport infrastructure, therefore they are also valid for autonomous vehicles. To better distinguish the new use cases derived during the current evaluation are marked in the following chapter. new use cases derived during the current evaluation are marked to distinguish from the results of D2.2 First Passenger needs analysis and specification.

4.1 General requirements for safe passenger exchange

4.1.1 Accessibility requirements related to blind and visually impaired passengers

- AVAS or a similar audio solution, blind users need audio feedback from arriving or departing busses for safety reasons at their bus stops
- spoken arrival and departure times, like e.g. by a loudspeaker system at the bus stop, or a time table that is presented in another accessible manner
- Spoken announcements of arriving vehicles to identify the correct bus at the bus stop
- Appropriate tactile markers or audio signals to be able to locate the position of the bus stop
- Appropriate audio signals or tactile markings that allow blind users to quickly locate the correct sensor button to open the door to get into the bus
- Appropriate sensor buttons that confirm their triggers in an accessible way, so that blind passengers get audible or haptic feedback after successfully activating a corresponding function
- An extra audio signal when a bus arrives (and halts) at the bus stop to inform blind users to pay attention
- An appropriate number of grips, handles and handrails within the interior of the autonomous bus to ensure safe movements for blind passengers
- A clear and non-complex interior to enable blind passengers an easy orientation, like e.g. to quickly find their seats or to quickly find the door to leave the bus
- Spoken announcements of the next bus stop.
- Other spoken hints e.g. infos on traffic situations that cause extraordinary halts of the bus
- Spoken hints like e.g. arrival or departure delays, remaining changeover times, etc.
- Easy to locate sensor buttons for halt- or SOS-requests
- Easy to identify and easy to operate sensor buttons for halt-requests or other functions, appropriate markings should be used in case of more than one button
- Appropriate accessible feedback, like e.g audible or haptic confirmations, after a successful activation of the exit sensor button to ensure blind passengers to finally leave the bus without any additional distraction

- If possible, a quick practical introduction of the autonomous vehicles to allow this specific passenger group to experience the systems in a safe environment before coping with these in real public transport situations

4.1.2 Outside the vehicle

Bus station /Bus stop			
ID/Number	Requirement	Expectation	Source
1	The infrastructure at each station shall be identical.	Should have	Userreq.
2	The infrastructure at each station shall offer shelter.	Must have	
3	The infrastructure at each station shall offer tactile paving.	?	
4	The infrastructure at each station shall offer sufficient lighting.	Must have	Userreq
5	Incoming busses shall be announced (audio) at the station (like at train stations): bus line and destination		Userreq
6	There shall be audio and visual information at the bus stop that indicates the direction of all bus lines departing from this stop.		Userreq

Line indicator / Identification of the line / Vehicle			
ID/Number	Requirement	Expectation	Source
7	The line shall be displayed on the vehicle (visual)	Must have	Userreq.
8	The bus shall announce itself at the bus station (audio) (route, branch letter, direction and destinations)	Should have	Userreq.
9	It shall be visually and acoustically recognizable when the vehicle has come to a standstill (very quiet vehicle).	Should have	Userreq.
	Acoustic Vehicle Alerting System (AVAS) Manufacturers shall install AVAS meeting the requirements set out in Annex VIII in new types of hybrid electric and pure electric vehicles by 1 July 2019. Manufacturers shall install AVAS in all new hybrid electric and pure electric vehicles by 1 July 2021.		EU 540/2014 Article 8

Doors and entrances			
ID/Nu	Requirement	Expectation	Source

mber			
10	Doors shall be reliably and safely detectable (visually and tactilely) outside of the vehicle.	Must have	Userreq.
	Doors or the outline of doors operated by passengers shall be detectable by the visually impaired on the outside of the vehicle.		Switzerland: VAböV Art. 15
	When a door is automatically or remotely opened by the driver or other member of the train crew a signal shall be given: • that is clearly audible to persons inside the train • that is clearly audible to persons outside the train • that is clearly visible to persons inside & outside the train • This signal shall last for a minimum of 3 s from the moment that the door starts to open		FprEN 16584-2:2015 5.3.3.2 ff
11	Doors shall recognize objects of ≤ 1.5 cm diameter over the entire height (white cane or dog leash).	Should have	Userreq
12	Doors shall open long enough for passengers to safely get in and out	Must have	Userreq
13	Doors shall indicate before they close	Must have	Userreq
14	Doors shall be prevented from closing on a passenger	Must have	Userreq
	Automatic and semi-automatic, doors shall incorporate devices that detect if they close on a passenger where a passenger is detected the doors shall automatically stop and remain free for a limited period of time.		TSI/PRM (2008) 4.2.2.4.2.1.
	If the passenger enters or leaves the vehicle while the door is closing, the closing process shall be interrupted automatically and the door shall return to the open position. The reversal may be actuated by one of the safety devices referred to in paragraph 7.6.6.3.1 above or by any other device.		UNECE R107 7.6.6.3.2
Interface of door control device			
15	There shall be an acoustic detection signal for door button (outside)	Should have	Userreq
	Door controls, whether manual, pushbuttons or other devices, shall contrast with the surface on which they are mounted.		TSI/PRM 4.2.2.3.1
	(1) A door control device shall have visual indication, on or around it when enabled and shall be operable by the palm of the hand exerting a force not greater than 15 N. (2) It shall be identifiable by touch (for example: tactile markings); this identification shall indicate the functionality.		TSI/PRM 5.3.2.1.

4.1.3 In the vehicle

Passenger Information system			
ID/Number	Requirement	Expectation	Source

16	The next stop shall be announced optically and acoustically (2-channel principle).	Must have	Userreq.
17	The announcements in the bus shall include information about available connections.	Should have	Userreq.
Displays			
	Displays shall be sized to show individual station names or words of messages. Each station name, or words of messages, shall be displayed for a minimum of 2 seconds.		TSI/PRM 5.3.1.1.
	If a scrolling display is used (either horizontal or vertical), each complete word shall be displayed for a minimum of 2 seconds and the horizontal scrolling speed shall not exceed 6 characters per second.		TSI/PRM 5.3.1.1.
	Displays shall be designed and assessed for an area of use defined by the maximum viewing distance according to the following formula: Reading distance in mm divided by 250 = font size (for example: 10 000 mm/250 = 40 mm).		TSI/PRM 5.3.1.1.
Acoustical announcements			
18	Volume of acoustical announcements shall adjust automatically depending on the noise level in the vehicle.	Must have	Userreq
	The spoken information shall have a minimum STI-PA level of 0,45, in accordance with the specification referenced in Appendix A, index 5.		TSI/PRM 4.1.2.11
	The spoken information shall have a minimum RASTI level of 0,5, in accordance with IEC 60268-16 part 16, in all areas. Where provided, spoken information shall be consistent with essential visual information that is being displayed. Where spoken information is not provided automatically, an audible communication system shall be provided to allow users to get information upon request.		TSI/PRM (2008) 4.1.2.11
	Acoustic passenger information must be easily understandable for the hearing impaired, and in particular appropriate acoustic announcements in passenger compartments must be provided. If necessary, they must be repeated or be repeatable on demand		Switzerland VAböV Art 5

Light			
ID/Number	Requirement	Expectation	Source
19	The lights in Busses shall be improved, lights shall not be dazzling.	Should have	Userreq
20	The lighting in the vehicle must be bright enough to enable unobstructed movement in the vehicle.	Must have	Userreq
21	Shadows shall be avoided in the vehicle	Should have	Userreq

22	Indirect lighting shall be provided to avoid glare and reflections (e.g. on glass surfaces).	Should have	Userreq
23	The door areas, step edges and danger areas shall be adequately illuminated	Must have	Userreq
	Internal electrical lighting shall be provided for the illumination of: All passenger compartments, crew compartments, toilet compartments and the articulated section of an articulated vehicle; Any step or steps; The access to any exits and the area immediately around the service door(s) including, when in use, any boarding device fitted; The internal markings and internal controls of all exits; All places where there are obstacles;		Regulation No 107 7.8. Artificial lighting

Vehicle			
ID/Number	Requirement	Expectation	Source
24	The floor shall be totally low with no steps.	Must have	Userreq.
25	The doors shall be reliably and safely detectable inside the vehicle.	Must have	Userreq.

Passenger Interaction			
ID/Number	Requirement	Expectation	Source
26	The interior of the vehicle shall be designed to enhance passenger interaction.	Nice to have	Userreq

5 Conclusions

Regardless of the different survey sources, the statements lead to the same positive result: The user acceptance increases to the same extent as the autonomous vehicles are optimised and adapted to fit the different user requirements.

Passengers with and without disabilities differ in their needs, but both user groups expect a significant added value in the use of autonomous buses in public transport.

While the problems of people with physical or sensory impairments are more related to the practical use of the technology used, other passengers tend to see difficulties in buying their tickets and in connecting to other public transport systems.

Looking at the results in detail, there is a high degree of potential for improvement, but these are all within a timeframe that can be accomplished within medium-term development cycles. This means that many of the outlined difficulties can be overcome without any higher efforts and optimized services could be provided for the individual user groups, so that an increasing user acceptance can also be predicted in the future.

6 Appendix : Personas

This chapter summarizes the requirements and users expectations by means of personas. The personas were created following the Alan Cooper and Kim Goodwin methodology [13] [14]

6.1 Personas 2nd Analysis – Passengers

[2]

Alex

Music makes mornings and public transport tolerable.

Age: 31

Gender: male

Special characteristics: – reduced hearing due to music; no hand free

Scenario: Alex commutes to his office every day. Since he loves sports, he rides his bike to the station every morning, from where he takes the train to work for 40 minutes. When he has a business meeting, however, he prefers the car to the train station, not only because then he wears a suit but also to make sure he doesn't miss the train. *"I need to be on time. I can't keep the customer waiting, can I?"*

The 40 min train ride to the city seems endlessly long to Alex. But with the right music he can relax and just forget about everything around him. But immersing yourself in the music like that brings with it its risks: Recently there was an announcement that the train would end prematurely and reverse and that everyone would have to get off the train. *"It was embarrassing, I didn't notice it and stayed in my seat! Luckily someone nudged me, otherwise I would have gone in the other direction."*

Since Alex constantly listens to music, he always has his mobile phone within reach. Last month it fell out of his pocket and the display broke. Now he's got a huge "spider web" on his display and it's difficult to use some of the apps, especially when reading details is required. The repair would be very expensive, so he decided against it. The phone is still good for phone calls and listening to music. These are the most important features for Alex, anyway. He can do without most other apps. He will surely buy a new mobile phone one day, but he's in no hurry.

[2] https://images.pexels.com/photos/846741/pexels-photo-846741.jpeg

[3]

Helena

These taxi drivers charge an arm and a leg.

Age: 74

Gender: female

Special characteristics: age-related limited mobility, hard of hearing

Scenario: Helena is in her seventies and has experienced a lot in her life: a wonderful marriage, great travels, but unfortunately also a lot of sorrow: the loss of her husband and a breast cancer diagnosis. That's why she has to see the doctor regularly to get checked out.

Helena has no relatives in her immediate vicinity (her daughter Katerina lives 250 km away, and her son Niko lives in New Zealand), so she has no one to drive her to her doctor's visits. She used to take the bus, but this is not an option anymore. A trip with the bus is too exhausting because she has to change twice to get to the doctor's office. That leaves the taxi as her only choice.

Helena likes to schedule her appointments for the late morning. She reserves the taxi for the way there in advance from home. The return trip cannot be booked in advance, because she cannot predict how long she will have to wait at the doctor's. When she's finished at the doctor's, she orders a taxi back with her senior mobile phone. *"My daughter got me this mobile phone with extra-large buttons. I don't really like it because it looks so clunky and I still find it difficult to use. But Katerina wants me to always carry it with me."* Sometimes, when she is too tired to deal with her phone, she knows she can ask the staff at the doctor's office to call her a taxi. They are always very helpful in the practice and let her wait in the waiting room so she can sit until the taxi arrives.

Many taxi drivers are very nice. They help her in and out of the car and even hold open the heavy front door to the doctor's practice. Over time, however, the taxi costs add up to a frightening amount. She asked her health insurance if she would get a refund, but the insurance refused. Helena is at a complete loss as how to go on: she can't afford taking the taxi but there is just no other option.

[3] https://cdn.pixabay.com/photo/2016/03/26/12/10/granny-1280445_1280.jpg

[4]

Henry

Can't I hire my own personal porter for when I go shopping?

Age: > 70

Gender: male

Special characteristics: dependent on a walker

Scenario: Henry is retired and lives alone in a suburb. It is not easy for him to master his everyday life by himself since he became a widower. He often feels lonely and bored. For some time now, walking hasn't been so easy for him. That is particularly annoying as Henry does not own a car anymore, so he depends on public transport. But with his walker he is well on his way.

He goes shopping several times a week because he likes to buy his groceries fresh. Also, leaving the house and going shopping is a welcome change in his everyday routine.

The local supermarket is very small and does not even have a deli counter. Henry prefers to buy his groceries at a big supermarket in the city centre where they have his favourite cereal, a large selection of fresh fruit and vegetables and a cheese counter that leaves nothing to be desired. It is quite a bit away from his home, so he takes the suburban train to get there.

Taking that train is the part Henry doesn't like about going shopping, especially the getting on and off with his walker is difficult. Once on the train he tries to quickly sit down because he is afraid that he might fall if the train starts before he sits. *"With my walker, it just takes a bit longer until I am at my seat. But the train doesn't wait for old people like me."*

The outward journey still works comparatively well but the way back with the shopping bags is quite a pain. Getting in and out of the train is the worst part. It is difficult to get everything on the train in time. He finds it works best when he first puts his bags in the train before he gets on the train himself with the rollator. He puts the bags in the light barrier so the doors cannot close on him.

Last month, it happened exactly as Henry always feared: the shopping bags fell over and no longer blocked the light barrier and the doors closed in front of him with all his shopping bags inside while he was still standing outside. *"When the doors closed, I panicked! Instead of just pressing the button to open*

[4] https://cdn.pixabay.com/photo/2019/03/01/10/23/old-4027651_1280.jpg

the doors again I screamed for help. How embarrassing!". Luckily a friendly man helped him and opened the doors for him again. But ever since this incident he feels insecure when boarding a train.

[5]

Carolin & John

A life in the countryside is only enjoyable as long as you are not stuck there.

Age: 77 & 79

Gender: female and male

Special characteristics: – no IT literate; no smart phone

Scenario: Carolin and John live together in their own little house in the countryside. They have a small garden where their grandchildren play when they come to visit. They love watching the wild gang run around. It reminds them of the times when their own children were small and grew up in this house.

They get along very well with their neighbours Sofia and Lucas who are about the same age as them. They get together several times a week to play cards or to chat. Because of their nice neighbours and the many beautiful memories that they associate with their house, they do not ever want to move elsewhere. A few years ago, they spent a lot of money to make their house barrier-free to make sure they could stay there – even if age with its annoying side effects slowly catches up with them.

Two months ago, their neighbours moved into an assisted living facility. Carolin and John miss them and now often feel lonely without them. Suddenly, the peace and quiet in the countryside that they enjoyed seems depressing to them and they sometimes feel stuck in their house. *"I would love to visit Lucas and Sofia in their new home or see other friends in town for an afternoon but I just don't know how we should get there."*

Carolin never had a driver's licence, and John stopped driving after his stroke last year. The nearest bus stop is 1,5 km away from their house and as walking is becoming increasingly difficult for them, taking the bus to the nearest town is not an attractive option. *"Honestly, once I made it to the bus stop, I'm so exhausted I could fall asleep right away. A trip to the town is the last thing I want to do then."*

Carlin and John don't use smart phones and are not familiar with social media so the option to stay in touch via video chats, instant messaging, etc. is not available for them. The lack of social contacts often makes Carolin sad, and the silence in the countryside feels suddenly depressing.

Only when their son has time to drive them to friends or to a café in town do they have the opportunity to socialize and chat with their friends again.

[5] https://cdn.pixabay.com/photo/2016/05/14/08/51/seniors-1391561_1280.jpg

[6]

Lilly & Lou

When they invented public transport, they sure didn't think about us mothers!

Age: 33 & 2

Gender: female

Special characteristics: – no hands free; space for buggy needed

Scenario: Lilly has a great two-year-old daughter with blond curly hair. She regularly brings her to the toddlers' group in the city, starting at 9:30 am. Lilly can't afford a car, so she and her daughter always use public transport. This is not ideal, as Lou's buggy makes it difficult to get on and off and it takes a lot of time. In addition, there aren't many bus drivers or other travellers who are helping her.

When Lou is in the playgroup, Lilly uses the time to do some shopping. In the city there is a much bigger choice and many things are available for a cheaper price. *"The diapers in the drugstore are much cheaper than in my local supermarket. I always get an XXL package."*

When Lilly picks up her daughter, usually around 11am, she carries lots of shopping with her. Lou is always very tired after the playgroup but too excited to fall asleep: an explosive condition…

Lou is determined not to stay in the buggy but walk instead. She whines until Lilly takes her by the hand. Handling her shopping, the buggy and her overtired child is not exactly a piece of cake. What's worse, she has no free hand to check the public transport connection on her mobile. Once they make it to the subway or bus, Lou insists on sitting next to her mother and soon starts climbing on the seat. When her mother tries to keep her in her seat, she tears herself loose and runs around in the vehicle. *"It's days like these when I swear I'll buy my own car."*

[6] https://cdn.pixabay.com/photo/2019/08/01/13/22/mom-and-daughter-4377491_1280.jpg

[7]

Fabio

The best party ends at some point – and then I have to see how I get home.

Age: 21

Gender: male

Special characteristics: –

Scenario: Fabio likes to party at the clubs. But even the best party night comes to an end at some point and then he has to look for an opportunity to get home. The night bus in this part of town runs hourly, that just never really works. *"Who wants to wait at this time of the night?"* A taxi would be convenient, of course, but Fabio doesn't have that much money, and he prefers to spend the little money he has in the club.

Sometimes he gets together with his friends and they carpool. Then they take turns driving. It doesn't always work and so Fabio is still looking for a suitable solution he can afford. *"If you drive your own car, you can't drink, that just ruins the night. We take turns driving, but sometimes the designated driver just drinks anyway, that's crap!"*

[7] https://cdn.pixabay.com/photo/2017/04/04/17/56/people-2202474_1280.jpg

[8]

Charlotte

Going home alone at night and in the dark scares me.

Age: 18

Gender: female

Special characteristics: –

Scenario: Charlotte loves to go dancing with the girls. In the industrial area, just outside the city a new club has opened where great parties regularly take place. *"The music is great, the atmosphere is awesome and the crowd is really cool."* It's currently their favourite club.

They usually start the evening in a little café downtown until it's time to take the subway to head for the club. When they arrive there at about 1am, the atmosphere is already fantastic. They have a great time there but as the end of the night approaches, Charlotte begins to feel uneasy because her way home gives her a headache.

For the first part the friends ride together in the subway. There are also many other people on the subway, so that she feels safe, even if the other girls have already got out. She has to walk the last part of the way home. That is very scary for her, especially because the way leads through empty streets and finally along the city park. She always has a pepper spray with her, yet she is afraid. *"That last bit to my front door, walking through empty streets, nobody out there, that's so scary."* Sometimes she talks to one of her friends on the phone while walking home. That gives her the feeling of not being all alone.

When she finally arrives at home and unlocks the apartment door, she has a knot in her stomach and has to take a deep breath. *"I wish someone walked me home to my front door."*

[8] https://cdn.pixabay.com/photo/2016/11/29/03/35/beautiful-1867092_1280.jpg

[9]

Hanna

The best thing about the bus ride in the morning is that I see my friends.

Age: 14

Gender: female

Special characteristics: –

Scenario: Hanna is looking forward to the bus ride to school every morning because she always meets her friends Anisa, Lara and Nadya there. The ride takes quite a while and so they watch videos on their mobile phones or play games. Anisa has the latest mobile phone and the coolest games. Hanna is a little jealous, because she only has her father's old phone, the battery of which doesn't even last all day and in addition her parents don't allow her to install a lot of games. *"My parents are so uncool; they just don't understand what is important to me. Everybody is playing Fortnite! Why can't I???"*

Sometimes they all look on Anisa's phone and watch her play but then the bus driver complains and tells them to stay seated or at least hold on to the handhold. Other passengers often feel annoyed because the girls and their school backpacks are in the way. Hanna and her friends don't care much.

[9] https://cdn.pixabay.com/photo/2017/04/19/15/50/girl-2242668_1280.jpg

[10]

Bill & Clara

We are true explorers – but nowadays gratefully accepting luxury and comfort.

Age: 71 & 70

Gender: male & female

Special characteristics: age-related restricted in their mobility and vision

Scenario: Bill and Clara, a couple from Liverpool, just love to travel. They have been looking forward to their retirement for a long time, when they finally have time to experience nature on long hikes. After a while, they began planning their hikes to be somewhat less extensive. Recently Bill and Clara discovered the charm of city holidays. Cities are easy to reach by train, and they appreciate the reachability and proximity of interesting sights and good restaurants in the city. They find that this way of travelling suits them well to their advanced age with their diminishing vision and mobility. They also love these Hop on – Hop Off buses. *"You can do sightseeing while sitting in the warm and dry and resting your feet. Fantastic!"*

As Bill and Clara like to be spontaneous, they plan their trips only roughly in advance and work out their concrete daily program on site depending on the weather and their mood. Bill is the one interested in computers and gadgets. That makes him responsible for researching all details on his mobile phone. Every evening in their Airbnb he looks up opening times, admission prices, guided tours, special offers and discounts, directions, bus timetables, etc. for the next day. On their trips, they really depend on the information which stop is next as they are not familiar with the area. Clara hates it when bus drivers mumble announcements or when the information on the monitors is not up-to-date. All of Bill's planning doesn't help if they got off at the wrong stop and don't know where they are.

[10] https://cdn.pixabay.com/photo/2018/01/28/12/57/couple-3113574_1280.jpg

[11]

Erik

The weak get eaten. That's the law of the jungle and the law of the school bus.

Age: 11

Gender: male

Special characteristics: –

Scenario: Erik is in secondary school and takes the bus to school and back home. On some days all classes have school out at the same time, and then all students want to travel on the same bus. So they all try to squeeze in one bus which makes the bus ride very unpleasant. *"I always try to get on the bus first. If I'm lucky I get a seat and then I am out of the way and have my peace and quiet."*

The worst thing about the bus ride – and the main reason why Erik wants to be "out of the way" are the bullies from ninth grade, especially Finn and Torsten. They always push and shove the other kids.

If he has managed to get a seat, Erik can take a deep breath and relax. His favorite thing to do is to pull out his new mobile phone and play during the entire bus ride.

Recently something stupid happened to Erik: He was playing "Brawl Stars" on his phone, and missed his stop, because he didn't hear the announcement of the stop. He got off at the next stop and since there was no bus back for another hour and a half, he had to call his mother to pick him up. *"Boy, she was mad! She even took away my mobile and give me her old one which can only be used for phoning and texting. Honestly!!! Luckily I got it back after a week."*

[11] https://cdn.pixabay.com/photo/2016/03/12/21/05/boy-1252771_1280.jpg

[12]

Philippe

Public transport is ok, I guess. I just wish that the bus would wait for me.

Age: 20

Gender: male

Special characteristics: –

Scenario: Philippe lives in a small apartment in Toulouse and has to take a 25 min bus ride to the university. He is definitely not a morning person and it's hard for him to get up early. So he gets up at the last minute and then has to hurry in order to get the bus. When he leaves home, he puts on his headphones and listens to Rage against the machine at high volume. He is used to other passengers telling him about the music being too loud. But without his music, leaving the house that early would be unbearable.

If he is early enough at the bus stop, he often takes a coffee-to-go from the Kiosk at the bus stop. *"You have to be able to juggle when you are carrying your laptop case, a coffee and trying to press the door open button of the bus. When the conductor wants to see my student ID card, I wish I had three arms or at least a table where I could put my coffee."* Philippe hates that busses do not wait for him. Every time he misses the bus (which happens quite frequently), he is annoyed that he doesn't have his own car which would offer him more flexibility. *"It is always the same, if you are on time the bus is delayed, but if you are late the bus even leaves half a minute early."* Listening to his music helps him to survive the morning but it also makes it impossible to hear any announcements in the bus, so he is happy to see all information on the screen.

Autonomous public transport would be a great thing: *"The bus starts when I am there and hopefully there will be a place for my coffee and no other passengers that can complain about my music."*

[12] https://cdn.pixabay.com/photo/2019/04/26/21/06/man-4158696_1280.jpg

6.2 Personas 2nd Analysis – Other Road Users

[13]

Cristina

I need a 26 hour day – and empty roads!

Age: 38

Gender: female

Special characteristics: –

Scenario: Cristina is a single mother of twins and has a full-time job as a hotel manager. Her everyday routine is organized and structured down to the last detail. Every disturbance, however small, shakes the fragile balance she has managed to establish and plunges everything into chaos. This happens about twice a week. *"It just never works the way it's supposed to! That kills me!"*

In the morning she drives the twins to the day care center and then drives to work. In the late afternoon she has to pick up the kids again. If time permits, she goes grocery shopping before picking up the kids because it is much more relaxed when she can do it alone compared to a shopping trip where she has to tame the twins.

Time often turns out to be an enemy. *"No matter what I do, I seem to be late all my life."*

It's always the same problem: traffic. Traffic in the city is so slow that she often arrives late for work and hardly ever manages to pick up the children on time, let alone run any errands after work. When she is stuck in the traffic, she takes the opportunity to check and write messages. She knows that it is quite dangerous, and she shouldn't check her phone while driving but she has so many urgent things on her to-do list that she uses every moment to get something done. *"When I'm stuck in a traffic jam and therefore late and can't pick up the kids in time, I just have to write a WhatsApp to let the child care center know. I know I shouldn't do that, but what can I do?"*

[13] https://cdn.pixabay.com/photo/2019/05/12/19/13/female-4198814_1280.jpg

[14]

Richard

When did I become this old? Everything takes so long these days.

Age: 84

Gender: male

Special characteristics: Rollator

Scenario: Richard lives in a small town near Geneva. He and his wife moved there after retirement to enjoy the nature. Since his wife is seriously ill and can't leave the house anymore, Richard has to take care of things like groceries. It's not easy for him to walk, so he needs a rollator.

He knows that drivers get impatient very quickly. He can remember very well how annoyed he used to get about old slow drivers. That makes the fact that he is now so slow even worse. He feels embarrassed when it takes him forever to cross a road or even to decide whether it is safe to cross it. *"I can't believe that now I'm the old fool who holds everybody up"*, he often thinks bitterly.

Richard feels very insecure in road traffic and therefore often seeks eye contact to drivers when he has to cross the street. In general, he prefers to cross the road when there is no car in sight, because he doesn't want to hinder anyone. He is even more uncomfortable when cars have to stop especially for him, and he wants to avoid that cars honk their horn at him when he is crossing. Sometimes young people offer their help by carrying his groceries or helping to cross the street. At that moment, he doesn't know whether to be grateful or embarrassed.

[14] https://cdn.pixabay.com/photo/2014/08/11/13/08/man-415552_1280.jpg

[15]

Manuel

I live in the fast lane.

Age: 22

Gender: male

Special characteristics: –

Scenario: Manuel is a bike courier who picks up and delivers packages on his bicycle in Madrid. The big advantage of bicycle travel in the city is that it is less subject to unexpected holdups in traffic jams, and that it is not deterred by parking limitations or the like. However, traffic in Madrid is getting worse and worse, making it increasingly difficult for Manuel to deliver the packages within the usual time. His dispatcher has already complained several times lately.

Manuel feels under pressure. He is afraid of losing his job if he can't deliver in time. As a student, there are not many jobs that fit his time schedule and provide him with the money needed for living in Madrid. Furthermore, he wouldn't want another job as he likes cycling, and the exercise is the perfect compensation for the many hours spent at his desk.

In order to deliver fast enough, he rides like the devil, fights his way through traffic, finds shortcuts, etc. *"Bike couriers live a dangerous life."* In order to survive city traffic without being injured, he literally has to see everything. Having an overview of the road situation gives Manuel the feeling of having everything under control and the freedom to interpret traffic laws more freely. *"If I can assess the traffic situation, I am able to decide when I have to stick to traffic rules and when I don't."* Unforeseeable behavior on the part of other road users poses a great risk to him.

[15] https://cdn.pixabay.com/photo/2018/07/05/14/45/portrait-3518463_1280.jpg

[16]

Marcus

Not every idiot should be allowed to get behind the wheel.

Age: 53

Gender: male

Special characteristics: –

Scenario: Marcus has been a taxi driver in Liverpool for 20 years. He likes his job and enjoys driving. To make good money in this job, he has to make a lot of trips and can't afford to lose time. He is always in a hurry and gets quickly annoyed when other road users slow him down.

There are days when he feels there are only idiots on the road. Driving behind a slow car makes Marcus go up the wall! He uses the first opportunity to overtake and tries not to take any risks. It's not easy with the passengers: *"They don't know what they want: they complain when they have to wait and when they don't reach their destination quickly enough. And they complain when I make it possible by overtaking and frequently changing lanes."*

Over the years he has perfected the art of "creative parking", which often comes handy in his job. When passengers have a walking disability, he parks directly in front of their destination so that they do not have to walk unnecessary distances – even if it is a towing zone. Although Marcus wants to drive on again quickly it is part of his professional ethics to help passengers out of the car and carry their luggage or hold the door if needed. Luckily, he has never got a parking ticket for this.

[16] https://cdn.pixabay.com/photo/2016/06/15/20/50/man-1459917_1280.jpg

6.3 Personas 1st Analysis

[17]

Carlo

The daily chat with the driver makes the bus ride quite enjoyable.

Age: 60 years and older

Gender: male

Special characteristics: visually impaired

Scenario: Carlo lives in a medium sized town, and is *partially sighted*. Although he still can see enough to find his way he is using a *white cane* thus the other road traffic participants can recognize his disability. He is riding the *bus daily* in order to go *to his workplace in all weather conditions* and mostly at the same time. He prefers the *early connection* thus avoiding the bus filled with crazy kids playing strange music from their smart phones. Although he likes soccer he prefers to leave work earlier or later if the local soccer team has a home game. He does not like drunk fans singing loudly in the bus.

Due to his daily rides he is already well known by most bus drivers in the city. Therefore he tries to get a seat near the driver to talk about the latest news in the city. At this time of the year he has to switch the bus once to get to his work, during winter he has a direct connection. Carlo likes to use his smart phone to keep an eye on the travel time because he does not want to miss the connecting bus. Some drivers know him so well, that they tend to call his connecting bus on their own, telling them to wait, as they will arrive soon. "*Some of these guys even open the window and tell me where to go thus I do not have to search the right bus with my monocular.*"
Carlo has been in trouble once: While driving home the passenger information system in the bus crashed thus there were no announcements of the stops anymore. Being tired from work he forgot to count the stops and the bus was crowded so he had no way to talk to the driver. Using the live traffic app from the local operator and the help of some other passengers he finally managed to leave the bus at the right stop.
Carlo has never used an autonomous bus, but has used an autonomous tram at an airport. He is not really convinced of it, as he is afraid that his friends, the bus drivers, might lose their jobs.

[17] https://cdn.pixabay.com/photo/2016/07/10/23/01/hamburg-1508736__480.jpg

[18]

Mary

Bus travel is super easy now that I use the new mobility app.

Age: 25 to 39

Gender: female

Special characteristics: blind

Scenario: Mary became blind after an accident. After this serious change in her life her parents always patronized her, which made her aggressive. Today she wants to be as independent as possible thus she does not accept unsolicited help by others. While she is able to walk to her office she takes the bus at least twice a week to go shopping or for meeting friends in the pub. Shopping is always a bit difficult, as the next bus stop is far more than 500m away from her home. Especially carrying the shopping bags and using the white cane for this distance is not very comfortable. At the shopping mall she likes to get assistance offered by some of the stores (some even carry her shopping bags to and even on the bus).

Mary does not really care about the passenger information system. She is using the new onboard feature which has been introduced last month to all busses in her hometown. Using the accessible app, her phone connects to the bus and helps her to find the correct line and the respective entrance. Inside the bus she receives notifications about next stops, connections at the next stops, and information about the next stops, e.g. roadwork. Besides getting information she could also request a stop, which she often uses at night, or triggering an emergency call.
Mary never has tried autonomous vehicles, but is very interested in this development. "*Especially for us blind passengers I am expecting a huge improvement in mobility.*"

[18] https://cdn.pixabay.com/photo/2017/08/01/09/41/people-2564026_1280.jpg

[19]

Ned

The lousy connection and the distance to the bus stop make bus travel a pain.

Age: 40 to 59

Gender: male

Special characteristics: motorically impaired

Scenario: Ned lives together with his wife in a small village. His office is in the near town, which is roughly a 30 km drive. When he was younger he enjoyed driving with his own car, but after his accident he cannot fully move his leg anymore. This has turned him into a user of public transport, because somehow he has to get to his office.

The next and only bus stop of the village is in the center, using his walking aids it takes him about 15 minutes to go there.

Due to his legs he needs a bit more time than the younger generations to enter the bus. Ned prefers to get a seat, if possible with a cane holder, where he can fixate his walking aids. For the ride to his office he needs to switch once. While the 1st bus leaves only every hour, the connection is far better. However, when it is cold and snowy he asks the driver to contact the connecting bus to wait for him if possible.

If everything goes well, the trip is about one hour and 15 minutes. "*The main problem is the bad connection from my home village, if you miss the bus you have to wait one hour*. *On the other hand I can understand that this connection does not pay off for the operator.*" Ned is technology affine thus he dreams of a Bus on demand service. "*This would definitely make living in a village more attractive to young families. This would allow an on demand connection to the city center, and there could be much more "bus stops" in our small village.*" The only thing that he is afraid of is, that hackers might highjack the vehicle.

[19] https://cdn.pixabay.com/photo/2017/08/14/21/19/senior-2642030_1280.jpg

[20]

Katie

I only use public transport to avoid traffic jams and the hunt for a parking lot.

Age: 25 to 39

Gender: female

Special characteristics: –

Scenario: Katie lives in a big city. She drives her car to work. But for going to the city center she takes public transportation to avoid traffic jams and the annoying hunt for a parking lot. So once or twice a week, when she wants to go shopping or meet up for a drink with friends, she takes the subway. If there is a soccer game, a concert or any other major event, she reschedules her appointments. Overcrowded subway cars are an absolute horror to her. "With so many people on the move I avoid public transport like the plague."

Her trip takes about 20 minutes. Katie checks the time table on her mobile phone and picks her route thus she does not have to change trains or to the bus. Changing is inconvenient; being stuck in traffic while on the bus is a pain; she rather walks a bit longer. *"If I take the bus, I'm just as stuck in traffic."*

She does not use public wifi on the train. *"I have my data plan, I don't register and submit my data just to use a public wifi."*

Katie hates it when the subway station or the subway car is dirty and littered. She feels a bit insecure in the late evenings when there are only few other passengers and when some passengers are drunk. *"I don't mind surveillance cameras in the subway at all. In fact, they make me feel safer."*

Katie has heard of autonomous cars being developed but had no idea that there were already autonomous buses in service. She finds the thought a bit unsettling, but believes that once technology is more advanced, using autonomous vehicles will be quite normal. She does expect a safety driver to be on the bus. "*I'd feel a lot safer with a safety driver on board. He could control the system and is simply someone who is there when needed."*

[20] https://cdn.pixabay.com/photo/2018/06/06/10/43/african-3457638_1280.jpg

6.4 Exemplary user stories and their significance for specific personas

6.4.1 User stories regarding the use of a smart phone

As a user, I want to be able to request the shuttle/locate a shuttle/pay for a shuttle without a smartphone so that I don't experience any restrictions

- when my smartphone has a flat battery (Hanna)
- when my smartphone has a broken display (Alex)
- when I have my hands full and can't use a smart phone (Lilly & Lou, Philippe)
- if I don't have or want to use a smartphone at all (Helena, Henry, Carolin & John, Erik).

As a user, I want all information also accessible without a mobile phone (Hanna, Alex, Lilly & Lou, Philippe, Helena, Henry, Carolin & John, Erik).

6.4.2 User stories regarding audio announcements

As a user, I want all audio announcements in the shuttle also displayed on a monitor so that I can perceive them when my hearing is impaired. (Helena)
As a user, I want all audio announcements in the shuttle directly displayed on my phone so that I don't miss them when I am not listening (Alex, Erik, Philippe).

6.4.3 User stories regarding the doors of the shuttle

As a user, I want to be sure that the doors will not close while I am getting on or off the shuttle so that I can feel safe (Henry).
As a user, I want the possibility to request the door to stay open longer, so that I have sufficient time to get on or off the shuttle (Henry).

6.4.4 User stories regarding the braking behaviour of the shuttle

As a user, I want the shuttle to brake in such a way that I will not lose my balance (Henry, Lilly & Lou, Hanna) or spill my coffee (Philippe).
As a road user, I want the shuttle to signal a clearly visible warning before it brakes so that I have a chance to brake as well (Cristina, Manuel, Marcus).

6.4.5 User stories regarding the safety in the shuttle

As a user, I want the possibility to report an issue or ask for assistance so that problems are taken care of (Helena, Charlotte, Erik).
As a user, I want a supervisor in the shuttle, so that I feel safe (Charlotte).
As a user, I want the possibility to reserve a shuttle for myself, so that I feel safe (Charlotte).
As a user, I want the possibility to request a shuttle with a supervisor, so that I feel safe (Charlotte) or get the assistance that I need (Helena).
As a user, I want everyone in the shuttle to show a decent behaviour, so that I am safe (Charlotte, Erik, Hanna).

6.4.6 User stories regarding the interior of the shuttle

As a user, I want storage space, so that I can store my luggage/shopping bags (without obstructing others) (Henry, Lilly &Lou).
As a user, I want space for a rollator, wheel chair or stroller, so that I can use the shuttle at all (Henry, Lilly &Lou).

6.4.7 User stories regarding the availability of the shuttle

As a user, I want an on-demand service, so that I don't have to wait at the bus stop (Fabio, Charlotte, Philippe).
As a user, I want a 24/7 service so that I can use a shuttle service whenever I need it (Fabio, Charlotte)
As a user, I want a door-to-door service so that I don't have to get to the bus stop or get from the bus-stop to the final destination (Helena, Charlotte, Carolin & John, Lilly & Lou).
As a user, I want to be escorted all the way to my front door (Charlotte).

6.4.8 User stories regarding information/entertainment

As a user, I want to be entertained during the bus ride so that I don't feel bored (Alex, Hanna, Erik).
As a user, Iwant to be entertained at the bus stop so that I don't feel bored while waiting (Philippe).
As a user, I want to know the exact time the shuttle will arrive so that I know if there is still enough time to get a coffee (Philippe).
As a user, I want information about local sights in the vicinity of the next bus stop so that I can better explore the city (Bill & Clara).
As a user, I want information about special offers or discounts of sights and shops in the vicinity so that I can use the opportunity to make a good bargain (Bill & Clara).

As a user, I want information in the shuttle displayed with sufficient size and contrast so that I can see it (Bill & Clara).
As a user, I want information in the shuttle displayed in a way so that I can see it from my seat.
As a user, I want information of the shuttle sent directly to my mobile phone so that I will not miss it (Bill & Clara, Alex, Erik).
As a user, I want the announcement of my bus stop sent to my phone so that I will not miss it (Erik, Alex, Philippe).
As a user, I want to select if and what type of information I get sent to my phone so that I only see what really interest me.

6.4.9 Other user stories

As a user, I want to be sure that my shuttle will not take any detours so that I arrive in time (Alex).
As a user, I want a notification when the shuttle has arrived at a destination so that I know that the passenger has arrived (Helena's daughter, Erik's mother).
As a user, I want a possibility to identify my shuttle (without having to use a mobile phone) so that I am getting on the right one (Charlotte).
As a road user, I want to be able to drive at the maximum speed allowed so that I can reach my destination in a reasonable time (Cristina, Marcus).
As a pedestrian, I want other road users to clearly signal to me if they will let me cross the street (Richard).

Annex A: Legal Overview

Annex A gives a brief overview on the related legal requirements for public transport.
Although TSI PRM has its focus on rails vehicles some requirements can easily be mapped to other means of public transport. Therefore, this Annex also has a focus on related rules of the TSI PRM.

The following section is an extract of the TSI PRM [3] Chapter 5:

5. INTEROPERABILITY CONSTITUENTS

5.1. Definition

According to Article 2(f) of Directive 2008/57/EC, 'interoperability constituents' means any elementary component, group of components, subassembly or complete assembly of equipment incorporated or intended to be incorporated into a subsystem, upon which the interoperability of the rail system depends directly or indirectly. The concept of a 'constituent' covers both tangible objects and intangible objects such as software.

5.2. Innovative solutions

As stated in point 4.1 of this TSI, innovative solutions may require new specifications and/or new assessment methods. These specifications and assessment methods shall be developed by the process described in article 6 of the Regulation.

5.3. List and characteristics of constituents

The interoperability constituents are covered by the relevant provisions of Directive 2008/57/EC and are listed below.

5.3.1. Infrastructure

The following items are identified as being interoperability constituents for infrastructure:

5.3.1.1. Displays

(1) Displays shall be sized to show individual station names or words of messages. Each station name, or words of messages, shall be displayed for a minimum of 2 seconds.

(2) If a scrolling display is used (either horizontal or vertical), each complete word shall be displayed for a minimum of 2 seconds and the horizontal scrolling speed shall not exceed 6 characters per second.

(3) Displays shall be designed and assessed for an area of use defined by the maximum viewing distance according to the following formula: Reading distance in mm divided by 250 = font size (for example: 10 000 mm/250 = 40 mm).

5.3.2.1. Interface of the door control device

(1) A door control device shall have visual indication, on or around it when enabled and shall be operable by the palm of the hand exerting a force not greater than 15 N.

(2)It shall be identifiable by touch (for example: tactile markings); this identification shall indicate the functionality.

5.3.2.6. Interface of the call for aid device

A call for aid device shall:

(1) be indicated by a sign having a green or yellow background (according to the specification referenced in appendix A, index 10) and a white symbol, representing a bell or a telephone; the sign can be on the button or bezel or on a separate pictogram;

(2) include tactile symbols;

(3) emit a visual and audible indication to the user that it has been operated;

(4) provide additional operating information if necessary;
(5) be operable by the palm of a person's hand and not require a force exceeding 30 N to operate.
5.3.2.7. Internal and External Displays
(1) Each station name (which may be abbreviated), or words of messages, shall be displayed for a minimum of 2 seconds.
(2) If a scrolling display is used (either horizontal or vertical), each complete word shall be displayed for a minimum of 2 seconds and the horizontal scrolling speed shall not exceed an average of 6 characters per second.
(3) The typeface used for texts shall be easily readable.
(4) Upper Case Letters and numbers used in external displays shall have a minimum height of 70 mm on front displays and 35 mm on side displays.
(5) Internal displays shall be designed and assessed for an area of use defined by the maximum viewing distance according to the following formula:

Area of use of the internal displays for rolling stock

Reading distance	Height of upper case letters and numbers
< 8 750 mm	(reading distance/250) mm
8 750 to 10 000 mm	35 mm
> 10 000 mm	(reading distance/285) mm

The following section is an extract of the Regulation No 107 [2]:

Regulation No 107 [2] of the Economic Commission for Europe of the United Nations (UNECE) — Uniform provisions concerning the approval of category M2 or M3 vehicles with regard to their general construction [2015/922]

R 107 defines PRM as:

> "'*Passenger with reduced mobility' means all passengers who have a difficulty when using public transport, such as disabled people (including people with sensory and intellectual impairments, and wheelchair users, people with limb impairments, people of small stature, people with heavy luggage, elderly people, pregnant women, people with shopping trolleys, and people with children (including children seated in pushchairs).*"

The following section contains an extract of relevant Requirements for persons with reduced mobility:

5. REQUIREMENTS

5.2. Vehicles of Class I shall be accessible for people with reduced mobility, including at least one wheelchair user and one unfolded pram or pushchair according to the technical provisions laid down in Annex 8. In rigid vehicles of Class I the area for the accommodation of a wheelchair may be combined with the area for the accommodation of an unfolded pushchair or pram. In such a case, the area shall

have signs fixed on or adjacent to the area with the following text, equivalent text or pictogram: 'Please give up this space for a wheelchair user'.

7.6.6.4. Inhibition of the automatic closing process on doors marked for special service, e.g. for passengers with prams, passengers with reduced mobility, etc.

7.6.6.4.1. The driver shall be able to inhibit the automatic closing process by actuation of a special control. A passenger shall also be able to inhibit the automatic closing process directly by pressing a special push-button.

7.6.6.4.2. The inhibition of the automatic closing process shall be indicated to the driver, e.g. by a visual tell-tale.

7.6.6.4.3. Re-establishment of the automatic closing process shall in any case be capable of being done by the driver.

7.6.6.4.4. Paragraph 7.6.6.3 above shall apply to the subsequent closing of the door.

Annex 8 ACCOMMODATION AND ACCESSIBILITY FOR PASSENGERS WITH REDUCED MOBILITY

3.2. Priority seats and space for passengers with reduced mobility

3.2.1. Seats shall be either forward or rearward facing and shall be situated in a position near to a service door(s) suitable for boarding and alighting and compliant with paragraph 3.1 above.

3.2.2. There shall be adequate space for a guide dog under, or adjacent to, at least one of the priority seats. This space shall not form a part of the gangway

3.2.8. Vehicles fitted with a priority seat shall have pictogram(s) in accordance with Annex 4, Figure 23B visible from the outside, both on the front nearside of the vehicle and adjacent to the relevant service door(s). A pictogram shall be placed internally adjacent to the priority seat.

3.3. Communication devices

3.3.1. Communication devices shall be placed adjacent to any priority seat and within any wheelchair area and shall be at a height between 700 mm and 1 200 mm above the floor.

3.3.2. Communication devices situated in the low floor area shall be at a height between 800 mm and 1 500 mm where there are no seats.

Annex B: Interview guideline safety operator

Interview Guideline Security Drivers

Document: WP2 Interview Guideline Security Drivers
Version: 1.0
Language: English
Date: 2019-07-03
Authors: Linda Mathé, Siemens AG
Markus Dubielzig, Siemens AG
Matthias Lindemann, Siemens AG

Introduction and Consent

Dear security driver,

- The AVENUE project wants to learn more about the acceptance and usability of autonomous shuttles.
- As you have direct contact to passengers and experience their reactions, open questions, requirements and problems every day, we would ask you to tell us about your impressions and experiences. We have prepared some questions for you.
- You can rely on us to treat your data confidentially. Under no circumstances will your name be disclosed. Your answers will only be used in anonymous form and will not be stored together with your name.
- After the survey, the data are only considered in aggregated form – i.e. together with all other surveys. They are used by the project partners for the further development of future offers in public transport.

0. Agreed to consent:

☐ yes ☐ no

Questions

1. What is your impression: how is the acceptance of the autonomous shuttle?

_____
_
_____
_
_____
_
_____
_

2. Are there occasions when more people use the shuttle?

_____
_
_____
_
_____
_

3. How do you estimate the age distribution of the passengers?
_____% youngsters and young adults (-25)
_____% passengers between 26 and 65
_____% generation 65+
_____
_
_____
_
_____
_

4. Estimate: what percentage of passengers use the shuttle to get to a specific destination and what percentage just want to take a ride and try the shuttle?
_____% want to get to a destination
_____% just take a ride
_____
_
_____
_
_____
_

5. Do your passengers often talk to you?
What do they talk about? What questions do they ask?
_____
_____
_____
_____
_____
_____

6. What do passengers like about the shuttle?
What don't they like? Do they complain about something?
_____
_____
_____
_____
_____
_____

7. What wishes and requests do your passengers express? Do they express worries or fears?

_____
_____
_____
_____
_____
_____

8. In which situations do you need to help your passengers?

_____
_____
_____
_____
_____

9. How do passengers react to technical problems of the shuttle?

_____
_
_____
_
_____
_
_____
_

10. Do passengers experience any problems when getting on or off the shuttle?

_____
_
_____
_
_____
_
_____
_

11. What do passengers do during the ride? (e.g., talk to you/each other, look out the window, listen to music, use their mobiles...)

_____
_
_____
_
_____
_
_____
_

12. Has there ever been a dangerous situation?

_____
_
_____
_
_____
_
_____
_

13. What was your funniest experience on the shuttle?

_____
_
_____
_
_____
_
_____
_

14. Which three things about the shuttle would you like to have changed?

_____
_
_____
_
_____
_
_____
_
_____
_

Thank you very much for your time!

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