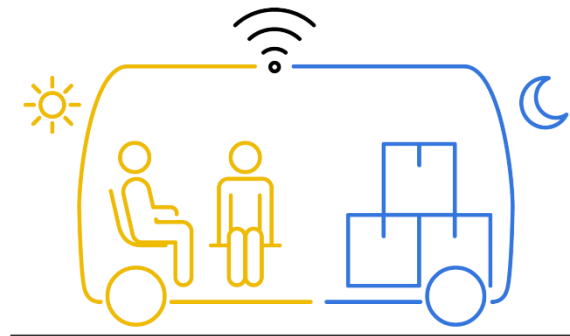




ULTIMO

Mobility with Automated Vehicles

DELIVERABLE

D2.1 Passenger and PTO Requirements, Needs, and Use Cases



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Acronyms

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

SAN	(Swiss) Cantonal Vehicle Service
SDK	Software Development Kit
SLA	Sales Lentz Autocars
SMB	Site Management Board
SoA	State of the Art
SOTIF	Safety Of The Intended Functionality
SWOT	Strengths, Weaknesses, Opportunities, and Threats.
T7.1	Task 7.1
TM	Technical Manager
TPG	Transport Publics Genevois
UITP	Union Internationale des Transports Publics (International Transport Union)
V2I	Vehicle to Infrastructure communication
WP	Work Package
WPL	Work Package Leader

Executive Summary

The project's ultimate goal is to create a large-scale, well-accepted, seamless-integrated and economically viable AV-based public transport service across diverse European regions. To achieve this goal, understanding stakeholders' needs is crucial. Within the scope of Work Package 2 (WP2), our central focus is the exploration of passenger and Public Transport Operator (PTO) requirements.

Deliverable 2.1 contributes to this goal by defining essential requirements and use cases, and aligning user needs with the development of AV-based transport system. We achieve this through active engagement with passengers and key stakeholders to collaboratively define use cases. This includes Public Transport Operators / Authorities (PTO/PTA), manufacturers, fleet managers, and passenger groups that express their public transport needs and potential solutions.

Deliverable 2.1 adopts a structured approach that involves the following key elements for passenger services:

Persona Creation: We create user personas representing different profiles to ensure understanding of user needs. These personas serve as representations of our passengers and enable us to gain an understanding of their diverse needs and expectations.

Journey Mapping: We outline the entire user journey, from the process of informing oneself to post-trip feedback. Journey mapping allows us to identify touchpoints where user interactions with the system can be enhanced.

Requirements Gathering: The input is gathered from various sources, including Public Transport Operators (PTOs/PTAs), potential users, ULTIMO project partners, and other relevant EU projects like AVENUE and INDIMO. This collaborative approach ensures that we capture a comprehensive set of requirements that enables us to align project objectives with real-world demands.

Vehicle Capability Identification: We match identified vehicle capabilities with the user requirements we've gathered. This process bridges the gap between what users need and what autonomous vehicles can deliver.

The deliverable forms the foundation for subsequent exploration and will contribute to future project deliverables that will consider the specific characteristics of the ULTIMO pilot sites and assess the feasibility within the project. As the project evolves and we gain further insights, the gathered requirements will be revised to ensure that they remain in alignment with the project's evolving priorities.

1 Introduction

During the past few years many projects and initiatives were undertaken to deploy and test Automated Vehicles (AVs) for public transportation and logistics. In spite of their ambition, all these projects have remained at the level of elaborated experimentation and have never reached the level of a large-scale commercial deployment of transport services. The reasons for this are many, the most important being the lack of economically viable and commercially realistic models, the lack of scalability of the business and operating models, and the lack of user-oriented services required for large end-user adoption of the solutions.

The ULTIMO project will create the very first economically feasible and sustainable integration of AVs for MaaS public transportation and LaaS urban goods transportation. ULTIMO aims to deploy in three sites in Europe 15 or more multi-vendor SAE L4 AVs per site. A user centric holistic approach, applied throughout the project, will ensure that all elements in a cross-sector business environment are incorporated to deliver large-scale on-demand, door-to-door, well-accepted, shared, seamless-integrated and economically viable CCAM services. We target the operation without safety driver on-board, in a fully automated and mission management mode with the support of innovative user centric passenger services.

ULTIMO's innovative transportation models are designed for a long-term sustainable impact on automated transportation in Europe, around the globe and on society. The composition of the consortium ensures the interoperability between multiple stakeholders by making adoption of new technology at minimum costs and maximum safety. The integration of the ongoing experiments of previous AV-demonstrator projects ensures highest possible technical and societal impacts from the very beginning of the project, as well as during the project lifetime and even long after its completion.

2 On-demand Mobility

Public transportation is a key component 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. On-demand transport necessitates both ride-sharing

and seamless integration with established public transportation systems and other complementary public transport services. An operator or an automated system takes care of the booking, planning and organization.

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

2.1 Fully Automated Vehicles

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

The terms *automated vehicles* and *autonomous vehicles* are often used together. The Regulation 2019/2144 of the European Parliament and of the Council of 27 November 2019 on type-approval requirements for motor vehicles defines "automated vehicle" and "fully automated vehicle" based on their autonomous capacity. An "automated vehicle" means a motor vehicle designed and constructed to move autonomously for certain periods of time without continuous driver supervision but in respect of which driver intervention is still expected or required. "Fully automated vehicle" means a motor vehicle that has been designed and constructed to move autonomously without any driver supervision. In ULTIMO we operate **Fully Automated mini and micro shuttles for shared public transportation**. In relation to the SAE levels, the ULTIMO project will operate SAE Level 4 vehicles.



SAE J3016™ LEVELS OF DRIVING AUTOMATION

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

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

3 The ULTIMO Dream for Public Transportation

Our city has a population of 700.000, and the local PTO (Public Transport Operator) operates 3.000 km of public transportation services' routes, with 4 backbone tram lines, 8 backbone large bus/trolley lines, and 340 fully automated multi-manufacturer mini and micro-shuttles in an on-demand, door-to-door shared public transport service. The fleet of the 340 automated mini-busses is composed of different vehicle generations and models from different manufacturers, as it was purchased in different batches during the last 12 years (it all started with the first 15 bought by a European project in 2023/24). It is today composed of the first 15 twelve-years old vehicles from manufacturer A, 160 eight-years old vehicles from manufacturer B and 160 two-years old vehicles from manufacturer A, which are the new generation of manufacturer's A vehicles. These last 160 vehicles re-placed the last 70 old, driver based, thermic busses that reached the end of their life after 18 years in operation. The change from driver large busses to automated mini-buses and from fixed line service to on-demand, door-to-door, for the last area of the city, was decided 6 years ago, and was based to the great success of the already deployed AV-based services in the other parts of the city.

The integration of new vehicles in the PTO fleet was done within just a few days, thanks to the now standardised APIs of the automate vehicles' connection with the AV fleet management and orchestration service, that allows a plug-and-operate functionality, but also enables the combination of AVs with all other means of transport, offering a seamless citizen centric journey to the users. Similarly, the now standardized High Definition (HD) maps between the vehicle manufacturers, allows us to reuse the maps created in the past for the 3.000 km of routes of the city, with small adaptations for the new vehicle capabilities. At the same time of the purchase of the last 160 AVs, we also switched to a new AV fleet management and orchestration service, from another provider, which offers more precise trip time estimations, considering also traffic jams in the city and weather conditions (that affect traffic in the city). The replacement was made within just two weeks, thanks to the new standardised interfaces between AV fleet management and PTO MaaS services.

Passengers are now able to reserve, via their mobile phone app, on the fly or with pre-reservation trips from one side of the city to another, using the optimal transport mode available for them, with a combination of different transport modes, and having the automated vehicle arriving next (or almost) to their door entrance and bringing them to their final destination or to a backbone transport connection. All trips are offered with highly reliable and accurate transport and arrival times, based on real time, dynamic route changes of the vehicles, responding to the passenger needs. Many passenger services are available in the AVs via a mobile phone app, adapted to all passengers' needs, from special needs passengers (visually impaired, wheel-chair users, pregnant women, elderly, children), to persons transporting suitcases or a baby-stroller, providing adapted information of their trip (where to get-off, PTO general information, and even infotainment, like city related information and historical facts and anecdotes, related to their current position).

With the full suppression of on-board operators, automated in-vehicle monitoring provides a multitude of passenger services, which were, and are developed with a continuous collaboration and innovation between users and the PTO. An on-board unit identifies locally (that is, in the bus) incidents and events, like aggressions, vandalism, forgotten objects, littering, accidents, etc., and raises incident alarms to the PTO back-office. The PTO officer at the back-office evaluates the incident and decides, based on the operator policies, what action to take: dismiss the incident, or stop the vehicle and call one of the intervention teams to go to the vehicle and take the required action. The back-office operator, based on the number of incidents and intervention time legal obligations, can deploy any of the 15 intervention teams available in the city, ready to reach within a few minutes any AV. At the back-office, service operators are able, with one set of screens linked to the fleet management, to follow the vehicle status, trip reservations, routes chosen, open and closed road segments (due to works, accidents, etc. thus adapting dynamically the trip routings), while in a second set of screens, the back-office operators can follow the passenger services' incidents and the status and location of the intervention teams. The two systems, although independent, are linked so that the back-office operator can transfer incidents to intervention teams and turn-on, when possible and under the local legal restrictions, video connection to inspect the incident.

The public transport services are operating 24/7 with different active vehicles, depending on passenger transport demands. The PTO, being eco-sensible, has defined that the vehicle must have an average occupancy of at least 3 passengers. This of course has implications, especially in off-peak hours, in the transport delays, but it is fully justified for an optimal and eco-responsible operation. Exceptions are made for people with special needs or when the passenger is ready to pay an additional price.

While at peak-hours the full 340 strong fleet of AVs is in service for public transportation, in the off-peak and night hours, due to the reduced transportation needs, part of the fleet is not serving passenger transportation. However, because having a vehicle waiting idly is a waste of resources, the PTO has signed an agreement with Logistics as a Service (LaaS) Service providers. During the off-peak hours the unused vehicles are dynamically chartered by the different LaaS providers to be used for other types of incidental transport of goods or even non-public transportation of passengers. Local shops and enterprises use the service, on demand with dynamic reservation, to offer home delivery of on-line purchases, or B2B delivery of goods from an urban consolidation centre to the distribution centre (hub, many to one or one to many, or even transport their VIP customers directly to their offices or exposition centres. This way they can deliver the goods to their customers in the city, with a delay of just 60 minutes with affordable prices, as the last mile is the most inefficient part of the goods delivery chain. The goods send can include books from local bookshops or libraries, supermarket bags or even documents exchanged between companies or waste. The local shops are even using the service in the early hours (5 o'clock in the morning) for re-provisioning their shops for the day. The so chartered AVs are "returned" to the PTO for public transport at the peak-hours automatically, at the end of the chartered time period.

4 Preamble – Passenger and PTO Requirements

Within the framework of Work Package 2 (WP2), our primary focus revolves around the exploration of passenger and PTO requirements. We aim to understand and define use cases through a co-creation process that actively engages passengers and public transport experts as well as other relevant stakeholders.

The objectives of WP2 can be summarized as follows:

- Engage passengers and users in autonomous mobility to ensure their input and perspective
- Create a passenger-centric, accessible on-demand public transport system for all, addressing diverse mobility patterns and social groups
- Improve travel comfort, trustworthiness, and safety throughout the journey, from planning to reaching the destination
- Enhance mobility for passengers, especially those with limited access to public transport
- Emphasize user interaction with mobility services and vehicle interaction with the environment, including testing new technologies like sensors, connectivity, AI, and addressing vulnerable road users
- Promoting PTO and PTA needs for on-demand transport and autonomous vehicles
- Proactively communicate passenger requirements to other project work packages and evaluate their implementation.

Deliverable 2.1 provides an overview of the relationship between passenger and PTO requirements, needs, and the operational capabilities of automated driving vehicles. It focuses on aligning the demands of real users with the evolution of automated transportation services. The process involves user engagement, persona development, and mapping the User Journey. We introduce personas that represent different user profiles to ensure the understanding of user needs. The deliverable takes a step-by-step approach by outlining the User Journey from the moment a user decides to embark on a trip until they disembark and review their experience. Next, we present the requirements gathered from PTO/PTAs, users, project partners and related EU projects. Once user requirements are established, the deliverable shifts its focus to identifying which vehicle capabilities are necessary to meet these requirements.

This initial version of the deliverable establishes a baseline and represents an initial, generic exploration without specific ties to pilot sites. Subsequent iterations of this deliverable will delve deeper into specific details and consider the unique characteristics and constraints of pilot sites. This more detailed version will be significant for assessing feasibility, limitations, and contextual factors.

5 Passenger and PTO Requirements, Needs and Use Cases

To follow a citizen-centric approach, it is essential to prioritize user experience and accessibility. Providing access to public transport for all individuals, including those who are vulnerable, who have disabilities or special needs, is both a human right and a legal requirement in Europe and its member states. To achieve an accessible user experience that meets the needs of all passengers, including those who are potentially vulnerable, we are utilizing the human-centered design process for interactive systems (ISO 9241-210). We are also ensuring that relevant stakeholders, including younger and older persons and their families, are involved in the project from the requirement phase onward, with disabled colleagues as part of the project team to ensure continuous reflection on user needs. In addition to building on existing research, such as that conducted by AVENUE, we are conducting further user research, including interviews, site visits, workshops, evaluations, and data science measurements, to ensure that our approach is fully informed by user perspectives. We will also examine the extent to which new services impact the daily use of public transportation and which passengers benefit most. To ensure that user needs are fully understood and implemented, we will conduct co-creation workshops (T2.5) and trials with relevant stakeholders, including PTOs, manufacturers, fleet managers, and passenger groups involved in the demo sites.

A use case refers to a specific situation to which we want to address specific need/requirements to achieve a desired outcome. It describes the interactions between users (individuals or entities) and the system or product to accomplish a specific goal or task. Use cases are often used in software development, project management, and system analysis to capture and document functional requirements. They provide a detailed depiction of how users will engage with the system, outlining the steps involved and the expected results. Use cases are valuable tools for understanding, analysing, and designing systems or products to ensure they meet the intended objectives and user requirements.

6 Personas

A persona is a hypothetical user archetype that can be used to help guide decisions about product features. By designing for the archetype whose goals and behaviour pattern are well understood one can satisfy the broader group of people represented by that archetype. A persona is not a real person but based on data of a real person. In most cases, personas are synthesized from a series of interviews with real people and captured in a description that includes behaviour patterns, goals, skills, attitudes, and environment, with a few fictional personal details to bring the persona to life.

Personas are a tool for understanding user needs, differentiating between different types of users and prioritizing which users are the most important to target in the design.

The ULTIMO personas are based on personas from the predecessor project AVENUE¹ where they were developed from interviews with public transport passengers, users of automated public transport, safety operators in pilot sites, bus drivers, etc.

The AVENUE personas were now reviewed and refined based on input by the ULTIMO PTA/PTOs, interviews with drivers of DRT services, as well as interviews with users of currently operated DRT services.

The age structure of the personas is divided into three groups: young (under 30), middle-aged (30-42) and older (58 to 82). Each group is represented by four personas.

There is a gap between 42 and 58 years. This reflects the age distribution of the participants who responded to our call for interviews and those who we met on site. Another reason for this gap is the fact that special needs particularly occurred among younger and older people.

Disabilities and Impairments often come with age, which is why the older age group leans toward 60+

Hanna, 14



¹ Further information within the AVENUE deliverable D2.18 available at this web-address: <https://h2020-avenue.eu/wp-content/uploads/2023/03/D2.18-Final-trials-use-cases-specification-and-evaluation-plan.pdf>

Figure 1: Picture of Hanna ²

Life's a game, and even with a crappy phone, I'm winning with my friends on the bus!

Specific Needs: Limited attention, old phone with weak battery

Desires: Connect with friends, have fun during the bus ride, be part of the group activities

Pains: Old phone with weak battery

Gains: Bonding with friends, enjoying social interactions, bus rides like a party

Baggage/Equipment: School backpack, outdated mobile phone

Scenario: Hanna 14 years old 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. She only has her father's old phone, which has a weak battery that usually doesn't even last all day.

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, for them the bus ride is an essential opportunity to connect with each other and have fun.

² https://cdn.pixabay.com/photo/2017/04/19/15/50/girl-2242668_1280.jpg

Helena, 74



Figure 2: Picture of Helena ³

These taxi drivers charge an arm and a leg.

Specific Needs Limited mobility, hearing impairment

Desires: Accessible and affordable transport that considers mobility and hearing needs

Pains: Difficulty with mobility and hearing, reliance on others for assistance, limited affordable transportation options

Gains: Independence, reliable and convenient transportation, improved access to medical appointments and daily activities

Baggage/Equipment: Walking aids, hearing aids, senior phone

Scenario: Helena 74 years old struggles with the challenges of her limited mobility and hearing impairment. She has no relatives in her immediate vicinity, so she has no one to drive her to her regular doctor's appointments. She used to take the bus, but this is too tiring for her because she must change buses twice to get to the doctor's office. That leaves the taxi as her only choice.

Helena books the taxi for the way there in advance from home. Unfortunately, this is not possible for the return journey, as she never knows how long she will have to wait. When she's finished at the doctor's, she orders a taxi back with her senior mobile phone which was a gift from her daughter. She uses it very reluctantly because she finds it difficult to use. If she

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

is lucky, the staff at the doctor's office will call her taxi and she can sit in the waiting room until it arrives.

Many taxi drivers are very nice. They help her in and out of the car. 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 she sees no other option.

Mary, 29



Figure 3: Picture of Mary ⁴

Life took my sight, but it couldn't take my independence. Navigating my world, my way.

Specific Needs: blind

Desires: Uncompromised independence, navigating the city without external assistance.

Pains: The fear of being reliant on others for navigation, the frustration of inaccessible public transportation options, using the white cane and carrying the bags at the same time

Gains: Empowerment through technology, confidence in using public transport independently, peace of mind knowing essential features are at her fingertips.

Baggage/Equipment: Mobility aid (white cane), smartphone with accessible app.

⁴ https://cdn.pixabay.com/photo/2017/08/01/09/41/people-2564026_1280.jpg

Scenario: Mary 19 years old became blind after an accident. After this serious change in her life her parents always patronized her, which totally annoyed her. Today she wants to be as independent as possible thus she does not accept unrequested 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 use the bus's passenger information system but uses her accessible app. There is a new onboard feature that was rolled out to all buses last month. Via her accessible app, her phone links to buses, guiding her to the right line and entrance of the bus. Onboard, she receives notifications for next stops, connections, and roadwork, plus the ability to request a stop or make an emergency call, especially at night. Mary never has tried driverless vehicles but is very interested in this development and expects a huge improvement in mobility for blind passengers like her.

Carlo, 62

Figure 4: Picture of Carlo⁵



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

Specific Needs: Partially sighted, white cane user

Desires: Coming to work by bus without being disturbed by loud passengers and reliable information on stops and travel times.

⁵ https://cdn.pixabay.com/photo/2016/07/10/23/01/hamburg-1508736__480.jpg

Pains: Noisy or disruptive passengers, lack of passenger announcements

Gains: Independence, social interactions, well-timed connections

Baggage/Equipment: White cane, smartphone, monocular

Scenario: Carlo 62 years old 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 so that other road traffic participants can recognize his disability. He relies on the bus for work, using a white cane to get around. He prefers to get to work and home early to avoid crowds and loud passengers, especially young people with loud music or rowdy soccer fans who are drunk and sing loudly.

Carlo always tries to get a seat near the driver to talk about the latest news in the city. Most bus drivers already know him well. To get to his workplace he must switch buses once. Carlo likes to use his smartphone to keep an eye on the travel time because he does not want to miss the connecting bus. Switching buses takes some time because he must find the right bus with his monocular. Some drivers know him so well that they tend to call his connecting bus on their own, telling the other driver to wait, as Carlo will arrive soon. Sometimes they also give him instructions on where to find the connecting bus.

Carlo has been in trouble once: On the way home the passenger information system on the bus crashed thus there were no announcements of the stops anymore. He lost orientation because, 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 with the help of some other passengers he finally managed to leave the bus at the right stop. Carlo has never used a fully automated bus but has used a self-driving 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.

Chloe, 32



Figure 5: Picture of Chloe ⁶

I would like to be perceived like any other person, but the wheelchair makes me the center of attention every time.

Specific Needs: in a wheelchair

Desires: Smooth and accessible bus travel

Gains: Increased independence through technology, confidence in using public transport, improved accessibility

Baggage/Equipment: Wheelchair, sometimes a bag

Scenario: Chloe 32 years old has been relying on a wheelchair since childhood due to a rare disease. Nevertheless, she wants to be independent and go to all the places where her friends go. Since she can't drive a car, she uses public transportation regularly to get to vocational school or to meet her friends. Due to her disease, she also lacks endurance and can only cover short distances on her own. Therefore, she is grateful for any help she gets but she is very introverted and shy and rarely dares to approach people and ask them if they can help her. As the disease continues to progress, there is a very high probability that she will have to switch to an electric wheelchair in the future.

⁶ <https://pixabay.com/photos/woman-beauty-face-portrait-facial-3289372/>

When she rides the bus, the wheelchair seat is often occupied, and she must send people away who are sitting there. This is unpleasant for her every time, because she doesn't want to inconvenience anyone. During the trip it is especially important to her to be well secured and to be able to get off the bus quickly, because she does not want to delay the bus traffic unnecessarily. She thinks there is already too much attention on her and she would prefer to draw as little attention to herself as possible.

Ned, 58

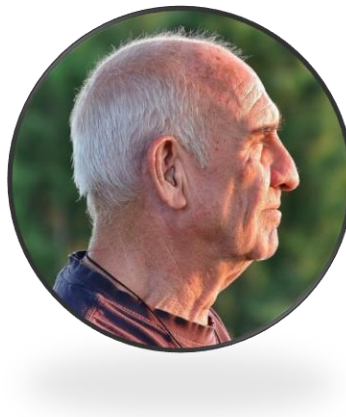


Figure 6: Picture of Ned ⁷

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

Specific Needs: Motor impairment

Desires: Improved accessibility at bus stops, efficient rural transportation, on-demand service

Pains: Mobility challenges, limited bus frequency, weather impact on commuting

Gains: Mobility, connectivity to work, hope for enhanced rural transportation

Baggage/Equipment: Walking aids

⁷ https://cdn.pixabay.com/photo/2017/08/14/21/19/senior-2642030_1280.jpg

Scenario: Ned 58 years old lives with his wife in a small village. He works in the nearby town, which is roughly a 30 km drive. He used to enjoy driving his own car, but after his accident he can't fully move his leg anymore. So, he turned into a public transport user.

The next and only bus stop of the village is in the center. Using his walking aids, it takes him about 15 minutes to get there. Due to his impairment, he needs a bit more time than the younger generations to get on the bus. Ned prefers to get a seat, if possible, with a cane holder, where he can fixate his walking aids. For the trip to his office, Ned must change buses once. While the bus leaving his village runs only once an hour, the connecting bus runs much more often. If everything goes well, the trip is about one hour and 15 minutes. But if he misses the connection on the way home, he must wait for an hour.

Ned is technology affine thus he dreams of an on-demand service with driverless vehicles. "This would definitely make living in a village more attractive – also for young families. It would allow an on-demand connection to the city center, and there could be much more stops in our small village." The only thing that he is afraid of is that hackers might hijack a driverless vehicle.

Fabio, 19



Figure 7: Picture of Fabio ⁸

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

Specific Needs: dependent on public transport at night

⁸ https://cdn.pixabay.com/photo/2017/04/04/17/56/people-2202474_1280.jpg

Desires: Reliable and affordable way to get home after partying

Pains: Limited options for transportation at night, discomfort when sharing public transport with drunk passengers but taxis are too expensive

Gains: Enjoying late-night parties without transportation worries, finding convenient solutions to avoid drunk driving

Baggage/Equipment: Phone

Scenario: Fabio 19 years old is a self-proclaimed night owl who loves partying at clubs. After enjoying a night full of dancing and fun, he faces the challenge of finding a way to get back home. The night bus in this part of town runs hourly, that just never really works. A taxi would be convenient, of course, but Fabio doesn't have that much money, and he prefers to spend his money in the club rather than for a taxi. Sometimes Fabio arranges carpooling with his friends to share the responsibility of getting home. However, this solution isn't always feasible, as it is difficult to find a driver who says they don't drink and then sticks to their promise. Fabio's desire is to maintain the excitement of the night without being burdened by transportation issues. He's on the lookout for affordable alternatives that allow him to enjoy his night out to the fullest and get home safely.

Carolyn & John, 77 & 82



Figure 8: Picture of Carolyn and John ⁹

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

⁹ https://cdn.pixabay.com/photo/2016/05/14/08/51/seniors-1391561_1280.jpg

Specific Needs: Limited mobility, assistance needed, accessible transport

Desires: Convenient and easily accessible transportation, support for reaching the bus stop

Pains: Long distance to the bus stop, challenges in mobility, reliance on others for assistance

Gains: Independence, reliable transportation, social interactions

Baggage/Equipment: Walking aids, shopping bags

Scenario: Carolin 77 years old and John 82 years old live in their own little house in the countryside. Carolin never had a driver's licence, and John stopped driving after his stroke last year. So they rely on public transport for their daily tasks and social activities.

The nearest bus stop is 1.5 km away from their home and as walking becomes increasingly difficult, it is a challenge to reach it. The worst part of the tiring journey to the next town is the return trip with the shopping bags, especially the boarding and disembarking. Carolin has to take care of the shopping and assist John to get on and off the bus. She finds it works best when she first puts the bags in the light barrier so the doors can't close and then helps John. Last month, it happened exactly as they always feared: the shopping bags fell over and no longer blocked the light barrier and the doors closed with all the bags inside while they were standing outside. Luckily a friendly young man helped them and opened the doors again. But ever since this incident they feel even more insecure when using the bus.

They wish for a more suitable transport option: a close bus stop and sufficient time for boarding and disembarking.

Lilly & Lou, 33 & 2



Figure 9: Picture of Lilly and Lou ¹⁰

“When they invented public transport, they sure didn’t think about us mothers!”

Specific Needs: no hand free and very challenged to manage child, stroller and shopping bags

Desires: Effortless and accessible public transport experience

Pains: Handling a tired and energetic child, managing shopping bags and a stroller, lack of assistance on public transport

Gains: to be able to use public transport for necessary everyday things for reasons of cost

Baggage/Equipment: Toddler's stroller, shopping bags

Scenario: Lilly 33 years old 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 help 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, so it is worth it for Lilly to buy large quantities.

¹⁰ https://cdn.pixabay.com/photo/2019/08/01/13/22/mom-and-daughter-4377491_1280.jpg

When she picks up her daughter, usually around 11am, she carries all her 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 when Lilly wishes she had her own car.

Philippe, 24

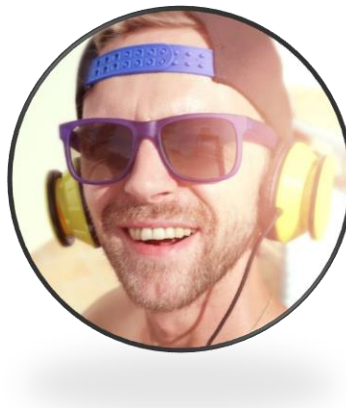


Figure 10 Picture of Philippe ¹¹

"Late mornings, loud music, and coffee – my daily bus adventure!"

Specific Needs Limited attention because he listens to music through headphones, does not have his hands free because he carries a laptop case and a coffee mug

Desires: Improved punctuality for his university commute, enjoyable ride including coffee and loud music

Pains: Frequently being late due to getting up late, challenges in carrying coffee and laptop

¹¹ https://cdn.pixabay.com/photo/2019/04/26/21/06/man-4158696_1280.jpg

Gains: Enjoying music during the commute, flexible departure times, staying updated with onboard information screens

Baggage/Equipment: Carrying a laptop case and coffee-to-go

Scenario: Philippe 24 years old 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 makes it to the bus stop early enough, he can get a coffee-to-go from the Kiosk near the bus stop which makes his start in the day much better. When the bus arrives, he juggles his laptop case, coffee-to-go, and belongings while boarding.

Philippe hates that he misses the bus so often. He swears that sometimes they even leave too early. Every time he misses the bus, he is annoyed that he doesn't have his own car which would offer him more flexibility. Listening to his music helps him to deal with all this trouble in 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. Public transport on demand 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."

Katie, 31



Figure 11: Picture of Katie ¹²

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

Specific Needs: Data privacy concerns, hygiene

Desires: efficient and hassle-free mobility in the city with little effort on efficient routes using clean public transport and feeling safe

Pains: Overcrowded subways, dirty and littered stations/cars, feeling unsafe during late hours

Gains: to avoid the disadvantages of a car in the city, like parking or traffic jams, but also the disadvantages of most public transports

Baggage/Equipment: Mobile phone, shopping bags

Scenario: Katie 31 years old lives in a city resident, swaps her car for public transit in the bustling city centre. She takes the subway to go downtown for shopping and meeting friends. If a soccer game, a concert, or another big event takes place in the city, she rather reschedules her plans than ride in an overcrowded subway with partying fans. During her 20-minute journey to the city centre, Katie checks the timetable on her mobile phone to optimize her

¹² https://cdn.pixabay.com/photo/2018/06/06/10/43/african-3457638_1280.jpg

route. She wants to avoid changing trains or to the bus. She rather walks a longer distance than having to change or risk being stuck in traffic on a bus.

Data privacy concerns keep her from using the public Wi-Fi on the subway.

She hates dirty stations and littered subway cars. Late-night travel with few other passengers makes her uneasy, valuing surveillance cameras for safety.

Aware of automated cars, she's surprised by existing automated buses. Curious yet cautious, she envisions a future with fully automated vehicles but insists on a safety driver in a shared shuttle bus for comfort.

Eva, 42



Figure 12: Picture of Eva

"Two electric bikes, two cars, two kids - time for downsizing our vehicle fleet, balancing convenience and environmental consciousness"

Specific Needs: Convenience based on time, perceived cost and 'feel good' environmental factors. Carries groceries several times a week.

Desires: Wants to be more environmentally conscious. Not opposed to trying new things or downsizing if it's convenient enough to do so.

Pains: No significant pains. Accustomed to multiple mobility choices and can choose the best option. Lack of affordable parking and rush hour delays means the family use their cars rarely in the city centre. Bad weather can prohibit bike use.

Gains: Time efficient and convenient mobility are necessary gains. Daily commute is not a social time for Eva and allows for a little 'alone time'.

Baggage/Equipment: Laptop bag and coat. After work: travelling with two children, food shopping and sometimes luggage for the cabin.

Scenario: Eva 42 years old lives with her partner and two children in the suburbs and has an office job in the city centre. The two each have a driver's license and together they own 2 cars and 2 electric bikes. In good weather, Eva prefers using an electric bike for commuting to work in the city centre. Otherwise, the subway is just a 5-minute walk from her house. She never uses her car for her daily commute because it takes longer during rush hours, and she doesn't have a parking space. Additionally, she's unwilling to pay for downtown parking. Her electric car primarily serves for leisure activities with her children in the area and for trips to the grocery store. Otherwise, they use cars sparingly during weekdays, and always the electric one. The diesel car is used for cabin trips during the weekend, or if different trips coincide -but that's rare.

7 PTO/PTA Use Cases

PTA stands for Public Transport Authority. It is a government or regulatory body responsible for overseeing and regulating public transportation services within a specific jurisdiction. The PTA sets policies, regulations, and standards for public transport operations, ensuring safety, efficiency, and quality of service. The authority may be responsible for issuing licenses to Public Transport Operators, managing contracts and subsidies, planning routes, coordinating services, and monitoring compliance with the established guidelines. A “heavy weight PTA” responsibility includes customer relationship, payments, customer interfaces, overarching customer service and accountability for quality of service across multiple transport services and modalities.

PTO stands for Public Transport Operator. It refers to a company or organization that operates and manages public transportation services, such as buses, trains, trams, or ferries. Public Transport Operators are responsible for running the day-to-day operations of the transportation system, including scheduling, maintenance, staffing, and transportation centric customer service. They may be privately owned, government-owned, or a combination of both, depending on the jurisdiction and the specific arrangements in place.

In summary, the main difference between PTO and PTA in the context of public transport is that PTO refers to the company or organization operating the transport services, while PTA refers to the government or regulatory body responsible for overseeing and regulating those

services, usually on behalf of the city or regional government. Customer relationship responsibility is partly split between the two.

In the realm of fully automated on-demand transportation, Passenger Transportation Operators (PTOs) and Passenger Transportation Authorities (PTAs) understand the critical importance of various aspects to deliver a successful service. Safety and regulatory compliance take precedence, as PTOs and PTAs prioritize the well-being of passengers and adhere to all necessary regulations and standards, ensuring a secure and reliable transportation experience.

Efficient demand and fleet management is crucial for PTAs, who focus on optimizing multiple and diverse fleet(s) for the overall citizen mobility within a city/area. While PTOs focus on vehicle allocation, charging, maintenance, and dispatching systems to meet passenger demand effectively and ensure smooth operations. Managing vast amounts of passenger data responsibly is a priority for PTOs and PTAs, who implement robust data management and security measures to protect sensitive information and leverage insights to enhance service quality.

An inclusive approach is embraced, as PTOs and PTAs aim to cater to passengers of all abilities, providing accessibility features and user-friendly interfaces, fostering an environment where everyone can comfortably access the service. Compliance with transportation regulations and reporting requirements is emphasized, with transparent record-keeping and timely reporting to regulatory bodies as part of their commitment to a well-regulated service. Customer support and effective communication are paramount, with PTOs and PTAs offering reliable assistance channels and keeping passengers informed throughout their journeys, ensuring a positive experience. Forming partnerships with various stakeholders, such as technology providers and city authorities, enables PTOs and PTAs to create a comprehensive and integrated fully automated transportation ecosystem. Environmentally friendly practices are embraced, with PTOs and PTAs exploring options like electric or low-emission vehicles to reduce the service's environmental impact and contribute to sustainability.

Flexibility and scalability are valued traits, allowing PTOs and PTAs to adapt to changing market demands, expand their service coverage, and accommodate more passengers as the service grows. Continued innovation and improvement are driving forces for PTOs and PTAs, as they stay at the forefront of the fully automated on-demand transportation industry, seeking new opportunities to enhance their offerings and operations.

7.1 User Journey and Use Cases

A User Journey contains all experiences a person has when interacting with a product or a service. This idea is generally used in service design, user experience design, web design etc. to focus on how users interact with the product/service.

User Journeys are focused on the user and what they see and what they do. They describe at a high level of detail exactly what steps users take to complete a specific task within a system or service.

In ULTIMO, the User Journey identifies the key interactions that the user has with the service, and it helps us to better understand the touchpoints that need to be considered to create a positive user experience with our ULTIMO services.

The following is a description of the entire User Journey. The specific characteristics of the ULTIMO pilot sites or the feasibility within the project are not considered. In the further course of the project, we will distinguish what is covered by the pilots and what will be explored for future projects and implementations beyond ULTIMO.

The User Journey described here is based on the Customer Journey developed by Ruter and was supplemented with input from DB and TPG. The PTO/PTA partners in the ULTIMO consortium have many years of experience with operating automated vehicles and DRT services¹³.

The User Journey consists of the three main phases Pre-Trip, Trip and Post-Trip.

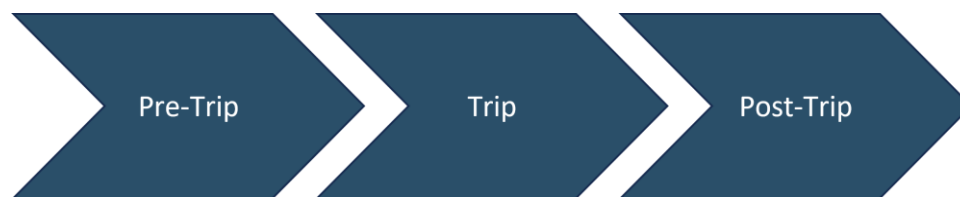


Figure 13: Journey phase sequence

The phases each include further steps and activities as described here:

The **Pre-Trip** phase describes everything that happens before a person uses the central service “Take me from A to B”. It contains the steps “Informing oneself/Deciding”, “Planning, Booking, Paying”, “Getting to Pickup Point”, “Waiting at the Pickup Point” and “Connecting to Vehicle”.

¹³ TPG's experience with automated public transport began in 2018 with NAVYA. Since then, continuous improvements and advancements have been achieved in numerous projects. DB Regio launched its first automated vehicles in 2017 in Bad Birnbach. Following the success of this project, the service was expanded to include the on-demand aspect. The app "Wohin du willst" serves as the user interface to guarantee a seamless user experience.

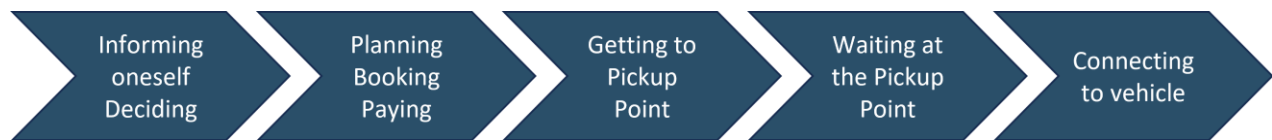


Figure 14: Pre-trip phase steps and activities sequence

The Phase **Trip** contains all direct touchpoints the passenger has with the vehicle: “Boarding the vehicle”, “Travelling”, “Incident during trip” (as an optional step), and “Disembarking/Switching transportation”.

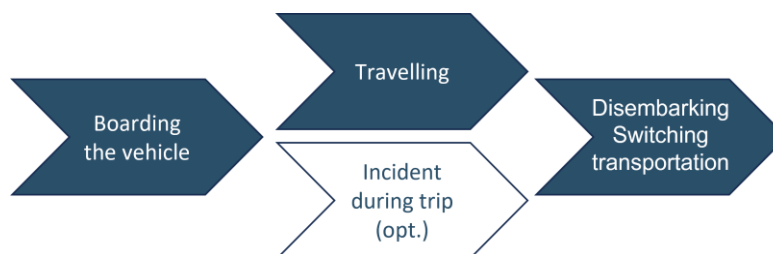


Figure 15: Trip phase steps and activities sequence

The User Journey is not over once the passenger has arrived at their destination. Phase

Post-Trip covers the step “Reviewing the experience” with all possible activities after a trip e.g., rating or sharing their experience.

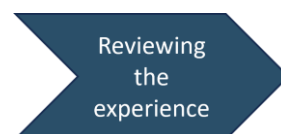


Figure 16: Post-trip phase steps and activities sequence

Within the User Journey there are different customer interfaces, which ensure a smooth and user-friendly result. The different elements are explained below.

SMARTPHONE APP

Smartphone app is the main interface where the customer plans trips, orders rides and communicates with the vehicle and the service throughout the trip. The smartphone app

should be fully accessible, user friendly, customisable and not demand a lot of interaction from the user.

INTERIOR INFO SCREEN

Info screen visible to all passengers during the ride. Used to inform the passengers of itinerary and changes to trip. The interior info screen should be user friendly but protect the privacy of the passengers.

EXTERIOR

External info screen, door handles, shape, colour and graphics on vehicle. The exterior must be immediately recognisable as public transport by the respective PTO/PTA.

INTERIOR

Seat belt, settings for windows, lighting and temperature, charging, soft stop button

PICKUP/DROP OFF POINTS

Dedicated locations within the serviced area that the customer can be picked up and dropped off from.

CUSTOMER SERVICE

Customer service department ready to help customers via chat or phone, either in customers smartphone app or via speaker call through the info screen.

Exemplary use cases

Table 2 : exemplary use cases

Phase	Step of User Journey	Use Case
Pre-Trip	Inform/Decide	The user gets information about the service, e.g., that it exists, where and when it is offered, what price to expect, what can be brought, etc.
		The user gets information about the vehicle, e.g. what it looks like, how it can be identified, etc.
		The user gets information about the booking process.
		The user gets information on how to access the service.
	Plan/Book	The user has the means to book a service (e.g. access to app, knowledge of phone no.).

		The user books a trip >1 week early / >24h before / 2h before / for right now.
		The user books a recurring trip (e.g., every weekday) / a one-time trip.
		The user books a trip for themselves or for someone else.
		The user books for themselves and another person.
		The user books a trip and selects a PUDO with specific conditions (e.g., sheltered/with roof, wheelchair ramp possible).
		The user books for a group of people all boarding at the same PUDO and going to the same PUDO.
		The user plans a trip and saves it as a favorite (with/without booking it).
		The user gets information/updates on changes for their trip (new prices, route changes, construction sites, etc.).
		The user cancels a booked trip.
	Get to PUDO	The user gets to pickup point in time.
		The user can't make it to pickup point in time and wants to know how long the vehicle will wait.
		The user can't make it to pickup point in time and wants to cancel the trip.
		The user needs help to locate the pickup point.
	Wait at PUDO	The user waits and knows when the vehicle will arrive at the PUDO.
		The user waits and is unsure if at the right position.
		The user waits and does not know when vehicle arrives.
	Connect	The vehicle arrives at the pickup point and is clearly recognized by the user.
		The vehicle arrives at the pickup point and has no available seats.
		The user can't localize the (correct) vehicle/door.
		The user can clearly identify the vehicle.
		The user authorizes him/herself to be able to unlock door.
		The user opens the door of the vehicle.
Trip	Board	The user boards the correct vehicle, and the vehicle provides the boarding confirmation (to ensure the passenger-vehicle match).
		The user boards the wrong vehicle.
		The user does not board the vehicle.
		Additional users board the vehicle.
		The user can't board the vehicle because of access height.
		The vehicle indicates before doors close and it starts when passengers are safely seated.

	Travel	The user sits in the vehicle until it is time to get out at the destination.
		The vehicle stops between pickup and drop-off point to let other passenger(s) out/in.
		The vehicle indicates every halt and its reason. It announces the arrival at a users' destination.
		The user has access to all relevant information during the trip: route information, time to destination, pickup and drop off points for other passengers, etc.
		The user wants to go back to the pickup point.
		The user wants to go to another destination.
		The user wants to end the trip as soon as possible.
	<i>Incident (opt.)</i>	<i>The vehicle stops unexpectedly and does not resume the trip (mechanical failure).</i>
		<i>There is an accident with another road user (car, bicycle, pedestrian).</i>
		<i>The user wants to ask for help.</i>
		<i>The user wants to leave the vehicle immediately.</i>
		<i>The user reports an issue (littering, smell, ...).</i>
		<i>The user is attacked in the vehicle.</i>
		<i>A fire breaks out in the vehicle.</i>
	Disembark	The user leaves the vehicle at the correct drop-off point.
		The user leaves the vehicle with large luggage and a stroller.
		A user in wheelchair leaves the vehicle and needs the ramp.
		The user requests more time to leave the vehicle.
		The vehicle provides information about changeover time for connections.
		The user does not leave the vehicle because the user doesn't want to leave.
		The user does not leave the vehicle because the user doesn't know it is the destination.
		Not all users who are supposed to leave the vehicle.
		User cannot disembark the vehicle because the vehicle does not arrive at/near destination.
		User cannot disembark the vehicle because the door is blocked.
Post -Trip	Review	The user provides feedback about the trip.
		The user shares the experience in social media.
		The user reports a forgotten item in the vehicle.
		The user requests a receipt of the trip.
		The user saves the trip as a "favourite".

7.2 Selection of Inform Use Cases

The user gets information about the service e.g., that it exists, where and when it is offered, what price to expect, what can be brought, etc.

The user gets information about the vehicle, e.g. what it looks like, how it can be identified, etc.

The user gets information about the booking service.

The user gets information on how to access the service.

7.3 Planning and Booking



Figure 17: Planning and booking (illustration sketch)

Booking for on-demand services is a hassle-free and user-friendly process that allows passengers to request and secure their desired transportation quickly and effortlessly. By following a few straightforward steps, passengers can easily access the on-demand service and book their rides with convenience. **Service Selection:** Passengers begin by selecting the specific type of on-demand service they require, whether it's a taxi, ridesharing, or another mode of transportation. They have the flexibility to choose from different service levels or vehicle categories based on their preferences and needs.

Pickup Location: Passengers can easily set their pickup location by utilizing a map interface that highlights the closest available locations. This allows for precise selection and ensures accurate and efficient pickup arrangements.

Drop-off Location: Similarly, passengers can conveniently set their drop-off location using the map interface, enabling them to specify their desired destination accurately.

Suggested Locations: To enhance the booking process, the app may provide helpful suggestions based on passengers' previous trips or commonly visited places. This feature saves time and effort by offering familiar or frequently chosen destinations for quick selection.

Ride Options: Passengers have the flexibility to customize their ride preferences according to their specific requirements. This includes selecting a preferred vehicle type, indicating the number of passengers, and requesting additional services such as wheelchair accessibility, assistance for visually impaired passengers, accommodation for luggage, stroller, bike, traveling with a service animal, etc. Additionally, passengers may have the option to schedule future rides and customize return trips as needed. It's important to note that passengers sharing the same booking will be traveling to the same destination.

Trip Information: The app provides passengers with various journey suggestions, along with estimated arrival times based on distance and vehicle availability. This valuable information empowers passengers to make well-informed decisions regarding their preferred itinerary.

Confirmation: Once passengers have reviewed and finalized their booking details, they can easily confirm their ride request with a simple tap or click. The app presents a confirmation screen that displays essential information such as the pickup location, destination, estimated arrival time, and any additional ride details for clarity and reassurance.

Driver Assignment and Tracking: The app automatically assigns a nearby vehicle to fulfil the ride request, considering factors such as vehicle availability, proximity to the pickup location, and passenger preferences. Passengers can conveniently track the assigned vehicle's real-time location and estimated time of arrival through the app's integrated map interface, providing peace of mind and visibility into the journey progress.

Communication: Passengers receive regular updates through the app regarding the vehicle's arrival status and estimated waiting time at the pickup location. This ensures effective communication and facilitates a smooth and seamless pickup experience.

By following these user-friendly steps, passengers can effortlessly book their on-demand services, guaranteeing a convenient, reliable, and efficient transportation experience.

7.3.1 Registration

Passengers can download the service provider's dedicated mobile app from their respective app stores or access the service provider's website through their preferred web browser.

Upon opening the app or website, passengers are greeted with a registration or signup option.

Passengers are prompted to provide their personal information, such as their full name, email address, phone number, and sometimes their date of birth or identification details, to create their account.

The phone number can be used by the dedicated client support team to inform them of real time issues related to their transport.

They may be required to set a password or use other authentication methods, such as two-factor authentication, to secure their account.

Depending on the public transport used, passengers can be prompted to provide their payment information, including credit/debit card details or link their digital wallet, ensuring a seamless and convenient payment experience for future rides.

The app or website may display the service provider's terms of service and privacy policy, allowing passengers to review and accept them before proceeding with the registration.

After successfully creating their account, passengers receive a confirmation email or in-app notification welcoming them to the service and providing additional information about how to use the app or website effectively.

By including these additional details, passengers can have a clear understanding of the registration process and confidently create their account to access the on-demand service.

7.3.2 Selection of Planning and Booking Use Cases:

The user has the means to book a service (e.g. access to app, knowledge of phone no.)

The user books a trip >1 week early / >24h before / 2h before / for right now

The user books a recurring trip (e.g., every weekday) / a one-time trip

The user books a trip for him/herself or for someone else

The user books for him/herself and another person

The user books a trip and selects a PUDO with specific conditions (e.g., sheltered/with roof, wheelchair ramp possible)

The user books for a group of people all boarding at the same PUDO and going to the same PUDO

The user plans a trip and saves it as a favorite (with/without booking it)

The user gets information/updates on changes for their trip (new prices, route changes, construction sites, etc.)

The user cancels a booked trip

7.4 Paying

This subject will be addressed in the upcoming deliverable as we are currently collaborating with our partners to further develop and refine this topic.

7.5 Getting to Pickup Point



Figure 18: Two users getting to the pickup point (illustration sketch)

The user tracks the approaching automated vehicle in real-time through the mobile app, which provides a visual map display showing the vehicle's precise location, along with regular updates on the estimated time of arrival (ETA). The navigation system considers various factors, such as real-time traffic conditions, road closures, and even weather conditions, to dynamically adjust the route if necessary. It leverages sophisticated algorithms to calculate the optimal path, considering factors like the shortest distance, fastest route, and potential congestion points. The user can rely on these updates to plan their departure time from their current location and ensure they arrive at the pickup location on time or be informed on how long they will have to wait at the pickup location for the vehicle to arrive. The pickup location could be details with nearby landmarks, or any specific instructions for locating the area where the vehicle will arrive. The user proceeds to the pickup location, which can be a designated curb or an easily identifiable spot.

Upon the automated vehicle's arrival at the designated pickup location, the user receives a notification through the app, alerting them that the vehicle has reached the specified spot. In some cases, the vehicle's exterior may display a digital sign or unique identifier to assist the user in identifying their ride. As the user approaches, the vehicle's doors may automatically open, providing a seamless boarding experience. Alternatively, the user may need to use the app to confirm their identity, ensuring that they are boarding the correct vehicle. This confirmation can involve scanning a QR code, entering a unique code, or verifying personal information. Once the user has boarded the vehicle, the doors close, and the journey to the user's specified destination begins. This still needs to be defined for each of the different pilot sites in relation to cultural and passed habits from users.

7.5.1 Selection of Getting to Pickup Point Use Cases:

The user gets to pickup point in time.

The user can't make it to pickup point in time and wants to know how long the vehicle will wait.

The user can't make it to pickup point in time and wants to cancel the trip.

The user needs help to locate the pickup point.

7.6 Waiting at the Pickup Point



Figure 19: Two users waiting at the pickup point (illustration sketch)

Once the user has arrived at the pickup location there might be some time until the vehicle arrives. In this situation the user depends on information e.g., an app confirmation that the location is the correct one, or the estimated time of arrival of the vehicle. Ideally, the user has the possibility to track the vehicle and has the option to contact customer service if the vehicle fails to arrive at the promised time.

7.6.1 Selection of Wait Use Cases:

The user waits and knows when the vehicle will arrive at the PUDO.

The user waits and is unsure if at the right position.

The user waits and does not know when vehicle arrives.

7.7 Connecting to Vehicle



Figure 20: A vehicle arriving to pick up a passenger (illustration sketch)

When vehicle and passenger both are at the pickup location, they have to connect.

When it comes to the connection step of an autonomous vehicle picking up passengers, several elements ensure a seamless experience:

To assist passengers, including those who are visually impaired, the fully automated vehicle system establishes a clear and reliable method for passengers to identify their assigned

vehicle as "my vehicle." This involves a direct correspondence between the vehicle's name or number displayed in the passenger's mobile app and the physical vehicle itself. For example, the app may show a unique identifier, such as a license plate number or a vehicle-specific name, any other distinctive feature, allowing passengers to match it with the corresponding vehicle.

To enhance the vehicle's locatability, it employs various techniques. For instance, the vehicle may employ visual cues like blinking lights or distinctive patterns to make itself easily visible in crowded or busy areas. Additionally, the vehicle might emit specific sounds or tones, acting as an auditory beacon to guide passengers towards its location.

To facilitate seamless recognition, the fully automated vehicle's onboard system utilizes advanced technologies. These technologies enable the vehicle to 'recognize' the authorized user. Ensuring that only authorized passengers are granted access to the vehicle.

To indicate that the vehicle is part of a service provided by the Public Transit Operator (PTO) or Public Transit Authority (PTA), it is clearly marked as such. This can include visible signage, logos, or branding on the exterior of the vehicle, ensuring passengers can easily identify it as an official service vehicle.

To assist passengers with door localization, the AV's vehicle is equipped with systems that accurately determine the position of the doors. This enables the vehicle to align itself appropriately for passenger entry and exit, ensuring convenience and safety.

By incorporating these elements, the connection step in fully automated vehicles ensures passengers can effortlessly identify, locate, be recognized by, and authorize themselves to access their assigned vehicle, guaranteeing a user-friendly and efficient boarding process.

7.7.1 Selection of Connect Use Cases:

The vehicle arrives at the pickup point and is clearly recognized by the user

The vehicle arrives at the pickup point and has no available seats

The user can't localize the (correct) vehicle/door

The user can clearly identify the vehicle

The user authorizes him/herself to be able to unlock door

The user opens the door of the vehicle

7.8 Boarding the Vehicle



Figure 21: A passenger is boarding an automated minibus (illustration sketch)

When boarding fully automated vehicles, the vehicle must trigger an automatic reminder a few seconds before to the passenger. Then automatically continue the ride if passenger do not respond to the notification. No show after one delay must automatically trigger continuation of the ride, without the passenger. The system integrated into the vehicle shall efficiently associate items with each passenger, ensuring that personal belongings are accounted for throughout the boarding process.

Similarly, passengers using walkers or strollers should have the means to securely fasten their mobility aids within the vehicle, ensuring their stability and safety during the journey.

For visually impaired passengers, the vehicle shall incorporate features that assist them in locating the boarding door effortlessly. Clear and distinct audio or tactile signals should guide them to the appropriate entry point, facilitating their safe and independent boarding and disembarking experience.

Passengers should be given adequate time to board the vehicle, accounting for their individual needs and requirements. The vehicle should wait until passengers are ready for departure. Passengers should have the capability to signal to the vehicle if they are not yet ready to commence the trip, allowing for additional time or assistance as required. This feature ensures that passengers are not rushed and can board the vehicle at their own pace whatever their needs are.

In cases where a booking has been made on behalf of another person, the user should receive clear indications and instructions to ensure the correct passenger boards the designated vehicle. This may include unique identifiers or verification methods to guarantee a seamless and accurate boarding process.

Upon the vehicle's arrival at the designated pickup location, the user should be able to unlock the doors promptly, either through manual means or automated systems, streamlining the boarding process.

Users should be provided with clear and concise information regarding the available time for boarding the vehicle, allowing them to plan their arrival accordingly and avoid any inconvenience or delays.

Seating options within the vehicle should be intuitively designed and easily identifiable, minimizing confusion or ambiguity for passengers. Clear signage or visual cues can assist passengers in quickly determining available seating arrangements.

If a passenger exceeds the allocated boarding time limit, the customer support team should be promptly notified, enabling them to address the situation and ensure the smooth continuation of the vehicle's journey.

Passengers should have convenient and sturdy handles or handrails available to hold onto while moving within the vehicle, ensuring their safety and stability during boarding, trip and disembarking.

The vehicle's doors should provide a clear and distinct alert signal before closing, allowing passengers to safely complete their boarding or disembarking without the risk of being caught by closing doors.

To confirm the accuracy of the boarding process, the vehicle should provide passengers with a boarding confirmation that matches their personal details, ensuring the correct passenger is associated with the correct vehicle. This feature enhances security and minimizes the potential for errors or confusion.

If a passenger encounters any issues fulfilling their booking, such as unavailability of space, a full vehicle, or the absence of a required ramp, they should be able to report these concerns to the customer service, allowing for immediate resolution and alternative arrangements to be made.

The vehicle's system should actively monitor passenger compliance with the booking agreement, including factors such as the number of persons or amount of luggage allowed. Any violations or discrepancies should be detected and flagged for appropriate action, ensuring adherence to the agreed-upon terms.

If required by authorities some safety rules and regulations could be applied within the vehicle, the following are only a few examples such as the requirement to wear seatbelts or remain seated during transit, should be clearly communicated and visibly displayed. If such rules are necessary, PTO/PTA will be obliged to enforce these measures to passengers in the best way possible.

Passengers should be able to board the vehicle without relying on a working smartphone or mobile device, this challenge will be tackled by Ultimo partners, providing inclusive access to individuals who may not possess or have access to such technology.

7.8.1 Selection of Boarding Use Cases:

The user boards the correct vehicle, and the vehicle provides the boarding confirmation (to ensure the passenger-vehicle match).

The user boards the wrong vehicle.

The user does not board the vehicle.

Additional users board the vehicle.

The user can't board the vehicle because of access height.

The vehicle indicates before doors close and it starts when passengers are safely seated.

7.9 Travelling



Figure 22: Two passengers during their travel (illustration sketch)

During a trip in our fully automated vehicle, we ensure that all passengers, including those with disabilities, receive essential information through both visual and auditory means for accessibility. Our technology seamlessly combines real-time audio announcements with clear visual displays to keep passengers informed.

Inside the vehicle, as PTO/PTA we prioritize a comfortable and practical environment with ample seating and storage capacity for passengers' belongings, such as luggage, strollers, and walkers. Passengers with guide or service dogs have dedicated space under their seats for their companions' well-being.

As the vehicle follows its planned route, passengers can access journey-related details through in-vehicle screens and a mobile app, including estimated arrival times and information about connecting stations.

To keep passengers informed, the vehicle provides updates about unexpected stops or delays, as well as notifications about new passengers or changes to ride-sharing arrangements. We have discreet reminders in place to encourage considerate behaviour, and a noise monitoring system ensures a peaceful journey. Responsive customer service is easily accessible through a simple interface, connecting passengers with our support team.

Automated vehicles ensure that only registered passengers board, preventing any unauthorized passengers. If waiting time is required for other passengers, we provide estimated durations to help passengers plan accordingly.

Vehicle can change their trip destinations, providing all necessary information for spontaneous detours or different routes. In cases where changes or cancellations are necessary, passengers are presented with alternatives and informed of potential consequences in advance. The vehicle discreetly informs passengers of upcoming locations to prepare for disembarking.

Throughout the journey, privacy and data security are respected and are of high importance for PTO/PTAs, safeguarding passengers' personal information. In-vehicle screens do not display private data, ensuring confidentiality. For safety, the vehicle provides emergency information and options to request help, all accessible through a user-friendly interface.

Transporters' commitment to passenger comfort, safety, and accessibility goes beyond transportation. The aim is to make every journey pleasant for all users, setting an example of inclusivity by accommodating individuals with diverse needs and abilities.

7.9.1 Selection of Travel Use Cases:

The user sits in the vehicle until it is time to get out at the destination

The vehicle stops between pickup and drop-off point to let other passenger(s) out/in

The vehicle indicates every halt and its reason. It announces the arrival at a user's destination

The user has access to all relevant information during the trip: route information, time to destination, pickup and drop off points for other passengers, etc.

The user wants to go back to the pickup point

The user wants to go to another destination

The user wants to end the trip as soon as possible

7.10 Incident during Trip

Ideally, the automated vehicle will transport the passenger smoothly from A to B. However, we also must consider potentially possible incidents that could happen during the route. The cause of these incidents can be manifold, it may lie in the vehicle hardware or software, in the fleet management, in the traffic situation or the behaviour of other road users or even the passenger itself. Whatever the reason, there will be a need for information and communication. Maybe passengers will even want to leave the vehicle.

7.10.1 Selection of Incident Use Cases:

The vehicle stops unexpectedly and does not resume the trip (mechanical failure)
There is an accident with another road user (car, bicycle, pedestrian)
The user wants to ask for help
The user wants to leave the vehicle immediately
The user reports an issue (littering, smell, ...)
The user is attacked in the vehicle
A fire breaks out in the vehicle

7.11 Disembarking/Switching Transportation



Figure 23: A passenger is disembarking an automated minibus

A journey with a fully automated vehicle is designed to prioritize passenger safety and convenience, especially for those with visual impairments.

Before passengers disembark, they are informed about their drop-off point through various methods such as voice announcements, in-vehicle displays, and a mobile app. The vehicle ensures passengers have enough time to exit safely by coming to a complete stop and unlocking its doors. A countdown timer is displayed, and passengers can request more time if needed. If a passenger encounters difficulties leaving the vehicle, the system notifies the Passenger Transportation Operator (PTO).

Passengers are reminded to check for their belongings before leaving, and the vehicle's doors are unlocked as they start to disembark, regardless of whether they have a smartphone. Safety checks are performed before the doors open.

The AV system should ideally provide information about connecting transportation options, helping passengers plan their journey live.

To enhance passenger comfort, the AV system is exploring ways to allow passengers to request extra disembarking time, and it prioritizes inclusivity and accessibility. Safety remains a top concern, with alerts about moving ramps.

Partnering with accessible Points of Disembarkation (PUDO), the AV ensures hassle-free experiences with ample space. Passengers can disembark safely without needing a smartphone, and when booking for others, users can trust the system to deliver them to the correct location.

The AV system prioritizes passenger well-being by promptly notifying Customer Service of any issues, ensuring swift assistance.

In conclusion, the disembarking process with a fully automated vehicle is designed with a user-centric and safety-first approach, catering to all passengers, including those with visual impairments. Travelers can embark on their journeys with confidence, knowing the system ensures a seamless, secure, and enjoyable experience from start to finish.

7.11.1 Selection of Disembark Use Cases:

The user leaves the vehicle at the correct drop-off point.

The user leaves the vehicle with large luggage and a stroller.

A user in wheelchair leaves the vehicle and needs the ramp.

The user requests more time to leave the vehicle.

The vehicle provides information about changeover time for connections.

The User does not leave the vehicle because the user doesn't want to leave.

The User does not leave the vehicle because the user doesn't know it is the destination.

Not all users who are supposed to leave the vehicle.

User cannot disembark the vehicle because the vehicle does not arrive at/near destination.

User cannot disembark the vehicle because the door is blocked.

7.12 Reviewing the Experience

Following each trip with a fully automated vehicle, passengers are not only invited but actively encouraged to engage in a comprehensive review process, underscoring the significance of the processes in place:

Gathering Feedback: This user-centric approach empowers passengers with the opportunity to rate their experiences, putting their feedback and satisfaction at the forefront of the service. It ensures that their voices are heard, and their insights are collected.

Aggregating Feedback: Passengers are not merely individuals sharing their thoughts; they become contributors to a thriving community of travellers. By openly sharing their journey experiences, they foster transparency, trust, and a collective knowledge base within the AV network. This collaborative spirit enhances the overall travel experience for all.

Implementing Changes: An efficient mechanism exists to address forgotten items, allowing passengers to promptly notify the service if they accidentally leave belongings behind. This seamless process ensures that lost items are identified and handled with the utmost care and urgency, further promoting reliability and attentiveness.

Feedback isn't just encouraged; it's highly valued. Passengers play an active role in shaping the fully automated vehicle system through constructive comments and suggestions, fostering an environment where continuous refinement and enhancement are the norm. This responsive and adaptive approach ensures that the service remains finely tuned to passengers' evolving needs and preferences.

In addition to these essential feedback processes, the service offers personalization and ease of use by allowing passengers to save trips as favourites.

In summary, the review process for AV usage signifies a deep commitment to passenger satisfaction, continuous improvement, and a strong sense of community among travellers. Through their contributions—whether it's providing ratings, sharing experiences, reporting forgotten items, offering feedback, saving trips, or accessing lost belongings—passengers actively participate in shaping a service that places their needs, preferences, and overall travel well-being at its core. With each journey, the fully automated vehicle system fortifies its foundation of trust, reliability, and passenger-centricity, creating a harmonious and enriching travel ecosystem for all.

7.12.1 Selection of Review Use Cases:

The user provides feedback about the trip.

The user shares the experience in social media.

The user reports a forgotten item in the vehicle.

The user requests a receipt of the trip.

The user saves the trip as a "favourite".

8 LaaS and non-public passenger transportation use cases



Figure 24: An automated minibus is used for goods-transportation

One of the targets of the ULTIMO project, is to explore via real life validations, how the excess capacity of public transportation vehicles can be used for non-public transportation services (nPTS) by third parties. In this context we target to propose a new model, where the Autonomous Vehicles' extra capacity, in principle low passenger needs' times, will be used for non-public transportation, like last urban logistics and non-public passenger transportation.

Public Transportation Authorities (PTAs) and Passenger Transportation Operators (PTOs) possess specialized expertise and authorization for passenger transport, but their knowledge in logistics is somewhat limited. To address this gap, we have reached out to logistics experts who, with their valuable insights, are expected to steer ULTIMO partners toward a more logistics-focused direction. The following are ideas collected and paths to explore with upcoming experts.

8.1 LaaS and non-public transportation service scenario overview

Urban logistics and especially last mile urban logistics is the most expensive part in the logistics chain. Today we can identify different types of urban logistics models, and namely: B2C, B2B, C2C and C2B. Not all types can be commercially interesting and viable today, but in the future, with the large expansion of AVs in the city, they can become commercially viable.

In order to better understand and explain the related issues, we first describe the **basic LaaS usage scenario**. In this scenario, the excess capacity of the AVs operated by the PTO, is made available for urban logistics.

The PTO identifies that during specific time frames in the day, a number of AVs will not be used for public transportation. These vehicles will be parked in the city, in well-defined parking spots, and will be available for reservations for non-public transportation services, being urban logistics or nPTS to different logistics or non-public transport operators.

The LaaS or nPTS operators, will request (via a connection to a dedicated on-line service) the use of a number of vehicles for a specific time period. It is expected that the requesting service provider will have its own logistics management system, with points of delivery and pickup, delivery time requirements, object dimensions and weight, etc. The PTO will provide a modified or dedicated non-Public transportation fleet orchestrator, that will manage the vehicles assigned to the LaaS and nPTS operators. What needs to be clarified is that nPTS and LaaS services will require a different fleet orchestration intelligence than the one used for public transportation, since the optimisation and options are very different from public passenger transportation. For example, in LaaS services the itinerary will not be changed, once the goods have been loaded, since the delivery points are well defined and there is no intermediate loading of new items. Furthermore, the LaaS provider, in a B2C model for example, should be able to provide to the fleet orchestrator the data concerning the items to be delivered and the fleet orchestrator should propose different options using different configurations and numbers of vehicles, with the different delivery delays, total Kms to run, etc, ideally considering the items' sizes and weight, or other related parameters. The LaaS service provider will choose the most suitable option and validate the vehicle reservations.

The assignment of the AVs to LaaS and nPTS operators will be governed by a set of **Service Level Agreements (SLAs)**, that will define the usage details. Some of the items that will be part of the SLAs include the start and end position of the vehicles, transit time charging, hours of usage, the status of the vehicle before and after (cleanness, temperature, battery load etc), vehicle malfunction and accident liability. It is expected that the vehicles will be positioned (parked) throughout the city in well selected parking spots from where they will be picked up and delivered. We would expect that some photographic material will be available to the operators from the vehicle cameras, to document the internal status of the vehicle before and after the service, and an automatic comparison will validate the status of the vehicle and its interior at the end of the LaaS and nPTS (and enforce the SLAs).

Using the AV for LaaS or nPTS. Once the vehicle has been assigned to the LaaS or nPTS operators, it will be sent to the LaaS pickup location, where it will be loaded with the items or persons to distribute/transport. For LaaS we expect that each item will be clearly labelled (QR code, bar code) and each item will be identified via the vehicle camera as it is deposited in the vehicle, with its exact position in the vehicle. The order of placing the items in the vehicle will be recorded and can be used to organise the itinerary, so it is always the top item that is next to be delivered.

The vehicle will then be dispatched with a well-defined itinerary for the delivery. For LaaS, and because we have a very detailed knowledge of the vehicle position, we will be able just a few minutes before arriving to the delivery stop, to send a message to the receiver of the item, to inform him about the imminent arrival. We can also anticipate that the receivers would be able to follow the vehicle trip on their app, and get a notification once the vehicle

is at certain time to arrival. This will allow a very fine tuning of delivery times slots, in the order of few minutes instead of hours as is today.

The vehicle will arrive at the defined delivery location and will wait for the receiver to identify himself and open the door. The receiver will pick its item, while the QR code of the pickup item will be scanned and validated as being the correct item. In case the receiver picks up the wrong item, a signal, light and sound, will alert him about the mistake and instruct him to leave the item and pickup the right one.

If upon arrival of the vehicle at the delivery location the receiver does not come to pickup the item, after waiting for a certain time period, the vehicle will leave for the next delivery. The item that was not picked up will finally be returned to the LaaS service provider (or to the sender) and service policies will define what happens next (delivery at another time with extra costs, pickup by the receiver at the depot etc).

At the end of the deliveries the vehicle will either be returned to the PTO control according to the SLAs or reused by the LaaS service provider for a new delivery round.

The above usage scenario is a typical B2C delivery. We can also anticipate other models, like B2B, where the AV arrives, for example, to the train station, loads several goods and delivers them to a shop. This can be the case for early morning transfer of goods to retail shops. Another scenario can be C2B, where the service provider organises a collection of returned items. That is, goods that had been ordered and are now returned to the seller. The vehicle will operate as in the basic scenario, only instead of delivery the users will place items in the vehicle (marked with a QR code for identification). Finally, we can even anticipate a C2C scenario, where private persons, via LaaS service provider, will request a transport service for the delivery of private goods from one place to another. Example, to transfer some boxes during a relocation, send heavy gifts etc. A combination of scenarios can also be anticipated, given sufficient information and organisation models.

In the LaaS scenario we can also consider other elements related to quality of service. Needs. The customer can define specific transport delays and delivery time to be observed or can also have requirements for specific temperature during the transfer. Different needs will be evaluated during the project deployments.

8.2 Use Cases for LaaS and nPTS services

8.2.1 LaaS Use cases

We consider three *basic use cases for LaaS services*. First a standalone LaaS service by a virtual provider, second as urban logistics service extension and third as pick capacity filler by an existing urban logistics service provider.

In the **standalone Urban logistics service**, any company can operate an urban logistics service provider, using the chartered AVs from the PTO. In this use case, the complete urban logistics service is made using AVs. The LaaS provider does not need to own any transportation means, since it is exclusively using the available AVs. The service provider will have its own customer service IT system, managing its customers and transport requests, and will request the use of AVs based on the dynamically evolving needs. Based on the volumes of transportation, a permanent reservation of a number of vehicles can be established and extra vehicles depending on needs can be requested dynamically.

In the **Urban Logistics Service extension**, an existing small items logistics service provider (like one delivering documents or small items using bicycle service) will be able to expand its service to larger objects' transfer. The service provider will be enlarger the set of objects that is able to transport, using for the larger objects AVs.

The **pick capacity filler** use case, would be the case of an existing confirmed logistics service provider, with own vehicles in a city, but who faces now and then capacity shortages and is not able to serve picks of transport requests. In this case, the service provider will be able to dynamically and in short notice (a few hours or less) request a number of vehicles to cover the missing capacity.

For the above use cases we can use different options for the "storage" of the goods during transport. The simpler way will be that the vehicle is used as-is: the items are simply placed on the floor and seats of the vehicle, piled up or not, depending on the number, type etc of the items.

A second method, that will allow for protection of the vehicle interior, would be to have modular, easy to install, solid protection, that will cover the floor and the seats of the vehicle. Each time the LaaS operator receives the vehicle, the protection will be installed and then the items will be loaded.

We can also anticipate specialised mobile installation for items with special needs, like fragile or items that require specific temperature. A specially designed "box", adapted to the vehicle interior can be implemented and used for these type goods.

8.2.2 Non Public Passenger Transportation Services

For non-public transportation services (nPTS), we consider use cases where citizens require transport to private (or public!) events and places. We have currently identified 3 use cases: transport of persons for events participation, transport of employees to company buildings and private transport of individuals. In the use cases we need to address cases that do enter in competition with taxi services, but are complementary.

In the **event participation** use case, we consider the case where there is special event in the city, like conference, meeting, concerts, etc. and there is a need to transfer the participants/delegates from a hub (train station, airport) to the event site. Alternatively we

can consider transferring the participants from the event place to a dinner location or even between buildings in the city.

In the **transport of company employees**, there is a need to support the transfer of employees, at a regular service from hub locations to the company premises, but for which there is no direct public transport service or the (private?) industrial area is not served by public transportation.

The third use of **private transport of individuals**, consists of cases where citizens will need ad-hoc transport for personal private needs, and for which a taxi service is not suitable. Examples can be when the person transports large objects (shopping), or requires to transport a larger number of persons (a family of 8 persons for example).

In all the above use cases, a key advantage of the ULTIMO service is that the reservation and dispatching of the vehicles for logistics or nPTS services, can be done dynamically, and under very short notice. The service provider can dynamically increase or decrease (subject to SLAs) the transport capacity based on its instant needs. This creates a higher flexibility and can drastically boost the service quality, by reducing transport delays.

8.3 Requirements for LaaS, nPTS

In order to provide efficient LaaS services, a number of functional and non-functional requirements need to be addressed. We enumerate here some of the most important. Other requirements will surely be identified during the real-life deployments.

8.3.1 Service requirements for LaaS

The LaaS operator will require that the fleet orchestrator provides him with different alternatives and options for the transport of a set of goods. Considering that the LaaS does not have the same strict time requirements as public transport service, (that is a good can be delivered 10 to 20 minutes earlier or later) it would be important for the LaaS operator to minimize its costs or increase the service quality. Therefore, the fleet orchestrator should be able, given a set of goods to be delivered at a specific destination, to provide a set of alternatives using more or less numbers of vehicles, and indicating the total delivery times anticipated, energy consumption prediction etc. This way the LaaS operator will optimize based on its own requirements. For example, in a B2C, the distribution of 60 items can be done with three AVs within 2.5 hours or with 5 AVs within 1.5 hours, that is we might have trade-off between delivery delay and number of vehicles.

A second requirement that should be included in the delivery option of the customers, can be a very short time slot for the delivery. The LaaS operator should be able to receive this customer need and, when “feeding” his data to the fleet orchestrator include “required time delivery” for a specific item. The fleet orchestrator should be able to propose an itinerary and configuration realising this customer requirement.

A third requirement is that the vehicle provide the required service to allow the clear identification of each item deposited in the vehicle. This can be done by placing QR codes on the items, or even by visual identification of the item, when placed in the vehicle. This identification will be used when the customer picks-up its order, to validate that the right order was pick-up. A visual and audio alarm should alert the customer in case the wrong item is picked-up, and the LaaS operator should be informed.

8.3.2 Service requirements for nPTS

The requirement of non-public transportation of passengers, do not differ from the LaaS service requirements, in the case of private transportation, and from the ones from public transportation for company employee's transportation.

For private transportation of individuals, (family, friends etc), we will have similar case when transporting goods from one point to another. The customer will provide its destination, times and itinerary and the fleet orchestrator will provide transport plan, integrating reaching the pick-up location.

For company personnel, the existing public transportation fleet orchestrator can be used, by defining stops in the company area where employees can ask for vehicle at a specific time. The only difference is the stops will be defined by the company and can be modified dynamically or at least at the start of the service, as needed.

9 Public Transport Requirements

The requirements were gathered from PTO/PTAs, (potential) users, ULTIMO project partners and other related EU projects like AVENUE and INDIMO. Requirements are categorized into user requirements, PTO/PTA requirements, Vehicle requirements and LaaS requirements. The user requirements are assigned to the steps of the User Journey as described in [chapter 2.3](#). The Logistic topic is not covered in-depth in this version of the deliverable because the project is looking for a new partner for Logistics as a Service use cases.

The requirements list is not final, it will be updated and revised as the project evolves.

The list of identified requirements can be found in [Annex A](#)

In a next iteration of the deliverable for each of the pilot sites and determined by local end users, PMRs as well as POT/PTAs, the requirements will be prioritized according to the MoSCoW Method, a commonly used prioritization technique. (see: https://en.wikipedia.org/wiki/MoSCoW_method)

This method uses the categories

Must have - Should have - Could have - Won't have (this time)

Must have requirements are critical to the service in order for it to be a success. Requirements labelled as *Should have* are important but not necessary for the initial implementation of the service. *Could have* Requirements are desirable but not necessary. They could improve the user experience or customer satisfaction. The requirements labelled as “*Won't have*” are been agreed by stakeholders to be the least critical or not appropriate or applicable at that time. *Won't have* requirements can be reconsidered for inclusion in a later state.

9.1 User Requirements

To get a deeper understanding of the users and to make sure that the requirements really match, the requirements were gathered in different ways. In order not to reinvent the wheel again, we started with the requirements already collected in the AVENUE project e.g., in Geneva, Vienna, Berlin and City of Luxembourg. To find out whether these requirements are still valid and to what extent they change when such a service can be used over a longer period, interviews were conducted with students and teachers of a school in Soest, Germany, which was connected with the main station by a free to use AV service for students and teachers (details will follow in deliverable D2.3 Inclusion accessibility and co-creation framework).

Another source for the user requirements has been interviews and discussions with persons with special needs, to learn about their expectations, needs and requirements in accordance with public transport in general and DRT-Service in special.

Meeting user needs and ensuring the social acceptance of a future autonomous mobility service is of paramount importance for the success and widespread adoption of the service. By detailing user interactions with fully automated public transportation systems, use cases offer insights into user requirements, pain points, and expectations from future users. They provide the foundation for designing use cases that are socially acceptable. They help in structuring test scenarios that reflect real-world user interactions, allowing for feedback on how well the proposed service meets user needs and helps iterate and improve the design.

Active user-involvement in the co-creation, testing and validation of existing and new use cases allows use cases to correspond to user needs. This bottom-up approach values qualitative contributions of users to the service provided. The active participation of citizens further fosters knowledge and a better understanding of automated mobility by the community the service will be deployed in, promoting a positive perception and social acceptance of the service. The inclusion of citizens in the creation and validation of use cases also allows for new innovative ideas to emerge through collective intelligence.

Within the ULTIMO project, citizen participation is done through in-person and online deliberation as well as hackathons. Citizens are invited to share their public transport needs and discuss how their needs can be addressed. During these co-creation events, citizens are able to discuss their needs and construct use-cases for autonomous public transport.

A major challenge to citizen participation in the co-creation of new use cases for autonomous public transport and the validation of existing use cases is the lack of experience with autonomous vehicles most participants have. It is therefore essential for the event format to either be general enough to not require an in-depth understanding of the new technology or service, or for the participants to be informed sufficiently about the technical, legal and policy limitations to a fully automated public transport service. Furthermore, user co-created use cases need to conform to technical, legal and policy requirements for deployment. This is achieved by including experts from PTOs and other project partners in the co-creation activities and by fostering an environment of active co-operation, without stifling the creativity of participants. Besides being stand-alone use cases, user created use cases may also be merged with existing use cases from PTOs and manufacturers, serve as a basis for the creation of new use cases or be used as an inspiration for future citizen co-creation activities.

9.2 PTO/PTA Requirements

The PTO/PTA requirements were gathered in several working sessions with the PTO/PTA partners DB, Ruter and TPG. Most PTO/PTA requirements are related to the topics Fleet Management, Monitoring, Remote operation and Communication.

A PTO/PTA needs to be informed immediately if there are any incidents that impact passenger health/safety, comfort or service availability. Statistics, AI based data analytics, etc. can be used for forecasting to provide a more efficient and optimised service.

A fleet overview containing all vehicles with status information and location is essential for PTO/PTA. PTO/PTA shall be able to remove operators from vehicles, seamlessly integrate new vehicles from different manufacturers and enable dynamic rerouting to accommodate changing demands.

Ensuring the seamless compatibility of both software and hardware utilized for Autonomous Vehicles (AVs) and on-demand services is of utmost importance, as it greatly improves the flexibility of public transportation systems.

One of the pivotal challenges lies in the intricate task of seamlessly integrating all transport services within a Mobility-as-a-Service (MaaS) application, a matter of paramount significance for Public Transportation Authorities (PTA) and Passenger Transportation Operators (PTOs).

Inclusivity plays an important role, requiring the dispatch of specialized vehicles for passengers with special needs. Efficient battery management is also important. The system shall monitor and recharge vehicles with low battery levels and ensure charged batteries during peak hours. Alerts should be generated for vehicles with low battery status to prevent service disruptions.

The monitoring subcategory includes a range of requirements. The PTO/PTA shall receive alerts for any issues with vehicles, software, or traffic disruptions, enabling quick response to problems. They should have real-time access to the fleet's status, including detailed

information on each vehicle's condition, both inside and out, with the ability to zoom in for a closer look. Another important requirement is the ability to detect anomalies with passengers or objects in the vehicles and highlight them in camera feeds. Monitoring also extends to critical aspects like seatbelt and seat sensors, as well as the detection of littering, air quality, and temperature outside specified ranges.

The PTO/PTA aims to establish rapid and secure remote operational capabilities, including functions like stopping, door-opening, and limited, low-speed maneuvering for safety and obstacle navigation; however, the realization of these objectives depends on both legal considerations and the capabilities of the OEMs.

In terms of communication, a PTO/PTA needs the possibility to interact with passengers in the vehicle. Initiating communication is as important as responding to any communication triggered by passengers. PTO/PTA should be able to talk to passengers in specific vehicles or all vehicles in an area.

To enhance passenger comfort, reduce incidents, and address maintenance issues more effectively, the PTO/PTA should seek assistance through the provision of relevant monitoring data for efficient problem-solving.

Equally critical are considerations such as special needs, passenger safety, and data protection. Ensuring accessibility, the app shall provide standard features like adjustable text size and voiceover mode while prioritizing user data protection. Further emphasizing inclusivity, customer service (CS) staff should receive training in disability awareness and accessible communication to assist passengers with diverse needs, including those who are mute, deaf, or visually impaired.

9.3 Other Requirements

In addition to user requirements, which prioritize passenger experience, and PTO/PTA Requirements, which address operational aspects, this section delves into some additional requirements consisting of two distinct categories: vehicle requirements and LaaS requirements. Vehicle requirements pertain specifically to the capabilities of the vehicles, while LaaS requirements extend the focus to the broader logistics ecosystem.

Vehicle requirements encompass several subcategories, with the most mentioned ones including HW specifications, interior, safety, security, and V2X (Vehicle-to-everything).

Vehicles shall detect discrepancies in occupied seats compared to registered passengers. For the convenience of passengers, the vehicles shall have handles for passengers to hold on to. In-vehicle screens shall be designed for easy readability, and display specifications shall ensure that individual station names or message words are displayed clearly and for a minimum duration. Adequate space shall be provided for passengers with wheelchairs, mobility aids, or strollers, as well as means to secure them.

Interior requirements include cleanliness, clean air, and pleasant temperatures. The seating arrangement should provide separation between passengers, such as separators between side-by-side seats. Special needs shall be addressed through contrasting door controls with visual indications. To meet all regional safety standards, the vehicle's interior shall contain emergency equipment, including window breakers and fire extinguishers.

Safety features also encompass audible and visible indicators for door openings, detectability for the visually impaired, and mechanisms to prevent closing in on passengers. Smooth braking behavior, incident detection systems, redundant systems to ensure fault tolerance, and robust safety protocols shall also be in place.

Cybersecurity measures shall protect against cyberattacks and ensure secure communication protocols, encryption techniques, intrusion detection, and regular security updates.

The V2X requirements include the requirements for vehicle's ability to interact with infrastructure, depots, barriers, traffic lights, other road users, and passenger apps.

LaaS requirements focus on ensuring the secure and efficient storage and delivery of goods and packages within the transit system. Vehicles shall provide safe and secure means to store packages to prevent damage or theft, as well as maintain the right temperature to prevent spoiling. To ensure accurate deliveries, customers should only have access to the correct package and be able to retrieve it while the vehicle does not move. In addition, customers shall be able to choose the exact delivery time and monitor their packages during transit until delivery. In cases where a package is not picked up, the vehicle shall promptly inform the LaaS service provider.

10 Automatic Countryside On-demand Services

To provide an excellent countryside on-demand service, several crucial elements must be considered to ensure the best possible experience:

Vehicle Size and Capacity: The vehicles used for on-demand services should have sufficient interior space to comfortably accommodate passengers, including those in large wheelchairs. Ample room for luggage is also essential. While it's important to have vehicles capable of seating at least 5 to 6 passengers to cater to various needs and group sizes, it's worth noting that the majority of rides are typically for 1 or 2 passengers.

Speed Capabilities: To operate effectively on countryside roads without significantly impacting traffic flow, on-demand vehicles should be capable of reaching speeds up to 90 km/h. This speed range allows the vehicles to maintain a pace similar to other vehicles on these roads, minimizing disruptions to other road users.

Road Compatibility: Vehicles must be designed and equipped to handle the diverse road conditions typically found in countryside areas. This includes incorporating robust suspension systems for a smoother ride on uneven surfaces, ensuring sufficient ground clearance to navigate rough patches or obstacles, and utilizing tires suitable for different terrains.

Weather Conditions: Vehicles should be suitable for all weather conditions, enabling them to operate in various environments without limitations based on perfect weather or ideal temperatures.

Accessibility Features: To accommodate passengers with disabilities, vehicles should be equipped with comprehensive accessibility features. This can include ramps or lifts for easy boarding and disembarking of passengers in wheelchairs, as well as appropriate restraints or securement systems to ensure passenger safety during the journey.

Charging Infrastructure: In the case of electric or hybrid vehicles, a well-established charging infrastructure is essential. This infrastructure ensures efficient recharging and provides an adequate range to serve multiple trips without requiring frequent charging sessions, supporting the reliable operation of the on-demand service.

Maintenance and Reliability: Given the continuous operation of on-demand services, vehicles should exhibit reliability and have robust maintenance protocols in place. This minimizes downtime, ensuring that vehicles are available for service and providing a seamless experience for passengers.

Integration with Service Platform: Vehicles need to be equipped with the necessary technology to seamlessly integrate with the service platform. This includes communication systems, data-sharing capabilities, and compatibility with the backend software used by the service provider to manage bookings, routing, and other operational aspects.

By considering these additional details, an on-demand service can provide passengers with a comfortable, efficient, and accessible experience while maintaining compatibility with the countryside road environment.

11 Automatic City Centre On-demand Services

To provide an excellent city centre on-demand service, several crucial elements must be considered to ensure the best possible experience:

Vehicle Size and Capacity: The vehicles used for city centre on-demand services should not only be compact and manoeuvrable but also designed to maximize passenger capacity. Adequate seating capacity to comfortably accommodate at least 2 to 6 passengers is crucial. Optimizing space efficiency within the vehicle, such as through clever seat configurations or

foldable seats, allows for the transportation of more passengers in a limited urban environment.

Speed Capabilities: City centre on-demand vehicles should be capable of operating at moderate speeds suitable for urban traffic conditions. Typically, speeds ranging from 40 to 50 km/h are sufficient for navigating through city streets safely and efficiently, while still maintaining an appropriate pace for passenger comfort and road safety.

Road Compatibility: Vehicles should be specifically designed to handle the unique challenges of city centre driving. This includes features such as responsive handling to navigate through narrow streets, compact dimensions for easy parking in limited spaces, and strong braking systems to ensure quick and safe stops in crowded areas. Equipping vehicles with advanced safety technologies like anti-lock braking systems (ABS) and electronic stability control (ESC) further enhances safety, especially on slippery surfaces or during abrupt manoeuvres.

Emission Standards: Given the emphasis on sustainability and air quality in city centres, on-demand vehicles should comply with stringent emission standards. Electric vehicles are increasingly preferred for their low or zero emissions, effectively reducing pollution levels in densely populated areas. These eco-friendly vehicle options contribute to a cleaner and healthier urban environment^{14,15,16}

Charging Infrastructure: For electric or hybrid vehicles used in city centre on-demand services, a well-established and conveniently located charging infrastructure is essential. Fast charging stations strategically placed throughout the area allow vehicles to recharge quickly, ensuring they remain operational and available for service without extended downtime. An extensive charging network provides the necessary energy support for an efficient and reliable on-demand service.

Maintenance and Reliability: Given the high-demand nature of city centre on-demand services, vehicles should adhere to a rigorous maintenance schedule to minimize downtime and ensure reliability. Maintenance checks, prompt repairs, and efficient fleet management protocols are crucial to maintaining a seamless service experience for passengers. Proactive maintenance practices contribute to a reliable and efficient transportation service.

Integration with Service Platform: Vehicles need to be seamlessly integrated into the service platform used for city centre on-demand services. This integration involves robust communication systems and data-sharing capabilities. Furthermore, compatibility with the backend software enables efficient management of bookings, routing, and other operational aspects. Real-time updates and communication between vehicles and the service platform enhance the overall efficiency and responsiveness of the on-demand service.

¹⁴ GOLDBACH, Carina, SICKMANN, Jorn, PITZ, Thomas, Towards autonomous public transportation: Attitudes and intentions of the local population, Transportation Research Interdisciplinary Perspectives, Volume 13, 2022

¹⁵ FAGNANT, Daniel, KOCKELMAN, Kara, Preparing a nation for autonomous vehicles: opportunities, barriers and policy recommendations, Transportation Research Part A: Policy and Practice, Volume 77, July 2015

¹⁶ KORKMAZ, Huseyin, FIDANOGLU, Akif, OZCELIK, Salih, User acceptance of autonomous public transport systems: Extended UTAUT2, Journal of Public Transportation, Volume 24, 2022

Vehicle-to-Infrastructure (V2I) Communication: Implementing V2I communication enables vehicles to connect and exchange information with the city's infrastructure. This technology allows vehicles to receive real-time traffic updates, road condition alerts, and traffic light information. By leveraging V2I communication, on-demand vehicles can optimize routes, make informed decisions, and navigate more efficiently within the city centre, reducing travel time and improving overall service quality.

By considering these elements, a city centre on-demand service can provide passengers with a convenient, efficient, and sustainable transportation option while effectively navigating the unique challenges of urban environments. The integration of V2I communication further enhances the service's efficiency and responsiveness, ensuring a seamless and enhanced travel experience for passengers.

12 Vehicle Capabilities

A list of vehicle capabilities was created in T2.2 by former ULTIMO partner Sensible4 with input from all other partners. The structure of the vehicle capability list is described in section [4.1.2](#). The complete list can be found in the [Annex B](#).

The key elements for automatic driving for a vehicle are the following elements:

Autonomous Driving,
Real-time Communication
GPS and Mapping,
Sensor Suite,
Safety Systems,
V2X Communication,
Onboard Computing and Software,

The required vehicle capabilities differ depending on the different deployment sites. The following shows the differences between countryside on-demand services and city centre on-demand services.

13 Matching of Requirements and Vehicle Capabilities

Having defined the requirements and vehicle capabilities, as described earlier in the document, the next step was to try to match them, i.e., to identify which vehicle capabilities are necessary in order to satisfy each of the set requirements. This has been the objective of the work performed in T2.3.

At this stage the aim is to provide a compendium of the desired vehicle capabilities (among the ones identified in T2.2) for each of the requirements (as defined in T2.1), so that the latter could be optimally met. Thus, the capabilities addressed are not vehicle, nor pilot specific. In the next version of this deliverable, and upon having finalised the pilots' set up, use cases to be addressed and vehicles to be used in each pilot, it would be possible to specify which are the capabilities actually available and, thus, the requirements that can be satisfied (even partly).

13.1 Methodology

13.1.1 Requirements

Requirements have been defined in T2.1 (see section 2.4) and organised in three groups:

- User requirements,
- PTO/PTA requirements and
- Other requirements (LaaS, Vehicle).

User requirements have in turn been structured following the User Journey throughout the service, i.e.:

- Informing oneself and Deciding
- Planning and Booking
- Getting to Pickup point
- Waiting at Pickup point
- Connecting pax-vehicle
- Boarding the Vehicle
- Travelling
- Incident during Trip
- Disembarking from Vehicle/Switching transportation
- Reviewing the trip

13.2 Vehicle Capability List

A list of vehicle capabilities was created in T2.2 by gathering input from all ULTIMO partners.

The vehicle capabilities have been recognised in three main categories, with relevant subcategories:

1. Hardware specifications
 - Vehicle dimensions (height, length, width, weight, etc.)
 - Technical specifications (top speed, turning diameter, ground clearance, battery capacity, door width and height, operation temperature, etc.)
 - Carrying capacity (passengers, cargo, other)
 - Passenger services (stop request button, pax counting system, ticket verification system, loudspeaker, etc.)
 - Accessibility and comfort (ramp, audio guidance to doors, passenger information system, heating/cooling/air conditioning, etc.)
 - Passenger Safety (assistance systems for visually and/or hearing impaired, seatbelts, emergency stop button, first aid kit, etc.)
 - Autonomous driving hardware (sensors, computer)
2. Software specifications
 - Operational Design domain, autonomous driving system (traffic lights, roundabouts, speed signs, road blocking obstacles, etc.)
 - Remote capabilities (safety operator, fleet management)
 - Connectivity
3. Other specifications
 - Legal and regulatory (type of licence of safety operator, speed authorization, data transfer to back office)

The complete vehicle capability list can be found in the [Annex B](#).

13.3 Procedure

Thus, in order to match the requirements with the vehicle capabilities a set of matrices have been built. Each matrix addresses one of the requirements categories to match the requirements with the vehicle capabilities. The **table 4.1** below shows an example of such a matrix.

				Vehicle capabilities										
				Hardware specifications							Software specifications			Other specifications
				Vehicle dimensions	Technical specifications	Carrying capacity	Passenger services	Accessibility and comfort	Passenger Safety	Autonomous driving hardware	Operational design domain, autonomous driving system	Remote capabilities	Connectivity	Legal and regulatory
ID	Step/Category	Topic	Requirement											
	63_4_Wait	Information	The user shall be informed about the time when the vehicle will arrive at the pick up point											
	64_4_Wait	special needs	The user with special needs shall not experience any additional waiting time for the vehicle to pick them up compared to any other passenger											
	65_4_Wait		The user shall have the ability to mark the ride as a no-show and contact customer support if the vehicle fails to arrive											
	66_4_Wait	Information	The vehicle shall let the user know when it is approaching the pick up point											
	67_4_Wait	Information	The system shall provide a time estimate of how far away the vehicle is											
	68_4_Wait	Information	The user shall be able to get a confirmation that this is the correct location											
	69_4_Wait	Information	The user shall be able to track the vehicle (its position and time to arrive at PUDO)											
	70_4_Wait	special needs	The vehicle shall have AVAS or similar (so that users can hear the vehicle coming)											
	71_4_Wait		The system shall be able to cancel the ride if no passenger shows up											

Table 3: Matrix used to match the requirements with the vehicle capabilities

To facilitate the process, the matrix has been organised so that when clicking on an empty cell, all the available options on vehicle requirements are presented, according to the corresponding column (Table 4.2).

			Vehicle capabilities										
			Hardware specifications							Software specifications			Other specifications
Step/Category	Topic	Requirement	Vehicle dimensions	Technical specifications	Carrying capacity	Passenger services	Accessibility and comfort	Passenger Safety	Autonomous driving hardware	Operational design domain, autonomous driving system	Remote capabilities	Connectivity	Legal and regulatory
63_4_Wait	Information	The user shall be informed about the time when the vehicle will arrive at the pick up point											
64_4_Wait	special needs	The user with special needs shall not experience any additional waiting time for the vehicle to pick them up compared to any other passenger											
65_4_Wait		The user shall have the ability to mark the ride as a no-show and contact customer support if the vehicle fails to arrive											
66_4_Wait	Information	The vehicle shall let the user know when it is approaching the pick up point											
67_4_Wait	Information	The system shall provide a time estimate of how far away the vehicle is											
68_4_Wait	Information	The user shall be able to get a confirmation that this is the correct location											
69_4_Wait	Information	The user shall be able to track the vehicle (its position and time to arrive at PUDO)											
70_4_Wait	special needs	The vehicle shall have AVAS or similar (so that users can hear the vehicle coming)											
71_4_Wait		The system shall be able to cancel the ride if no passenger shows up											

Table 4: Matrix used to match the requirements with the vehicle capabilities (when clicking on an empty cell)

14 Results

In order to gather the required input and match the vehicle capabilities with the requirements, the matrices have been shared with ULTIMO experts, with the aim to gather different views, from the point of the vehicle manufacturers, the PTOs, the users, the OEMs, the services providers, the equipment providers, etc.

The gathered inputs have been synthesized in one overall set of matrices, providing all the vehicle capabilities that are considered necessary for each of the identified requirements.

The complete set of matrices can be found in [Annex C](#), while in the description of the results below, a separate link is provided for each requirement category, leading directly to the corresponding matrix.

14.1 User Requirements

14.1.1 Informing/Deciding

For the “Informing” step of the user requirements, a series of capabilities are identified as necessary, as seen in [Annex C](#). It should however be noted, that for this step, the capabilities are actually intended for the website, application or other means of communication with the users, rather than the vehicle itself. They are thus presented here in the sense that these are the vehicle capabilities that the communication means should present to the users as information regarding the vehicle which will perform the service.

In terms of hardware specifications, there are mostly related to *Accessibility and Comfort*, *Carrying capacity* and *Passengers’ Safety*, while *Technical Specifications* and *Autonomous Driving Hardware* are less relevant for the requirements in this step. As for the software and other specifications, in this step the most relevant ones are dealing with *Remote Capabilities* and *Connectivity*.

14.1.2 Booking

In the “[Booking](#)” step, as in the previous one, the vehicle capabilities are again intended for the communication means (website, application, etc.) that will assist the user in making the booking of the desired service.

The most relevant hardware specification in this step are *Carrying Capacity*, *Passenger Services*, *Accessibility and Comfort* and *Passenger Safety*, while for the software and other specifications, several *Remote Capabilities* are required along with V2Passenger in terms of *Connectivity* and Data transfers as *Legal and regulatory*.

14.1.3 Getting to Pick up Point

For the next step, “[Getting to Pick up Point](#)”, it is mostly required (in terms of hardware) to provide indication of the line number, along passenger information system (*Accessibility and Comfort*), while also some *Autonomous Driving Hardware* is necessary, mainly for localisation purposes. Moreover, *Remote Capabilities* (GNSS location, Communication with passengers, etc.) and some *Legal and regulatory specifications* are also necessary in this case.

14.1.4 Waiting at Pick up Point

The vehicle capabilities that were assigned to the “[Waiting at Pick up Point](#)” include hardware specifications related mostly to *Technical Specifications*, *Accessibility and Comfort* and *Autonomous Driving Hardware*, while for software and other specifications, *Remote Capabilities* such as Communication with Passengers and GNSS location along with Speed Authorization, in terms of *Legal and Regulatory* specifications.

14.1.5 Connect Pax-Vehicle

In the next step, the vehicle has arrived at the pick up point and it should be connected to the passenger. Thus, in order to [Connect Pax-Vehicle](#), several different vehicle capabilities are required. First, regarding hardware, many *Technical Specifications* are necessary (Number of doors and their dimensions, Bluetooth), along with *Accessibility and Comfort* ones (Passenger information system, audio guidance to doors, etc.), *Passenger Safety* and *Autonomous Driving hardware*. Additionally, in terms of software and other specifications requirements, these mostly refer to *Remote Capabilities* (Communication with Passengers, Door control, etc.), and V2Passenger and V2V *Connectivity*.

14.1.6 Boarding AV

Now that the vehicle has arrived, the passenger successful [boarding](#) to the vehicle needs to be assured. There are numerous requirements linked to this step, involving almost all categories of vehicle capabilities. Regarding hardware requirements, there are several ones lying in the *Vehicle Dimensions*, *Carrying Capacity*, *Accessibility and Comfort* (Accessibility seats spots, Passenger information system, Audio guidance to doors, etc.), *Passenger Safety* (Assistance systems for impaired) and *Autonomous Driving Hardware* (Camera, IMU, etc.). On the other hand, on software and other specifications, these are mainly related to *Remote Capabilities* (Video/Audio feed, Mission cancelation/modification, etc.) along with *Connectivity* (V2Passengers, V2V, etc.) and Data transfer to back office in *Legal and Regulatory* specifications.

14.1.7 Travelling

A great variety of requirements are included in the [Travelling](#) step, which involves the duration of the passenger being onboard the AV. The required hardware specifications in this case are mostly related to *Accessibility and Comfort*, *Passenger Services* and *Passenger Safety* (Emergency button, Seatbelts, SOS mechanism, etc.), while a variety of Autonomous Driving hardware is also involved. At the same time, *V2Passenger Connectivity* is essential, along with several *Remote Capabilities* (Indoor temperature, Door opening/closing control, video/audio feed, etc.).

14.1.8 Incident

During Travelling there might be the case of an [Incident](#), which would stimulate a series of additional requirements. In this case, *Passenger Safety* specifications are naturally the most prominent ones (Ability to contact remote operator, Emergency button, SOS mechanism, Assistance systems for impaired), together with *Passenger Services* (Loudspeaker, Stop request button), *Accessibility & Comfort* (Passenger information). Of course, *Remote Capabilities* are also necessary (Communication with passengers, State of sensors, Mission cancelation/modification, video/audio feed) along with *Connectivity* and transfer of data to back office (*Legal and Regulatory*)

14.1.9 Disembark/Switch transportation

At the [Disembarking](#) stage, when the traveller has reached the destination and is getting out the vehicle, the specifications are quite relevant to the ones of the Boarding stage. *Accessibility and Comfort* issues are important, in terms of Guidance to the doors, Passenger information system, etc., as well as *Passenger Safety* ones (Assistance systems for impaired) and *Passenger Services* (Loudspeaker, Stop button), along with the necessary *Autonomous Driving Hardware*. Moreover, *Remote Capabilities* and *Connectivity* issues are important, along with *Operational Design Domain*, *Autonomous Driving System* specifications (Road conditions, Road blocking obstacles, Pedestrian crossings, etc.).

14.1.10 Review

In the [Review](#) stage, after the trip, the passenger is assessing the whole experience, thus the hardware specifications linked are mostly related to *Passenger Safety* and *Accessibility and Comfort*, while the software and other ones with *Remote Capabilities* and *Connectivity*.

14.2 PTO/PTA Requirements

There is a long list of [PTO/PTA](#) requirements and the corresponding vehicle capabilities that could satisfy them. The latter are mostly related to *Autonomous Driving Hardware* (Camera, LiDAR, Radar, 5G), *Technical Specifications* (Top Speed, Fuel/Battery Capacity, Battery charging time), as well as *Carrying Capacity* and *Passenger Safety*. Also, in terms of software specifications, almost all of the *Remote Capabilities* are necessary, along with certain *Connectivity*, *Operational Design Domain* (Road blocking obstacles, Traffic lights, Other road users, etc.) and *Legal & Regulatory* ones.

14.3 LaaS Requirements

In the case of [LaaS](#) requirements these are mostly related to *Carrying Capacity* (max cargo weight/dimensions, fixing to secure cargo) and *Autonomous Driving Hardware*, as well as *Vehicle Dimensions* and *Technical Specifications* (Operation temperature). Moreover, *Remote Capabilities* such as GNSS location, Indoor temperature and Video feed are considered necessary, as well as Data transfers to back office (*Legal & Regulatory*) and *Connectivity*.

14.4 Vehicle Requirements

Finally, looking at the capabilities that are necessary in terms of [Vehicle](#) Requirements, all categories are included, with *Autonomous Driving Hardware* being the most necessary ones, together with *Accessibility and Comfort*, *Carrying Capacity* and *Technical Specifications*. In terms of software and other specifications, the ones needed for most of the requirements are related to *Remote Capabilities* and *Operational Design Domain*, while *Connectivity* and *Legal/Regulatory* ones are also important.

15 Discussion

Having defined the requirements and vehicle capabilities, in this chapter we have attempted a first matching between them. The aim is to find which vehicle capabilities are necessary in order to satisfy each of the identified needs and requirements.

At this first version, the topic is treated at a general level, not focussing on specific pilots and/or vehicles and use cases. This can serve for the pilot sites to look up and identify the requirements their vehicles could satisfy, and vice-versa, to choose the appropriate vehicles according to the requirements existing (or planned) to be treated at site. Moreover, it could serve to vehicle manufacturers for developing further capabilities for their vehicles, as well as for planners and PTO's in developing their strategies.

Of course, this is not exhaustive nor complete; in a later version, and as the pilot planning shall advance and be further specified, requirements and capabilities may be more specific and even enriched and the matching between the two could be more targeted and complete.

16 Operational Design Domains

ODDs, short for Operational Demonstration Documents, are currently under development for various pilot sites within the framework of Work Package 5. These documents are an integral component of Deliverable D5.1, which is the Large-Scale Demonstration Report.

17 Conclusion

In conclusion, Deliverable 2.1 lays a strong foundation for the ULTIMO project's pursuit of automated mobility. It has enriched all of the ULTIMO partners and participants comprehension of passenger and PTO/PTA requirements, which are pivotal in achieving our ambitious goal of establishing a widespread, seamlessly integrated, economically sustainable AV-based public transport system. Our approach, encompassing persona development, journey mapping, requirements assessment, and vehicle capabilities identification, is guiding our path forward.

As we progress, the project will place emphasis on several critical aspects:

Prioritization of Requirements: Section 2.4 outlines our commitment to continually prioritize requirements, ensuring alignment with the evolving needs of passengers and stakeholders.

Persona Development: The ongoing development of personas will deepen our insight into user diversity and preferences, enabling us to tailor our services more effectively.

Tailored Pilot Sites: Our next deliverable will carefully consider the unique characteristics of each ULTIMO pilot site. Feasibility assessments will distinguish between aspects covered by the pilots and those earmarked for future exploration beyond ULTIMO.

Fleet Composition: Determining the composition of our autonomous vehicle fleet is a key focus. Conventional statistics fall short in accounting for variations in disability distributions across locations and the benefits of accessibility features for all passengers. Features like low-floor buses not only enhance accessibility but also improve efficiency, benefiting PTOs and PTAs.

Additionally, we are actively exploring the following elements:

- Cybersecurity
- Payments
- MaaS (Mobility as a Service)
- Logistics

Our forthcoming deliverable will offer comprehensive insights into these topics, complete with site-specific details. These collective efforts propel us toward a future where automated mobility is not just a concept but a practical, inclusive, and seamlessly integrated reality.

Annex A Requirements

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D2.1 Passenger and PTO requirements, needs, and use cases



ID	Step/Category	Topic	Requirement	Comment
1	1_Inform	Information	The user shall have access to complete information on the service and the vehicle	
2	1_Inform	Information	The PTO/PTA shall provide complete and accessible information about the service e.g., that it exists, where and when it is offered, what price to expect, what can be brought, how to book it, etc.	
3	1_Inform	Information	The PTO/PTA shall provide accessible information about the vehicle e.g., what it looks like (outside and inside), how it can be identified, implemented safety measures, etc.	
4	1_Inform	Information	The system shall provide FAQs (Website and in-app), plus form to send in other questions	
5	2_Book	special needs	The user shall be able to book a ride, pay for a ride, take a ride without a (working) smartphone	
6	2_Book	MaaS integration	The passenger shall be able to use different public transport services seamlessly (including first mile/last mile to and from mobility hub)	
7	2_Book	booking data	The user shall be able to book a trip with a fixed ETA (e.g. to doctor's appointment or to a connecting means of transport)	
8	2_Book	booking data	The passenger shall be able to book a trip for the current moment	
9	2_Book	booking data	The passenger shall be able to schedule a trip in advance	
10	2_Book	booking data	The user shall be able to book for other passengers, for example for children that do not use smartphones, grandmother. etc.	
11	2_Book	special needs	The user shall be able to book a solo ride e.g., at night, for a young child, etc.	
12	2_Book	special needs	The user shall be able to book a ride with safety operator on board	

D2.1 Passenger and PTO requirements, needs, and use cases



13	2_Book	special needs	The user with special needs shall be able to book a ride specifying the needs, e.g., with/without ramp, space for luggage, space for guide dog, low-floor vehicle, group of people, dog-free vehicle, ...	automatic ramps are a potential safety risk for visually impaired persons
14	2_Book	special needs	The system shall confirm that all special needs are considered, e.g., that vehicle with ramp is booked and that space in the vehicle is reserved, and if necessary, provide details e.g., how much weight the ramp can support	
15	2_Book	special needs	The passenger with special needs shall be able to book their ride spontaneously just like any other passenger	
16	2_Book	special needs	A user with a mild cognitive impairment shall be able to book a ride independently, with the booking process designed in plain language and featuring intuitive operation	
17	2_Book	booking data	The user shall be able to book recurring trips	
18	2_Book	booking data	The user shall be able to book a shuttle for additional persons (=me plus others)	
19	2_Book	Change Trip	The user shall be able to make changes or cancel a trip at short notice.	
20	2_Book	Information	The user shall be informed about the (time) consequences and/or price benefits of ride sharing	
21	2_Book	Information	The user shall be informed about the location of the PUDOs and be able to view the chosen PUDOs on a map with the walking distance between their current location/destination and the designated PUDOs	
22	2_Book	booking data	When booking for a group, the user shall have the option to add multiple destinations, accommodating the needs of person(s) accompanying them	
23	2_Book	booking data	When booking for a group, the user shall have the option to add multiple pickup points, accommodating the needs of person(s) accompanying them	



D2.1 Passenger and PTO requirements, needs, and use cases



24	2_Book	booking data	The passenger shall be able to select pickup and drop off points with criteria important to them (e.g., shortest walk vs. no road to cross)	
25	2_Book	special needs	The passenger without a (working) smartphone shall be able to get a confirmation of the booking for the trip	
26	2_Book	Information	The confirmation of the booking shall contain all essential information including location of PUDOS, estimated time of arrival (ETA) at start and destination, properties of vehicle (when indicated), price, wait time of the vehicle and (if applicable) connections at a connecting station	
27	2_Book	Information	The user shall have the option to confirm the trip details, including the assigned vehicle	
28	2_Book	Payment	Classic PT tickets shall be valid for this service as well	
29	2_Book	Data protection	The user shall be informed about potential video surveillance	
30	2_Book	Information	The specified price shall be reliable	
31	2_Book	Payment	The user shall be able to register a payment card or use vipps or the like	
32	2_Book	Payment	The user shall be able to pay automatically for the trip	
33	2_Book	Information	The user shall be clearly informed of the time period available for boarding the vehicle	
34	2_Book	booking data	The user shall be able to input their start and stop points	
35	2_Book	Information	The system shall provide suggestions for trips with the estimated journey time and specified price	
36	2_Book	booking data	The system shall onboard the user easily, requiring only essential information such as name, relevant details, and payment method	
37	2_Book	Information	The user shall be provided with information regarding the presence/absence of a safety operator in the AV	

D2.1 Passenger and PTO requirements, needs, and use cases



38	2_Book	Information	The user shall be promptly notified during the early stages of the booking process if no transportation options are available	
39	2_Book	Information	The user shall be informed if the service cancels or changes their trip	
40	2_Book	Information	The user shall receive updates on any changes to their itinerary (new prices, route changes, new ETAs)	Actually after booking
41	2_Book	booking data	The user shall be able to save favourites (trips, PUDOs) - also without booking it	
42	2_Book	special needs	The user shall be able to request longer boarding and disembarking time during booking process	extra time required due to factors such as carrying bags, mobility issues, or assisting children
43	2_Book	Change Trip	The user shall be informed of the consequences of changes to a booking before they confirm the changes or cancellation.	
44	2_Book	special needs	The system shall provide suitable PUDOs when user asks for specific criteria (e.g. no road to cross to destination, suited for wheelchair ramp --> gradient)	criteria tbd.
45	2_Book	Information	If booked route is available with conventional service, the system shall inform the user of this fixed line service providing the same route and encourage user to book fixed line	different price?
46	2_Book	special needs	The Service shall be accessible by all passengers (visually impaired, blind, deaf, motorically impaired, cognitive impairment, etc.)	
47	2_Book	special needs	When of another nationality (language!), the passenger shall be able to book and use the service	
48	2_Book	booking data	The user shall be able to save and edit a user profile including preferences and special needs	
49	2_Book	Information	The system shall provide the properties of the booked vehicle (if special requirements are part of the booking)	e.g. equipped with ramp, space for stroller
50	2_Book	Information	The user shall be able to compare costs - travel time - CO2 footprint of different PT options	



D2.1 Passenger and PTO requirements, needs, and use cases



51	2_Book		Information	The system shall inform the user about the expected demand (how crowded the vehicle might be)	
52	3_Getting PUDO	to	Information	The system shall provide the essential boarding information: the estimated arrival time of the AV at the PUDOS and the AV's identifier, such as its name or license plate number	
53	3_Getting PUDO	to	Information	The user shall be provided with an accurate and accessible description of how to find their pick-up point	
54	3_Getting PUDO	to	Information	The user shall be provided with a real-time time estimate indicating the distance between their current location and the PUDO/the vehicle	
55	3_Getting PUDO	to	Information	The user shall receive confirmation when they have arrived at the correct PUDO	app? on site?
56	3_Getting PUDO	to	Information	The user shall get updated with how long the AV will wait for them at the PUDO	
57	3_Getting PUDO	to	Information	The system shall provide a map with PUDOS and the user position marked	
58	3_Getting PUDO	to	Change Trip	The user shall be able to cancel the trip if they can't make it to pickup point in time	
59	3_Getting PUDO	to	Information	If system predicts that user will be late and vehicle can wait, the system shall ask user if waiting period shall be extended (and inform about consequences)	
60	3_Getting PUDO	to	Information	If system predicts that user will be late and vehicle can't wait, the system shall ask user if new trip in next vehicle shall be booked (and inform about consequences)	
61	3_Getting PUDO	to		PUDO shall be marked in such a way that it can be easily recognised	
62	3_Getting PUDO	to		The user shall be able to report an issue with a PUDO	
63	4_Wait		Information	The user shall be informed about the time when the vehicle will arrive at the pickup point	



D2.1 Passenger and PTO requirements, needs, and use cases



64	4_Wait	special needs	The user with special needs shall not experience any additional waiting time for the vehicle to pick them up compared to any other passenger	
65	4_Wait		The user shall have the ability to mark the ride as a no-show and contact customer support if the vehicle fails to arrive	
66	4_Wait	Information	The vehicle shall let the user know when it is approaching the pickup point	
67	4_Wait	Information	The system shall provide a time estimate of how far away the vehicle is	
68	4_Wait	Information	The user shall be able to get a confirmation that this is the correct location	
69	4_Wait	Information	The user shall be able to track the vehicle (its position and time to arrive at PUDO)	
70	4_Wait	special needs	The vehicle shall have AVAS or similar (so that users can hear the vehicle coming)	
71	4_Wait		The system shall be able to cancel the ride if no passenger shows up	
72	5_Connecting pax and vehicle		The user (incl. visually impaired) shall be able to clearly identify their assigned vehicle as "my vehicle" (e.g. clear correspondence between the vehicle's name or number displayed in the app and the physical vehicle itself)	
73	5_Connecting pax and vehicle	Vehicle HW	The vehicle shall make itself easy to locate (e.g., blink or make a noise)	
74	5_Connecting pax and vehicle		The vehicle shall be able to 'recognize' the user	
75	5_Connecting pax and vehicle	Information	The vehicle shall be clearly marked as a service from the PTO/PTA	
76	5_Connecting pax and vehicle	special needs	The vehicle shall provide door localisation	for visually impaired users

D2.1 Passenger and PTO requirements, needs, and use cases



77	5_Connecting pax and vehicle	Communication	The user shall be able to authorize themselves easily to unlock doors	
78	6_Boarding AV	Incident	The vehicle shall inform the PTO if pax do not board as supposed to	
79	6_Boarding AV	Monitoring	The system shall associate items with passenger	to detect forgotten items, to inform owner of forgotten item, to calculate available space, etc.
80	6_Boarding AV	Communication	The vehicle shall welcome (regular) passengers by name	
81	6_Boarding AV	special needs	When using a wheelchair, the user shall be able to access the vehicle, i.e. vehicle has a ramp, ramp has appropriate gradient, ramp supports weight of wheelchair	
82	6_Boarding AV	special needs	The user shall be able to get heavy luggage into the vehicle	
83	6_Boarding AV	special needs	When using a wheelchair, the user shall be able to securely fix the wheelchair in the vehicle	
84	6_Boarding AV	Vehicle HW	The wheelchair ramp shall indicate how much weight it supports	
85	6_Boarding AV	special needs	When using a walker or stroller, the user shall be able to securely fix the walker or stroller in the vehicle	
86	6_Boarding AV	special needs	The visually impaired passenger shall be able to locate the door	
87	6_Boarding AV	special needs	The visually impaired passenger shall be able to board and disembark safely e.g., ramp does not move towards waiting passenger, ramp not in the way of passenger, etc.	
88	6_Boarding AV	Boarding Time	The user shall be able to board safely using the time they need	
89	6_Boarding AV	Safety	The vehicle shall wait until door, seat sensors and seatbelt sensors say 'OK' before it starts moving	The vehicle shall start only when user is safely seated
90	6_Boarding AV	Safety	The passenger shall be ensured that the vehicle is not driving off before being seated	should not be necessary if vehicle does not start until everyone is seated



D2.1 Passenger and PTO requirements, needs, and use cases



91	6_Boarding AV	Boarding Time	The user shall be able to signal if they are not ready to start the trip	should not be necessary if vehicle does not start until everyone is seated
92	6_Boarding AV	Monitoring	When having booked for another person, the user shall be sure the passenger boards the correct vehicle	
93	6_Boarding AV		The user shall be able to unlock the door as soon as the vehicle arrives	
94	6_Boarding AV	Boarding Time	The user shall be clearly informed of the time period available for boarding the vehicle	
95	6_Boarding AV	Interior	The user shall easily identify available seating options without any confusion or ambiguity	
96	6_Boarding AV	Monitoring	If a passenger exceeds the boarding time limit, the customer support team shall be alerted to address the situation to facilitate the movement of the vehicle	also for Disembark
97	6_Boarding AV	Vehicle HW	The user shall be able to hold on to handles etc to be able to safely get to seat/door	see Vehicle requirement
98	6_Boarding AV	Communication	The user shall be able to request that the vehicle drives on a few meters if the PUDO is not safe to embark (e.g., if there is a big puddle, pile of snow, etc.)	redundant to Disembarking Req
99	6_Boarding AV	Vehicle HW	The vehicle shall provide alert signal when ramp is moving	
100	6_Boarding AV	Safety	The doors shall indicate before they close (alert signal)	
101	6_Boarding AV	Information	The vehicle shall provide boarding confirmation (Pax-AV match)	
102	6_Boarding AV	Incident	The user shall be able to report to the PTO if booking can't be fulfilled (vehicle is full, requested space not available, no ramp, etc.)	
103	6_Boarding AV	Monitoring	The system shall detect if passenger violates booking agreement (e.g. no. of persons, luggage, ...)	
104	6_Boarding AV	Information	Rules in the vehicle shall be obvious (e.g. seat belt or sitting down required etc.)	Boarding or Onboard?



105	6_Boarding AV	Safety	The user shall be able to board the vehicle without a (working) smartphone	
106	7_Onboard	Information	The system shall communicate all information following the dual-channel principle	acoustic, visual, app, ...
107	7_Onboard	special needs	The disabled user (deaf, hearing impaired, blind, visually impaired, ...) shall get the same amount of information everyone else gets (preferably by following the dual-channel principle)	
108	7_Onboard	Safety	The user shall be able to feel and be safe and secure inside the AV	
109	7_Onboard	Information	The user shall be informed about the time when the vehicle will arrive at the drop off point	
110	7_Onboard	Information	The system shall provide the information how the passengers will get from the drop off point to the destination	But only on the smartphone not in the bus
111	7_Onboard	Information	The user shall be informed about the connections at the connecting station	
112	7_Onboard	Information	The user shall be able to access all relevant information via app and via PIS onboard	
113	7_Onboard	Interior	The passenger shall have the means to securely stow luggage, a stroller or a walker	
114	7_Onboard	Interior	The passenger shall have space under their seat for a guide dog/service dog	
115				
116	7_Onboard	Information	The (blind) passenger shall be informed about unforeseen stops during the ride (construction site, traffic jam, rail crossing etc.)	
117	7_Onboard	special needs	The (disabled) user shall be able to get help / have a contact person in case of unforeseen situations (e.g. technical issues, lack of information, accident etc.)	

D2.1 Passenger and PTO requirements, needs, and use cases



118	7_Onboard	Monitoring	When having booked for another person, the user shall be sure that the passenger arrives safely	
119	7_Onboard	Communication	The passenger shall be able to report littering/damages, etc.	
120	7_Onboard	Information	The passenger shall have alternative travel options suggested in the event of a disruption	
121	7_Onboard	Interior	The passenger shall have a comfortable distance from other passengers	
122	7_Onboard	Interior	The passenger shall have enough space for their belongings/luggage	
123	7_Onboard	Safety	The passenger shall be guaranteed a seat during the ride	
124	7_Onboard	Change Trip	The passenger shall be able to return to their starting point without finishing the booked ride	
125	7_Onboard	Change Trip	The passenger shall be able to initiate a halt request to immediately leave the vehicle at the next possible stop	
126	7_Onboard	Change Trip	The passenger shall be able to change their trip destination (during the trip)	
127	7_Onboard	Information	The user shall be informed how long the AV will wait at the PUDOS (when vehicle is waiting on route for other pax)	
128	7_Onboard		The vehicle shall arrive at the user's destination by the "promised" ETA, regardless of ride sharing	
129	7_Onboard	Vehicle HW	The user shall be able to open and use the trunk	
130	7_Onboard	Safety	The service shall implement measures to identify and address any instances of "ghostriders" before driving	
131	7_Onboard		The fellow passengers shall behave in a respectful and appropriate manner / The service provider shall promote and encourage good behaviour among passengers	
132	7_Onboard	Information	The system shall inform users about rules regarding the use of the AV (e.g. "This is a shared service. Remember to respect other passengers")	plus info like passengers have to be seated, what about seat belts etc.



D2.1 Passenger and PTO requirements, needs, and use cases



133	7_Onboard		If all sensors indicate that the vehicle is in operational state, both the Voice Over system and the in-car screen shall display a message instructing the user to "Press GO to start the ride."	also communicated via app plus GO functionality available in app
134	7_Onboard	Information	The in-vehicle screen shall display the route information and the pickup and drop off points (PUDOs)	PUDOs for different passengers are displayed differently
135	7_Onboard	Information	The user shall be informed if new passengers will board their bus	
136	7_Onboard	Information	The user shall be informed of changes to their itinerary due to new passengers	
137	7_Onboard	Information	The user shall be informed about the (time) consequences and/or price benefits of ride sharing	
138	7_Onboard	Information	The system shall inform the passengers about the interim stop and the vehicle's arrival/departure time there	
139	7_Onboard	Information	The user shall receive the reasons for slowing down or stops (AV 'stream of consciousness'?)	
140	7_Onboard	Information	The AV shall indicate the name of the PUDO as the vehicle arrives at each location (acoustic, visual, in app)	
141	7_Onboard	Monitoring	The vehicle shall monitor e.g., seatbelt and seat sensors, decibel levels, help request of pax, etc.	This can be split.
142	7_Onboard	Communication	The user shall be able to contact the customer service via a button in the AV, via app functionality, via shouting for help, etc.	
143	7_Onboard	information	The vehicle shall inform passengers about any unforeseen events or changes to the route and their cause (dual-channel principle!)	e.g., onscreen, VO or CS etc. cause for sudden stop, pull over etc.
144	7_Onboard	Safety	Customer service shall be able to provide assistance on how to disembark using the onboard camera to see what is happening	
145	7_Onboard	Change Trip	When user discontinues/cancels trip, the user shall be offered a list of close PUDOs to choose from (closest PUDO = default)	



D2.1 Passenger and PTO requirements, needs, and use cases



146	7_Onboard	Change Trip	User shall be informed of being dropped off before they confirm the cancellation	
147	7_Onboard	Safety	The customer service (CS) shall be notified if the system detects that passengers experience problems	drunk pax, pax walking around, pax falls, pax harmed, etc.
148	7_Onboard	Information	The vehicle shall signal (a beep or the like) if the doors are not properly locked.	
149	7_Onboard	Information	The system shall activate a notification (Voice Over script or the like) to notify the user if the user fails to properly close the door or clear the door area.	Monetary penalty if no action?
150	7_Onboard		The user shall not be required to confirm their intention to leave the vehicle	?
151	7_Onboard		As a user, I need to be reminded if I have to confirm that my trip is concluded, but I'd rather not have to	?
152	7_Onboard	Communication	The user shall be able to interact with the control centre in the way that suits them	
153	7_Onboard	Data protection	The in-vehicle screen shall not display any private or personal information of the user	
154	7_Onboard	Information	The in-vehicle screen shall provide a map display with the position of the vehicle and the PUDOS and POIs	POI display could be sponsored (e.g. movie theatre, supermarket)
155	7_Onboard	Information	The in-vehicle screen shall provide emergency information and the option to request help	
156	7_Onboard	Information	The in-vehicle screen shall provide information about the ride like upcoming PUDOS, ETA at the PUDOS, delays, interchange information (MaaS)	
157	7_Onboard	Information	The in-vehicle screen shall provide information about the vehicle like battery status, sensor info, speed, etc.	pax want to "see with the eyes of the vehicle"
158	7_Onboard	Information	The user shall be able to see an in-vehicle screen from every seat	
159	7_Onboard	Information	The vehicle shall inform passengers about upcoming stop	



160	7_Onboard	Information	The vehicle shall alert passengers about arriving at their destination at an appropriate time before reaching it	via all channels: acoustic, visual, via app (display as pop-up notification)
161	7_Onboard	MaaS integration	The user shall arrive in time to reach the connection	
162	7_Onboard	MaaS integration	If vehicle fails to reach the connection, it shall inform the user and offer an alternative.	
163	7_Onboard	MaaS integration	If vehicle fails to reach the connection, the system shall inform the driver of the connecting vehicle and ask to wait	
164	7_Onboard	Change Trip	User shall be informed of the consequences (e.g. re payment) of a change in booking before they confirm the changes or cancellation	
165	7_Onboard	Communication	The user shall be able to see the person from CS when talking	video call instead of just audio
166	7a_Incident	Communication	The user shall be able to talk directly to customer service in case of an incident or any concerns	must also work without a smartphone
167	7a_Incident	Safety	The user shall be able to stop the vehicle and open the doors so they can exit the vehicle in case of an incident	must also work without a smartphone
168	7a_Incident	Communication	Customer service shall automatically come on audio call if something happens	stop button is pressed, camera detects incident etc.
169	7a_Incident	Monitoring	Customer service shall be able to activate and watch video feed in case of unexpected events	
170	7a_Incident	Information	The system shall inform the passengers about any unforeseen events and ask if they want to resume the ride	two in one?
171	7a_Incident	Safety	The doors shall unlock automatically if emergency stop button is pressed	and AV has found a safe place to stop???
172	7a_Incident	Safety	Emergency personnel shall be notified automatically when required	
173	7a_Incident	Payment	The user shall get a full refund if the reason for discontinuing is the service providers fault	

D2.1 Passenger and PTO requirements, needs, and use cases



174	7a_Incident		The user shall be able to report an incident	
175	7a_Incident	Information	The system shall provide instructions to the pax in the event of an incident (using dual channel principle)	e.g. evacuation procedure
176	7a_Incident	fleet management	The system shall send another vehicle if there is a problem with the vehicle and inform the passengers	or vehicle can't drive on due to medical emergency
177	8_Disembark	Safety	The vehicle shall drop (visually impaired) passengers off only at safe locations (no traffic, no puddles, no pile of snow, no sprouted bush)	
178	8_Disembark	Safety	The visually impaired passenger shall be informed about any obstacles between the drop off point and their destination	
179	8_Disembark	Safety	The (visually impaired) passenger shall be guided from the drop off point to their destination	e.g. navigation functionality in app: idea for visual navigation: AR arrows in camera view point the way
180	8_Disembark	Boarding Time	The user shall be able to disembark safely using the time they need	
181	8_Disembark		For disembarking, the vehicle shall stop, automatically unlock the doors, and inform pax about destination PUDO (e.g. voice-over announcement or display or app)	
182	8_Disembark	Information	The system (e.g., app, in-vehicle screen) shall inform the passenger that the vehicle has now reached the passenger's destination	
183	8_Disembark	Boarding Time	The vehicle shall indicate the remaining time available for disembarking (e.g. timer on big screen, with an option to request more time)	
184	8_Disembark	Information	The user shall get a reminder to ensure they remember their belongings.	ideally only when they have brought anything
185	8_Disembark		The door of the fully automated vehicle shall be automatically unlocked when the user is disembarking	
186	8_Disembark	Safety	The doors shall indicate before they close (alert signal)	already at boarding



D2.1 Passenger and PTO requirements, needs, and use cases



187	8_Disembark	Communication	The user shall be able to request that the vehicle drives on a few meters if the PUDO is not safe to disembark (e.g., if there is a big puddle, pile of snow, etc.)	ideally the vehicle detects it automatically
188	8_Disembark	Safety	The user shall be able to exit the vehicle without a (working) smartphone	
189	8_Disembark	Safety	The vehicle shall check if it is safe before it opens the doors for passengers to disembark	e.g. camera detects obstacles, approaching bike rider etc.
190	8_Disembark	MaaS integration	The system shall provide info about changeover time for connecting means of transport	112
191	8_Disembark	Incident	The vehicle shall inform the PTO if pax do not disembark as supposed to	
192	8_Disembark	Boarding Time	The user shall have the option to request additional time for disembarking	
193	8_Disembark	Vehicle HW	The vehicle shall provide alert signal when ramp is moving	already at boarding
194	8_Disembark	Monitoring	The customer service (CS) shall be notified after a certain time if pax exceed the boarding time limit to address the situation to facilitate the movement of the vehicle.	
195	8_Disembark	Safety	PUDO must provide space to move on safely and be free of obstacles	
196	8_Disembark	Monitoring	When having booked for another person, the user shall be sure the passenger disembarks at the correct location	
197	8_Disembark	Monitoring	The vehicle shall inform Customer Service if a passenger falls while disembarking	
198	9_Review		The user shall be able to rate the experience	
199	9_Review		The user shall be able to share the experience	
200	9_Review		The user shall be able to report forgotten items in the vehicle	
201	9_Review		The user shall be able to provide feedback on the service	
202	9_Review	Payment	The user shall be able to receive a receipt of the trip	
203	9_Review		The service shall provide a process for retrieving/returning lost items (e.g. vehicle could bring item back to PUDO etc.)	



D2.1 Passenger and PTO requirements, needs, and use cases



204	9_Review	booking data	The user shall be able to save a trip as a favourite	
205	9_Review		The user shall be able to report an issue with a PUDO	
206	LaaS	Vehicle HW	The vehicle shall provide means to store goods/packages safely so that they cannot fall or break	
207	LaaS	Vehicle HW	The vehicle shall provide means to store goods/package securely so that they cannot be stolen	
208	LaaS	Vehicle HW	The customer shall only have access to the correct package (to avoid they take the wrong one)	
209	LaaS		The customer shall be able to pickup a package while the vehicle does not move/drive off	
210	LaaS	Monitoring	The customer shall be able to monitor their package in transit until delivery	
211	LaaS	Information	The vehicle shall inform the LaaS service provider if package is not picked up	
212	LaaS	Vehicle HW	The vehicle shall provide means to store goods/package with the right temperature so that they won't spoil	
213	LaaS		The customer shall be able to choose an exact time for the delivery of the parcel	
214	PTO	special needs	The app shall support standard accessibility features like text size and voiceover mode to guarantee access to all	
215	PTO	Monitoring	The PTO shall know the location of all vehicles	
216	PTO	Monitoring	The PTO shall be informed about events impacting passengers in real time	
217	PTO	Data protection	The user shall have their data protected	
218	PTO	Monitoring	The PTO shall see in real time the status of the service	
219	PTO		The PTO shall have statistics on the services	or: system shall provide statistics on the services
220	PTO	Remote operation	The PTO shall be able to respond to any events impacting the services	



D2.1 Passenger and PTO requirements, needs, and use cases



221	PTO	Monitoring	The PTO shall be able to monitor vehicle, passengers and activities	too many things in one requirement?? and too generic
222	PTO		The system shall provide an integrated control centre in another branch. The PTO shall be able to test reliability at another location	two requirements?
223	PTO	Communication	The PTO shall be able to communicate to passengers inside a specific vehicle	
224	PTO	Communication	The PTO shall be able to communicate to passengers inside all vehicles in an area	
225	PTO	Remote operation	The PTO shall be able at all times to remotely stop the vehicle and open the doors	
226	PTO	Remote operation	The PTO shall be able to remotely manoeuvre the vehicle to a safe location at low speeds	
227	PTO	Remote operation	The PTO shall be able to remotely manoeuvre the vehicle at low speeds to overcome an obstacle	
228	PTO	Remote operation	The PTO must be the only one to remotely manoeuvre vehicles	
229	PTO	fleet management	The PTO shall be able to remove operators from vehicles to make certain services financially viable	
230	PTO	fleet management	The PTO shall be able to easily integrate new vehicles procured from different manufacturers	
231	PTO	fleet management	The services shall be able to reroute to pickup other demands (pax?)	
232	PTO	fleet management	The services shall be able to dispatch vehicles adapted to passengers with special needs when required.	
233	PTO	fleet management	The services shall be able to make predictions to have the right equipped vehicle already in the area, when a booking is made with special needs.	
234	PTO	MaaS integration	The services shall be integrated into the existing transport services	



D2.1 Passenger and PTO requirements, needs, and use cases



235	PTO	MaaS integration	The PTO shall communicate connecting options between conventional PT and OnDemand Services	
236	PTO	Safety	The PUDOs shall be maintained for safe boarding/disembarking (e.g. clear of ice and snow, treated with salt to prevent slippery conditions, etc.)	
237	PTO	Monitoring	The PTO shall be alerted if there are any problems with any of the vehicles	
238	PTO	Monitoring	The PTO shall be alerted if there are any problems with the fleet management software	
239	PTO	Monitoring	The PTO shall be alerted if there are any traffic problems on the route	
240	PTO	Monitoring	The PTO shall see the status of the fleet	
241	PTO	Monitoring	The PTO shall see the status of each vehicle (in-vehicle camera, sensors, outside camera for 360 view, etc.): overview plus option to have a closer look	
242	PTO	Monitoring	The PTO shall be able to see the interior of the vehicle	
243	PTO	Monitoring	The PTO shall be alerted if the system detects any anomalies with passengers or objects in the vehicle	
244	PTO	Monitoring	Thy system shall highlight relevant pax/objects in camera feed if anomaly is detected	
245	PTO	Communication	The PTO shall be able to quickly contact an ambulance if required	
246	PTO	Communication	The PTO shall be able to request a maintenance team if required with all relevant monitoring data included in the request.	
247	PTO	Monitoring	The PTO shall be able to identify passengers	data protection???
248	PTO	Data protection	All audio and video recordings shall be encrypted and securely stored and accessible only by authorized personnel	
249	PTO	Monitoring	The system shall add "smart" annotations to the audio and video recordings	



D2.1 Passenger and PTO requirements, needs, and use cases



250	PTO	Monitoring	The PTO shall be able to monitor seatbelt and seat sensors	
251	PTO	Monitoring	The system shall alert CS if it detects littering	
252	PTO	Monitoring	The system shall alert CS if it detects low air quality	
253	PTO	Monitoring	The system shall alert CS if it detects temperature outside specified range	
254	PTO		Someone (like an official state or EU department) shall provide standardized HD mapping	Data shall be accessible by anyone who wants but hosted by one unique entity
255	PTO	special needs	CS staff shall be trained for disability awareness and accessible communication	
256	PTO	special needs	The PTO shall provide communication means for all, e.g. also for mute, deaf or visually impaired passengers	
257	PTO	fleet management	The system shall dispatch vehicles with special features only when needed by users with special needs or when all other vehicle are in use in order for them to be as highly available as possible	to avoid longer waiting times for pax with special needs
258	PTO	Monitoring	The PTO shall be able to monitor the battery status of all vehicles of the fleet	
259	PTO	fleet management	The system shall send vehicles with low battery to the depot for charging	
260	PTO	fleet management	The system shall make sure the vehicles are operational with charged batteries during peak hours	
261	PTO	fleet management	The system shall alert if battery status of a vehicle is below a certain threshold	... if battery status is too low to fulfill expected demands?
262	Vehicle	Vehicle HW	The vehicle shall be able to detect if number of occupied seats deviates from number of registered passengers in the vehicle ("ghostriders")	
263	Vehicle	V2X	The vehicle shall be able to interact with elements of infrastructure	

D2.1 Passenger and PTO requirements, needs, and use cases



264	Vehicle	V2X	The vehicle shall be able to interact with the depot it is entering/leaving	
265	Vehicle	V2X	The vehicle shall be able to interact with barriers and gates	
266	Vehicle	V2X	The vehicle shall be able to interact with traffic lights equipped with V2X	
267	Vehicle	V2X	The vehicle shall be able to interact safely with other road users	
268	Vehicle	Vehicle HW	The vehicle shall provide handles for passengers to hold on to when getting to the seat/door	
269	Vehicle	Interior	The vehicle shall be clean	
270	Vehicle	Interior	The vehicle shall provide clean air throughout the journey	
271	Vehicle	Interior	The vehicle shall provide a pleasant temperature throughout the journey	
272	Vehicle	Vehicle HW	The in-vehicle screen shall be designed with a size that allows for easy readability of information	
273	Vehicle	Interior	The seating arrangement in the vehicle shall provide some separation between passengers (e.g., include separators between side-by-side seats)	
274	Vehicle	Interior	The vehicle shall provide emergency equipment like window breaker, fire extinguisher (vehicle shall meet all regional safety standards)	
275	Vehicle	Interior	The vehicle shall be equipped with onboard cameras, microphones and speakers	
276	Vehicle		The vehicle shall be able to detect forgotten items (and inform owner if ownership is known?)	
277	Vehicle	Vehicle HW	The vehicle shall have a wheelchair ramp with the appropriate gradient so that a wheelchair user can board and disembark without assistance.	or a wheelchair lift?
278	Vehicle		The vehicle shall have an identifier (unique, easy to identify, accessible)	
279	Vehicle	V2X	The vehicle shall be able to interact with the passenger app	also with PIS?



280	Vehicle	Vehicle HW	The in-vehicle screen shall provide sufficient contrast	
281	Vehicle		The vehicle shall get the user to their destination significantly faster than walking	
282	Vehicle	Security	All systems shall be secured against cyber attacks	
283	Vehicle	Vehicle HW	The vehicle shall have space for passengers using wheelchairs, mobility aids or strollers etc.	
284	Vehicle	Vehicle HW	The vehicle shall have means to secure wheelchairs, mobility aids or strollers etc.	
285	Vehicle		The vehicle shall provide data like battery status, etc. to other systems	
286	Vehicle	Interior	The passenger shall be able to comfortably transport their shopping	
287	Vehicle	Safety	The doors shall indicate when they open (alert signal). The signal shall... • be clearly audible to persons inside the train & outside the train • be clearly visible to persons inside & outside the train • last for a minimum of 3 s from the moment that the door starts to open	
288	Vehicle	Safety	Doors or the outline of doors operated by passengers shall be detectable by the visually impaired on the outside of the vehicle.	
289	Vehicle	Safety	Doors shall recognize objects of 1.5 cm diameter over the entire height (white cane or dog leash).	
290	Vehicle	Safety	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.	

291	Vehicle	Safety	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.	
292	Vehicle	special needs	Door controls, whether manual, pushbuttons or other devices, shall contrast with the surface on which they are mounted.	
293	Vehicle	special needs	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. It shall be identifiable by touch (for example: tactile markings); this identification shall indicate the functionality.	
294	Vehicle	Vehicle HW	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.	
295	Vehicle	Vehicle HW	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	
296	Vehicle	Vehicle HW	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).	
297	Vehicle		Volume of acoustical announcements shall adjust automatically depending on the noise level in the vehicle.	
298	Vehicle		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).	
299	Vehicle		The spoken information shall have a minimum RASTI level of 0,5, in accordance with IEC 60268-16 part 16, in all areas.	
300	Vehicle		Where provided, spoken information shall be consistent with essential visual information that is being displayed.	

D2.1 Passenger and PTO requirements, needs, and use cases



301	Vehicle		Where spoken information is not provided automatically, an audible communication system shall be provided to allow users to get information upon request.	
302	Vehicle		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	
303	Vehicle		The vehicle shall clearly indicate its status while waiting or boarding (e.g., hazard lights or blinker)	
304	Vehicle		The vehicle shall inform the PTO about forgotten items and provide any available information about it (e.g. video sequences, data of owner)	
305	Vehicle	Safety	The vehicle shall have smooth braking behaviour	
306	Vehicle	Safety	The system shall detect incidents in the vehicle (unconscious pax, fighting, fire, vandalism, attacks, etc.)	
307	Vehicle	Communication	The system shall inform the PTO about any detected incidents	
308	Vehicle		The vehicle shall be able to detect if sensors are damaged or dirty (and inform the PTO)	
309	Vehicle		The vehicle shall be able to go above 70 km/h while still been safe for passengers and its environments	
310	Vehicle		The vehicle shall be able to accommodate at least # passengers (number of pax to be defined per site)	- TPG site: vehicle going up to 8 passengers
311	Vehicle		The vehicle shall be able to monitor its own health e.g., tire pressure, (and inform the PTO)	



D2.1 Passenger and PTO requirements, needs, and use cases



312	Vehicle		The vehicle shall be able to operate without human intervention under most or all driving conditions	Conditions are different for each country e.g., Switzerland requires to have a supervision centre to monitor vehicles. Laws are still getting defined by SAAM and the Swiss authorities.
313	Vehicle	Detection	The vehicle shall have advanced sensor systems, including cameras, lidar, radar, and other relevant sensors, to accurately detect and monitor its surroundings in real-time.	
314	Vehicle	Recognition	These sensors should provide comprehensive coverage and be capable of recognizing various objects, such as pedestrians, cyclists, and other vehicles, within the detected environment.	
315	Vehicle	Planning Reorganization	The vehicle should employ sophisticated algorithms and artificial intelligence (AI) techniques to process sensor data and plan safe and efficient routes, considering dynamic traffic situations, obstacles, and unforeseen events.	
316	Vehicle	Real-time Decision	The vehicle should make real-time decisions based on the processed data, ensuring it responds appropriately to the ever-changing conditions of the road.	
317	Vehicle	Safety	The vehicle shall have redundant systems, both hardware and software, to ensure fault tolerance and reliability. Redundancy may include duplicate sensors, redundant computing systems, and backup power supply to prevent critical failures and enable safe operation in the event of component malfunctions.	
318	Vehicle	Security	The vehicle shall have robust cybersecurity measures to protect against potential hacking or unauthorized access --> secure communication protocols, encryption techniques, intrusion detection systems, and regular security updates.	

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319	Vehicle		The vehicle must adhere to applicable regulatory standards and requirements specific to autonomous driving. This may involve obtaining necessary certifications, passing safety assessments, and meeting specific guidelines established by transportation authorities.	
320	Vehicle	Testing	The vehicle shall have undergone rigorous testing.	
321	Vehicle	Safety	The vehicle shall have robust safety protocols in place, including collision avoidance systems, emergency braking mechanisms, and fail-safe mechanisms to mitigate risks and protect passengers, pedestrians, and other road users in critical situations.	
322	Vehicle		The vehicle shall be able to operate in difficult weather conditions: Extremes Temperature, Rain and Wet Conditions, Snow and Ice, Strong Winds, Fog and Reduced Visibility, Off-Road Capability, Salt and Corrosion Resistance	
323	Vehicle		The vehicle shall be able to operate in difficult traffic situations: Heavy Traffic Congestion, Urban Street Gridlock, Highways and Interchanges, Roundabouts and Traffic Circles, Busiest Intersections, Emergency Vehicle Response	
324	Vehicle		The vehicle shall use standardized HD maps	

Table 5: Requirement table

Annex B Vehicle Capabilities

0

Vehicle
Vehicle name
Vehicle manufacturer
Automation software provider
Country
Launch Date Europe
Launch Date USA
Hardware specifications
Vehicle dimensions
Height (mm)
Length (mm)
Width (mm)
Weight (kg)
Height off the ground of the vehicle with respect to the road (Adaptability) (mm)
Technical specifications
Top speed (km/h)
Range (km)
Turning diameter (m)
Steering (Two wheel - all wheel)
Steering wheel / controller (For safety operator)
Driving direction or directions
Maximum slope
Ground clearance
Fuel capacity (Petrol/diesel/etc) (liter)
Battery capacity (kWh)

Battery health
Battery charger
Battery charging time (0 to 100%) (minutes)
Charger type, inductive charging, other type
Number of doors
Door width
Door height
Operation temperature min/max
Bluetooth low energy (Angle of Arrival/Departure services)
Spare wheel

Carrying capacity	
Passenger	
Passenger capacity	
Number of seating positions	
Number of standing positions	
Seating positions (in direction of travel, against direction of travel, across direction of travel?)	
Cargo	
Max cargo weight	
Max cargo dimensions	
Fixing to secure the cargo	
Specific space for baggage	
Other	
Room for wheelchair, walker, stroller	

Passenger services	
Stop request button	
Passenger counting system	
Ticket verification system	
Loudspeaker	
Charging port for passengers (USB type and amount)	

Accessibility and comfort
Screen(s)/Other to indicate line number
Passenger information system (Number of units and placement)
Audio guidance to doors
Wheelchair / baby carriage ramp
Wheelchair / baby carriage access - No assistance
Wheelchair / baby carriage access - With assistance
Accessibility seats spots (Elderly, pregnant etc)
Tinted or darkened windows
Heating / Cooling /Air conditioning
Indoor CO2 sensor
Passenger Safety
Assistance systems for visually and/or hearing impaired
Seatbelts
Emergency stop button
Ability to contact remote operator (No safety driver on board)
Automated External Defibrillator (resuscitation device)
First aid kit
Emergency windows
SOS mechanism

Autonomous driving hardware
Sensors
LiDARs
Radar
Camera
Infrared camera
4G
5G
IMU
RTK-GNSS

Computer
Size, location
Protection level of vehicle computer hardware (ease of access)

Software specifications

Operational design domain, autonomous driving system
Traffic lights
Roundabouts
Pedestrian crossings
Speed signs
Pedestrians
Low visibility conditions (Rain, snow, fog, dust, night etc)
Other road users
Road blocking obstacles
Road conditions (Icy road, holes)
Tunnels
Highway

Remote capabilities
Safety operator
Remote driving/steering
Tire pressure
State of sensors
State of autonomous system
Battery level (Electric vehicle)
Fuel level (Petrol/Diesel/etc)
Passengers counter
Video feed (Internal / External)
Audio feed
Indoor temperature

Indoor co2 level
GNSS location
Remote navigation control
Door opening / closing control
Communication with passengers
Fleet management
Multi routing
Mission cancellation
Mission modification (During the mission)

Connectivity
V2V
V2X
V2Passenger
Integration of roadside sensors

Other specifications
Legal and regulatory
Type of licence of the safety operator
Speed authorisation (km/h)
Data transfer to back office: video, audio, other

Annex C Requirements matched with Vehicle Capabilities

Inform

Hardware specifications

1. Inform		Hardware specifications						
ID	Requirement	Vehicle dimensions	Technical specifications	Carrying capacity	Passenger services	Accessibility and comfort	Passenger Safety	Autonomous driving hardware
1	The user shall have access to complete information on the service and the vehicle	Height off the ground of the vehicle with respect to the road (Adaptability) (mm)	Driving direction or directions	Room for wheelchair, walker, stroller, Specific space for baggage, Passenger capacity, Number of seating positions, Number of standing positions, Seating positions (in direction of travel, against direction of travel, across direction of travel)	Charging port for passengers (USB type and amount), Ticket verification system	Screen(s)/Other to indicate line number , Passenger information system (Number of units and placement), Wheelchair / baby carriage ramp, Wheelchair / baby carriage access - No assistance, Wheelchair / baby carriage access - With assistance, Accessibility seats spots (Elderly, pregnant etc.)	Assistance systems for visually and/or hearing impaired	Size, location
2	The PTO/PTA shall provide complete and accessible information about the service e.g., that it exists,			Passenger capacity	Charging port for passengers (USB type and amount)	Screen(s)/Other to indicate line number , Passenger information system (Number of units and placement), Wheelchair / baby carriage ramp, Wheelchair / baby carriage access - No assistance,	Assistance systems for visually and/or hearing impaired	

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	where and when it is offered, what price to expect, what can be brought, how to book it, etc.					Wheelchair / baby carriage access - With assistance, Accessibility seats spots (Elderly, pregnant etc.), Tinted or darkened windows		
3	The PTO/PTA shall provide accessible information about the vehicle e.g., what it looks like (outside and inside), how it can be identified, implemented safety measures, etc.	Height (mm), Width (mm), Length (mm)	Number of doors	Number of seating positions, Number of standing positions, Room for wheelchair, walker, stroller, Seating positions (in direction of travel, against direction of travel, across direction of travel), Passenger capacity		Screen(s)/Other to indicate line number , Passenger information system (Number of units and placement), Wheelchair / baby carriage access - No assistance, Wheelchair / baby carriage access - With assistance, Accessibility seats spots (Elderly, pregnant etc.), Audio guidance to doors	Seatbelts, Assistance systems for visually and/or hearing impaired , Ability to contact remote operator (No safety driver on board), Emergency stop button, First aid kit, Emergency windows	4G, Size, location
4	The system shall provide FAQs (Website and in-app), plus form to send in other questions	N/R	N/R	N/R	N/R	N/R	N/R	N/R

Table 6: Inform, hardware specifications

Software & Other Specifications

1. Inform		Software specifications			Other specifications
ID	Requirement	Operational design domain, autonomous driving system	Remote capabilities	Connectivity	Legal and regulatory
1	The user shall have access to complete information on the service and the vehicle		Communication with passengers	V2Passenger	
2	The PTO/PTA shall provide complete and accessible information about the service e.g., that it exists, where and when it is offered, what price to expect, what can be brought, how to book it, etc.		Communication with passengers	V2Passenger	
3	The PTO/PTA shall provide accessible information about the vehicle e.g., what it looks like (outside and inside), how it can be identified, implemented safety measures, etc.		GNSS location	V2Passenger	Type of license of the safety operator
4	The system shall provide FAQs (Website and in-app), plus form to send in other questions	N/R	N/R	N/R	N/R

Table 7: Inform, software and other specifications

Book

Hardware specifications

2. Book		Hardware specifications						
ID	Requirement	Vehicle dimensions	Technical specifications	Carrying capacity	Passenger services	Accessibility and comfort	Passenger Safety	Autonomous driving hardware
5	The user shall be able to book a ride, pay for a ride,		Range (km)	Passenger capacity	Passenger count	Passenger information system (Number of units and placement),	Ability to contact remote operator (No safety driver on board),	

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	take a ride without a (working) smartphone				ng system , Stop request button , Ticket verification system	Screen(s)/Other to indicate line number	Assistance systems for visually and/or hearing impaired	
6	The passenger shall be able to use different public transport services seamlessly (including first mile/last mile to and from mobility hub)					Screen(s)/Other to indicate line number	Assistance systems for visually and/or hearing impaired	
7	The user shall be able to book a trip with a fixed ETA (e.g. to doctor's appointment or to a connecting means of transport)		Top speed (km/h)	Passenger capacity	Passenger counting system	Screen(s)/Other to indicate line number , Passenger information system (Number of units and placement)	Assistance systems for visually and/or hearing impaired	Size, location
8	The passenger shall be able to book a trip for the current moment			Passenger capacity, Specific space for baggage, Room for wheelchair, walker, stroller	Stop request button	Screen(s)/Other to indicate line number , Passenger information system (Number of units and placement)	Assistance systems for visually and/or hearing impaired	Size, location
9	The passenger shall be able to schedule a trip in advance			Passenger capacity, Specific space for baggage, Room for wheelchair, walker, stroller		Screen(s)/Other to indicate line number , Passenger information system (Number of units and placement)	Assistance systems for visually and/or hearing impaired	Size, location
10	The user shall be able to book for other passengers, for example for children that do not use smartphones, grandmother. etc.			Passenger capacity, Specific space for baggage, Room for wheelchair, walker, stroller		Accessibility seats spots (Elderly, pregnant etc), Passenger information system (Number of units and placement), Wheelchair / baby carriage access - No assistance,	Assistance systems for visually and/or hearing impaired	Size, location



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						Wheelchair / baby carriage access - With assistance, Screen(s)/Other to indicate line number		
11	The user shall be able to book a solo ride e.g., at night, for a young child, etc.			Passenger capacity, Specific space for baggage, Room for wheelchair, walker, stroller		Screen(s)/Other to indicate line number , Passenger information system (Number of units and placement)	Assistance systems for visually and/or hearing impaired	Size, location
12	The user shall be able to book a ride with safety operator on board			Passenger capacity, Specific space for baggage, Room for wheelchair, walker, stroller		Wheelchair / baby carriage ramp, Wheelchair / baby carriage access - With assistance, Screen(s)/Other to indicate line number , Passenger information system (Number of units and placement)	Assistance systems for visually and/or hearing impaired	Size, location
13	The user with special needs shall be able to book a ride specifying the needs, e.g. with/without ramp, space for luggage, space for guide dog, low-floor vehicle, group of people, dog-free vehicle, ...					Wheelchair / baby carriage ramp, Wheelchair / baby carriage access - No assistance, Wheelchair / baby carriage access - With assistance, Accessibility seats spots (Elderly, pregnant etc), Audio guidance to doors, Passenger information system (Number of units and placement), Screen(s)/Other to indicate line number	Assistance systems for visually and/or hearing impaired	
14	The system shall confirm that all special needs are considered, e.g. that vehicle with ramp is booked and that space in the vehicle is reserved, and if necessary provide details e.g., how much weight the ramp can support	Weight (kg), Height off the ground of the vehicle with respect to		Passenger capacity, Specific space for baggage, Room for wheelchair, walker, stroller		Wheelchair / baby carriage ramp, Wheelchair / baby carriage access - No assistance, Wheelchair / baby carriage access - With assistance, Accessibility seats spots (Elderly, pregnant etc), Screen(s)/Other to indicate line number , Passenger information system (Number of units and placement)	Assistance systems for visually and/or hearing impaired	

D2.1 Passenger and PTO requirements, needs, and use cases



		the road (Adaptability) (mm)						
15	The passenger with special needs shall be able to book their ride spontaneously just like any other passenger	Weight (kg), Height off the ground of the vehicle with respect to the road (Adaptability) (mm)		Passenger capacity, Specific space for baggage, Room for wheelchair, walker, stroller	Stop request button	Wheelchair / baby carriage ramp, Wheelchair / baby carriage access - No assistance, Wheelchair / baby carriage access - With assistance, Accessibility seats spots (Elderly, pregnant etc), Screen(s)/Other to indicate line number, Passenger information system (Number of units and placement)	Assistance systems for visually and/or hearing impaired	RTK-GNSS, Size, location
16	A user with a mild cognitive impairment shall be able to book a ride independently, with the booking process designed in plain language and featuring intuitive operation			Passenger capacity, Specific space for baggage, Room for wheelchair, walker, stroller		Accessibility seats spots (Elderly, pregnant etc), Passenger information system (Number of units and placement), Screen(s)/Other to indicate line number, Audio guidance to doors	Assistance systems for visually and/or hearing impaired	Size, location
17	The user shall be able to book recurring trips			Passenger capacity, Specific space for baggage, Room for wheelchair, walker, stroller		Screen(s)/Other to indicate line number, Passenger information system (Number of units and placement)	Assistance systems for visually and/or hearing impaired	Size, location



D2.1 Passenger and PTO requirements, needs, and use cases



18	The user shall be able to book a shuttle for additional persons (=me plus others)			Passenger capacity, Specific space for baggage, Room for wheelchair, walker, stroller		Screen(s)/Other to indicate line number , Passenger information system (Number of units and placement)	Assistance systems for visually and/or hearing impaired	Size, location
19	The user shall be able to make changes or cancel a trip at short notice.					Screen(s)/Other to indicate line number , Passenger information system (Number of units and placement)	Assistance systems for visually and/or hearing impaired	
20	The user shall be informed about the (time) consequences and/or price benefits of ride sharing					Screen(s)/Other to indicate line number , Passenger information system (Number of units and placement)	Assistance systems for visually and/or hearing impaired	
21	The user shall be informed about the location of the PUDOs and be able to view the chosen PUDOs on a map with the walking distance between their current location/destination and the designated PUDOs					Screen(s)/Other to indicate line number , Passenger information system (Number of units and placement)	Assistance systems for visually and/or hearing impaired	
22	When booking for a group, the user shall have the option to add multiple destinations, accommodating the needs of person(s) accompanying them					Screen(s)/Other to indicate line number , Passenger information system (Number of units and placement)	Assistance systems for visually and/or hearing impaired	RTK-GNSS, Size, location
23	When booking for a group, the user shall have the option to add multiple pick up points, accommodating the needs of person(s) accompanying them					Screen(s)/Other to indicate line number , Passenger information system (Number of units and placement)	Assistance systems for visually and/or hearing impaired	RTK-GNSS, Size, location
24	The passenger shall be able to select pick up and drop off points with criteria important to them (e.g. shortest walk vs. no road to cross)					Screen(s)/Other to indicate line number , Passenger information system (Number of units and placement)	Assistance systems for visually and/or hearing impaired	

D2.1 Passenger and PTO requirements, needs, and use cases



25	The passenger without a (working) smartphone shall be able to get a confirmation of the booking for the trip					Screen(s)/Other to indicate line number , Passenger information system (Number of units and placement)	Assistance systems for visually and/or hearing impaired	
26	The confirmation of the booking shall contain all essential information including location of PUDOS, estimated time of arrival (ETA) at start and destination, properties of vehicle (when indicated), price, wait time of the vehicle and (if applicable) connections at a connecting station					Screen(s)/Other to indicate line number , Passenger information system (Number of units and placement)	Assistance systems for visually and/or hearing impaired	
27	The user shall have the option to confirm the trip details, including the assigned vehicle				Passenger counting system , Ticket verification system	Screen(s)/Other to indicate line number , Passenger information system (Number of units and placement)	Ability to contact remote operator (No safety driver on board), Assistance systems for visually and/or hearing impaired	
28	Classic PT tickets shall be valid for this service as well				Ticket verification system	Screen(s)/Other to indicate line number , Passenger information system (Number of units and placement)	Assistance systems for visually and/or hearing impaired	
29	The user shall be informed about potential video surveillance				Loudspeaker	Screen(s)/Other to indicate line number , Passenger information system (Number of units and placement)	Assistance systems for visually and/or hearing impaired	
30	The specified price shall be reliable					Screen(s)/Other to indicate line number , Passenger information system (Number of units and placement)	Assistance systems for visually and/or hearing impaired	

D2.1 Passenger and PTO requirements, needs, and use cases



31	The user shall be able to register a payment card or use vipps or the like					Screen(s)/Other to indicate line number , Passenger information system (Number of units and placement)	Assistance systems for visually and/or hearing impaired	
32	The user shall be able to pay automatically for the trip					Screen(s)/Other to indicate line number , Passenger information system (Number of units and placement)	Assistance systems for visually and/or hearing impaired	
33	The user shall be clearly informed of the time period available for boarding the vehicle				Loudspeaker	Screen(s)/Other to indicate line number , Passenger information system (Number of units and placement)	Assistance systems for visually and/or hearing impaired	
34	The user shall be able to input their start and stop points					Screen(s)/Other to indicate line number , Passenger information system (Number of units and placement)	Assistance systems for visually and/or hearing impaired	
35	The system shall provide suggestions for trips with the estimated journey time and specified price				Passenger counting system , Ticket verification system	Screen(s)/Other to indicate line number , Passenger information system (Number of units and placement)	Assistance systems for visually and/or hearing impaired	
36	The system shall onboard the user easily, requiring only essential information such as name, relevant details, and payment method					Screen(s)/Other to indicate line number , Passenger information system (Number of units and placement)	Assistance systems for visually and/or hearing impaired	
37	The user shall be provided with information regarding the presence/absence of a safety operator in the AV					Screen(s)/Other to indicate line number , Passenger information system (Number of units and placement)	Assistance systems for visually and/or hearing impaired	
38	The user shall be promptly notified during the early stages of the booking process if no transportation options are available			Passenger capacity, Specific space for baggage, Room for wheelchair, walker, stroller		Screen(s)/Other to indicate line number , Passenger information system (Number of units and placement)	Assistance systems for visually and/or hearing impaired	RTK-GNSS, Size, location



D2.1 Passenger and PTO requirements, needs, and use cases



39	The user shall be informed if the service cancels or changes their trip					Screen(s)/Other to indicate line number , Passenger information system (Number of units and placement)	Assistance systems for visually and/or hearing impaired	
40	The user shall receive updates on any changes to their itinerary (new prices, route changes, new ETAs)					Screen(s)/Other to indicate line number , Passenger information system (Number of units and placement)	Assistance systems for visually and/or hearing impaired	
41	The user shall be able to save favorites (trips, PUDOs) - also without booking it					Screen(s)/Other to indicate line number , Passenger information system (Number of units and placement)	Assistance systems for visually and/or hearing impaired	
42	The user shall be able to request longer boarding and disembarking time during booking process					Screen(s)/Other to indicate line number , Passenger information system (Number of units and placement)	Assistance systems for visually and/or hearing impaired	
43	The user shall be informed of the consequences of changes to a booking before they confirm the changes or cancellation.					Screen(s)/Other to indicate line number , Passenger information system (Number of units and placement)		
44	The system shall provide suitable PUDOs when user asks for specific criteria (e.g. no road to cross to destination, suited for wheelchair ramp --> gradient)	Height off the ground of the vehicle with respect to the road (Adaptability) (mm)	Maximum slope			Screen(s)/Other to indicate line number , Passenger information system (Number of units and placement)		
45	If booked route is available with conventional service, the system shall inform the user of this fixed line service providing the same route and encourage user to book fixed line					Screen(s)/Other to indicate line number , Passenger information system (Number of units and placement)		



D2.1 Passenger and PTO requirements, needs, and use cases



46	The Service shall be accessible by all passengers (visually impaired, blind, deaf, motorically impaired, cognitive impairment, etc.)	Height off the ground of the vehicle with respect to the road (Adaptability) (mm)		Room for wheelchair, walker, stroller, Passenger capacity		Audio guidance to doors, Wheelchair / baby carriage ramp, Wheelchair / baby carriage access - No assistance, Wheelchair / baby carriage access - With assistance, Accessibility seats spots (Elderly, pregnant etc), Screen(s)/Other to indicate line number , Passenger information system (Number of units and placement)	Assistance systems for visually and/or hearing impaired	
47	When of another nationality (language!), the passenger shall be able to book and use the service					Screen(s)/Other to indicate line number , Passenger information system (Number of units and placement)	Assistance systems for visually and/or hearing impaired	
48	The user shall be able to save and edit a user profile including preferences and special needs					Screen(s)/Other to indicate line number , Passenger information system (Number of units and placement)		
49	The system shall provide the properties of the booked vehicle (if special requirements are part of the booking)	Height off the ground of the vehicle with respect to the road (Adaptability) (mm)				Wheelchair / baby carriage ramp, Wheelchair / baby carriage access - No assistance, Wheelchair / baby carriage access - With assistance, Screen(s)/Other to indicate line number , Passenger information system (Number of units and placement)	Assistance systems for visually and/or hearing impaired	
50	The user shall be able to compare costs - travel time - CO2 footprint of different PT options					Screen(s)/Other to indicate line number , Passenger information system (Number of units and placement)	Assistance systems for visually and/or hearing impaired	
51	The system shall inform the user about the expected demand (how crowded the vehicle might be)			Passenger capacity, Number of seating positions,	Passenger counting system	Screen(s)/Other to indicate line number , Passenger information system (Number of units and placement)	Assistance systems for visually and/or hearing impaired	

D2.1 Passenger and PTO requirements, needs, and use cases



				Number of standing positions, Seating positions (in direction of travel, against direction of travel, across direction of travel)				
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Table 8: Book, hardware specifications

Software & Other specifications

2.Book		Software specifications			Other specifications
ID	Requirement	Operational design domain, autonomous driving system	Remote capabilities	Connectivity	Legal and regulatory
5	The user shall be able to book a ride, pay for a ride, take a ride without a (working) smartphone		Passengers counter, Communication with passengers	V2Passenger	Data transfer to back office: video, audio, other
6	The passenger shall be able to use different public transport services seamlessly (including first mile/last mile to and from mobility hub)		Communication with passengers	V2Passenger	Data transfer to back office: video, audio, other
7	The user shall be able to book a trip with a fixed ETA (e.g. to doctor's appointment or to a connecting means of transport)		GNSS location, Multi routing, Communication with passengers	V2Passenger	Speed authorisation (km/h), Data transfer to back office: video, audio, other
8	The passenger shall be able to book a trip for the current moment		GNSS location, Mission modification (During the mission), Multi routing,	V2Passenger	Data transfer to back office: video, audio, other



D2.1 Passenger and PTO requirements, needs, and use cases



			Battery level (Electric vehicle), Communication with passengers		
9	The passenger shall be able to schedule a trip in advance		GNSS location, Multi routing, Communication with passengers	V2Passenger	Data transfer to back office: video, audio, other
10	The user shall be able to book for other passengers, for example for children that do not use smartphones, grandmother. etc.		GNSS location, Multi routing, Communication with passengers	V2Passenger	Data transfer to back office: video, audio, other
11	The user shall be able to book a soloride e.g., at night, for a young child, etc.		GNSS location, Multi routing, Communication with passengers	V2Passenger	Data transfer to back office: video, audio, other
12	The user shall be able to book a ride with safety operator on board		GNSS location, Multi routing, Communication with passengers	V2Passenger	Data transfer to back office: video, audio, other
13	The user with special needs shall be able to book a ride specifying the needs, e.g. with/without ramp, space for luggage, space for guide dog, low-floor vehicle, group of people, dog-free vehicle, ...		Communication with passengers	V2Passenger	Data transfer to back office: video, audio, other
14	The system shall confirm that all special needs are considered, e.g. that vehicle with ramp is booked and that space in the vehicle is reserved, and if necessary provide details e.g., how much weight the ramp can support		Communication with passengers	V2Passenger	Data transfer to back office: video, audio, other
15	The passenger with special needs shall be able to book their		GNSS location, Multi routing,	V2Passenger	Data transfer to back office: video, audio, other

D2.1 Passenger and PTO requirements, needs, and use cases



	ride spontaneously just like any other passenger		Mission modification (During the mission), Battery level (Electric vehicle), Communication with passengers		
16	A user with a mild cognitive impairment shall be able to book a ride independently, with the booking process designed in plain language and featuring intuitive operation		GNSS location, Multi routing, Communication with passengers	V2Passenger	Data transfer to back office: video, audio, other
17	The user shall be able to book recurring trips		GNSS location, Multi routing, Communication with passengers	V2Passenger	Data transfer to back office: video, audio, other
18	The user shall be able to book a shuttle for additional persons (=me plus others)		GNSS location, Multi routing, Communication with passengers	V2Passenger	Data transfer to back office: video, audio, other
19	The user shall be able to make changes or cancel a trip at short notice.		Mission cancellation, Mission modification (During the mission), Communication with passengers	V2Passenger	Data transfer to back office: video, audio, other
20	The user shall be informed about the (time) consequences and/or price benefits of ride sharing		Communication with passengers	V2Passenger	Data transfer to back office: video, audio, other
21	The user shall be informed about the location of the PUDOs and be able to view the chosen PUDOs on a map with the walking distance between their		Communication with passengers	V2Passenger	Data transfer to back office: video, audio, other



D2.1 Passenger and PTO requirements, needs, and use cases



	current location/destination and the designated PUDOs				
22	When booking for a group, the user shall have the option to add multiple destinations, accommodating the needs of person(s) accompanying them		GNSS location, Multi routing, Communication with passengers	V2Passenger	Data transfer to back office: video, audio, other
23	When booking for a group, the user shall have the option to add multiple pick up points, accommodating the needs of person(s) accompanying them		GNSS location, Multi routing, Communication with passengers	V2Passenger	Data transfer to back office: video, audio, other
24	The passenger shall be able to select pick up and drop off points with criteria important to them (e.g. shortest walk vs. no road to cross)		Communication with passengers	V2Passenger	Data transfer to back office: video, audio, other
25	The passenger without a (working) smartphone shall be able to get a confirmation of the booking for the trip		Communication with passengers	V2Passenger	Data transfer to back office: video, audio, other
26	The confirmation of the booking shall contain all essential information including location of PUDOS, estimated time of arrival (ETA) at start and destination, properties of vehicle (when indicated), price, wait time of the vehicle and (if applicable) connections at a connecting station		Communication with passengers	V2Passenger	Data transfer to back office: video, audio, other
27	The user shall have the option to confirm the trip details, including the assigned vehicle		Passengers counter, Communication with passengers	V2Passenger	Data transfer to back office: video, audio, other
28	Classic PT tickets shall be valid for this service as well		Communication with passengers	V2Passenger	Data transfer to back office: video, audio, other
29	The user shall be informed about potential video surveillance		Communication with passengers, Video feed (Internal / External)	V2Passenger	Data transfer to back office: video, audio, other



D2.1 Passenger and PTO requirements, needs, and use cases



30	The specified price shall be reliable		Communication with passengers	V2Passenger	Data transfer to back office: video, audio, other
31	The user shall be able to register a payment card or use vipps or the like		Communication with passengers	V2Passenger	Data transfer to back office: video, audio, other
32	The user shall be able to pay automatically for the trip		Communication with passengers	V2Passenger	Data transfer to back office: video, audio, other
33	The user shall be clearly informed of the time period available for boarding the vehicle		Communication with passengers	V2Passenger	Data transfer to back office: video, audio, other
34	The user shall be able to input their start and stop points		Multi routing, Remote navigation control, Communication with passengers	V2Passenger	Data transfer to back office: video, audio, other
35	The system shall provide suggestions for trips with the estimated journey time and specified price		Passengers counter, Communication with passengers	V2Passenger	Data transfer to back office: video, audio, other
36	The system shall onboard the user easily, requiring only essential information such as name, relevant details, and payment method		Communication with passengers	V2Passenger	Data transfer to back office: video, audio, other
37	The user shall be provided with information regarding the presence/absence of a safety operator in the AV		Communication with passengers	V2Passenger	Data transfer to back office: video, audio, other
38	The user shall be promptly notified during the early stages of the booking process if no transportation options are available		GNSS location, Battery level (Electric vehicle), Communication with passengers	V2Passenger	Data transfer to back office: video, audio, other
39	The user shall be informed if the service cancels or changes their trip		Communication with passengers	V2Passenger	Data transfer to back office: video, audio, other
40	The user shall receive updates on any changes to their itinerary		GNSS location,	V2Passenger	Data transfer to back office: video, audio, other



D2.1 Passenger and PTO requirements, needs, and use cases



	(new prices, route changes, new ETAs)		Remote navigation control, State of autonomous system, Communication with passengers		
41	The user shall be able to save favorites (trips, PUDOs) - also without booking it		Communication with passengers	V2Passenger	Data transfer to back office: video, audio, other
42	The user shall be able to request longer boarding and disembarking time during booking process		Communication with passengers	V2Passenger	Data transfer to back office: video, audio, other
43	The user shall be informed of the consequences of changes to a booking before they confirm the changes or cancellation.		Communication with passengers	V2Passenger	Data transfer to back office: video, audio, other
44	The system shall provide suitable PUDOs when user asks for specific criteria (e.g. no road to cross to destination, suited for wheelchair ramp --> gradient)		Communication with passengers	V2Passenger	Data transfer to back office: video, audio, other
45	If booked route is available with conventional service, the system shall inform the user of this fixed line service providing the same route and encourage user to book fixed line			V2Passenger	Data transfer to back office: video, audio, other
46	The Service shall be accessible by all passengers (visually impaired, blind, deaf, motorically impaired, cognitive impairment, etc.)		Communication with passengers, Door opening / closing control	V2Passenger	Data transfer to back office: video, audio, other
47	When of another nationality (language!), the passenger shall be able to book and use the service		Communication with passengers	V2Passenger	Data transfer to back office: video, audio, other



D2.1 Passenger and PTO requirements, needs, and use cases



48	The user shall be able to save and edit a user profile including preferences and special needs		Communication with passengers	V2Passenger	Data transfer to back office: video, audio, other
49	The system shall provide the properties of the booked vehicle (if special requirements are part of the booking)		Communication with passengers	V2Passenger	Data transfer to back office: video, audio, other
50	The user shall be able to compare costs - travel time - CO2 footprint of different PT options		Battery level (Electric vehicle), Fuel level (Petrol/Diesel/etc), Communication with passengers	V2Passenger	Data transfer to back office: video, audio, other
51	The system shall inform the user about the expected demand (how crowded the vehicle might be)		Passengers counter, GNSS location, Communication with passengers	V2Passenger	Data transfer to back office: video, audio, other

Table 9: Book, software and other specifications

Getting to Pick up Point

Hardware specifications

3.Getting to Pick up Point		Hardware specifications						
ID	Requirement	Vehicle dimensions	Technical specifications	Carrying capacity	Passenger services	Accessibility and comfort	Passenger Safety	Autonomous driving hardware
52	The system shall provide the essential boarding		Top speed			Screen(s)/Other to indicate line number ,		RTK-GNSS, Size, location



D2.1 Passenger and PTO requirements, needs, and use cases



	information: the estimated arrival time of the AV at the PUDOS and the AV's identifier, such as its name or license plate number		(km/h)			Passenger information system (Number of units and placement)		
53	The user shall be provided with an accurate and accessible description of how to find their pick-up point							
54	The user shall be provided with a real-time time estimate indicating the distance between their current location and the PUDO/the vehicle		Top speed (km/h)					RTK-GNSS, Size, location
55	The user shall receive confirmation when they have arrived at the correct PUDO							Size, location
56	The user shall get updated with how long the AV will wait for them at the PUDO				Loudspeaker			Size, location
57	The system shall provide a map with PUDOS and the user position marked							Size, location
58	The user shall be able to cancel the trip if they can't make it to pick up point in time							
59	If system predicts that user will be late and vehicle can wait, the system shall ask user if waiting period shall be extended (and inform about consequences)							
60	If system predicts that user will be late and vehicle can't wait, the system shall ask user if new trip in next vehicle shall be booked (and inform about consequences)							



61	PUDO shall be marked in such a way that it can be easily recognised							
62	The user shall be able to report an issue with a PUDO							

Table 10: Getting to pickup point, hardware specifications

Software & Other Specifications

3. Getting to Pick up Point		Software specifications			Other specifications
ID	Requirement	Operational design domain, autonomous driving system	Remote capabilities	Connectivity	Legal and regulatory
52	The system shall provide the essential boarding information: the estimated arrival time of the AV at the PUDOS and the AV's identifier, such as its name or license plate number		GNSS location, Communication with passengers		Speed authorisation (km/h), Type of licence of the safety operator
53	The user shall be provided with an accurate and accessible description of how to find their pick-up point				
54	The user shall be provided with a real-time time estimate indicating the distance between their current location and the PUDO/the vehicle		GNSS location		Speed authorisation (km/h)
55	The user shall receive confirmation when they have arrived at the correct PUDO		Communication with passengers, GNSS location		
56	The user shall get updated with how long the AV will wait for them at the PUDO		Communication with passengers		
57	The system shall provide a map with PUDOS and the user position marked		GNSS location		
58	The user shall be able to cancel the trip if they can't make it to pick up point in time		Mission modification (During the mission), Mission cancellation		
59	If system predicts that user will be late and vehicle can wait, the system shall ask user if waiting period shall be extended (and inform about consequences)		Mission modification (During the mission)		

60	If system predicts that user will be late and vehicle can't wait, the system shall ask user if new trip in next vehicle shall be booked (and inform about consequences)		Mission modification (During the mission)		
61	PUDO shall be marked in such a way that it can be easily recognised				
62	The user shall be able to report an issue with a PUDO				

Table 11: Getting to pickup point, software and other specifications

Waiting at Pick up Point

Hardware specifications

4.Waiting at Pick up Point		Hardware specifications						
ID	Requirement	Vehicle dimensions	Technical specifications	Carrying capacity	Passenger services	Accessibility and comfort	Passenger Safety	Autonomous driving hardware
63	The user shall be informed about the time when the vehicle will arrive at the pick up point		Top speed (km/h)					RTK-GNSS, Size, location
64	The user with special needs shall not experience any additional waiting time for the vehicle to pick them up compared to any other passenger							
65	The user shall have the ability to mark the ride as a no-show and contact customer support if the vehicle fails to arrive							RTK-GNSS, Size, location
66	The vehicle shall let the user know when it is approaching the pick up point		Driving direction or directions					RTK-GNSS, Size, location
67	The system shall provide a time estimate of how far away the vehicle is		Top speed (km/h),					RTK-GNSS, Size, location

D2.1 Passenger and PTO requirements, needs, and use cases



			Driving direction or directions					
68	The user shall be able to get a confirmation that this is the correct location							
69	The user shall be able to track the vehicle (its position and time to arrive at PUDO)							RTK-GNSS, Size, location
70	The vehicle shall have AVAS or similar (so that users can hear the vehicle coming)					Audio guidance to doors, Passenger information system (Number of units and placement)		
71	The system shall be able to cancel the ride if no passenger shows up			Number of seating positions, Number of standing positions, Passenger capacity	Passenger counting system			

Table 12: Waiting at pickup point, hardware specifications

Software & other specifications

4.Waiting at Pick up Point		Software specifications			Other specifications
ID	Requirement	Operational design domain, autonomous driving system	Remote capabilities	Connectivity	Legal and regulatory
63	The user shall be informed about the time when the vehicle will arrive at the pick up point		GNSS location, Communication with passengers, Door opening / closing control		Speed authorisation (km/h)
64	The user with special needs shall not experience any additional waiting time for		Communication with passengers		



D2.1 Passenger and PTO requirements, needs, and use cases

	the vehicle to pick them up compared to any other passenger				
6 5	The user shall have the ability to mark the ride as a no-show and contact customer support if the vehicle fails to arrive		GNSS location, Video feed (Internal / External), Passengers counter, Communication with passengers	V2Passenger	
6 6	The vehicle shall let the user know when it is approaching the pick-up point		GNSS location, Communication with passengers	V2Passenger	
6 7	The system shall provide a time estimate of how far away the vehicle is		GNSS location, Communication with passengers		Speed authorisation (km/h)
6 8	The user shall be able to get a confirmation that this is the correct location		GNSS location		
6 9	The user shall be able to track the vehicle (its position and time to arrive at PUDO)		GNSS location		
7 0	The vehicle shall have AVAS or similar (so that users can hear the vehicle coming)		Mission cancellation, Communication with passengers		
7 1	The system shall be able to cancel the ride if no passenger shows up		Mission cancellation, Passengers counter		

Table 13: Waiting at pickup point, software and other specifications

Connect pax-vehicle

Hardware specifications

5.Connect pax-vehicle		Hardware specifications						
I D	Requirement	Vehicle dimensions	Technical specifications	Carrying capacity	Passenger services	Accessibility and comfort	Passenger Safety	Autonomous driving hardware
7 2	The user (incl. visually impaired) shall be able to clearly identify their assigned vehicle as "my vehicle" (e.g. clear correspondence between the vehicle's name		Bluetooth low energy (Angle of Arrival/Departure services)		Loudspeaker	Passenger information system (Number of units and placement), Screen(s)/Other to indicate line number Audio guidance to doors	Assistance systems for visually and/or hearing impaired	5G, 4G, IMU, RTK-GNSS

D2.1 Passenger and PTO requirements, needs, and use cases



	or number displayed in the app and the physical vehicle itself)							
7 3	The vehicle shall make itself easy to locate (e.g., blink or make a noise)		Bluetooth low energy (Angle of Arrival/Departure services)		Loudspeaker	Screen(s)/Other to indicate line number Passenger information system (Number of units and placement), Audio guidance to doors	Assistance systems for visually and/or hearing impaired	5G, RTK-GNSS, Size, location, 4G, IMU
7 4	The vehicle shall be able to 'recognize' the user		Bluetooth low energy (Angle of Arrival/Departure services)		Passenger counting system, Ticket verification system	Passenger information system (Number of units and placement), Screen(s)/Other to indicate line number	Assistance systems for visually and/or hearing impaired	Camera, 4G, 5G, RTK-GNSS, IMU
7 5	The vehicle shall be clearly marked as a service from the PTO/PTA		Bluetooth low energy (Angle of Arrival/Departure services)			Screen(s)/Other to indicate line number Passenger information system (Number of units and placement)		
7 6	The vehicle shall provide door localisation		Number of doors, Door width, Door height, Bluetooth low energy (Angle of Arrival/Departure services)			Audio guidance to doors		4G, 5G, IMU , Size, location
7 7	The user shall be able to authorize themselves easily to unlock doors		Number of doors, Door width, Door height			Audio guidance to doors, Passenger information system (Number of units and placement)	Assistance systems for visually and/or hearing impaired	5G

Table 14: Connect pax vehicle, hardware specifications



Software & other specifications

5.Connect pax-vehicle		Software specifications			Other specifications
I D	Requirement	Operational design domain, autonomous driving system	Remote capabilities	Connectivity	Legal and regulatory
7 2	The user (incl. visually impaired) shall be able to clearly identify their assigned vehicle as "my vehicle" (e.g. clear correspondence between the vehicle's name or number displayed in the app and the physical vehicle itself)		Communication with passengers, GNSS location	V2Passenger	
7 3	The vehicle shall make itself easy to locate (e.g., blink or make a noise)		Communication with passengers, GNSS location	V2Passenger, V2X	
7 4	The vehicle shall be able to 'recognize' the user		Video feed (Internal / External), Door opening / closing control, Passengers counter, Communication with passengers, GNSS location	V2Passenger, V2X	Data transfer to back office: video, audio, other
7 5	The vehicle shall be clearly marked as a service from the PTO/PTA				Type of license of the safety operator
7 6	The vehicle shall provide door localisation		Door opening / closing control, Communication with passengers	V2Passenger, V2X	
7 7	The user shall be able to authorize themselves easily to unlock doors		Door opening / closing control		

Table 15: Connect pax vehicle, software and other specifications

Boarding AV

Hardware specifications

6.Boarding AV	Hardware specifications
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D2.1 Passenger and PTO requirements, needs, and use cases



ID	Requirement	Vehicle dimensions	Technical specifications	Carrying capacity	Passenger services	Accessibility and comfort	Passenger Safety	Autonomous driving hardware
78	The vehicle shall inform the PTO if pax do not board as supposed to		Bluetooth low energy (Angle of Arrival/Departure services)		Passenger counting system, Ticket verification system		Ability to contact remote operator (No safety driver on board)	Camera, 4G, 5G, IMU RTK-GNSS
79	The system shall associate items with passenger			Specific space for baggage	Passenger counting system	Passenger information system (Number of units and placement)	Ability to contact remote operator (No safety driver on board)	4G, 5G, Camera, IMU
80	The vehicle shall welcome (regular) passengers by name				Passenger counting system, Ticket verification system, Loudspeaker	Passenger information system (Number of units and placement)		Camera, 4G, 5G, IMU RTK-GNSS
81	When using a wheelchair, the user shall be able to access the vehicle, i.e. vehicle has a ramp, ramp has appropriate gradient, ramp supports weight of wheelchair	Height off the ground of the vehicle with respect to the road (Adaptability) (mm)	Door width, Door height	Room for wheelchair, walker, stroller		Wheelchair / baby carriage ramp, Wheelchair / baby carriage access - No assistance, Wheelchair / baby carriage access - With assistance, Accessibility seats spots (Elderly, pregnant etc)		4G
82	The user shall be able to get heavy luggage into the vehicle	Height off the ground of the vehicle with respect to the road (Adaptability)	Door width, Door height	Specific space for baggage, Max cargo weight, Max cargo dimensions, Fixing to secure the cargo		Wheelchair / baby carriage ramp	Assistance systems for visually and/or hearing impaired	Camera

D2.1 Passenger and PTO requirements, needs, and use cases



		bility) (mm)						
8 3	When using a wheelchair, the user shall be able to securely fix the wheelchair in the vehicle			Room for wheelchair, walker, stroller	Loudspeaker	Wheelchair / baby carriage ramp, Wheelchair / baby carriage access - No assistance, Wheelchair / baby carriage access - With assistance, Accessibility seats spots (Elderly, pregnant etc.)	Seatbelts, Assistance systems for visually and/or hearing impaired, Ability to contact remote operator (No safety driver on board)	
8 4	The wheelchair ramp shall indicate how much weight it supports	Height off the ground of the vehicle with respect to the road (Adaptability) (mm)		Fixing to secure the cargo, Max cargo weight, Max cargo dimensions	Loudspeaker	Wheelchair / baby carriage ramp, Passenger information system (Number of units and placement), Accessibility seats spots (Elderly, pregnant etc.)	Assistance systems for visually and/or hearing impaired	Camera, 4G, 5G
8 5	When using a walker or stroller, the user shall be able to securely fix the walker or stroller in the vehicle			Room for wheelchair, walker, stroller, Fixing to secure the cargo	Loudspeaker	Accessibility seats spots (Elderly, pregnant etc.), Wheelchair / baby carriage ramp	Seatbelts, Assistance systems for visually and/or hearing impaired	
8 6	The visually impaired passenger shall be able to locate the door	Height off the ground of the vehicle with respect to the road (Adaptability) (mm)	Bluetooth low energy (Angle of Arrival/Departure services), Number of doors		Loudspeaker	Audio guidance to doors, Passenger information system (Number of units and placement)	Assistance systems for visually and/or hearing impaired	Camera

D2.1 Passenger and PTO requirements, needs, and use cases



87	The visually impaired passenger shall be able to board and disembark safely e.g., ramp does not move towards waiting passenger, ramp not in the way of passenger, etc.	Height off the ground of the vehicle with respect to the road (Adaptability) (mm)	Number of doors	Room for wheelchair, walker, stroller	Loudspeaker	Wheelchair / baby carriage ramp, Wheelchair / baby carriage access - With assistance, Wheelchair / baby carriage access - No assistance, Accessibility seats spots (Elderly, pregnant etc.), Audio guidance to doors, Passenger information system (Number of units and placement)	Assistance systems for visually and/or hearing impaired	4G, Camera, 5G
88	The user shall be able to board safely using the time they need		Number of doors	Room for wheelchair, walker, stroller		Accessibility seats spots (Elderly, pregnant etc.), Audio guidance to doors, Passenger information system (Number of units and placement), Wheelchair / baby carriage ramp	Ability to contact remote operator (No safety driver on board), Assistance systems for visually and/or hearing impaired	Camera
89	The vehicle shall wait until door, seat sensors and seatbelt sensors say 'OK' before it starts moving			Number of seating positions	Passenger counting system, Loudspeaker	Passenger information system (Number of units and placement)	Seatbelts, Ability to contact remote operator (No safety driver on board), Emergency stop button	4G, 5G
90	The passenger shall be ensured that the vehicle is not driving off before being seated			Number of seating positions, Seating positions (in direction of travel, against direction of travel, across direction of travel)	Loudspeaker, Passenger counting system	Passenger information system (Number of units and placement), Accessibility seats spots (Elderly, pregnant etc.)	Seatbelts, Ability to contact remote operator (No safety driver on board), Emergency stop button	Camera, IMU, RTK-GNSS, Protection level of vehicle computer hardware (ease of access)
91	The user shall be able to signal if they are not ready to start the trip				Loudspeaker, Stop request button		Emergency stop button, Ability to contact remote operator (No safety driver on board)	Camera, 4G, 5G

D2.1 Passenger and PTO requirements, needs, and use cases



9 2	When having booked for another person, the user shall be sure the passenger boards the correct vehicle				Passenger counting system, Ticket verification system, Loudspeaker	Passenger information system (Number of units and placement), Screen(s)/Other to indicate line number	Assistance systems for visually and/or hearing impaired	Camera, 4G, 5G
9 3	The user shall be able to unlock the door as soon as the vehicle arrives		Bluetooth low energy (Angle of Arrival/Departure services), Number of doors		Ticket verification system, Stop request button	Audio guidance to doors, Wheelchair / baby carriage ramp	Assistance systems for visually and/or hearing impaired, Ability to contact remote operator (No safety driver on board)	RTK-GNSS, 5G, 4G, IMU
9 4	The user shall be clearly informed of the time period available for boarding the vehicle	Height off the ground of the vehicle with respect to the road (Adaptability) (mm)		Room for wheelchair, walker, stroller	Loudspeaker	Audio guidance to doors, Passenger information system (Number of units and placement)	Assistance systems for visually and/or hearing impaired	4G, 5G, IMU, RTK-GNSS
9 5	The user shall easily identify available seating options without any confusion or ambiguity			Number of seating positions, Number of standing positions, Seating positions (in direction of travel, against direction of travel, across direction of travel), Room for wheelchair,	Passenger counting system, Loudspeaker	Passenger information system (Number of units and placement), Accessibility seats spots (Elderly, pregnant etc)	Assistance systems for visually and/or hearing impaired	4G, 5G, IMU, RTK-GNSS, Size, location, Camera

D2.1 Passenger and PTO requirements, needs, and use cases



				walker, stroller				
9 6	If a passenger exceeds the boarding time limit, the customer support team shall be alerted to address the situation to facilitate the movement of the vehicle				Passenger counting system, Ticket verification system, Loudspeaker	Passenger information system (Number of units and placement)	Ability to contact remote operator (No safety driver on board)	Camera, 5G, Size, location
9 7	The user shall be able to hold on to handles etc to be able to safely get to seat/door	Height off the ground of the vehicle with respect to the road (Adaptability) (mm)	Number of doors	Room for wheelchair, walker, stroller	Loudspeaker	Passenger information system (Number of units and placement), Audio guidance to doors, Accessibility seats spots (Elderly, pregnant etc)	Assistance systems for visually and/or hearing impaired	
9 8	The user shall be able to request that the vehicle drives on a few meters if the PUDO is not safe to embark (e.g., if there is a big puddle, pile of snow, etc.)	Height off the ground of the vehicle with respect to the road (Adaptability) (mm)	Maximum slope, Door height, Ground clearance	Room for wheelchair, walker, stroller	Stop request button, Loudspeaker	Passenger information system (Number of units and placement), Audio guidance to doors, Wheelchair / baby carriage ramp	Ability to contact remote operator (No safety driver on board), Assistance systems for visually and/or hearing impaired	RTK-GNSS, Camera, LiDARS
9 9	The vehicle shall provide alert signal when ramp is moving				Loudspeaker	Wheelchair / baby carriage ramp, Passenger information system (Number of units and placement)	Assistance systems for visually and/or hearing impaired	Camera, 4G, 5G



D2.1 Passenger and PTO requirements, needs, and use cases



100	The doors shall indicate before they close (alert signal)		Number of doors		Loudspeaker	Audio guidance to doors, Passenger information system (Number of units and placement)	Assistance systems for visually and/or hearing impaired	
101	The vehicle shall provide boarding confirmation (Pax-AV match)		Bluetooth low energy (Angle of Arrival/Departure services)	Passenger capacity	Passenger counting system, Loudspeaker, Ticket verification system	Passenger information system (Number of units and placement)		Size, location, Camera
102	The user shall be able to report to the PTO if booking can't be fulfilled (vehicle is full, requested space not available, no ramp, etc.)			Passenger capacity, Number of seating positions, Number of standing positions, Room for wheelchair, walker, stroller	Passenger counting system	Passenger information system (Number of units and placement), Wheelchair / baby carriage ramp	Ability to contact remote operator (No safety driver on board), Assistance systems for visually and/or hearing impaired	Size, location
103	The system shall detect if passenger violates booking agreement (e.g. no. of persons, luggage, ...)	Weight (kg)		Passenger capacity, Specific space for baggage, Room for wheelchair, walker, stroller, Max cargo weight, Max cargo dimensions	Passenger counting system, Ticket verification system, Loudspeaker	Passenger information system (Number of units and placement)	Assistance systems for visually and/or hearing impaired, Ability to contact remote operator (No safety driver on board)	Camera, 4G, 5G, IMU, RTK-GNSS, Size, location
104	Rules in the vehicle shall be obvious (e.g. seat belt or sitting down required etc.)			Seating positions (in direction of travel, against direction of travel, across direction of travel), Fixing to secure the cargo,	Loudspeaker, Passenger counting system	Accessibility seats spots (Elderly, pregnant etc), Passenger information system (Number of units and placement)	Assistance systems for visually and/or hearing impaired, Seatbelts	Camera



D2.1 Passenger and PTO requirements, needs, and use cases



				Specific space for baggage, Passenger capacity, Number of seating positions, Room for wheelchair, walker, stroller				
105	The user shall be able to board the vehicle without a (working) smart phone				Passenger counting system, Ticket verification system, Charging port for passengers (USB type and amount), Loudspeaker	Passenger information system (Number of units and placement), Screen(s)/Other to indicate line number, Audio guidance to doors	Ability to contact remote operator (No safety driver on board), Assistance systems for visually and/or hearing impaired	Camera, 4G, Size, location

Table 16: Boarding AV, hardware specifications

Software & other specifications

6.Boarding AV		Software specifications			Other specifications
I D	Requirement	Operational design domain, autonomous driving system	Remote capabilities	Connectivity	Legal and regulatory
78	The vehicle shall inform the PTO if pax do not board as supposed to		- Video feed (Internal / External), - Audio feed, - Passengers counter, - Communication with passengers, - Mission cancellation, - Mission modification (During the mission)	- V2X, - V2Passenger	Data transfer to back office: video, audio, other
79	The system shall associate items with passenger		Video feed (Internal / External)	V2X, V2Passenger	Data transfer to back office: video, audio, other



D2.1 Passenger and PTO requirements, needs, and use cases

80	The vehicle shall welcome (regular) passengers by name		• Video feed (Internal / External), • Audio feed, • Communication with passengers	V2Passenger	Data transfer to back office: video, audio, other
81	When using a wheelchair, the user shall be able to access the vehicle, i.e. vehicle has a ramp, ramp has appropriate gradient, ramp supports weight of wheelchair		• Door opening / closing control, • Video feed (Internal / External), • Audio feed	• V2X, • V2Passenger	Data transfer to back office: video, audio, other
82	The user shall be able to get heavy luggage into the vehicle		• Video feed (Internal / External), • Audio feed	V2Passenger	Data transfer to back office: video, audio, other
83	When using a wheelchair, the user shall be able to securely fix the wheelchair in the vehicle		• Video feed (Internal / External), • Audio feed	V2Passenger	Data transfer to back office: video, audio, other
84	The wheelchair ramp shall indicate how much weight it supports		• Video feed (Internal / External), • Communication with passengers, • Audio feed	• V2Passenger, • V2X	Data transfer to back office: video, audio, other
85	When using a walker or stroller, the user shall be able to securely fix the walker or stroller in the vehicle		• Video feed (Internal / External), • Audio feed	V2Passenger	Data transfer to back office: video, audio, other
86	The visually impaired passenger shall be able to locate the door		Communication with passengers	V2Passenger	Data transfer to back office: video, audio, other
87	The visually impaired passenger shall be able to board and disembark safely e.g., ramp does not move towards waiting passenger, ramp not in the way of passenger, etc.		• Door opening / closing control, • Communication with passengers, • Video feed (Internal / External), • GNSS location	• Integration of roadside sensors, • V2Passenger, • V2X	Data transfer to back office: video, audio, other
88	The user shall be able to board safely using the time they need		• Video feed (Internal / External), • Audio feed, • Door opening / closing control, • Communication with passengers	V2Passenger	Data transfer to back office: video, audio, other
89	The vehicle shall wait until door, seat sensors and seatbelt sensors say 'OK' before it starts moving		• State of sensors, • Video feed (Internal / External), • Door opening / closing control, • Communication with passengers	• V2Passenger, • V2V, • V2X	Data transfer to back office: video, audio, other
90	The passenger shall be ensured that the vehicle is not driving off before being seated		• Door opening / closing control, • Communication with passengers, • State of sensors, • Video feed (Internal / External), • Passengers counter,	• V2Passenger, • V2X	Data transfer to back office: video, audio, other

D2.1 Passenger and PTO requirements, needs, and use cases



			• GNSS location, • Audio feed, • State of autonomous system		
9 1	The user shall be able to signal if they are not ready to start the trip		• Communication with passengers, • Mission cancellation, • Video feed (Internal / External), • Audio feed, • Door opening / closing control	• V2Passenger, • V2X	Data transfer to back office: video, audio, other
9 2	When having booked for another person, the user shall be sure the passenger boards the correct vehicle		• Video feed (Internal / External), • Audio feed, • Passengers counter, • Communication with passengers, • GNSS location, • Mission modification (During the mission)	• V2Passenger, • V2X	Data transfer to back office: video, audio, other
9 3	The user shall be able to unlock the door as soon as the vehicle arrives		• Door opening / closing control, • Communication with passengers, • GNSS location, • State of autonomous system, • Video feed (Internal / External), • Audio feed	V2Passenger	Data transfer to back office: video, audio, other
9 4	The user shall be clearly informed of the time period available for boarding the vehicle		• Communication with passengers, • Door opening / closing control, • GNSS location, • Video feed (Internal / External), • Audio feed	V2Passenger	Data transfer to back office: video, audio, other
9 5	The user shall easily identify available seating options without any confusion or ambiguity		• Video feed (Internal / External), • State of sensors, • Passengers counter, • GNSS location, • Audio feed	V2Passenger	Data transfer to back office: video, audio, other
9 6	If a passenger exceeds the boarding time limit, the customer support team shall be alerted to address the situation to facilitate the movement of the vehicle		• Door opening / closing control, • Passengers counter, • Video feed (Internal / External), • Communication with passengers, • Mission modification (During the mission), • GNSS location	• V2Passenger, • V2X	Data transfer to back office: video, audio, other

D2.1 Passenger and PTO requirements, needs, and use cases



97	The user shall be able to hold on to handles etc to be able to safely get to seat/door		• Video feed (Internal / External), • Audio feed, • Communication with passengers	Integration of roadside sensors	Data transfer to back office: video, audio, other
98	The user shall be able to request that the vehicle drives on a few meters if the PUDO is not safe to embark (e.g., if there is a big puddle, pile of snow, etc.)	• Road blocking obstacles, • Road conditions (Icy road, holes)	• Remote driving/steering, • State of autonomous system, • GNSS location, • Remote navigation control, • Video feed (Internal / External), • Mission modification (During the mission), • State of sensors, • Communication with passengers	• V2Passenger, • Integration of roadside sensors, • V2X	Data transfer to back office: video, audio, other
99	The vehicle shall provide alert signal when ramp is moving		Communication with passengers	• V2Passenger, • V2X	Data transfer to back office: video, audio, other
1000	The doors shall indicate before they close (alert signal)		• Door opening / closing control, • Communication with passengers	V2Passenger	Data transfer to back office: video, audio, other
1001	The vehicle shall provide boarding confirmation (Pax-AV match)		• Passengers counter, • Communication with passengers, • Video feed (Internal / External)	• V2Passenger, • V2X	Data transfer to back office: video, audio, other
1002	The user shall be able to report to the PTO if booking can't be fulfilled (vehicle is full, requested space not available, no ramp, etc.)		• Communication with passengers, • Mission cancellation, • Passengers counter	• V2Passenger, • V2X	Data transfer to back office: video, audio, other
1003	The system shall detect if passenger violates booking agreement (e.g. no. of persons, luggage, ...)		• Passengers counter, • Video feed (Internal / External), • Audio feed, • Communication with passengers, • Mission cancellation, • GNSS location	• V2Passenger, • V2X	Data transfer to back office: video, audio, other
1004	Rules in the vehicle shall be obvious (e.g. seat belt or sitting down required etc.)		• Communication with passengers, • Video feed (Internal / External), • Audio feed	• V2Passenger, • V2X	Data transfer to back office: video, audio, other
1005	The user shall be able to board the vehicle without a (working) smart phone		• Passengers counter, • Video feed (Internal / External), • Door opening / closing control, • Audio feed	V2Passenger	Data transfer to back office: video, audio, other

Table 17: Boarding AV, software and other specifications



Travelling

Hardware specifications

7.Travelling		Hardware specifications						
I D	Requirement	Vehicle dimensions	Technical specifications	Carrying capacity	Passenger services	Accessibility and comfort	Passenger Safety	Autonomous driving hardware
106	The system shall communicate all information following the dual-channel principle				- Loudspeaker, - Stop request button, - Charging port for passengers (USB type and amount), - Ticket verification system	- Screen(s)/Other to indicate line number, - Passenger information system (Number of units and placement), - Audio guidance to doors, - Accessibility seats spots (Elderly, pregnant etc), - Tinted or darkened windows, - Heating / Cooling /Air conditioning, - Indoor CO2 sensor	- Ability to contact remote operator (No safety driver on board), - Assistance systems for visually and/or hearing impaired , - Seatbelts, - Emergency stop button, - Automated External Defibrillator (resuscitation device), - First aid kit, - Emergency windows, - SOS mechanism	4G, 5G
107	The disabled user (deaf, hearing impaired, blind, visually impaired, ...) shall get the same amount of information everyone else gets (preferably by following the dual-channel principle)			- Room for wheelchair, walker, stroller, - Number of standing positions, - Number of seating positions	- Loudspeaker, - Stop request button, - Charging port for passengers (USB type and amount), - Ticket verification system	- Screen(s)/Other to indicate line number, - Passenger information system (Number of units and placement), - Audio guidance to doors, - Accessibility seats spots (Elderly, pregnant etc.), - Tinted or darkened windows, - Heating / Cooling /Air conditioning, - Indoor CO2 sensor	- Assistance systems for visually and/or hearing impaired, - Ability to contact remote operator (No safety driver on board), - Seatbelts, - Emergency stop button, - Automated External Defibrillator (resuscitation device), - First aid kit, - Emergency windows, - SOS mechanism	4G, 5G

D2.1 Passenger and PTO requirements, needs, and use cases



108	The user shall be able to feel and be safe and secure inside the AV			Room for wheelchair, walker, stroller	- Loudspeaker, - Stop request button	- Accessibility seats spots (Elderly, pregnant etc.), - Heating / Cooling /Air conditioning, - Indoor CO2 sensor, - Screen(s)/Other to indicate line number, - Passenger information system (Number of units and placement), - Audio guidance to doors	- Assistance systems for visually and/or hearing impaired, - Seatbelts, - Emergency stop button, - Ability to contact remote operator (No safety driver on board), - Automated External Defibrillator (resuscitation device), - First aid kit, - Emergency windows, - SOS mechanism	- Camera, 4G, 5G, - IMU, - RTK-GNSS
109	The user shall be informed about the time when the vehicle will arrive at the drop off point		Top speed (km/h)		Loudspeaker	- Screen(s)/Other to indicate line number, - Passenger information system (Number of units and placement), - Audio guidance to doors	- Assistance systems for visually and/or hearing impaired, - Ability to contact remote operator (No safety driver on board)	- RTK-GNSS, - Size, location, 4G, - IMU, 5G
110	The system shall provide the information how the passengers will get from the drop off point to the destination				Loudspeaker	- Passenger information system (Number of units and placement), - Screen(s)/Other to indicate line number	- Assistance systems for visually and/or hearing impaired, - Ability to contact remote operator (No safety driver on board)	4G, 5G
111	The user shall be informed about the connections at the connecting station				Loudspeaker	- Passenger information system (Number of units and placement), - Screen(s)/Other to indicate line number, - Audio guidance to doors	Assistance systems for visually and/or hearing impaired	4G, - IMU, - RTK-GNSS, 5G
112	The user shall be able to access all relevant information via				Loudspeaker	- Passenger information system (Number of units and placement), - Screen(s)/Other to indicate line number		4G, 5G



D2.1 Passenger and PTO requirements, needs, and use cases



	app and via PIS onboard							
1 1 3	The passenger shall have the means to securely stow luggage, a stroller or a walker			- Room for wheelchair, walker, stroller, - Specific space for baggage, - Fixing to secure the cargo		- Wheelchair / baby carriage ramp, - Wheelchair / baby carriage access - No assistance, - Wheelchair / baby carriage access - With assistance, - Accessibility seats spots (Elderly, pregnant etc.)	Assistance systems for visually and/or hearing impaired	
1 1 4	The passenger shall have space under their seat for a guide dog/service dog			- Specific space for baggage, - Room for wheelchair, walker, stroller		Accessibility seats spots (Elderly, pregnant etc.)	Assistance systems for visually and/or hearing impaired	
1 1 6	The (blind) passenger shall be informed about unforeseen stops during the ride (construction site, traffic jam, rail crossing etc.)				Loudspeaker	Passenger information system (Number of units and placement)	- Assistance systems for visually and/or hearing impaired, - Ability to contact remote operator (No safety driver on board)	- Camera, - LiDARs, 5G, - RTK-GNSS, - Size, location
1 1 7	The (disabled) user shall be able to get help / have a contact person in case of unforeseen situations (e.g. technical issues, lack of information, accident etc.)				Loudspeaker	Passenger information system (Number of units and placement)	- Ability to contact remote operator (No safety driver on board), - Assistance systems for visually and/or hearing impaired	- Camera, 5G, - RTK-GNSS, 4G, - Size, location
1 1 8	When having booked for another person,				Passenger counting system,			- Camera, - RTK-GNSS, - Size, location,



D2.1 Passenger and PTO requirements, needs, and use cases



	the user shall be sure sure that the passenger arrives safely				Ticket verification system			4G, 5G, - IMU
1 1 9	The passenger shall be able to report littering/damages, etc.					Passenger information system (Number of units and placement)	- Emergency stop button, - Ability to contact remote operator (No safety driver on board), - SOS mechanism	- RTK-GNSS, - Camera, 5G
1 2 0	The passenger shall have alternative travel options suggested in the event of a disruption				Loudspeaker	- Passenger information system (Number of units and placement), - Screen(s)/Other to indicate line number	- Ability to contact remote operator (No safety driver on board), - Assistance systems for visually and/or hearing impaired	
1 2 1	The passenger shall have a comfortable distance from other passengers	- Length (mm), - Width (mm), - Height (mm)		- Passenger capacity, - Room for wheelchair, walker, stroller, - Number of seating positions, - Number of standing positions, - Seating positions (in direction of travel, against direction of travel, across direction of travel)	Passenger counting system	- Accessibility seats spots (Elderly, pregnant etc), - Passenger information system (Number of units and placement)	Assistance systems for visually and/or hearing impaired	
1 2 2	The passenger shall have enough space for	- Height (mm), - Length (mm),		Specific space for baggage	Passenger counting system	Accessibility seats spots (Elderly, pregnant etc.)		



D2.1 Passenger and PTO requirements, needs, and use cases



	belongings/luggage	• Width (mm)						
1 2 3	The passenger shall be guaranteed a seat during the ride			• Passenger capacity, • Number of seating positions	• Passenger counting system, • Ticket verification system	• Accessibility seats spots (Elderly, pregnant etc.), • Passenger information system (Number of units and placement)	Assistance systems for visually and/or hearing impaired	• 4G, • Camera
1 2 4	The passenger shall be able to return to their starting point without finishing the booked ride					Passenger information system (Number of units and placement)	Ability to contact remote operator (No safety driver on board)	4G
1 2 5	The passenger shall be able to initiate a halt request to immediately leave the vehicle at the next possible stop				Stop request button		• Emergency stop button, • Ability to contact remote operator (No safety driver on board)	Camera, 5G, RTK-GNSS
1 2 6	The passenger shall be able to change their trip destination (during the trip)					• Passenger information system (Number of units and placement), • Screen(s)/Other to indicate line number	Ability to contact remote operator (No safety driver on board)	• 5G, • RTK-GNSS, • Size, location
1 2 7	The user shall be informed how long the AV will wait at the PUDOS (when vehicle is waiting on route for other pax)		Top speed (km/h)		Loudspeaker	• Passenger information system (Number of units and placement), • Screen(s)/Other to indicate line number	Assistance systems for visually and/or hearing impaired	• RTK-GNSS, • Size, location
1 2 8	The vehicle shall arrive at the user's destination by		Top speed (km/h)			Passenger information system (Number of units and placement)		• RTK-GNSS, • Size, location



D2.1 Passenger and PTO requirements, needs, and use cases



	the "promised" ETA, regardless of ride sharing							
1 2 9	The user shall be able to open and use the trunk			Specific space for baggage			- Ability to contact remote operator (No safety driver on board), - Assistance systems for visually and/or hearing impaired	
1 3 0	The service shall implement measures to identify and address any instances of "ghostriders" before driving			Passenger capacity	- Passenger counting system, - Ticket verification system	Passenger information system (Number of units and placement)	Ability to contact remote operator (No safety driver on board)	- Camera, 4G, 5G, - RTK-GNSS
1 3 1	The fellow passengers shall behave in a respectful and appropriate manner / The service provider shall promote and encourage good behavior among passengers				Loudspeaker	- Passenger information system (Number of units and placement), - Screen(s)/Other to indicate line number	Ability to contact remote operator (No safety driver on board)	
1 3 2	The system shall inform users about rules regarding the use of the AV (e.g. "This is a shared service. Remember to respect other passengers")				Loudspeaker	- Passenger information system (Number of units and placement), - Screen(s)/Other to indicate line number		

D2.1 Passenger and PTO requirements, needs, and use cases



1 3 3	If all sensors indicate that the vehicle is in operational state, both the Voice Over system and the in-car screen shall display a message instructing the user to "Press GO to start the ride."		Ground clearance		Loudspeaker	• Passenger information system (Number of units and placement), • Screen(s)/Other to indicate line number	Assistance systems for visually and/or hearing impaired	• IMU, • RTK-GNSS, • Size, location, • 5G, • 4G
1 3 4	The in-vehicle screen shall display the route information and the pick up and drop off points (PUDOs)				Loudspeaker	• Passenger information system (Number of units and placement), • Screen(s)/Other to indicate line number	Assistance systems for visually and/or hearing impaired	• 4G, • 5G, • IMU, • RTK-GNSS
1 3 5	The user shall be informed if new passengers will boarding their bus			Passenger capacity	• Passenger counting system, • Loudspeaker	• Passenger information system (Number of units and placement), • Screen(s)/Other to indicate line number	Assistance systems for visually and/or hearing impaired	4G
1 3 6	The user shall be informed of changes to their itinerary due to new passengers				Loudspeaker	• Passenger information system (Number of units and placement), • Screen(s)/Other to indicate line number	Assistance systems for visually and/or hearing impaired	4G
1 3 7	The user shall be informed about the (time) consequences and/or price benefits of ride sharing				Loudspeaker	• Passenger information system (Number of units and placement), • Screen(s)/Other to indicate line number		

D2.1 Passenger and PTO requirements, needs, and use cases



1 3 8	The system shall inform the passengers about the interim stop and the vehicle's arrival/departure time there		Top speed (km/h)		Loudspeaker	- Passenger information system (Number of units and placement), - Screen(s)/Other to indicate line number	Assistance systems for visually and/or hearing impaired	- RTK-GNSS, - Size, location, 4G
1 3 9	The user shall receive the reasons for slowing down or stops (AV 'stream of consciousness'?)				Loudspeaker	- Passenger information system (Number of units and placement), - Screen(s)/Other to indicate line number		4G, - IMU, - RTK-GNSS, - LiDARs
1 4 0	The AV shall indicate the name of the PUDO as the vehicle arrives at each location (acoustic, visual, in app)				Loudspeaker	- Passenger information system (Number of units and placement), - Screen(s)/Other to indicate line number		4G, - IMU, - RTK-GNSS
1 4 1	The vehicle shall monitor e.g., seatbelt and seat sensors, decibel levels, help request of pax, etc.			- Passenger capacity, - Number of seating positions, - Number of standing positions, - Fixing to secure the cargo		- Heating / Cooling /Air conditioning, - Indoor CO2 sensor	- Seatbelts, - Ability to contact remote operator (No safety driver on board)	- Camera, 4G, 5G, - RTK-GNSS, - Size, location, - Protection level of vehicle computer hardware (ease of access) , IMU
1 4 2	The user shall be able to contact the customer service via a button in the AV, via app						- Ability to contact remote operator (No safety driver on board), - SOS mechanism, - Assistance systems for visually and/or hearing impaired	- Camera, 4G, - RTK-GNSS, - Size, location, 5G, - IMU



D2.1 Passenger and PTO requirements, needs, and use cases



	functionality, via shouting for help, etc.							
1 4 3	The vehicle shall inform passengers about any unforeseen events or changes to the route and their cause (dual-channel principle!)				Loudspeaker	- Passenger information system (Number of units and placement), - Screen(s)/Other to indicate line number	- Assistance systems for visually and/or hearing impaired, - Ability to contact remote operator (No safety driver on board)	- RTK-GNSS, - Size, location, 4G, - IMU
1 4 4	Customer service shall be able to provide assistance on how to disembark using the onboard camera to see what is happening				Loudspeaker	- Passenger information system (Number of units and placement), - Screen(s)/Other to indicate line number	- Assistance systems for visually and/or hearing impaired, - Ability to contact remote operator (No safety driver on board)	- Camera, 5G, - IMU, - RTK-GNSS
1 4 5	When user discontinues/cancels trip, the user shall be offered a list of close PUDOs to choose from (closest PUDO = default)				Loudspeaker	- Passenger information system (Number of units and placement), - Screen(s)/Other to indicate line number	Assistance systems for visually and/or hearing impaired	- RTK-GNSS, - Size, location, 5G, - IMU
1 4 6	User shall be informed of being dropped off before they confirm the cancellation				Loudspeaker	- Passenger information system (Number of units and placement), - Screen(s)/Other to indicate line number	Assistance systems for visually and/or hearing impaired	5G, - IMU, - RTK-GNSS



D2.1 Passenger and PTO requirements, needs, and use cases



1 4 7	The customer service (CS) shall be notified if the system detects that passengers experience problems						Ability to contact remote operator (No safety driver on board)	• Camera, • 5G, • RTK-GNSS, • Size, location, • IMU
1 4 8	The vehicle shall signal (a beep or the like) if the doors are not properly locked.				Loudspeaker	Audio guidance to doors		
1 4 9	The system shall activate a notification (Voice Over script or the like) to notify the user if the user fails to properly close the door or clear the door area.				Loudspeaker	• Passenger information system (Number of units and placement), • Audio guidance to doors		• Camera, • 4G
1 5 0	The user shall not be required to confirm their intention to leave the vehicle							
1 5 1	As a user, I need to be reminded if I have to confirm that my trip is concluded, but i'd rather not have to				• Ticket verification system, • Loudspeaker	Screen(s)/Other to indicate line number		4G

D2.1 Passenger and PTO requirements, needs, and use cases



1 5 2	The user shall be able to interact with the control centre in the way that suits them				Loudspeaker		Ability to contact remote operator (No safety driver on board)	• Camera, • 4G
1 5 3	The in-vehicle screen shall not display any private or personal information of the user					• Screen(s)/Other to indicate line number, • Passenger information system (Number of units and placement)		
1 5 4	The in-vehicle screen shall provide a map display with the position of the vehicle and the PUDOS and POIs					• Passenger information system (Number of units and placement), • Screen(s)/Other to indicate line number	Assistance systems for visually and/or hearing impaired	• RTK-GNSS, • Size, location, • IMU
1 5 5	The in-vehicle screen shall provide emergency information and the option to request help					• Screen(s)/Other to indicate line number, • Passenger information system (Number of units and placement)	• Emergency stop button, • SOS mechanism, • Ability to contact remote operator (No safety driver on board)	• Camera, • 5G, • RTK-GNSS, • 4G
1 5 6	The in-vehicle screen shall provide information about the ride like upcoming PUDOS, ETA at the PUDOS, delays, interchange information (MaaS)				Loudspeaker	• Passenger information system (Number of units and placement), • Screen(s)/Other to indicate line number	Assistance systems for visually and/or hearing impaired	• 4G, • IMU, • RTK-GNSS

D2.1 Passenger and PTO requirements, needs, and use cases



1 5 7	The in-vehicle screen shall provide information about the vehicle like battery status, sensor info, speed, etc.		Top speed (km/h)			- Screen(s)/Other to indicate line number, - Passenger information system (Number of units and placement)		
1 5 8	The user shall be able to see an in-vehicle screen from every seat			Seating positions (in direction of travel, against direction of travel, across direction of travel)		- Screen(s)/Other to indicate line number, - Passenger information system (Number of units and placement)	Assistance systems for visually and/or hearing impaired	
1 5 9	The vehicle shall inform passengers about upcoming stop				Loudspeaker	- Screen(s)/Other to indicate line number, - Passenger information system (Number of units and placement)	Assistance systems for visually and/or hearing impaired	- RTK-GNSS, - Size, location, - IMU
1 6 0	The vehicle shall alert passengers about arriving at their destination at an appropriate time before reaching it				Loudspeaker	- Passenger information system (Number of units and placement), - Screen(s)/Other to indicate line number	Assistance systems for visually and/or hearing impaired	- RTK-GNSS, - Size, location, - IMU
1 6 1	The user shall arrive in time to reach the connection							
1 6 2	If vehicle fails to reach the connection, it shall inform the user and offer an alternative.		Top speed (km/h)		Loudspeaker	- Passenger information system (Number of units and placement), - Screen(s)/Other to indicate line number		- RTK-GNSS, - Size, location, - IMU
1 6 3	If vehicle fails to reach the connection, the						Ability to contact remote operator (No safety driver on board)	- IMU, - RTK-GNSS



D2.1 Passenger and PTO requirements, needs, and use cases



	system shall inform the driver of the connecting vehicle and ask to wait							
1 6 4	User shall be informed of the consequences (e.g. re payment) of a change in booking before they confirm the changes or cancellation					Passenger information system (Number of units and placement)	Assistance systems for visually and/or hearing impaired	RTK-GNSS
1 6 5	The user shall be able to see the person from CS when talking					Screen(s)/Other to indicate line number	• Ability to contact remote operator (No safety driver on board), • Assistance systems for visually and/or hearing impaired	• Camera, • 5G

Table 18: Travelling, hardware specifications

Software & other specifications

7.Travelling		Software specifications			Other specifications
I D	Requirement	Operational design domain, autonomous driving system	Remote capabilities	Connectivity	Legal and regulatory
1 0 6	The system shall communicate all information following the dual-channel principle		• Communication with passengers, • Passengers counter	• V2Passenger, • V2X	
1 0 7	The disabled user (deaf, hearing impaired, blind, visually impaired, ...) shall get the same amount of information everyone else gets (preferably by following the dual-channel principle)		• Communication with passengers, • Audio feed, • Passengers counter	V2Passenger	Data transfer to back office: video, audio, other



D2.1 Passenger and PTO requirements, needs, and use cases



108	The user shall be able to feel and be safe and secure inside the AV		• Video feed (Internal / External), • Audio feed, • Indoor temperature, • Indoor co2 level, • Door opening / closing control, • Communication with passengers, • State of autonomous system	V2Passenger	Data transfer to back office: video, audio, other
109	The user shall be informed about the time when the vehicle will arrive at the drop off point		GNSS location	V2Passenger	Speed authorisation (km/h)
110	The system shall provide the information how the passengers will get from the drop off point to the destination		• Multi routing, • GNSS location, • Communication with passengers	V2Passenger	
111	The user shall be informed about the connections at the connecting station		• Communication with passengers, • Multi routing	V2Passenger	
112	The user shall be able to access all relevant information via app and via PIS onboard		GNSS location	V2Passenger	
113	The passenger shall have the means to securely stow luggage, a stroller or a walker				
114	The passenger shall have space under their seat for a guide dog/service dog			V2Passenger	
116	The (blind) passenger shall be informed about unforeseen stops during the ride (construction site, traffic jam, rail crossing etc.)	• Road blocking obstacles, • Other road users	• Video feed (Internal / External), • Communication with passengers, • GNSS location	• V2X, • V2Passenger	Data transfer to back office: video, audio, other
117	The (disabled) user shall be able to get help / have a contact person in case of unforeseen situations (e.g. technical issues, lack of information, accident etc.)		• GNSS location, • Door opening / closing control,	V2Passenger	Data transfer to back office: video, audio, other

D2.1 Passenger and PTO requirements, needs, and use cases



			• Communication with passengers, • Remote driving/steering, • Video feed (Internal / External), • Audio feed		
1 1 8	When having booked for another person, the user shall be sure sure that the passenger arrives safely		• Video feed (Internal / External), • Communication with passengers, • Passengers counter, • GNSS location	V2Passenger	Data transfer to back office: video, audio, other
1 1 9	The passenger shall be able to report littering/damages, etc.		• GNSS location, • Communication with passengers	V2Passenger	Data transfer to back office: video, audio, other
1 0	The passenger shall have alternative travel options suggested in the event of a disruption		• Multi routing, • Mission modification (During the mission), • Communication with passengers, • Mission cancellation	V2Passenger	Data transfer to back office: video, audio, other
1 2 1	The passenger shall have a comfortable distance from other passengers		• Passengers counter, • Video feed (Internal / External), • Audio feed	V2Passenger	Data transfer to back office: video, audio, other
1 2 2	The passenger shall have enough space for their belongings/luggage				
1 2 3	The passenger shall be guaranteed a seat during the ride		Passengers counter	V2Passenger	Data transfer to back office: video, audio, other
1 2 4	The passenger shall be able to return to their starting point without finishing the booked ride		• Multi routing, • Mission cancellation, • Mission modification (During the mission), • Communication with passengers	V2Passenger	Data transfer to back office: video, audio, other



D2.1 Passenger and PTO requirements, needs, and use cases



1 2 5	The passenger shall be able to initiate a halt request to immediately leave the vehicle at the next possible stop		• Communication with passengers, • Door opening / closing control, • Mission modification (During the mission), • Multi routing, • GNSS location, • Remote driving/steering	V2Passenger	Data transfer to back office: video, audio, other
1 2 6	The passenger shall be able to change their trip destination (during the trip)		• Mission modification (During the mission), • GNSS location, • Communication with passengers	V2Passenger	Data transfer to back office: video, audio, other
1 2 7	The user shall be informed how long the AV will wait at the PUDOS (when vehicle is waiting on route for other pax)		• GNSS location, • Multi routing	V2Passenger	• Speed authorisation (km/h), • Data transfer to back office: video, audio, other
1 2 8	The vehicle shall arrive at the user's destination by the "promised" ETA, regardless of ride sharing		• GNSS location, • Multi routing		Speed authorisation (km/h)
1 2 9	The user shall be able to open and use the trunk		Communication with passengers	V2Passenger	Data transfer to back office: video, audio, other
1 3 0	The service shall implement measures to identify and address any instances of "ghostriders" before driving		• Video feed (Internal / External), • Passengers counter, • GNSS location, • Communication with passengers, • Door opening / closing control, • Mission cancellation	• V2Passenger, • V2X	Data transfer to back office: video, audio, other
1 3 1	The fellow passengers shall behave in a respectful and appropriate manner / The service provider shall promote and encourage good behavior among passengers		• Communication with passengers, • Video feed (Internal / External)	V2Passenger	
1 3 2	The system shall inform users about rules regarding the use of the AV (e.g. "This is a		• Communication with passengers,	V2Passenger	



D2.1 Passenger and PTO requirements, needs, and use cases



	shared service. Remember to respect other passengers")		• Video feed (Internal / External), • Audio feed		
1 3 3	If all sensors indicate that the vehicle is in operational state, both the Voice Over system and the in-car screen shall display a message instructing the user to "Press GO to start the ride."		• GNSS location, • Door opening / closing control, • State of sensors, • Communication with passengers, • Video feed (Internal / External), • Audio feed	V2Passenger	Data transfer to back office: video, audio, other
1 3 4	The in-vehicle screen shall display the route information and the pick up and drop off points (PUDOs)		• GNSS location, • Communication with passengers, • Video feed (Internal / External), • Audio feed	V2Passenger	Data transfer to back office: video, audio, other
1 3 5	The user shall be informed if new passengers will boarding their bus		• GNSS location, • Communication with passengers	V2Passenger	Data transfer to back office: video, audio, other
1 3 6	The user shall be informed of changes to their itinerary due to new passengers		• Mission modification (During the mission), • Communication with passengers	V2Passenger	Data transfer to back office: video, audio, other
1 3 7	The user shall be informed about the (time) consequences and/or price benefits of ride sharing		Communication with passengers	V2Passenger	
1 3 8	The system shall inform the passengers about the interim stop and the vehicle's arrival/departure time there		GNSS location	V2Passenger	Speed authorisation (km/h)
1 3 9	The user shall receive the reasons for slowing down or stops (AV 'stream of consciousness'?)		• State of sensors, • GNSS location	• V2X, • V2Passenger	Data transfer to back office: video, audio, other
1 4 0	The AV shall indicate the name of the PUDO as the vehicle arrives at each location (acoustic, visual, in app)		GNSS location	V2Passenger	Data transfer to back office: video, audio, other



D2.1 Passenger and PTO requirements, needs, and use cases



1 4 1	The vehicle shall monitor e.g., seatbelt and seat sensors, decibel levels, help request of pax, etc.		• Video feed (Internal / External), • Audio feed, • State of sensors, • Communication with passengers, • GNSS location		Data transfer to back office: video, audio, other
1 4 2	The user shall be able to contact the customer service via a button in the AV, via app functionality, via shouting for help, etc.		• GNSS location, • Video feed (Internal / External), • Audio feed, • Communication with passengers	V2Passenger	Data transfer to back office: video, audio, other
1 4 3	The vehicle shall inform passengers about any unforeseen events or changes to the route and their cause (dual-channel principle!)	• Road blocking obstacles, • Low visibility conditions (Rain, snow, fog, dust, night etc)	• Communication with passengers, • GNSS location, • Remote navigation control, • Video feed (Internal / External), • Audio feed	V2Passenger	Data transfer to back office: video, audio, other
1 4 4	Customer service shall be able to provide assistance on how to disembark using the onboard camera to see what is happening		• Video feed (Internal / External), • Audio feed, • Communication with passengers	V2Passenger	Data transfer to back office: video, audio, other
1 4 5	When user discontinues/cancels trip, the user shall be offered a list of close PUDOs to choose from (closest PUDO = default)		• GNSS location, • Multi routing, • Mission cancellation, • Mission modification (During the mission), • Communication with passengers, • Video feed (Internal / External)	V2Passenger	Data transfer to back office: video, audio, other
1 4 6	User shall be informed of being dropped off before they confirm the cancellation		Communication with passengers	V2Passenger	Data transfer to back office: video, audio, other



D2.1 Passenger and PTO requirements, needs, and use cases



1 4 7	The customer service (CS) shall be notified if the system detects that passengers experience problems		• Video feed (Internal / External), • Audio feed, • GNSS location, • State of sensors, • State of autonomous system, • Indoor co2 level	V2Passenger, V2X	Data transfer to back office: video, audio, other
1 4 8	The vehicle shall signal (a beep or the like) if the doors are not properly locked.		• State of sensors, • Door opening / closing control		Data transfer to back office: video, audio, other
1 4 9	The system shall activate a notification (Voice Over script or the like) to notify the user if the user fails to properly close the door or clear the door area.		• Video feed (Internal / External), • Door opening / closing control, • Communication with passengers, • State of sensors	V2Passenger	Data transfer to back office: video, audio, other
1 5 0	The user shall not be required to confirm their intention to leave the vehicle			V2Passenger	
1 5 1	As a user, I need to be reminded if I have to confirm that my trip is concluded, but i'd rather not have to			V2Passenger	
1 5 2	The user shall be able to interact with the control centre in the way that suits them		• Video feed (Internal / External), • Audio feed, • Communication with passengers	V2Passenger	Data transfer to back office: video, audio, other
1 5 3	The in-vehicle screen shall not display any private or personal information of the user				Data transfer to back office: video, audio, other
1 5 4	The in-vehicle screen shall provide a map display with the position of the vehicle and the PUDOS and POIs		• GNSS location, • Communication with passengers, • Video feed (Internal / External)	V2Passenger	

D2.1 Passenger and PTO requirements, needs, and use cases



1 5 5	The in-vehicle screen shall provide emergency information and the option to request help		• GNSS location, • Communication with passengers, • Video feed (Internal / External)	V2Passenger	Data transfer to back office: video, audio, other
1 5 6	The in-vehicle screen shall provide information about the ride like upcoming PUDOS, ETA at the PUDOS, delays, interchange information (MaaS)		• GNSS location, • Communication with passengers, • Video feed (Internal / External), • Audio feed	V2Passenger	
1 5 7	The in-vehicle screen shall provide information about the vehicle like battery status, sensor info, speed, etc.		• Battery level (Electric vehicle), • State of sensors, • Tire pressure, • State of autonomous system, • Fuel level (Petrol/Diesel/etc.), • Passengers counter, • Indoor temperature, • Indoor co2 level, • GNSS location	• V2Passenger, • V2X	• Speed authorisation (km/h), • Data transfer to back office: video, audio, other
1 5 8	The user shall be able to see an in-vehicle screen from every seat		Communication with passengers	V2Passenger	Data transfer to back office: video, audio, other
1 5 9	The vehicle shall inform passengers about upcoming stop		• Communication with passengers, • GNSS location	V2Passenger	
1 6 0	The vehicle shall alert passengers about arriving at their destination at an appropriate time before reaching it		• GNSS location, • Communication with passengers, • Audio feed	V2Passenger	
1 6 1	The user shall arrive in time to reach the connection		Mission modification (During the mission)		Data transfer to back office: video, audio, other
1 6 2	If vehicle fails to reach the connection, it shall inform the user and offer an alternative.		GNSS location	V2Passenger	• Speed authorisation (km/h), • Data transfer to back office: video, audio, other



D2.1 Passenger and PTO requirements, needs, and use cases



1 6 3	If vehicle fails to reach the connection, the system shall inform the driver of the connecting vehicle and ask to wait		GNSS location	• V2V, • V2X	Data transfer to back office: video, audio, other
1 6 4	User shall be informed of the consequences (e.g. re payment) of a change in booking before they confirm the changes or cancellation		• Communication with passengers, • Mission modification (During the mission), • Mission cancellation, • GNSS location	V2Passenger	
1 6 5	The user shall be able to see the person from CS when talking		• Communication with passengers, • Video feed (Internal / External), • Audio feed	V2Passenger	Data transfer to back office: video, audio, other

Table 19: Travelling, software and other specifications

Incident

Hardware specifications

8.Incident		Hardware specifications						
I D	Requirement	Vehicle dimensions	Technical specifications	Carrying capacity	Passenger services	Accessibility and comfort	Passenger Safety	Autonomous driving hardware
1 6 6	The user shall be able to talk directly to customer service in case of an incident or any concerns				• Loudspeaker, • Stop request button	Passenger information system (Number of units and placement)	• Ability to contact remote operator (No safety driver on board), • Assistance systems for visually and/or hearing impaired, • Emergency stop button, SOS mechanism	• Camera, • 4G, • 5G, • Size, location
1 6 7	The user shall be able to stop the vehicle and	Height off the ground	Number of doors		• Stop request button, • Loudspeaker	• Audio guidance to doors, • Wheelchair / baby carriage ramp	• Emergency stop button, • Assistance systems for visually and/or hearing impaired,	• Camera, • 4G, • Size, location



D2.1 Passenger and PTO requirements, needs, and use cases



	open the doors so they can exit the vehicle in case of an incident	of the vehicle with respect to the road (Adaptability) (mm)					- Emergency windows, - SOS mechanism, - Ability to contact remote operator (No safety driver on board)	
1 6 8	Customer service shall automatically come on audio call if something happens				Loudspeaker	Passenger information system (Number of units and placement)	- Ability to contact remote operator (No safety driver on board), - Assistance systems for visually and/or hearing impaired	- Camera, 4G, - IMU, - RTK-GNSS, 5G
1 6 9	Customer service shall be able to activate and watch video feed in case of unexpected events			Passenger capacity	- Loudspeaker, - Passenger counting system	Passenger information system (Number of units and placement)	Ability to contact remote operator (No safety driver on board)	4G, 5G, - Camera, - IMU, RTK-GNSS, Size, location
1 7 0	The system shall inform the passengers about any unforeseen events and ask if they want to resume the ride				- Loudspeaker, - Stop request button	Passenger information system (Number of units and placement)	- Assistance systems for visually and/or hearing impaired, - Ability to contact remote operator (No safety driver on board)	4G, - IMU, - RTK-GNSS, 5G
1 7 1	The doors shall unlock automatically if emergency stop button is pressed		Number of doors		Loudspeaker	Audio guidance to doors	- Emergency stop button, - Emergency windows, - SOS mechanism, - Ability to contact remote operator (No safety driver on board), - Assistance systems for visually and/or hearing impaired	



D2.1 Passenger and PTO requirements, needs, and use cases



1 7 2	Emergency personnel shall be notified automatically when required				Loudspeaker	Passenger information system (Number of units and placement)	- SOS mechanism, - Emergency stop button	- Camera, - Infrared camera, 5G, - IMU, RTK-GNSS, - Size, location
1 7 3	The user shall get a full refund if the reason for discontinuing is the service providers fault				- Passenger counting system, - Ticket verification system			
1 7 4	The user shall be able to report an incident					Passenger information system (Number of units and placement)	- Emergency stop button, - Ability to contact remote operator (No safety driver on board), - Assistance systems for visually and/or hearing impaired	- Camera, 5G
1 7 5	The system shall provide instructions to the pax in the event of an incident (using dual channel principle)				Loudspeaker	- Passenger information system (Number of units and placement), - Audio guidance to doors	- Assistance systems for visually and/or hearing impaired, - Ability to contact remote operator (No safety driver on board), - SOS mechanism	- Camera, 5G, - IMU, - RTK-GNSS
1 7 6	The system shall send another vehicle if there is a problem with the vehicle and inform the passengers			Passenger capacity	Loudspeaker	- Passenger information system (Number of units and placement), - Audio guidance to doors, - Wheelchair / baby carriage ramp	- Assistance systems for visually and/or hearing impaired, - Ability to contact remote operator (No safety driver on board)	- RTK-GNSS, 5G, - Size, location, - IMU

Table 20: Incident, hardware specifications

Software & other specifications

8.Incident		Software specifications			Other specifications
I D	Requirement	Operational design domain, autonomous driving system	Remote capabilities	Connectivity	Legal and regulatory
1 6 6	The user shall be able to talk directly to customer service in case of an incident or any concerns		- Communication with passengers, - Video feed (Internal / External), - Audio feed	- V2Passenger, - V2X	Data transfer to back office: video, audio, other
1 6 7	The user shall be able to stop the vehicle and open the doors so they can exit the vehicle in case of an incident		- Door opening / closing control, - Communication with passengers, - State of autonomous system	- V2Passenger, - V2X	Data transfer to back office: video, audio, other
1 6 8	Customer service shall automatically come on audio call if something happens		- Video feed (Internal / External), - Audio feed, - Communication with passengers, - GNSS location	- V2Passenger, - V2X	Data transfer to back office: video, audio, other
1 6 9	Customer service shall be able to activate and watch video feed in case of unexpected events		- State of autonomous system, - Video feed (Internal / External), - Audio feed, Passengers counter, - GNSS location, - State of sensors	- V2Passenger, - V2X	Data transfer to back office: video, audio, other
1 7 0	The system shall inform the passengers about any unforeseen events and ask if they want to resume the ride		- Communication with passengers, - State of sensors, - State of autonomous system, - Audio feed, - GNSS location, - Mission cancellation, - Video feed (Internal / External)	V2Passenger	Data transfer to back office: video, audio, other
1 7 1	The doors shall unlock automatically if emergency stop button is pressed		- Door opening / closing control, - State of autonomous system	V2X	Data transfer to back office: video, audio, other
1 7 2	Emergency personnel shall be notified automatically when required		- Video feed (Internal / External), - Audio feed, - GNSS location, - Communication with passengers	- V2X, - V2Passenger	Data transfer to back office: video, audio, other
1 7 3	The user shall get a full refund if the reason for discontinuing is the service providers fault		- State of sensors, - State of autonomous system, - Passengers counter	V2Passenger	

D2.1 Passenger and PTO requirements, needs, and use cases



1 7 4	The user shall be able to report an incident		• Video feed (Internal / External), • Audio feed, • Communication with passengers, • GNSS location	• V2Passenger, • V2X	Data transfer to back office: video, audio, other
1 7 5	The system shall provide instructions to the pax in the event of an incident (using dual channel principle)		• Communication with passengers, • Video feed (Internal / External), • Audio feed	• V2Passenger, • V2X	Data transfer to back office: video, audio, other
1 7 6	The system shall send another vehicle if there is a problem with the vehicle and inform the passengers		• Mission modification (During the mission), • Multi routing, • GNSS location, • Communication with passengers, • Audio feed	• V2V, • V2Passenger, • V2X	Data transfer to back office: video, audio, other

Table 21: Incident, software and other specifications

Disembark

Hardware specifications

9.Disembark		Hardware specifications						
I D	Requirement	Vehicle dimensions	Technical specifications	Carrying capacity	Passenger services	Accessibility and comfort	Passenger Safety	Autonomous driving hardware
1 7 7	The vehicle shall drop (visually impaired) passengers off only at safe locations (no traffic, no puddles, no pile of snow, no sprouted bush)	Height off the ground of the vehicle with respect to the road (Adaptability) (mm)	• Maximum slope , • Ground clearance		Loudspeaker	• Audio guidance to doors, • Wheelchair / baby carriage ramp, • Accessibility seats spots (Elderly, pregnant etc)	Assistance systems for visually and/or hearing impaired	• LiDARs, • Camera, • RTK-GNSS, • Size, location
1 7 8	The visually impaired passenger shall be informed about any obstacles between	Height off the ground of the vehicle with respect to the road (Adaptability) (mm)	• Maximum slope , • Ground clearance		Loudspeaker	• Audio guidance to doors, • Passenger information system (Number of units and placement)	Assistance systems for visually and/or hearing impaired	• LiDARs, • Camera



D2.1 Passenger and PTO requirements, needs, and use cases



	the drop off point and their destination							
1 7 9	The (visually impaired) passenger shall be guided from the drop off point to their destination	Height off the ground of the vehicle with respect to the road (Adaptability) (mm)			Loudspeaker	Audio guidance to doors	Assistance systems for visually and/or hearing impaired	
1 8 0	The user shall be able to disembark safely using the time they need				Stop request button	- Wheelchair / baby carriage ramp, - Wheelchair / baby carriage access - No assistance, - Wheelchair / baby carriage access - With assistance, - Audio guidance to doors	Assistance systems for visually and/or hearing impaired	Camera
1 8 1	For disembarking, the vehicle shall stop, automatically unlock the doors, and inform pax about destination PUDO (e.g. voice-over announcement or display or app)				- Loudspeaker, - Stop request button	- Passenger information system (Number of units and placement), - Screen(s)/Other to indicate line number, - Audio guidance to doors	Assistance systems for visually and/or hearing impaired	
1 8 2	The system (e.g., app, in-vehicle screen) shall inform the passenger that the vehicle has now reached the passenger's destination				Loudspeaker	- Screen(s)/Other to indicate line number, - Passenger information system (Number of units and placement)	Assistance systems for visually and/or hearing impaired	- RTK-GNSS, - Size, location
1 8 3	The vehicle shall indicate the remaining time available for disembarking (e.g. timer on big screen, with an option to request more time)				- Loudspeaker, - Stop request button	- Passenger information system (Number of units and placement), - Screen(s)/Other to indicate line number	- Assistance systems for visually and/or hearing impaired, - Ability to contact remote operator (No safety driver on board)	

D2.1 Passenger and PTO requirements, needs, and use cases



1 8 4	The user shall get a reminder to ensure they remember their belongings.			Specific space for baggage	Loudspeaker	- Passenger information system (Number of units and placement), - Screen(s)/Other to indicate line number	Assistance systems for visually and/or hearing impaired	Camera
1 8 5	The door of the autonomous vehicle shall be automatically unlocked when the user is disembarking						Assistance systems for visually and/or hearing impaired	Camera
1 8 6	The doors shall indicate before they close (alert signal)				Loudspeaker		Assistance systems for visually and/or hearing impaired	
1 8 7	The user shall be able to request that the vehicle drives on a few meters if the PUDO is not safe to disembark (e.g., if there is a big puddle, pile of snow, etc.)				Loudspeaker	Screen(s)/Other to indicate line number	- Assistance systems for visually and/or hearing impaired, - Ability to contact remote operator (No safety driver on board)	- LiDARs, - Camera, - Radar
1 8 8	The user shall be able to exit the vehicle without a (working) smart phone				Stop request button	Audio guidance to doors	Ability to contact remote operator (No safety driver on board)	
1 8 9	The vehicle shall check if it is safe before it opens the doors for passengers to disembark	Height off the ground of the vehicle with respect to the road (Adaptability) (mm)	- Maximum slope, - Ground clearance					- LiDARs, 4G, - RTK-GNSS, - Camera, - Radar
1 9 0	The system shall provide info about changeover time for connecting means of transport				Loudspeaker	- Screen(s)/Other to indicate line number, - Passenger information system (Number of units and placement)	Assistance systems for visually and/or hearing impaired	5G
1 9 1	The vehicle shall inform the PTO if pax				Passenger counting system			- Camera, 4G,



D2.1 Passenger and PTO requirements, needs, and use cases



	do not disembark as supposed to							5G
1 9 2	The user shall have the option to request additional time for disembarking				- Loudspeaker, - Stop request button	- Screen(s)/Other to indicate line number, - Passenger information system (Number of units and placement), - Audio guidance to doors	- Ability to contact remote operator (No safety driver on board), - Assistance systems for visually and/or hearing impaired	
1 9 3	The vehicle shall provide alert signal when ramp is moving				Loudspeaker	- Screen(s)/Other to indicate line number , - Wheelchair / baby carriage ramp		
1 9 4	The customer service (CS) shall be notified after a certain time if pax exceed the boarding time limit to address the situation to facilitate the movement of the vehicle.				- Passenger counting system, - Loudspeaker	Screen(s)/Other to indicate line number	Ability to contact remote operator (No safety driver on board)	- Camera, 5G, - LiDARs, - Radar, 4G, - IMU, - RTK-GNSS, - Size, location
1 9 5	PUDO must provide space to move on safely and be free of obstacles							- Radar, - Camera, - Infrared camera, - LiDARs, 4G, 5G, - IMU, - RTK-GNSS, - Size, location
1 9 6	When having booked for another person, the user shall be sure the passenger disembarks at the correct location				Passenger counting system	- Passenger information system (Number of units and placement), - Screen(s)/Other to indicate line number		- Camera, 5G



D2.1 Passenger and PTO requirements, needs, and use cases



1 9 7	The vehicle shall inform Customer Service if a passenger falls while disembarking						Ability to contact remote operator (No safety driver on board)	• Camera, • 5G, • 4G
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Table 22: Disembark, hardware specifications

Software & other specifications

9.Disembark		Software specifications			Other specifications
I D	Requirement	Operational design domain, autonomous driving system	Remote capabilities	Connectivity	Legal and regulatory
1 7 7	The vehicle shall drop (visually impaired) passengers off only at safe locations (no traffic, no puddles, no pile of snow, no sprouted bush)	• Low visibility conditions (Rain, snow, fog, dust, night etc), • Road conditions (Icy road, holes)	• Remote driving/steering, • Video feed (Internal / External)	• Integration of roadside sensors, • V2Passenger	Data transfer to back office: video, audio, other
1 7 8	The visually impaired passenger shall be informed about any obstacles between the drop off point and their destination	• Road blocking obstacles, • Road conditions (Icy road, holes)	• Audio feed, • Communication with passengers	V2Passenger	
1 7 9	The (visually impaired) passenger shall be guided from the drop off point to their destination		• Communication with passengers, • Audio feed	V2Passenger	
1 8 0	The user shall be able to disembark safely using the time they need		• Door opening / closing control, • State of sensors, • Video feed (Internal / External)	V2Passenger	Data transfer to back office: video, audio, other
1 8 1	For disembarking, the vehicle shall stop, automatically unlock the doors, and inform pax about destination PUDO (e.g. voice-over announcement or display or app)		• Door opening / closing control, • Communication with passengers, • Audio feed, • Video feed (Internal / External)	V2Passenger	Data transfer to back office: video, audio, other



D2.1 Passenger and PTO requirements, needs, and use cases



1 8 2	The system (e.g., app, in-vehicle screen) shall inform the passenger that the vehicle has now reached the passenger's destination		- GNSS location, - Communication with passengers	V2Passenger	
1 8 3	The vehicle shall indicate the remaining time available for disembarking (e.g. timer on big screen, with an option to request more time)		- Communication with passengers, - Door opening / closing control, - Video feed (Internal / External)	V2Passenger	
1 8 4	The user shall get a reminder to ensure they remember their belongings.		Audio feed	V2Passenger	
1 8 5	The door of the autonomous vehicle shall be automatically unlocked when the user is disembarking		Door opening / closing control	V2Passenger	
1 8 6	The doors shall indicate before they close (alert signal)		- Communication with passengers, - Door opening / closing control, - Video feed (Internal / External), - Audio feed	V2Passenger	
1 8 7	The user shall be able to request that the vehicle drives on a few meters if the PUDO is not safe to disembark (e.g., if there is a big puddle, pile of snow, etc.)	- Low visibility conditions (Rain, snow, fog, dust, night etc.), - Road blocking obstacles, - Other road users, - Pedestrian crossings, - Traffic lights	- Remote driving/steering, - Communication with passengers	- V2Passenger, - V2X	
1 8 8	The user shall be able to exit the vehicle without a (working) smart phone		Communication with passengers	V2Passenger	
1 8 9	The vehicle shall check if it is safe before it opens the doors for passengers to disembark	- Low visibility conditions (Rain, snow, fog, dust, night etc.), - Road conditions (Icy road, holes)	- Video feed (Internal / External), - Door opening / closing control, - GNSS location	- V2X, - Integration of roadside sensors	Data transfer to back office: video, audio, other



D2.1 Passenger and PTO requirements, needs, and use cases



190	The system shall provide info about changeover time for connecting means of transport		• Video feed (Internal / External), • Audio feed, • GNSS location	• V2Passenger, • V2X	Data transfer to back office: video, audio, other
191	The vehicle shall inform the PTO if pax do not disembark as supposed to		• Video feed (Internal / External), • Passengers counter, • Door opening / closing control, • Audio feed, • GNSS location, • Communication with passengers	V2X	Data transfer to back office: video, audio, other
192	The user shall have the option to request additional time for disembarking		• Communication with passengers, • Video feed (Internal / External), • Door opening / closing control	• V2Passenger, • V2X	Data transfer to back office: video, audio, other
193	The vehicle shall provide alert signal when ramp is moving		Communication with passengers	V2Passenger	
194	The customer service (CS) shall be notified after a certain time if pax exceed the boarding time limit to address the situation to facilitate the movement of the vehicle.		• Door opening / closing control, • Passengers counter, • Video feed (Internal / External), • Communication with passengers, • Audio feed, • GNSS location	V2X	Data transfer to back office: video, audio, other
195	PUDO must provide space to move on safely and be free of obstacles	• Road blocking obstacles, • Road conditions (Icy road, holes)		V2X	Data transfer to back office: video, audio, other
196	When having booked for another person, the user shall be sure the passenger disembarks at the correct location		• Video feed (Internal / External), • Audio feed, • Passengers counter	V2Passenger	Data transfer to back office: video, audio, other

197	The vehicle shall inform Customer Service if a passenger falls while disembarking		• Video feed (Internal / External), • Audio feed, • Communication with passengers	• V2Passenger, • V2X	Data transfer to back office: video, audio, other
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Table 23: Disembark, software and other specifications

1

Review

Hardware specifications

10. Review		Hardware specifications						
ID	Requirement	Vehicle dimensions	Technical specifications	Carrying capacity	Passenger services	Accessibility and comfort	Passenger Safety	Autonomous driving hardware
198	The user shall be able to rate the experience					Screen(s)/Other to indicate line number		Camera
199	The user shall be able to share the experience							
200	The user shall be able to report forgotten items in the vehicle						• Ability to contact remote operator (No safety driver on board), • Assistance systems for visually and/or hearing impaired	
201	The user shall be able to provide feedback on the service					Screen(s)/Other to indicate line number		Camera

D2.1 Passenger and PTO requirements, needs, and use cases



202	The user shall be able to receive a receipt of the trip							
203	The service shall provide a process for retrieving/returning lost items (e.g. vehicle could bring item back to PUDO etc.)							
204	The user shall be able to save a trip as a favorite							
205	The user shall be able to report an issue with a PUDO	Height off the ground of the vehicle with respect to the road (Adaptability) (mm)		Room for wheelchair, walker, stroller		Passenger information system (Number of units and placement)	- Assistance systems for visually and/or hearing impaired, - Ability to contact remote operator (No safety driver on board)	- Camera, 5G, 4G

Table 24: Review, hardware specifications

Software & other specifications

10.Review		Software specifications			Other specifications
ID	Requirement	Operational design domain, autonomous driving system	Remote capabilities	Connectivity	Legal and regulatory
198	The user shall be able to rate the experience		- Video feed (Internal / External), - Communication with passengers	V2Passenger	Data transfer to back office: video, audio, other



D2.1 Passenger and PTO requirements, needs, and use cases



1 9 9	The user shall be able to share the experience			V2Passenger	Data transfer to back office: video, audio, other
2 0 0	The user shall be able to report forgotten items in the vehicle		• Communication with passengers, • Video feed (Internal / External), • Audio feed, • GNSS location	V2Passenger	Data transfer to back office: video, audio, other
2 0 1	The user shall be able to provide feedback on the service		• Video feed (Internal / External), • Communication with passengers	V2Passenger	Data transfer to back office: video, audio, other
2 0 2	The user shall be able to receive a receipt of the trip			V2Passenger	
2 0 3	The service shall provide a process for retrieving/returning lost items (e.g. vehicle could bring item back to PUDO etc.)		• Mission modification (During the mission), • Multi routing	V2Passenger	
2 0 4	The user shall be able to save a trip as a favorite			V2Passenger	
2 0 5	The user shall be able to report an issue with a PUDO		• Video feed (Internal / External), • Audio feed, Mission cancellation, • Communication with passengers	V2Passenger	Data transfer to back office: video, audio, other

Table 25: Review, software and other specifications

LaaS

Hardware specifications

11.LaaS		Hardware specifications						
ID	Requirement	Vehicle dimensions	Technical specifications	Carrying capacity	Passenger services	Accessibility and comfort	Passenger Safety	Autonomous driving hardware
206	The vehicle shall provide means to store goods/packages safely so that they cannot fall or break			- Max cargo weight, - Max cargo dimensions, - Fixing to secure the cargo, - Specific space for baggage				- Camera, 4G
207	The vehicle shall provide means to store goods/package securely so that they cannot be stolen			- Max cargo weight, - Max cargo dimensions, - Fixing to secure the cargo, - Specific space for baggage			Ability to contact remote operator (No safety driver on board)	
208	The customer shall only have access to the correct package (to avoid they take the wrong one)			Fixing to secure the cargo		Passenger information system (Number of units and placement)	- Assistance systems for visually and/or hearing impaired, - Ability to contact remote operator (No safety driver on board)	Camera
209	The customer shall be able to pick up a package while the vehicle does not move/drive off	Height off the ground of the vehicle with respect to the road (Adaptability) (mm)	Number of doors	Specific space for baggage		Screen(s)/Other to indicate line number		- Camera, 4G, 5G

D2.1 Passenger and PTO requirements, needs, and use cases



210	The customer shall be able to monitor their package in transit until delivery							• Camera, • RTK-GNSS, • 4G, • 5G, • IMU, • Size, location
211	The vehicle shall inform the LaaS service provider if package is not picked up							• 4G, • 5G
212	The vehicle shall provide means to store goods/package with the right temperature so that they won't spoil		Operation temperature min/max	• Fixing to secure the cargo, • Specific space for baggage		Heating / Cooling /Air conditioning		Infrared camera
213	The customer shall be able to choose an exact time for the delivery of the parcel							• 4G, • 5G

Table 26: Laas, hardware specifications

Software & other specifications

11.LaaS		Software specifications			Other specifications
I D	Requirement	Operational design domain, autonomous driving system	Remote capabilities	Connectivity	Legal and regulatory
206	The vehicle shall provide means to store goods/packages safely so that they cannot fall or break		• Video feed (Internal / External), • GNSS location	• V2X, • V2Passenger	Data transfer to back office: video, audio, other
207	The vehicle shall provide means to store goods/package securely so that they cannot be stolen		Video feed (Internal / External)	V2X	Data transfer to back office: video, audio, other
208	The customer shall only have access to the correct package (to avoid they take the wrong one)		Communication with passengers	V2X	Data transfer to back office: video, audio, other
209	The customer shall be able to pick up a package while the vehicle does not move/drive off			V2Passenger	Data transfer to back office: video, audio, other



D2.1 Passenger and PTO requirements, needs, and use cases

210	The customer shall be able to monitor their package in transit until delivery		• Video feed (Internal / External), • GNSS location	• V2Passenger , • V2X	Data transfer to back office: video, audio, other
211	The vehicle shall inform the LaaS service provider if package is not picked up		• Video feed (Internal / External), • Mission cancellation	• V2Passenger , • V2X	Data transfer to back office: video, audio, other
212	The vehicle shall provide means to store goods/package with the right temperature so that they won't spoil		Indoor temperature	• V2X, V2Passenger	Speed authorisation (km/h)
213	The customer shall be able to choose an exact time for the delivery of the parcel		Communication passengers	with V2Passenger	Data transfer to back office: video, audio, other

Table 27: Laas software and other specifications

PTO

Hardware specifications

12.PTO		Hardware specifications						
ID	Requirement	Vehicle dimensions	Technical specifications	Carrying capacity	Passenger services	Accessibility and comfort	Passenger Safety	Autonomous driving hardware
214	The app shall support standard accessibility features like text size and voiceover mode to guarantee access to all				Loudspeaker		Assistance systems for visually and/or hearing impaired	
215	The PTO shall know the location of all vehicles							• RTK-GNSS, • Size, location, • 4G, • 5G, • IMU
216	The PTO shall be informed about events impacting passengers in real time				Passenger counting system	Passenger information system (Number of units and placement)	• Ability to contact remote operator (No safety driver on board),	• Camera, • 4G, • 5G

D2.1 Passenger and PTO requirements, needs, and use cases



							• SOS mechanism	
2 1 7	The user shall have their data protected							Protection level of vehicle computer hardware (ease of access)
2 1 8	The PTO shall see in real time the status of the service			Number of seating positions	Passenger counting system	Passenger information system (Number of units and placement)	Assistance systems for visually and/or hearing impaired	• Camera, • LiDARs, • Radar, • 4G, • 5G, • IMU, • RTK-GNSS, • Protection level of vehicle computer hardware (ease of access), • Infrared camera
2 1 9	The PTO shall have statistics on the services			Number of seating positions	Passenger counting system	Passenger information system (Number of units and placement)	Assistance systems for visually and/or hearing impaired	• Camera, • LiDARs, • Radar, • Infrared camera, • Protection level of vehicle computer hardware (ease of access), • 4G, • 5G, • IMU, • RTK-GNSS
2 2 0	The PTO shall be able to respond to any events impacting the services			Number of seating positions	Passenger counting system, Loudspeaker	• Passenger information system (Number of units and placement), • Screen(s)/Other to indicate line number	• Assistance systems for visually and/or hearing impaired, • Ability to contact remote operator (No safety driver on board)	• Camera, • 4G, • 5G, • LiDARs, • Radar, • Infrared camera, • IMU, • RTK-GNSS, • Size, location, • Protection level of vehicle computer hardware (ease of access)

D2.1 Passenger and PTO requirements, needs, and use cases



2 2 1	The PTO shall be able to monitor vehicle, passengers and activities			• Passenger capacity, • Number of seating positions	Passenger counting system	• Passenger information system (Number of units and placement), • Heating / Cooling /Air conditioning, • Indoor CO2 sensor	• Seatbelts, • Emergency stop button, • Assistance systems for visually and/or hearing impaired	• Camera, • 4G, • 5G, • RTK-GNSS, • LiDARs, • Radar, • Infrared camera, • IMU, • Size, location, • Protection level of vehicle computer hardware (ease of access)
2 2 2	The system shall provide an integrated control centre in another branch.			Number of seating positions	• Passenger counting system, • Loudspeaker	• Passenger information system (Number of units and placement), • Screen(s)/Other to indicate line number	Assistance systems for visually and/or hearing impaired	• Camera, • LiDARs, • Radar, • Infrared camera, • 4G, • 5G, • IMU, • RTK-GNSS, • Size, location, • Protection level of vehicle computer hardware (ease of access)
	The PTO shall be able to test reliability at another location			Number of seating positions	Passenger counting system	Passenger information system (Number of units and placement)	Assistance systems for visually and/or hearing impaired	• Camera, • LiDARs, • Radar, • Infrared camera, • Protection level of vehicle computer hardware (ease of access), • 4G, • 5G, • IMU, • RTK-GNSS, • Size, location
2 2 3	The PTO shall be able to communicate to passengers inside a specific vehicle				Loudspeaker	• Screen(s)/Other to indicate line number,		Camera



D2.1 Passenger and PTO requirements, needs, and use cases



						• Passenger information system (Number of units and placement)		
2 2 4	The PTO shall be able to communicate to passengers inside all vehicles in an area				Loudspeaker	• Screen(s)/Other to indicate line number, • Passenger information system (Number of units and placement)		• Camera, • RTK-GNSS, • Size, location
2 2 5	The PTO shall be able at all times to remotely stop the vehicle and open the doors							• 4G, • 5G, • LiDARs, • Radar, • Camera, • Infrared camera, IMU, • RTK-GNSS, • Size, location, • Protection level of vehicle computer hardware (ease of access)
2 2 6	The PTO shall be able to remotely maneuver the vehicle to a safe location at low speeds							• Camera, • 4G, • 5G, • IMU, • RTK-GNSS, • LiDARs, • Radar, • Infrared camera, • Size, location, • Protection level of vehicle computer hardware (ease of access)
2 2 7	The PTO shall be able to remotely maneuver the vehicle at low speeds to overcome an obstacle							• LiDARs, • Radar, • Camera, • 4G, • 5G, • IMU, • RTK-GNSS, • Size, location,



D2.1 Passenger and PTO requirements, needs, and use cases



								Protection level of vehicle computer hardware (ease of access)
2 2 8	The PTO must be the only one to remotely manoeuvre vehicles							Protection level of vehicle computer hardware (ease of access)
2 2 9	The PTO shall be able to remove operators from vehicles to make certain services financially viable			- Passenger capacity, - Number of seating positions	- Passenger counting system, - Ticket verification system, - Loudspeaker, - Stop request button	- Screen(s)/Other to indicate line number, - Passenger information system (Number of units and placement), - Audio guidance to doors, - Wheelchair / baby carriage access - No assistance, - Indoor CO2 sensor, - Heating / Cooling /Air conditioning	- Ability to contact remote operator (No safety driver on board), - Assistance systems for visually and/or hearing impaired, - SOS mechanism, - Emergency windows, - First aid kit, - Automated External Defibrillator (resuscitation device), - Emergency stop button	- LiDARs, - Camera, - RTK-GNSS, - Size, location, 5G, - Radar, - Infrared camera, - IMU, - Protection level of vehicle computer hardware (ease of access)
2 3 0	The PTO shall be able to easily integrate new vehicles procured from different manufacturers	- Height (mm), - Length (mm), - Width (mm)	- Top speed (km/h), - Range (km), - Turning diameter (m), - Maximum slope - Fuel capacity (Petrol/diesel/etc.) (litre), - Battery capacity (kWh),	- Number of seating positions, - Passenger capacity, Max cargo weight, - Max cargo dimensions	Passenger counting system	Passenger information system (Number of units and placement)	Assistance systems for visually and/or hearing impaired	- Camera, 4G, 5G



D2.1 Passenger and PTO requirements, needs, and use cases



			• Battery health, • Battery charging time (0 to 100%) (minutes), • Charger type, • inductive charging, other type , • Operation temperature min/max					
2 3 1	The services shall be able to reroute to pickup other demands (pax)			Specific space for baggage				• 4G, • 5G
2 3 2	The services shall be able to dispatch vehicles adapted to passengers with special needs when required.		Door width	• Room for wheelchair, walker, stroller, • Number of seating positions	Stop request button	• Wheelchair / baby carriage access - No assistance, • Wheelchair / baby carriage access - With assistance, • Accessibility seats spots (Elderly, pregnant etc.)	Assistance systems for visually and/or hearing impaired	• Camera, • 4G, • 5G
2 3 3	The services shall be able to make predictions to have the right equiped vehicle already in the area, when a booking is made with special needs.		Door width	• Room for wheelchair, walker, stroller, • Number of seating positions		• Wheelchair / baby carriage access - No assistance, • Wheelchair / baby carriage access - With assistance, • Accessibility seats spots (Elderly, pregnant etc)	Assistance systems for visually and/or hearing impaired	• Camera, • RTK-GNSS, • Size, location, • IMU
2 3 4	The services shall be integrated into the existing transport services							

D2.1 Passenger and PTO requirements, needs, and use cases



2 3 5	The PTO shall communicate connecting options between conventional PT and OnDemand Services							5G
2 3 6	The PUDOs shall be maintained for safe boarding/disembarking (e.g. clear of ice and snow, treated with salt to prevent slippery conditions, etc.)		Ground clearance					
2 3 7	The PTO shall be alerted if there are any problems with any of the vehicles						• Assistance systems for visually and/or hearing impaired, • Ability to contact remote operator (No safety driver on board)	• 4G, • 5G, • Camera
2 3 8	The PTO shall be alerted if there are any problems with the fleet management software							
2 3 9	The PTO shall be alerted if there are any traffic problems on the route							
2 4 0	The PTO shall see the status of the fleet							• Size, location, • 4G, • 5G
2 4 1	The PTO shall see the status of each vehicle (in-vehicle camera, sensors, outside camera for 360 view, etc.): overview plus option to have a closer look							• LiDARs, • Radar, • Camera, • Infrared camera, • 4G, • 5G, • IMU, • RTK-GNSS, • Size, location
2 4 2	The PTO shall be able to see the interior of the vehicle							• 4G, • 5G, • Camera



D2.1 Passenger and PTO requirements, needs, and use cases



2 4 3	The PTO shall be alerted if the system detects any anomalies with passengers or objects in the vehicle				Passenger counting system	Passenger information system (Number of units and placement)		• 4G, • 5G, • Camera
2 4 4	Thy system shall highlight relevant pax/objects in camera feed if anomaly is detected							• Camera, • 4G, • 5G
2 4 5	The PTO shall be able to quickly contact an ambulance if required				Stop request button		• Emergency stop button, • SOS mechanism	• Camera, • 4G, • 5G
2 4 6	The PTO shall be able to request a maintenance team if required with all relevant monitoring data included in the request .							• Camera, • Size, location, RTK-GNSS, • 4G, • 5G, • IMU
2 4 7	The PTO shall be able to identify passengers			Passenger capacity	• Passeng er counting system, • Ticket verificati on system	Passenger information system (Number of units and placement)		• Camera, • 4G, • 5G
2 4 8	All audio and video recordings shall be encrypted and securely stored and accessible only by authorized personel							• Camera, • 4G, • 5G, • Protection level of vehicle computer hardware (ease of access)
2 4 9	The system shall add "smart" annotations to the audio and video recordings							• Camera, • 4G, • 5G
2 5 0	The PTO shall be able to monitor seatbelt and seat sensors			Number of seating positions	Passenger counting system		Seatbelts	• Camera, • 4G, • 5G
2 5 1	The system shall alert CS if it detects littering							• Camera, • 5G, • 4G

D2.1 Passenger and PTO requirements, needs, and use cases



2 5 2	The system shall alert CS if it detects low air quality					Indoor CO2 sensor		• 4G, • 5G
2 5 3	The system shall alert CS if it detects temperature outside specified range		Operation temperature min/max			Heating / Cooling /Air conditioning		• 4G, • 5G
2 5 4	Standardized HD mapping shall be provided							
2 5 5	CS staff shall be trained for disability awareness and accessible communication							
2 5 6	The PTO shall provide communication means for all, e.g. also for mute, deaf or visually impaired passengers				• Loudspeaker	• Audio guidance to doors, • Screen(s)/Other to indicate line number, • Passenger information system (Number of units and placement)	• Assistance systems for visually and/or hearing impaired • Emergency stop button, • Ability to contact remote operator (No safety driver on board)	• 4G, • 5G
2 5 7	The system shall dispatch vehicles with special features only when needed by users with special needs or when all other vehicle are in use in order for them to be as highly available as possible			• Room for wheelchair, walker, stroller		• Wheelchair / baby carriage access - No assistance, • Wheelchair / baby carriage access - With assistance, • Accessibility seats spots (Elderly, pregnant etc.)		• RTK-GNSS, • Size, location, • IMU
2 5 8	The PTO shall be able to monitor the battery status of all vehicles of the fleet		• Battery capacity (kWh), • Battery health					• 4G, • 5G
2 5 9	The system shall send vehicles with low battery to the depot for charging		• Battery capacity (kWh),					• RTK-GNSS, • Size, location, • 5G,



D2.1 Passenger and PTO requirements, needs, and use cases



			- Battery health, - Battery charging time (0 to 100%) (minutes)					4G
260	The system shall make sure the vehicles are operational with charged batteries during peak hours		- Battery charging time (0 to 100%) (minutes), - Battery capacity (kWh), - Battery health					4G, 5G
261	The system shall alert if battery status of a vehicle is below a certain threshold		- Battery health, - Battery capacity (kWh)					4G, 5G

Table 28: PTO, hardware specifications

Software & other specifications

12.PTO		Software specifications			Other specifications
I D	Requirement	Operational design domain, autonomous driving system	Remote capabilities	Connectivity	Legal and regulatory
214	The app shall support standard accessibility features like text size and voiceover mode to guarantee access to all			V2Passenger	Data transfer to back office: video, audio, other
215	The PTO shall know the location of all vehicles		GNSS location	V2X	Data transfer to back office: video, audio, other



D2.1 Passenger and PTO requirements, needs, and use cases



2 1 6	The PTO shall be informed about events impacting passengers in real time		• State of sensors, • Passengers counter, • Video feed (Internal / External), • Audio feed, • State of autonomous system, • Communication with passengers	• V2Passenger, • V2X	Data transfer to back office: video, audio, other
2 1 7	The user shall have their data protected				Data transfer to back office: video, audio, other
2 1 8	The PTO shall see in real time the status of the service		• GNSS location, • State of sensors, • State of autonomous system, • Battery level (Electric vehicle), • Fuel level (Petrol/Diesel/etc), • Indoor temperature, • Indoor co2 level, • Tire pressure, • Passengers counter, • Video feed (Internal / External), • Audio feed, • Communication with passengers, • Mission modification (During the mission)	V2X	Data transfer to back office: video, audio, other
2 1 9	The PTO shall have statistics on the services		• Tire pressure, • State of sensors, • State of autonomous system, • Battery level (Electric vehicle), • Fuel level (Petrol/Diesel/etc), • Video feed (Internal / External), • Audio feed, • Indoor temperature, • Indoor co2 level, • GNSS location, • Communication with passengers, • Mission modification (During the mission),	V2X	Data transfer to back office: video, audio, other



D2.1 Passenger and PTO requirements, needs, and use cases



			• Mission cancellation		
2 2 0	The PTO shall be able to respond to any events impacting the services		• GNSS location, • Video feed (Internal / External), • Remote navigation control, • Remote driving/steering, • Tire pressure, • State of sensors, • State of autonomous system, • Battery level (Electric vehicle), • Fuel level (Petrol/Diesel/etc.), • Passengers counter, • Audio feed, • Indoor temperature, • Indoor co2 level, • Communication with passengers, • Mission cancellation, • Mission modification (During the mission)	V2X	Data transfer to back office: video, audio, other
2 2 1	The PTO shall be able to monitor vehicle, passengers and activities		• Passengers counter, • Video feed (Internal / External), • Audio feed, • Indoor temperature, • Indoor co2 level, • GNSS location, • Remote driving/steering, • Remote navigation control, • Door opening / closing control, • Communication with passengers, • Tire pressure, • State of sensors, • State of autonomous system, • Battery level (Electric vehicle), • Fuel level (Petrol/Diesel/etc.), • Mission cancellation, • Mission modification (During the mission)	V2X	Data transfer to back office: video, audio, other



D2.1 Passenger and PTO requirements, needs, and use cases



2 2 2	The system shall provide an integrated control centre in another branch.		• GNSS location, • Remote navigation control, • Tire pressure, • State of sensors, • State of autonomous system, • Battery level (Electric vehicle), • Fuel level (Petrol/Diesel/etc.), • Passengers counter, • Video feed (Internal / External), • Audio feed, • Indoor temperature, • Indoor co2 level, • Communication with passengers, • Mission modification (During the mission), • Mission cancellation	V2X	Data transfer to back office: video, audio, other
	The PTO shall be able to test reliability at another location		• GNSS location, • State of sensors, • State of autonomous system, • Multi routing, • Tire pressure, • Battery level (Electric vehicle), • Fuel level (Petrol/Diesel/etc.), • Passengers counter, • Video feed (Internal / External), • Audio feed, • Indoor temperature, • Indoor co2 level, • Communication with passengers, • Mission modification (During the mission), • Mission cancellation	V2X	Data transfer to back office: video, audio, other
2 2 3	The PTO shall be able to communicate to passengers inside a specific vehicle		• Audio feed, • Video feed (Internal / External), • Communication with passengers	V2Passenger	Data transfer to back office: video, audio, other



D2.1 Passenger and PTO requirements, needs, and use cases



2 2 4	The PTO shall be able to communicate to passengers inside all vehicles in an area		• Video feed (Internal / External), • Audio feed, • Communication with passengers, • GNSS location	V2Passenger	Data transfer to back office: video, audio, other
2 2 5	The PTO shall be able at all times to remotely stop the vehicle and open the doors		• Door opening / closing control, • Remote navigation control, • GNSS location, • Video feed (Internal / External), • Mission cancellation	V2X	Data transfer to back office: video, audio, other
2 2 6	The PTO shall be able to remotely manoeuvre the vehicle to a safe location at low speeds		• Remote driving/steering, • Video feed (Internal / External), • GNSS location, • Remote navigation control, • Mission cancellation, • Mission modification (During the mission)	V2X	• Data transfer to back office: video, audio, other, • Speed authorisation (km/h), • Type of license of the safety operator
2 2 7	The PTO shall be able to remotely manoeuvre the vehicle at low speeds to overcome an obstacle	Road blocking obstacles	• Remote driving/steering, • Video feed (Internal / External), • GNSS location, • Remote navigation control, • Mission cancellation	V2X	• Type of license of the safety operator, • Speed authorisation (km/h), • Data transfer to back office: video, audio, other
2 2 8	The PTO must be the only one to remotely manoeuvre vehicles		Remote driving/steering	V2X	Data transfer to back office: video, audio, other
2 2 9	The PTO shall be able to remove operators from vehicles to make certain services financially viable	• Road blocking obstacles, • Low visibility conditions (Rain, snow, fog, dust, night etc.)	• Remote driving/steering, • State of sensors, • Battery level (Electric vehicle), • Passengers counter, • Video feed (Internal / External), • Audio feed, • GNSS location, • Door opening / closing control, • Communication with passengers, • Mission cancellation, • Mission modification (During the mission), • Multi routing,	• V2V, • V2X, • V2Passenger • Integration of roadside sensors	• Data transfer to back office: video, audio, other, • Type of license of the safety operator • Speed authorization (km/h)

D2.1 Passenger and PTO requirements, needs, and use cases



			• Remote navigation control, • Tire pressure, • Fuel level (Petrol/Diesel/etc.), • Indoor temperature		
2 3 0	The PTO shall be able to easily integrate new vehicles procured from different manufacturers		GNSS location	V2X	Data transfer to back office: video, audio, other
2 3 1	The services shall be able to reroute to pickup other demands (pax)		• Multi routing, • Mission modification (During the mission), • Mission cancellation	V2X	Data transfer to back office: video, audio, other
2 3 2	The services shall be able to dispatch vehicles adapted to passengers with special needs when required.		• GNSS location, • Multi routing, • Mission modification (During the mission)	V2X	Data transfer to back office: video, audio, other
2 3 3	The services shall be able to make predictions to have the right equipped vehicle already in the area, when a booking is made with special needs.		• GNSS location, • Multi routing, • Mission modification (During the mission), • Remote navigation control	V2Passenger	Data transfer to back office: video, audio, other
2 3 4	The services shall be integrated into the existing transport services				Data transfer to back office: video, audio, other
2 3 5	The PTO shall communicate connecting options between conventional PT and OnDemand Services			V2V, V2X	Data transfer to back office: video, audio, other
2 3 6	The PUDOs shall be maintained for safe boarding/disembarking (e.g. clear of ice and snow, treated with salt to prevent slippery conditions, etc.)				
2 3 7	The PTO shall be alerted if there are any problems with any of the vehicles	Other road users	• State of autonomous system, • State of sensors, • GNSS location, • Tire pressure, • Battery level (Electric vehicle), • Fuel level (Petrol/Diesel/etc.), • Indoor temperature, • Indoor co2 level, • Remote driving/steering, • Passengers counter,	V2V	Data transfer to back office: video, audio, other



D2.1 Passenger and PTO requirements, needs, and use cases



			• Video feed (Internal / External), • Audio feed, • Mission cancellation		
2 3 8	The PTO shall be alerted if there are any problems with the fleet management software				Data transfer to back office: video, audio, other
2 3 9	The PTO shall be alerted if there are any traffic problems on the route	• Road blocking obstacles, • Traffic lights, • Roundabouts, • Pedestrian crossings, • Low visibility conditions (Rain, snow, fog, dust, night etc.), • Other road users, • Road conditions (Icy road, holes)		V2X	Data transfer to back office: video, audio, other
2 4 0	The PTO shall see the status of the fleet		• GNSS location, • State of sensors, • State of autonomous system, • Video feed (Internal / External), • Remote navigation control		Data transfer to back office: video, audio, other
2 4 1	The PTO shall see the status of each vehicle (in-vehicle camera, sensors, outside camera for 360 view, etc.): overview plus option to have a closer look	Pedestrian crossings	• State of sensors, • State of autonomous system, • GNSS location, • Tire pressure, • Battery level (Electric vehicle), • Fuel level (Petrol/Diesel/etc.), • Video feed (Internal / External), • Indoor temperature, • Indoor co2 level	V2X	Data transfer to back office: video, audio, other
2 4 2	The PTO shall be able to see the interior of the vehicle		• Video feed (Internal / External), • Communication with passengers	V2X	Data transfer to back office: video, audio, other
2 4 3	The PTO shall be alerted if the system detects any anomalies with passengers or objects in the vehicle		• Passengers counter, • Video feed (Internal / External), • Audio feed, • Communication with passengers	V2X	Data transfer to back office: video, audio, other

D2.1 Passenger and PTO requirements, needs, and use cases



2 4 4	Thy system shall highlight relevant pax/objects in camera feed if anomaly is detected		• Video feed (Internal / External), • Communication with passengers	V2X	Data transfer to back office: video, audio, other
2 4 5	The PTO shall be able to quickly contact an ambulance if required		• Communication with passengers, • Video feed (Internal / External), • GNSS location	V2X	Data transfer to back office: video, audio, other
2 4 6	The PTO shall be able to request a maintenance team if required with all relevant monitoring data included in the request .		• State of autonomous system, • Video feed (Internal / External), • GNSS location	V2X	Data transfer to back office: video, audio, other
2 4 7	The PTO shall be able to identify passengers		• Passengers counter, • Video feed (Internal / External)	• V2Passenger, • V2X	Data transfer to back office: video, audio, other
2 4 8	All audio and video recordings shall be encrypted and securely stored and accessible only by authorized personel		• Video feed (Internal / External), • Audio feed	V2X	Data transfer to back office: video, audio, other
2 4 9	The system shall add "smart" annotations to the audio and video recordings		• Video feed (Internal / External), • Audio feed	V2X	Data transfer to back office: video, audio, other
2 5 0	The PTO shall be able to monitor seatbelt and seat sensors		• State of sensors, • Video feed (Internal / External)	V2X	Data transfer to back office: video, audio, other
2 5 1	The system shall alert CS if it detects littering		Video feed (Internal / External)		Data transfer to back office: video, audio, other
2 5 2	The system shall alert CS if it detects low air quality		Indoor co2 level	V2X	Data transfer to back office: video, audio, other
2 5 3	The system shall alert CS if it detects temperature outside specified range		Indoor temperature	V2X	Data transfer to back office: video, audio, other
2 5 4	Standardized HD mapping shall be provided				
2 5 5	CS staff shall be trained for disability awareness and accessible communication				

D2.1 Passenger and PTO requirements, needs, and use cases

2 5 6	The PTO shall provide communication means for all, e.g. also for mute, deaf or visually impaired passengers		Communication with passengers	V2Passenger, V2X	Data transfer to back office: video, audio, other
2 5 7	The system shall dispatch vehicles with special features only when needed by users with special needs or when all other vehicle are in use in order for them to be as highly available as possible		- Multi routing, - GNSS location, - Mission modification (During the mission)	V2Passenger	
2 5 8	The PTO shall be able to monitor the battery status of all vehicles of the fleet		Battery level (Electric vehicle)	V2X	Data transfer to back office: video, audio, other
2 5 9	The system shall send vehicles with low battery to the depot for charging		- Battery level (Electric vehicle), - GNSS location, - Mission modification (During the mission), - Multi routing	V2X	Data transfer to back office: video, audio, other
2 6 0	The system shall make sure the vehicles are operational with charged batteries during peak hours		- Battery level (Electric vehicle), - Mission modification (During the mission), - Multi routing		
2 6 1	The system shall alert if battery status of a vehicle is below a certain threshold		Battery level (Electric vehicle)		

Table 29: PTO, software and other specifications

2 Vehicle

Hardware specifications

13.Vehicle		Hardware specifications						
I D	Requirement	Vehicle dimensions	Technical specifications	Carrying capacity	Passenger services	Accessibility and comfort	Passenger Safety	Autonomous driving hardware



D2.1 Passenger and PTO requirements, needs, and use cases



2 6 2	The vehicle shall be able to detect if number of occupied seats deviates from number of registered passengers in the vehicle ("ghostriders")			Passenger capacity	• Passenger counting system • Ticket verification system	Passenger information system (Number of units and placement)		• Camera, • 4G, • 5G
2 6 3	The vehicle shall be able to interact with elements of infrastructure							• 4G, • 5G, • LiDARs, • IMU, • Radar
2 6 4	The vehicle shall be able to interact with the depot it is entering/leaving							• 4G, • 5G, • LiDARs, • IMU, • Radar
2 6 5	The vehicle shall be able to interact with barriers and gates							• 4G, • 5G, • LiDARs, • IMU, • Radar
2 6 6	The vehicle shall be able to interact with traffic lights equipped with V2X							• 4G, • 5G, • LiDARs, • IMU, • Radar
2 6 7	The vehicle shall be able to interact safely with other road users							• Camera, • 5G, • 4G, • LiDARs, • Radar, • IMU
2 6 8	The vehicle shall provide handles for passengers to hold on to when getting to the seat/door			Number of standing positions		Accessibility seats spots (Elderly, pregnant etc.)	• Seatbelts, • Assistance systems for visually and/or hearing impaired	



D2.1 Passenger and PTO requirements, needs, and use cases



2 6 9	The vehicle shall be clean					Indoor CO2 sensor		• Camera, • 4G, • 5G
2 7 0	The vehicle shall provide clean air throughout the journey					• Indoor CO2 sensor, • Heating / Cooling /Air conditioning		• 4G, • 5G
2 7 1	The vehicle shall provide a pleasant temperature throughout the journey					Heating / Cooling /Air conditioning		• 4G, • 5G
2 7 2	The in-vehicle screen shall be designed with a size that allows for easy readability of information	• Length (mm), • Height (mm), • Width (mm)		Passenger capacity		• Screen(s)/Other to indicate line number, • Passenger information system (Number of units and placement)	Assistance systems for visually and/or hearing impaired	
2 7 3	The seating arrangement in the vehicle shall provide some separation between passengers (e.g., include separators between side-by-side seats)			• Passenger capacity, • Seating positions (in direction of travel, against direction of travel, across direction of travel)		Accessibility seats spots (Elderly, pregnant etc.)		
2 7 4	The vehicle shall provide emergency equipment like window breaker, fire extinguisher (vehicle shall meet all regional safety standards)				Stop request button	Passenger information system (Number of units and placement)	• Emergency windows, • First aid kit, • SOS mechanism, • Emergency stop button	
2 7 5	The vehicle shall be equipped with onboard cameras, microphones and speakers				Loudspeaker	Screen(s)/Other to indicate line number		• Camera, • Infrared camera
2 7 6	The vehicle shall be able to detect forgotten items (and inform owner if ownership is known?)			Room for wheelchair, walker, stroller	Loudspeaker			• 4G, • 5G, • Camera

D2.1 Passenger and PTO requirements, needs, and use cases



2 7 7	The vehicle shall have a wheelchair ramp with the appropriate gradient so that a wheelchair user can board and disembark without assistance.	Height off the ground of the vehicle with respect to the road (Adaptability) (mm)	Maximum slope	Room for wheelchair, walker, stroller	Passenger counting system	- Wheelchair / baby carriage access - No assistance, - Wheelchair / baby carriage ramp	Seatbelts	Camera
2 7 8	The vehicle shall have an identifier (unique, easy to identify, accessible)				Passenger counting system			
2 7 9	The vehicle shall be able to interact with the passenger app							4G, 5G
2 8 0	The in-vehicle screen shall provide sufficient contrast					Screen(s)/Other to indicate line number		
2 8 1	The vehicle shall get the user to their destination significantly faster than walking		Top speed (km/h)					
2 8 2	All systems shall be secured against cyber attacks							Protection level of vehicle computer hardware (ease of access)
2 8 3	The vehicle shall have space for passengers using wheelchairs, mobility aids or strollers etc.			Room for wheelchair, walker, stroller			Assistance systems for visually and/or hearing impaired	
2 8 4	The vehicle shall have means to secure wheelchairs, mobility aids or strollers etc.			- Room for wheelchair, walker, stroller, - Fixing to secure the cargo	Passenger counting system	- Wheelchair / baby carriage access - No assistance, - Wheelchair / baby carriage access - With assistance	Assistance systems for visually and/or hearing impaired	Camera
2 8 5	The vehicle shall provide data like battery status, etc. to other systems		- Battery capacity (kWh), - Battery health					



D2.1 Passenger and PTO requirements, needs, and use cases



2 8 6	The passenger shall be able to comfortably transport their shopping			- Room for wheelchair, walker, stroller, - Specific space for baggage, - Number of seating positions, - Fixing to secure the cargo				
2 8 7	The doors shall indicate when they open (alert signal). The signal shall...				Loudspeaker	Audio guidance to doors		
	be clearly audible to persons inside the train & outside the train				Loudspeaker			
	be clearly visible to persons inside & outside the train					Screen(s)/Other to indicate line number	Assistance systems for visually and/or hearing impaired	
	last for a minimum of 3 s from the moment that the door starts to open				Loudspeaker			
2 8 8	Doors or the outline of doors operated by passengers shall be detectable by the visually impaired on the outside of the vehicle.				Loudspeaker	Audio guidance to doors	Assistance systems for visually and/or hearing impaired	
2 8 9	Doors shall recognize objects of 1.5 cm diameter over the entire height (white cane or dog leash).							- Infrared camera, - Camera
2 9 0	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.							Camera



D2.1 Passenger and PTO requirements, needs, and use cases



2 9 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.							Camera
2 9 2	Door controls, whether manual, pushbuttons or other devices, shall contrast with the surface on which they are mounted.				Stop request button			
2 9 3	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. It shall be identifiable by touch (for example: tactile markings); this identification shall indicate the functionality.				Stop request button			
2 9 4	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.					• Screen(s)/Other to indicate line number, • Passenger information system (Number of units and placement)		
2 9 5	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					• Screen(s)/Other to indicate line number, • Passenger information system (Number of units and placement)		



D2.1 Passenger and PTO requirements, needs, and use cases



2 9 6	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).					- Screen(s)/Other to indicate line number, - Passenger information system (Number of units and placement)		
2 9 7	Volume of acoustical announcements shall adjust automatically depending on the noise level in the vehicle.				Loudspeaker			
2 9 8	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).				Loudspeaker			
2 9 9	The spoken information shall have a minimum RASTI level of 0,5, in accordance with IEC 60268-16 part 16, in all areas.				Loudspeaker			
3 0 0	Where provided, spoken information shall be consistent with essential visual information that is being displayed.				Loudspeaker	- Screen(s)/Other to indicate line number, - Passenger information system (Number of units and placement)		
3 0 1	Where spoken information is not provided automatically, an audible communication system shall be provided to allow users to get information upon request.				Loudspeaker	- Screen(s)/Other to indicate line number, - Passenger information system (Number of units and placement)		

D2.1 Passenger and PTO requirements, needs, and use cases



302	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				Loudspeaker		Ability to contact remote operator (No safety driver on board)	
303	The vehicle shall clearly indicate its status while waiting or boarding (e.g., hazard lights or blinker)							
304	The vehicle shall inform the PTO about forgotten items and provide any available information about it (e.g. video sequences, data of owner)							• Camera, • 4G, • 5G
305	The vehicle shall have smooth braking behaviour		• Top speed (km/h), • Ground clearance					
306	The system shall detect incidents in the vehicle (unconscious pax, fighting, fire, vandalism, attacks, etc.)				Loudspeaker	• Passenger information system (Number of units and placement), • Heating / Cooling /Air conditioning, • Indoor CO2 sensor	• Seatbelts, Emergency stop button, • SOS mechanism, • Assistance systems for visually and/or hearing impaired, • Ability to contact remote operator (No safety driver on board)	Camera



D2.1 Passenger and PTO requirements, needs, and use cases



307	The system shall inform the PTO about any detected incidents				Loudspeaker	• Passenger information system (Number of units and placement), • Heating / Cooling /Air conditioning, • Indoor CO2 sensor	Ability to contact remote operator (No safety driver on board)	• Camera, • 4G, • 5G
308	The vehicle shall be able to detect if sensors are damaged or dirty (and inform the PTO)							• 4G, • 5G, • Camera, • Infrared camera
309	The vehicle shall be able to go above 70 km/h while still been safe for passengers and its environments		Top speed (km/h)					
310	The vehicle shall be able to accommodate at least # passengers (number of pax to be defined per site)			• Number of seating positions, • Passenger capacity	Passenger counting system			
311	The vehicle shall be able to monitor its own health e.g., tire pressure, (and inform the PTO)							
312	The vehicle shall be able to operate without human intervention under most or all driving conditions		Driving direction or directions		Stop request button	Screen(s)/Other to indicate line number	Assistance systems for visually and/or hearing impaired	LiDARs
313	The vehicle shall have advanced sensor systems, including cameras, lidar, radar, and other relevant sensors, to accurately detect and monitor its surroundings in real-time.							• LiDARs, Radar, Camera, Infrared camera, • 4G, • 5G, • RTK-GNSS, • Protection level of vehicle computer hardware



D2.1 Passenger and PTO requirements, needs, and use cases



								(ease of access)
3 1 4	These sensors should provide comprehensive coverage and be capable of recognizing various objects, such as pedestrians, cyclists, and other vehicles, within the detected environment.							• LiDARs, • Camera, • Infrared camera
3 1 5	The vehicle should employ sophisticated algorithms and artificial intelligence (AI) techniques to process sensor data and plan safe and efficient routes, considering dynamic traffic situations, obstacles, and unforeseen events.							• LiDARs, • Camera, • Infrared camera
3 1 6	The vehicle should make real-time decisions based on the processed data, ensuring it responds appropriately to the ever-changing conditions of the road.							• LiDARs, • Camera, • Infrared camera
3 1 7	The vehicle shall have redundant systems, both hardware and software, to ensure fault tolerance and reliability. Redundancy may include duplicate sensors, redundant computing systems, and backup power supply to prevent critical failures and enable safe operation in the event of component malfunctions.		• Driving direction or directions, • Battery health, • Battery capacity (kWh)		• Stop request button, • Passenger counting system, • Ticket verification system	• Screen(s)/Other to indicate line number • Passenger information system (Number of units and placement)	• Assistance systems for visually and/or hearing impaired, • Ability to contact remote operator (No safety driver on board)	• LiDARs, • Camera, • Infrared camera, • Protection level of vehicle computer hardware (ease of access)

D2.1 Passenger and PTO requirements, needs, and use cases



318	The vehicle shall have robust cybersecurity measures to protect against potential hacking or unauthorized access --> secure communication protocols, encryption techniques, intrusion detection systems, and regular security updates.							Protection level of vehicle computer hardware (ease of access)
319	The vehicle must adhere to applicable regulatory standards and requirements specific to autonomous driving. This may involve obtaining necessary certifications, passing safety assessments, and meeting specific guidelines established by transportation authorities.							
320	The vehicle shall have undergone rigorous testing.		Driving direction or directions		Stop request button	Screen(s)/Other to indicate line number	Assistance systems for visually and/or hearing impaired	• LiDARs, • Protection level of vehicle computer hardware (ease of access)
321	The vehicle shall have robust safety protocols in place, including collision avoidance systems, emergency braking mechanisms, and fail-safe mechanisms to mitigate risks and protect passengers, pedestrians, and other road users in critical situations.				Stop request button			• Protection level of vehicle computer hardware (ease of access), • Camera, • Infrared camera, • LiDARs



D2.1 Passenger and PTO requirements, needs, and use cases



3 2 2	The vehicle shall be able to operate in difficult weather conditions:		Driving direction or directions					• Radar, • LiDARs, • Camera, • RTK-GNSS
	Extreme Temperature, Rain and Wet Conditions, Snow and Ice, Strong Winds, Fog and Reduced Visibility, Off-Road Capability, Salt and Corrosion Resistance		Driving direction or directions					
3 2 3	The vehicle shall be able to operate in difficult traffic situations:							• LiDARs, • Radar, • Camera, • RTK-GNSS
	Heavy Traffic Congestion, Urban Street Gridlock, Highways and Interchanges, Roundabouts and Traffic Circles, Busiest Intersections, Emergency Vehicle Response							
3 2 4	The vehicle shall use standardized HD maps							

Table 30: Vehicle: hardware specifications

Software & other specifications

13.Vehicle		Software specifications			Other specifications
I D	Requirement	Operational design domain, autonomous driving system	Remote capabilities	Connectivity	Legal and regulatory
2 6 2	The vehicle shall be able to detect if number of occupied seats deviates from number of registered passengers in the vehicle ("ghostriders")		• Video feed (Internal /External) • Passengers counter	V2Passenger	Data transfer to back office: video, audio, other



D2.1 Passenger and PTO requirements, needs, and use cases



2 6 3	The vehicle shall be able to interact with elements of infrastructure			• V2X, • V2V, • Integration of roadside sensors	
2 6 4	The vehicle shall be able to interact with the depot it is entering/leaving			• V2X, • Integration of roadside sensors	
2 6 5	The vehicle shall be able to interact with barriers and gates			• V2X, • Integration of roadside sensors	
2 6 6	The vehicle shall be able to interact with traffic lights equipped with V2X	Traffic lights		• V2X, • Integration of roadside sensors	
2 6 7	The vehicle shall be able to interact safely with other road users	Other road users	Video feed (Internal / External)	• V2Passenger, • Integration of roadside sensors	Data transfer to back office: video, audio, other
2 6 8	The vehicle shall provide handles for passengers to hold on to when getting to the seat/door				
2 6 9	The vehicle shall be clean		Video feed (Internal / External)		Data transfer to back office: video, audio, other
2 7 0	The vehicle shall provide clean air throughout the journey		Indoor CO2 level		Data transfer to back office: video, audio, other
2 7 1	The vehicle shall provide a pleasant temperature throughout the journey		Indoor temperature		Data transfer to back office: video, audio, other
2 7 2	The in-vehicle screen shall be designed with a size that allows for easy readability of information		Communication with passengers	V2Passenger	Data transfer to back office: video, audio, other
2 7 3	The seating arrangement in the vehicle shall provide some separation between passengers (e.g., include separators between side-by-side seats)				
2 7 4	The vehicle shall provide emergency equipment like window breaker, fire extinguisher (vehicle shall meet all regional safety standards)				

D2.1 Passenger and PTO requirements, needs, and use cases



2 7 5	The vehicle shall be equipped with onboard cameras, microphones and speakers		• Video feed (Internal / External), • Audio feed		
2 7 6	The vehicle shall be able to detect forgotten items (and inform owner if ownership is known?)		Video feed (Internal / External)	V2Passenger	Data transfer to back office: video, audio, other
2 7 7	The vehicle shall have a wheelchair ramp with the appropriate gradient so that a wheelchair user can board and disembark without assistance.				
2 7 8	The vehicle shall have an identifier (unique, easy to identify, accessible)				Type of license of the safety operator
2 7 9	The vehicle shall be able to interact with the passenger app		Communication with passengers	V2Passenger	
2 8 0	The in-vehicle screen shall provide sufficient contrast				
2 8 1	The vehicle shall get the user to their destination significantly faster than walking		State of autonomous system		
2 8 2	All systems shall be secured against cyber attacks				
2 8 3	The vehicle shall have space for passengers using wheelchairs, mobility aids or strollers etc.				
2 8 4	The vehicle shall have means to secure wheelchairs, mobility aids or strollers etc.				
2 8 5	The vehicle shall provide data like battery status, etc. to other systems		Battery level (Electric vehicle)	V2X	Data transfer to back office: video, audio, other
2 8 6	The passenger shall be able to comfortably transport their shopping				
2 8 7	The doors shall indicate when they open (alert signal). The signal shall...		• Communication with passengers,		

D2.1 Passenger and PTO requirements, needs, and use cases



			• Door opening / closing control		
	• be clearly audible to persons inside the train & outside the train		• Communication with passengers, • Audio feed		
	• be clearly visible to persons inside & outside the train		Communication with passengers		Type of license of the safety operator
	• last for a minimum of 3 s from the moment that the door starts to open		• Communication with passengers, • Door opening / closing control		
288	Doors or the outline of doors operated by passengers shall be detectable by the visually impaired on the outside of the vehicle.		• Communication with passengers, • Audio feed		Type of license of the safety operator
289	Doors shall recognize objects of 1.5 cm diameter over the entire height (white cane or dog leash).		• State of sensors, • Door opening / closing control		
290	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.		• State of sensors, • Door opening / closing control		Data transfer to back office: video, audio, other
291	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.		• State of sensors, • Video feed (Internal / External), • Door opening / closing control		
292	Door controls, whether manual, pushbuttons or other devices, shall contrast with the surface on which they are mounted.				
293	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. It shall be identifiable by touch (for example: tactile markings); this identification shall indicate the functionality.				
294	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.				

D2.1 Passenger and PTO requirements, needs, and use cases



2 9 5	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				
2 9 6	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).				
2 9 7	Volume of acoustical announcements shall adjust automatically depending on the noise level in the vehicle.		Audio feed		
2 9 8	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).		Audio feed		
2 9 9	The spoken information shall have a minimum RASTI level of 0,5, in accordance with IEC 60268-16 part 16, in all areas.		Audio feed		
3 0 0	Where provided, spoken information shall be consistent with essential visual information that is being displayed.				
3 0 1	Where spoken information is not provided automatically, an audible communication system shall be provided to allow users to get information upon request.				
3 0 2	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				
3 0 3	The vehicle shall clearly indicate its status while waiting or boarding (e.g., hazard lights or blinker)				
3 0 4	The vehicle shall inform the PTO about forgotten items and provide any available information about it (e.g. video sequences, data of owner)		Video feed (Internal / External)	• V2Passenger, • V2X	Data transfer to back office: video, audio, other
3 0 5	The vehicle shall have smooth braking behaviour				
3 0 6	The system shall detect incidents in the vehicle (unconscious pax, fighting, fire, vandalism, attacks, etc.)		• Passengers counter, • Video feed (Internal / External),	V2X	Data transfer to back office: video, audio, other



D2.1 Passenger and PTO requirements, needs, and use cases



			• Audio feed, Indoor temperature, • Indoor co2 level		
307	The system shall inform the PTO about any detected incidents		• Passengers counter, • Video feed (Internal / External), • Audio feed, Indoor temperature, • Indoor co2 level, • Communication with passengers	V2X	Data transfer to back office: video, audio, other
308	The vehicle shall be able to detect if sensors are damaged or dirty (and inform the PTO)		• State of sensors, • State of autonomous system		Data transfer to back office: video, audio, other
309	The vehicle shall be able to go above 70 km/h while still been safe for passangers and its environments				Speed authorisation (km/h)
310	The vehicle shall be able to accommodate at least # passengers (number of pax to be defined per site)		Passengers counter		
311	The vehicle shall be able to monitor its own health e.g., tire pressure, (and inform the PTO)		• State of autonomous system, • State of sensors, • Tire pressure, • Battery level (Electric vehicle), • Fuel level (Petrol/Diesel/etc.), • Indoor temperature, • Indoor co2 level	V2X	Data transfer to back office: video, audio, other
312	The vehicle shall be able to operate without human intervention under most or all driving conditions		• State of autonomous system, • Remote navigation control		
313	The vehicle shall have advanced sensor systems, including cameras, lidar, radar, and other relevant sensors, to accurately detect and monitor its surroundings in real-time.		• State of autonomous system, • State of sensors	V2X	Data transfer to back office: video, audio, other



D2.1 Passenger and PTO requirements, needs, and use cases



3 1 4	These sensors should provide comprehensive coverage and be capable of recognizing various objects, such as pedestrians, cyclists, and other vehicles, within the detected environment.		State of autonomous system, State of sensors	V2X	Data transfer to back office: video, audio, other
3 1 5	The vehicle should employ sophisticated algorithms and artificial intelligence (AI) techniques to process sensor data and plan safe and efficient routes, considering dynamic traffic situations, obstacles, and unforeseen events.	• Traffic lights, • Roundabouts, • Pedestrian crossings, • Speed signs, Pedestrians, • Low visibility conditions (Rain, snow, fog, dust, night etc.), • Other road users, • Road blocking obstacles, • Road conditions (Icy road, holes), • Tunnels, • Highway	State of autonomous system	V2X	Data transfer to back office: video, audio, other
3 1 6	The vehicle should make real-time decisions based on the processed data, ensuring it responds appropriately to the ever-changing conditions of the road.	• Pedestrians, • Road conditions (Icy road, holes), • Other road users, • Road blocking obstacles, • Pedestrian crossings, • Low visibility conditions (Rain, snow, fog, dust, night etc.)	• Video feed (Internal / External), • Audio feed, • State of autonomous system	V2X	Data transfer to back office: video, audio, other
3 1 7	The vehicle shall have redundant systems, both hardware and software, to ensure fault tolerance and reliability. Redundancy may include duplicate sensors, redundant computing systems, and backup power supply to prevent critical failures and enable safe operation in the event of component malfunctions.		• State of autonomous system, • State of sensors	V2X	Data transfer to back office: video, audio, other
3 1 8	The vehicle shall have robust cybersecurity measures to protect against potential hacking or unauthorized access --> secure communication protocols, encryption techniques, intrusion detection systems, and regular security updates.		State of autonomous system	V2X	Data transfer to back office: video, audio, other

D2.1 Passenger and PTO requirements, needs, and use cases



3 1 9	The vehicle must adhere to applicable regulatory standards and requirements specific to autonomous driving. This may involve obtaining necessary certifications, passing safety assessments, and meeting specific guidelines established by transportation authorities.		State of autonomous system		- Speed authorisation (km/h), - Type of license of the safety operator
3 2 0	The vehicle shall have undergone rigorous testing.	Pedestrians	State of autonomous system		Data transfer to back office: video, audio, other
3 2 1	The vehicle shall have robust safety protocols in place, including collision avoidance systems, emergency braking mechanisms, and fail-safe mechanisms to mitigate risks and protect passengers, pedestrians, and other road users in critical situations.	- Other road users, - Pedestrians, - Pedestrian crossings	- State of autonomous system, - State of sensors	V2X	Data transfer to back office: video, audio, other
3 2 2	The vehicle shall be able to operate in difficult weather conditions:	Low visibility conditions (Rain, snow, fog, dust, night etc.)	State of autonomous system	V2X	
	Extreme Temperature, Rain and Wet Conditions, Snow and Ice, Strong Winds, Fog and Reduced Visibility, Off-Road Capability, Salt and Corrosion Resistance	Low visibility conditions (Rain, snow, fog, dust, night etc.)	State of autonomous system		
3 2 3	The vehicle shall be able to operate in difficult traffic situations:	- Road blocking obstacles, - Low visibility conditions (Rain, snow, fog, dust, night etc.)	- State of autonomous system, - State of sensors	V2X	Data transfer to back office: video, audio, other
	Heavy Traffic Congestion, Urban Street Gridlock, Highways and Interchanges, Roundabouts and Traffic Circles, Busiest Intersections, Emergency Vehicle Response	- Other road users, - Low visibility conditions (Rain, snow, fog, dust, night etc.)	State of autonomous system		
3 2 4	The vehicle shall use standardized HD maps		State of autonomous system		

Table 31: Vehicle, software and other specifications

References

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