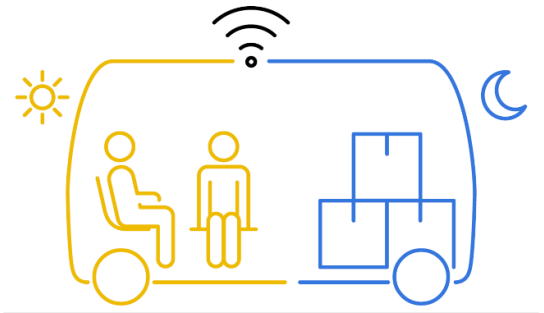

ULTIMO

DELIVERABLE

D2.2 Passenger and PTO Requirements, Needs, and Use Cases – Final Version

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Acronyms

AV	Automated Vehicle
ADS	Automated Driving Systems
AI	Artificial Intelligence
AM	Automated Mobility
API	Application Protocol Interface
AV	Automated Vehicle
BM	Bestmile
BMM	Business Modelling Manager
CAV	Connected and Automated Vehicles
CB	Consortium Body
CERN	European Organization for Nuclear Research
D7.1	Deliverable 7.1
DC	Demonstration Coordinator
DI	The department of infrastructure (Swiss Canton of Geneva)
DMP	Data Management Plan
DRT	Demand Responsive Transport

DSES	Department of Security and Economy - Traffic Police (Swiss Canton of Geneva)
DTU test track	Technical University of Denmark test track
EAB	External Advisory Board
EC	European Commission
ECSEL	Electronic Components and Systems for European Leadership
EM	Exploitation Manager
EU	European Union
EUCAD	European Conference on Connected and Automated Driving
F2F	Face to face meeting
FEDRO	(Swiss) Federal Roads Office
FM	Fleet Management
FOT	(Swiss) Federal Office of Transport
GDPR	General Data Protection Regulation
GIMS	Geneva International Motor Show
GNSS	Global Navigation Satellite System
HARA	Hazard Analysis and Risk Assessment
IPR	Intellectual Property Rights
IT	Information Technology
ITU	International Telecommunications Union
LA	Leading Author
LIDAR	Light Detection And Ranging
MEM	Monitoring and Evaluation Manager
MT	MobileThinking
nPTS	Non-Public Transportation Services
OCT	General Transport Directorate of the Canton of Geneva
ODD	Operational Design Domain
OEDR	Object And Event Detection And Response
OFCOM	(Swiss) Federal Office of Communications
PC	Project Coordinator

PEB	Project Executive Board
PGA	Project General Assembly
PRM	Persons with Reduced Mobility
PSA	Group PSA (PSA Peugeot Citroën)
PTA	Public Transport Authority
PTO	Public Transportation Operator
PTS	Public Transportation Services
PUDO	Pickup and drop off (point)
QRM	Quality and Risk Manager
QRMB	Quality and Risk Management Board
RN	Risk Number
SA	Scientific Advisor
SAE Level	Society of Automotive Engineers Level (Vehicle Autonomy Level)
SAN	(Swiss) Cantonal Vehicle Service
SDK	Software Development Kit
SLA	Sales Lentz Autocars
SMB	Site Management Board
SoA	State of the Art
SOTIF	Safety Of The Intended Functionality
SWOT	Strengths, Weaknesses, Opportunities, and Threats.
T7.1	Task 7.1
TM	Technical Manager
TPG	Transport Publics Genevois
UITP	Union Internationale des Transports Publics (International Transport Union)
V2I	Vehicle to Infrastructure communication
WP	Work Package
WPL	Work Package Leader

Executive Summary

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 with a user-centric approach regarding the use of automated vehicles.

Deliverable 2.2 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 2.2 aims to be a bridge connecting the needs of real users, both passengers and operators, with target ODDs and the capabilities of different vehicles to specific use cases to be deployed.

To achieve this objective, deliverable 2.2 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.
- **Use Cases:** We outline the entire user journey, from the process of informing oneself to post-trip feedback. Through multiple use cases, we 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.
- **Matching Use Cases to Vehicle Capabilities**: The vehicle requirements are matched to the use cases, and to always keep the focus on the optimal user experience.

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.

1.1 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.

1.1.1 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.

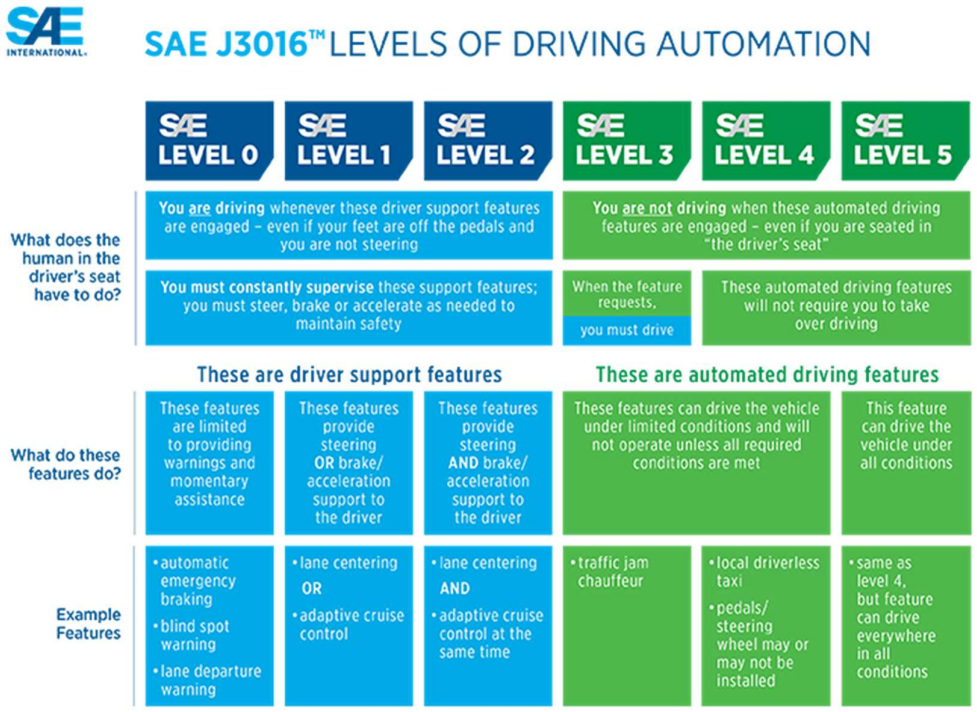

Table 1: SAE Driving Automation levels (©2020 SAE International)

1.2 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-buses 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 replaced the last 70 old, driver based, thermic buses that reached the end of their life after 18 years in operation. The change from driver large buses 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 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.

1.3 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 Connected and Automated Mobility (CCAM) 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 for those with a high dependence on private vehicle use.
- Provide solutions via Human-Machine Interfaces (HMI) that enable interaction with value-added services and AVs. This includes elements such as 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 2.2 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 through use cases.

We introduce personas that represent different user profiles or target groups 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, the use cases helped us to establish technical needs, service needs, vehicle capability needs, and policy needs.

This deliverable considers the PTOs/PTA feedback and the unique characteristics and constrains of their pilot sites to assess feasibility, limitations, and contextual factors.

2 ULTIMO Use Cases

2.1 From Requirements to Use Cases

In 2023, more than 300 requirements have been collected and categorized according to the steps of our user journey. These requirements describe user expectations as well as system and vehicle functionalities. They were analysed for feasibility and completeness and prioritized by different partners.

This collection of requirements provides a good foundation for understanding the diverse stakeholder needs and expectations and also served as input for WP4, where they worked as an indicator to measure the level of compliance expected under a user-centric approach. Not only from the user's point of view (MaaS, DRT, or Vehicle/OBU), but also from the operator's point of view. This gave us a way to measure progress, as well as input on what to tackle in the next iterations such as unavailable or partially answered requirements.

In the further course of the project, we changed from working with single requirements to developing use cases to express requirements and expectations in a more narrative and contextualized form. These use cases describe how specific personas use the ULTIMO service in more realistic environments. They contain the goals of the personas, their special needs, their actions as well as the reactions of the service/system.

When creating the use cases, we followed an iterative and collaborative approach. We begin the process by drafting an initial set of use cases based on requirements and the characteristics of the pilot sites. Once these drafts were completed, they were reviewed by project partners, such as operators who provide feedback, prioritize based on relevance, and identify missing use cases. This step served as a key stage that ensured that the use cases reflected as realistically as possible conditions of each site, as well as the needs of users in different contexts.

2.2 Service Blueprint workshop

Based on the results obtained in the first iterations of 2023, we developed a **Service Blueprint Canvas** that visualizes the ULTIMO user journey and in addition some optional incidents. The canvas was structured like this:

- Horizontal axis: User journey steps, including a selection of incidents
- Vertical axis: Involved stakeholders (User, Customer Service, PTO, Fleet Orchestrator, etc.)

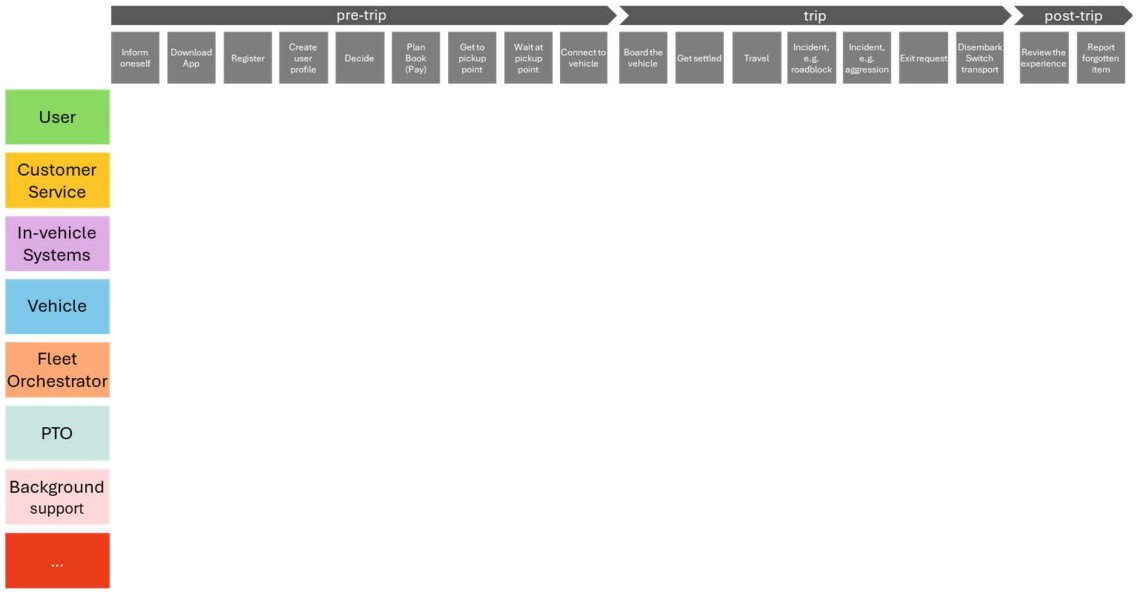

Figure 1*. Example of the Service Blueprint Canvas developed*

To help participants fill out the canvas, they were asked to start with an empathy exercise using Mary as a reference (see Annex A). This allowed participants to propose elements close to the target group's reality represented by Mary, as well as to propose new ideas based on the identified needs.

The methodology implemented is based on a workshop with the different multidisciplinary stakeholders who are part of the project consortium. All participants were divided into 13 working groups, each of which was assigned a poster with three stages of the user journey to be analysed in detail under the two aforementioned axes. The aim of this activity was to build

a shared and comprehensive understanding — across all project partners — of what happens throughout the entire user journey. Specifically, we wanted to:

- Deepen our understanding of the needs, challenges, and perspectives of each stakeholder involved.
- Encourage meaningful exchange across partners and viewpoints.
- Uncover potential blocking points in the journey and identify opportunities for improvement or innovation.
- Make visible the interconnected systems, tools, and processes that support the service.
- Create awareness for the special needs of our blind persona, Mary.

The task given to each group was the same: to do an empathy exercise that would allow them to put themselves in Mary's shoes and respond to her reaction to each stage of the journey. Below is a non-exhaustive list that participants were invited to reflect on in order to respond to the exercise:

- Describe Mary's actions and her expectations or fears at this specific journey step.
- Identify the components of the service, such as personnel, equipment, systems, technologies, etc., that are actively involved at each stage.
- Illustrate, for each of the stakeholders in the vertical axis, the potential tools that can be used, the actions or behaviors expected in the different stages that will be analyzed in Mary's journey.
- Point out the elements that could go wrong or should be avoided in each stage.

Figure 2. *Snapshot of the Service Blueprint workshop*

2.2.1 Workshop outcomes

During the workshop, there were lively discussions within each group – a sign that the format fostered exchange and collaboration. After the group work, all posters were hung on a wall, creating a mural with the entire user journey. Participants were invited to walk around and look at all the posters, much like at a vernissage but with the explicit invitation to comment, add, etc. to the posters.

Figure 3. *Example of group posters created during the workshop*

The outcome is a comprehensive Service Blueprint that covers the complete user journey from getting initial information to post-ride feedback and shows how the different stakeholders align and interact to deliver the service for our persona. This blueprint is available in Annex F.

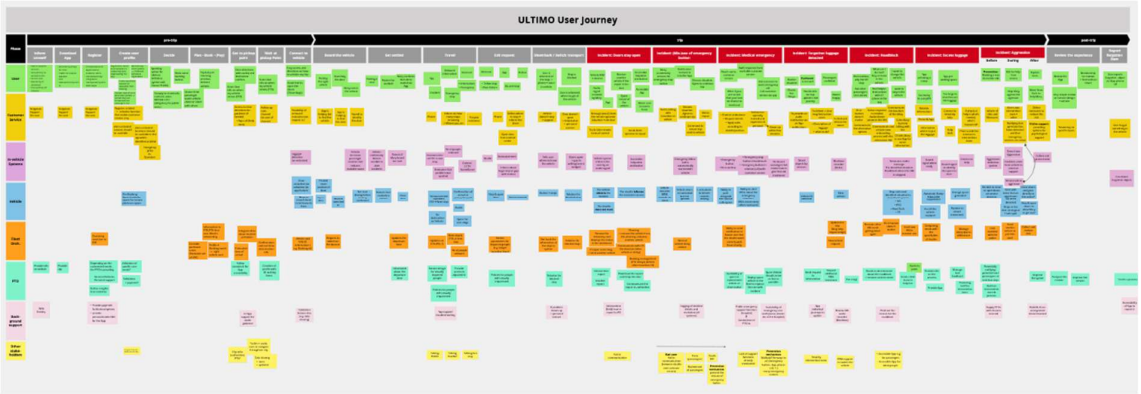

Figure 4: Thumbnail of the complete Service Blueprint

2.3 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 AVENUE[1] where they were developed from interviews with public transport passengers, users of automated public transport, safety operators in pilot sites, bus drivers, etc. Moreover, these personas have evolved to align with the user-centric approach of ULTIMO and the PTOs and OEM feedback. Based on the results obtained, three segments of personas could be identified regarding age: young (under 30), middle-aged (30-42) and older (58 to 82). Each group is represented by 6 personas. It was possible to observe a gap between 42 and 58 years. This may reflect the age distribution of participants who responded to the call for interviews and those we met on site. Other possible explanations for this gap may be the fact that special needs occur more frequently among young people and older adults. Remembering that disabilities and impairments often come with age, this explains why they are more prevalent in the over-60 age group. The complete list of personas created is available in the Annex A.

2.4 Use Cases

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 groups) and the system/product/service 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. For the ULTIMO project, use cases serve as a bridge between identified needs and the capabilities of autonomous vehicles.

Use cases defined in this section describe a user using an on-demand responsive transport service with autonomous vehicles and help to define specific needs/requirements to achieve a desired outcome. They provide a detailed depiction of how users will engage with the system, outlining the steps involved and the expected results. The present use cases are taken from all partners experiences accumulated throughout this project and focus on the user interaction with the service and AV. These use cases have then been used to establish a list of needs for the technologies, the service, the vehicle capabilities and the policies. Each use case contains actions taken either by the user or by the vehicle that lead to specific needs described in the next section (Needs).

These use cases follow a flow of 9 parts as describe in the list below and based on the PTOs experience with DRT service. These stages, also described as User Journey, contain information about how a person interacts with the service and it helps us to better understand the touchpoints that need to be considered during the creation of the ULTIMO services. Among the elements that can benefit from this categorization are service design, user experience design, or even interface design.

1. **Inform**: all actions taken to share information related to the service.
2. **Book**: all actions taken to book a trip.
3. **Get to pick-up point**: all actions taken for a user to get to pick-up point.
4. **Wait**: all actions occurring during the waiting phase.
5. **Connect**: all actions taken for a user to connect with the AV.
6. **Board**: all actions taken for a user to board the AV.
7. **Travel**: all actions taken while traveling on board the AV.

8. **Disembark**: all actions taken for a user to disembark from the AV.
9. **Review**: all actions taken to review the service/trip.

Below, the list of use cases is given and the first use case is described. The use cases were made to cover the main possible events/interactions that could happen between a user and a DRT service with AVs according to PTOs experiences. Each use case is valid[1] for all pilot sites depending on the AV technology they use. All use cases are available and fully described in the annex B.

2.4.1 List of use cases

The following list gives all use cases with a short description.

1. UC-01: A normal trip of a person
2. UC-02: Service abuse by a passenger
3. UC-03: Health incident during transport
4. UC-04: On-board aggression
5. UC-05: Vehicle doors stay opened
6. UC-06: Missing bus stop
7. UC-07: No show
8. UC-08: Excess luggage
9. UC-09: Forgotten luggage
10. UC-10: Public transport at night
11. UC-11: Blind user
12. UC-12: Using on-demand services without the app
13. UC-13: User in a wheelchair
14. UC-14: Passenger unbuckles his seatbelt while vehicle is in motion
15. UC-15: Vehicle breaks down
16. UC-16: Vehicle meets a roadblock
17. UC-17: Yield to an emergency vehicle
18. UC-18: Vehicle stopped by the police

[1] The final implementation of the use case will depend on the conditions at each site (e.g., availability of vehicles or services capable of responding to the use case in question).

19. UC-19: Object under the vehicle
20. UC-20: Vehicle loses internet connection
21. UC-21: Deaf user
22. UC-22: No vehicle available
23. UC-23: Use and misuse of emergency stop button
24. UC-24: Extra passengers

2.4.2 UC-01: A normal trip of a person

This is the first use case describing a basic or normal trip of a person: no issues or incident and the user flawlessly reaches his destination.

Actor(s)

Markus, 55 years old.

User background

Markus has been driving for decades and loves the freedom and convenience his car provides. However, his daughter and new girlfriend have been nudging him to adopt a more sustainable lifestyle, suggesting he use public transport more often.

Goal

Markus would like to go to see some friends who live in the countryside.

Preconditions

Markus doesn't know about ULTIMO service.

Flow:

1. Markus looks for a transfer service as it is the first time he visits his friends' house, and he knows it is not close to any public transport station/stop and he does not want to walk far. He finds the ULTIMO app and downloads it to his mobile. The ULTIMO app informs Markus that it proposes an on-demand automated public transport available day and night. Markus creates his profile entering his information (first name, last name, phone number and email).

2. Once Markus has created his profile, he starts the booking process and sets information about his departure and arrival point. The app shows Markus all available points and he selects the one he wants. Markus indicates the number of passengers. He can also set the number of passengers in a wheelchair. Then he chooses the desired time of departure or arrival. The app shows him the immediate availabilities or allows him to book for a later day. Markus picks a trip and, after confirming his booking, the app informs him about the expected pick-up time and arrival time.
3. The app is informing Markus when and where he needs to go to be picked up. When he leaves home, the app is guiding him there through a map and a voice guidance and informs him when he has reached the PUDO. The PUDO are all clearly indicated through the DRT app.
4. While waiting at the PUDO, Markus receives information on the remaining time until the shuttle arrives, and – if any – on delays.
5. When the shuttle is approaching the PUDO, Markus receives an alert from the app. The app also informs Markus of the vehicle name for him to easily identify the vehicle. The name of the vehicle is displayed on a screen outside the vehicle.
6. When the vehicle has reached the PUDO it stops and opens the doors for Markus to board. The doors can also be opened with a button. Markus enters the vehicle, validate his trip with a code or QR code or his ULTIMO app and looks for a seat. Once Markus is inside the vehicle, the doors close. And once he is seated with his seat belt fastened, the vehicle departs. The in-vehicle display and sound information systems announce the vehicle departure.
7. During Markus' trip, the vehicle may make stops to pick up and disembark other passengers. The in-vehicle display and sound information systems provide details on the upcoming stops as well as information to connections to other lines (bus, trams, trains, airports, ...). The app is dynamically displaying the same info, along with the remaining number of stops to his destination.
8. When arriving at the destination, Markus receives a notification through the app that the next stop is his and the vehicle stops at the defined drop off point. When the vehicle stops, Markus goes to the door, the door opens, and he disembarks. As soon as he is safely out the vehicle, the doors close and the vehicle departs for its next mission. The app is then guiding him on foot until he reaches his friends' house.
9. Finally, Markus decides to review his trip using the app review feature.

2.5 Needs

All use cases given in the previous chapter, allow any reader - an OEM, a PTO, etc. - to anticipate what could be the needs of the users. Here, a numbering system is used to link all

these needs to the corresponding parts in any use cases. Below, an explanation on the numbering system and the list of needs associated to each use case are given.

2.5.1 Structure of the numbering system

To ensure consistency, traceability, and scalability throughout the project, a hierarchical numbering structure is used for identifying **Elementary Usage Blocks (EUBs)** and their associated needs. This structure provides a systematic way to reference and organize components across use cases and scenarios. Based to a small number of EUBs, all use cases and usage scenarios can be composed. Any new EUB (special case) does not modify the rest of the scenario, simply adds a special case to be handled at a specific moment of the scenario.

2.5.1.1 Structure of the numbering system

A structured numbering system is defined. That allows to simply identify each need (technical, service etc) and link it to the scenario and circumstances around the need, thus making clearer for the implementing partner to identify how the need can be best implemented and what are the consequences of any specific options taken.

2.5.1.1.1 Elementary Usage Blocks (EUBs)

Each **EUB** is assigned a unique identifier based on the use case (UC) it belongs to and its sequential number within that use case.

Format: EUB-<Use Case Number>-<Block Number>

> **Use Case Number**: The unique number of the use case where the EUB was first introduced.
> **Block Number**: The sequential number of the EUB within the specified use case.

Example:

> EUB-01-05: The 5th elementary usage block first defined in **UC-01 (Normal Trip)**.
> EUB-03-02: The 2nd elementary usage block defined in **UC-03 (Health incident during transport)**.

In the general case the EUB will be associated with a specific Use Case and service. However, there is a set of non-service EUBs, that are not associated with a passenger use case. Thus, a Vehicle Service Use Case is defined, numbered 90, which includes all the usage scenarios of vehicle service. These EUBs can be engaged at any point in the vehicle operation. Some examples of these EUBs are the following:

- **EUB 90-01: Idle Vehicle -** There are no trip reservations, so the vehicle moves to a parking spot where it will wait for a new reservation.
- **EUB 91-02: Change of usage LaaS/MaaS** - The vehicle is reassigned for LaaS or vice-versa
- **EUB 92-03: Low battery** - The vehicle has a low battery level, so it is directed to a charging stop (and removed from the fleet).
- **EUB 93-04: Maintenance** - Due to a non-disabling incident (vandalism in the vehicle, littering etc) the vehicle is directed to the maintenance location and removed temporarily form the fleet.
- **EUB 94-05: Malfunction** - Due to major incident the vehicle can no longer operate on the street (accident, malfunction, sever damage, etc.). It is removed from the fleet and a team is sent to move it for repair.

2.5.1.1.2 Needs Associated with EUBs

Each need—whether **Technology (T)**, **Service (S)**, **Vehicle Capability (V)**, or **Policy (P)**—is assigned a unique identifier tied to the EUB and UC it originates from.

Format: <Need Type>-<Use Case Number>-<Block Number>-<Need Number>

Need Type:

- T: Technology Need
- S: Service Need
- V: Vehicle Capability Need
- P: Policy Need

Use Case Number: Matches the use case where the EUB is defined.

Block Number: Matches the block number of the EUB.

Need Number: The sequential number of the need within that EUB.

Example:

> T-01-05-01: The first technology need associated with **EUB-01-05 (Boarding the Vehicle).**
> P-03-02-02: The second policy need associated with **EUB-03-02 (Remote Supervisor Assesses the Severity of the Situation).**

2.5.1.1.3 Reuse of EUBs and Needs

EUBs and their needs retain their original numbering across all scenarios and use cases where they are referenced. This ensures consistency and traceability.

Example of Reuse:

> EUB-01-05 (Boarding the Vehicle) defined in **UC-01** is reused in **UC-03** without renumbering. Its needs, such as T-01-05-01 (External vehicle identification display), remain the same.

2.5.1.1.4 Benefits of the Numbering Structure

This structured numbering system provides a clear and organized framework for managing the complex relationships between use cases, scenarios, and their requirements. It ensures efficient communication and coordination across development and implementation teams.

- **Traceability**: All EUBs and needs can be traced back to their originating use case and block.
- **Consistency**: The numbering remains consistent even when EUBs are reused in different scenarios.
- **Scalability**: New EUBs and needs can be added without disrupting the existing structure.
- **Modularity**: EUBs are designed as reusable building blocks that can be combined to create complex scenarios.

2.5.2 Needs associated

The preceding parts describe the use cases and the numbering system. These use cases are divided in elementary usage blocks which are associated to needs (Technology (T), Service (S), Vehicle Capability (V), or Policy (P)) identified and listed here.

2.5.2.1 UC-01: A normal trip of a person

Associated EUB	Description & Identified needs
EUB-01-01: Mobile App Download and Configuration	Markus finds the ULTIMO app on the app store, downloads, and installs it. **T-01-01-01**: Support for Android/iOS platforms. **P-01-01-01**: Policy defining supported OS versions.
	He creates his profile and enters preferences (e.g., walking distance, special needs). **T-01-01-02**: Secure profile storage (on-device or in PTO database). **S-01-01-01**: Option to specify permanent special needs in the profile. **P-01-01-02**: GDPR compliance for data storage and handling.
	The app confirms the profile setup and readiness for trip booking. **S-01-01-02**: Confirmation message for successful setup.
EUB-01-02: Reserving a Trip	Markus opens the app, activates geolocation, and selects a nearby PUDO as his starting point. **T-01-02-01**: Integration of city maps with PUDO locations. **S-01-02-01**: Accurate identification of PUDOs within proximity.
	He sets the destination either by name or by pinning it on the map. **T-01-02-02**: Search capabilities for locations by name or map.
	The app calculates and offers trip options (e.g., departure times, travel duration). **T-01-02-03**: Provide the different options, with related time delays and possible cost differentiation. **P-01-02-01**: Policy defining maximum response time (e.g., 5 seconds).
	Markus selects a trip, confirms, and receives vehicle identification details and ETA.

	T-01-02-04: Delivery of trip confirmation, vehicle identification and ETA. **P-01-02-02**: Policy defining acceptable delays in trip confirmation.
EUB-01-03: Guidance to PUDO	The app provides navigation to the selected PUDO using map and voice guidance. **T-01-03-01**: Real-time navigation with location tracking. **S-01-03-01**: Notifications to guide the passenger to the PUDO.
	Markus follows the guidance and receives confirmation upon reaching the PUDO. **S-01-03-02**: Confirmation of arrival at PUDO.
EUB-01-04: Waiting for the Ride	Markus waits at the PUDO, monitoring the app for the vehicle's ETA and identification details. **T-01-04-01**: Real-time updates on ETA and vehicle identification. **S-01-04-01**: Reliable notifications for any delays.
EUB-01-05: Connecting to the vehicle	The vehicle arrives, and displays in the external panel the unique identification, which is also presented in Markus's app. This way Markus knows that the arriving vehicle is the one he should board. **T-01-05-01**: External vehicle identification display. **T-01-05-02**: Real-time updates of the vehicle ID in the app. **V-01-05-01**: External display synchronised with the app information.
EUB-01-06: Boarding the Vehicle	The door opens. **P-01-06-01**: Policy defining if the door opens automatically or requires a button press.
	The door opens automatically when the vehicle arrives at the PUDO. **T-01-06-01-A**: Automated door opening system triggered upon arrival at the PUDO. **P-01-06-01-A**: Policy defining under what conditions the door opens automatically (e.g., detection of a confirmed passenger in proximity).
	Markus presses an external button located on the vehicle to open the door. **T-01-06-01-B**: External button mechanism for manual door operation. **V-01-06-01-B**: Button placement ensuring accessibility and usability for all passengers. **P-01-06-01-B**: Policy defining how long the door remains unlocked for boarding after the button press.
	Markus enters and takes a seat. **T-01-06-02**: Identification if the passenger has been seated.

	P-01-06-02: Policy defining if seating is mandatory before departure.
	The door closes, and the vehicle departs (once Markus is seated – If mandatory). **T-01-06-03**: Automated door closing mechanism. **V-01-06-02**: Optional: Passenger detection system to confirm boarding. **P-01-06-03**: Optional: Time duration that the door stays open.
EUB-01-07: Travel to Destination	The vehicle drives towards the destination, making stops for other passengers if necessary. **T-01-07-01**: Fleet orchestrator to dynamically adjust routes.
	In-vehicle displays and audio announcements provide updates on upcoming stops. **T-01-07-02**: In-vehicle display system synchronized with app updates (touch screen enable). **P-01-07-01**: Policy defining required information for stop announcements.
	Markus monitors the app for real-time trip updates and remaining stops. **T-01-07-03**: App updates with route, stops and ETA.
EUB-01-08: Disembarking	When nearing the destination, Markus receives alerts from both the app and in-vehicle systems. **T-01-08-01**: Vehicle notification system for approaching stops (display/audio). **S-01-08-01**: Reliable alerts for passenger readiness.
	The vehicle stops at the destination PUDO, and the door opens **P-01-08-01**: Policy defining acceptable door opening and closing times.
	The door opens automatically once the vehicle is stationary at the PUDO. **T-01-08-02-A**: Automated door opening system triggered upon arrival at the PUDO. **P-01-08-02-A**: Policy defining conditions for automatic door opening.
	Markus presses an internal button located near the door to open it. **T-01-08-02-B**: Internal button mechanism for manual door operation. **V-01-08-01-B**: Accessible button design to ensure ease of use for all passengers. **P-01-08-02-B**: Policy defining how long the door remains unlocked after the button press.
	Markus exits, and the door closes before the vehicle resumes its trip.

	T-01-08-03: Passenger detection system to confirm disembarking.
EUB-01-09: Post-Trip Feedback and Guidance	The app confirms the trip's completion and requests feedback. **T-01-09-01**: Trip completion information and Feedback submission interface (if required). **S-01-09-01**: Clear and simple feedback mechanism.
	If needed, the app guides Markus to his destination on foot. **T-01-09-02**: Navigation support for walking to the destination.

3 Definition of vehicle capabilities and ODD

A list of vehicle capabilities was created in T2.2 [*Definition of vehicle capabilities and ODD*] by former ULTIMO partner Sensible4 with input from all other partners. The complete list of categories considered in the analysis is available in Annex C.

Based on the different inputs provided by the partners, taking into account the aforementioned categorization, it was possible to determine some key elements to ensure good performance by the automated driving system are:

- Real-time Communication
- GPS and Mapping,
- Sensor Suite,
- Safety Systems,
- V2X Communication,
- On-board 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. More information regarding the details of each ODD per ULTIMO site is available in D5.2 - Large Scale Demonstration - Second Version.

3.1 Fundamental principles

3.1.1 ISO 34503 - Specification for Operational Design Domain (ODD)

Description of the standard

ISO 34503:2023[2] specifies a taxonomy and a standardized format for defining the Operational Design Domain (ODD) of Automated Driving Systems (ADS), primarily targeting Level 3 and Level 4 automation. The ODD describes the specific environmental, road, and operational conditions within which an ADS is designed to function safely.

Key elements of the standard include:

- ODD attribute taxonomy: ISO 34503 sets out a hierarchical structure, classifying ODD attributes into three top-level groups:
    - Scenery elements: Fixed features of the environment, such as roads, junctions, signage, and road geometry.
    - Environmental conditions: Weather, illumination, particulates, and connectivity affecting safe operation.
    - Dynamic elements: Moving components of the environment, including traffic agents and the subject vehicle itself.
- ODD definition format: The standard outlines methods to express the ODD in a clear, objective, and human-readable manner, supporting stakeholder communication and

[2] https://www.iso.org/standard/78952.html

scenario-based testing. It introduces “permissive,” “restrictive,” and “default” modes to define inclusion/exclusion of attributes, enabling flexibility for technical and non-technical users.

- Application context: ISO 34503 is intended for vehicle manufacturers, ADS developers, authorities, operators, and others involved in creating safety cases and deployment strategies for automated vehicles. The structured ODD definition supports conformity with legal requirements, procurement processes, and validation activities.

ODD vs. TOD: Clarifying the distinction

- Operational Design Domain (ODD):

  The ODD is a specification of conditions (e.g., road types, weather, traffic situations) under which a particular ADS is designed and validated to operate safely. The ODD is a product-focused definition prepared by ADS manufacturers and developers.

- Target Operational Domain (TOD):

  The TOD refers to the actual, expected real-world environment and operating conditions where an ADS will be deployed. It is often shaped by user needs, regulatory requirements, and operational contexts and may encompass a broader set of scenarios than the ODD.

Key Differences:

Aspect	ODD	TOD
Focus	Limits/capabilities of a specific ADS	Real-world domain where ADS is expected to work
Defined by	Manufacturer or developer	End-user, authority, or regulating body
Scope	Typically narrower than TOD, based on safe operation	May include conditions outside a given ADS’s ODD

Role in deployment	Used in safety cases, documentation, certification	Used to define operational needs and requirements

Table 2: Distinction between ODDs and TODs

The ODD is the declared and tested capability of an ADS, while the TOD is the targeted use environment. Mismatches may require risk mitigations, adaptation, or fallback strategies (e.g., an ADS exiting its ODD during unexpected events must stay safe within the broader TOD).

Summary

ISO 34503:2023 enables a harmonized, granular, and practical method to define, communicate, and evaluate the operating scope of automated driving systems. The distinction between ODD and TOD is crucial for transparent deployment, regulatory alignment, and safe operation of ADS-equipped vehicles.

In the context of authorization requests for AV pilot projects, e.g. in Switzerland (Geneva), in Germany (Herford) and in Norway (Oslo), it is required to provide a detailed description of both the ODD and the TOD to road offices. Authorities require these definitions to determine whether the AV can safely handle all conditions and scenarios present within the designated driving area. A clear alignment and comparison between the ODD (system capability) and the TOD (deployment context) are mandatory components of the authorization process for pilot testing. This requirement ensures regulators can verify that the vehicle is equipped to manage every situation it may encounter on the defined test routes, supporting both public safety and robust operational validation in these territories

3.1.2 Vehicle specifications

To obtain circulation rights for an automated vehicle in Europe, there are currently two main approaches:

- European vehicle type approval
    - Description: The European vehicle type approval is a harmonized process established under regulation (EU) 2022/1426. It enables the commercial

deployment of automated vehicles by ensuring compliance with EU-wide safety, environmental, and technical standards. Vehicles must undergo standardized testing and certification procedures, with particular focus on functional safety, cybersecurity and other sector-specific requirements (e.g. UN R155, UN R156, UN R171). Successful type approval grants authorization for series production and unrestricted circulation within all EU member states.

- Authorization for pilot projects
    - Description: For vehicles not yet seeking full market approval or intended for limited-scale, experimental operation, a national authority may grant special authorization for pilot projects. These permits allow temporary circulation under defined conditions and supervision. The scope and specific requirements for such authorizations differ by country and are tailored to mitigate risks associated with technical innovation. Applications must typically provide a comprehensive dossier detailing the vehicle's technical specifications, ODD, safety measures, and risk mitigation strategies.
    - Examples of fact sheets and guidelines:
        - *Switzerland (FEDRO):* Applications must describe the automated vehicle's characteristics in detail, covering hardware and software architecture, system functionalities, safety concept, cybersecurity measures, remote operation capability (if applicable), and operational monitoring. Authorities assess the robustness of these features against relevant national and international standards before granting permission for pilot operations.
        - *Germany (KBA):* Applicants are required to submit an extensive technical description, including system architecture, software/hardware components, sensor setup, functional safety protocols, and data protection strategies. A detailed risk analysis must demonstrate compliance with the German regulatory framework for experimenting with automated and autonomous vehicles.

- *Norway (Statens Vegvesen):* Pilot projects with automated vehicles in Norway are regulated by the *Act relating to testing of self-driving vehicles* and the associated *Regulation on testing of self-driving motor vehicles*. These provide the legal framework for granting permits, processing personal data, and conducting supervision. The objective is to enable gradual testing of self-driving vehicles while safeguarding road safety and data protection.

  All testing requires a permit from the Norwegian Public Roads Administration (Statens Vegvesen). Applicants – both private companies and individuals – must submit a comprehensive application to the Directorate of Roads, including technical specifications, operational design domain (ODD), safety and risk assessments, supervision arrangements, liability and insurance coverage, and emergency procedures. Testing without a permit is strictly prohibited and subject to penalties.

  The regulation allows for exemptions from existing technical approval requirements and traffic rules, depending on the maturity of the technology and the scope of the trial. Permits are typically limited in time and geographic scope, ensuring controlled experimentation. Applications are normally processed within 3–4 weeks once complete documentation is provided.

  Further information and application templates are available on the Statens Vegvesen website (in Norwegian)[3].

[3] https://www.vegvesen.no/fag/trafikk/its-portalen/automatisert-vegtransport/utproving-av-selvkjorende-kjoretoy/

In all cases, a type approval or pilot project authorization, a detailed description of the automated vehicle's specifications is essential. For type approval, demonstration of compliance with key European standards is mandatory. For pilot projects, while the level of detail and exact type of documentation vary between countries, applicants must generally provide comprehensive technical information on vehicle design, control software, safety systems, sensor technologies, and operational frameworks.

Within the framework of the ULTIMO project, WP2 provides a comprehensive overview directly relevant to the processes described above. Specifically:

- A dedicated list has been developed to systematically document and compare the capabilities of various automated vehicles involved in the project. This list captures critical aspects such as system functionalities, technology stack, safety features, and operational constraints.
- Moreover, an ODD description has been established, detailing the precise environmental, road, and traffic conditions under which these vehicles are designed and validated to operate.

3.2 Vehicle capabilities list structure

The format used to collect the information is organized into two main specifications: Hardware and Software.

Hardware specifications are composed by 7 subsections including dimensions, technical specifications, carrying capacity for both goods and people transportation, passenger services, accessibility and comfort, passengers' safety and autonomous driving hardware (sensors). On the other hand, software specifications mainly focus on ODD and ADS, remote capabilities including the safety operator and the fleet management, and finally the connectivity.

Other specifications such as legal and regulatory are also described.

The list reflects PTOs requirements according to their respective ODD. As the project progresses, the list of vehicles is being reduced to select the ones fitting with the ODD of each

operator. The list has been updated three times between March 2024 and September 2025 to finally achieve a list of 10 vehicles. This list is available in Annex G.

3.3 PTO's ODD

All PTOs drew its ODD Operational Design Domain. The ODD describes the operating conditions under which each driving automation system or feature is specifically designed to function, including environmental, geographical, and time-of-the-day restrictions and/or the requisite presence or absence of certain traffic roadway characteristics. The figure below describes an ODD taxonomy in 2 standards used in the project to help PTOs defining their operating conditions. From these standards, a vehicle capabilities list has been established to ensure the AV features meet the PTOs requirements.

Each PTO has established its ODD and described it in the Deliverable 5.3 (D5.3).

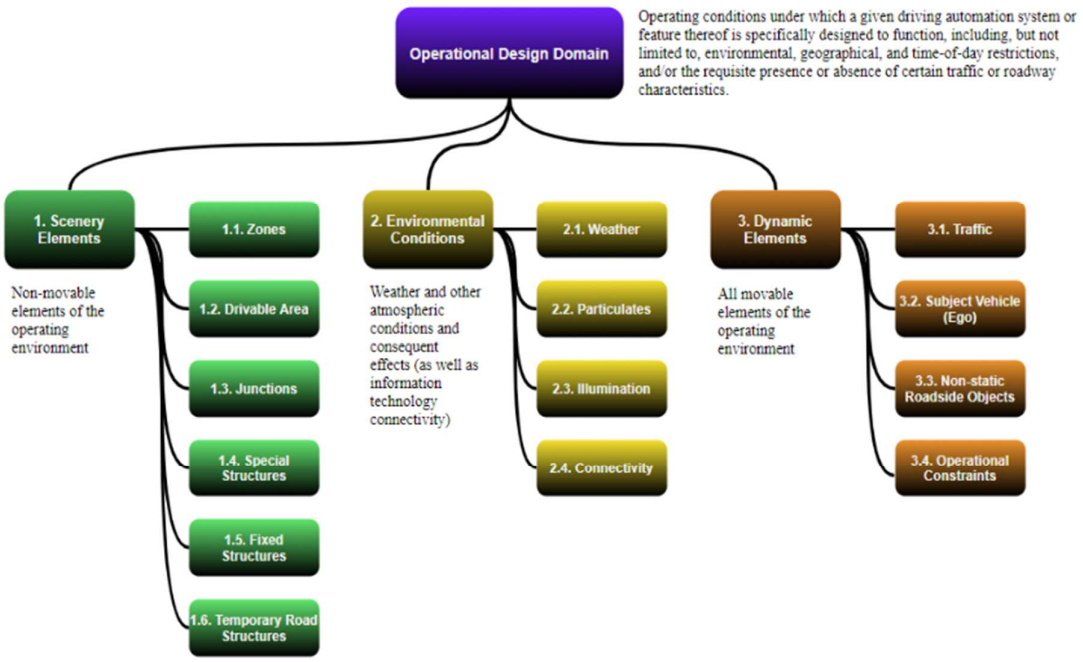

Figure 5. *Overview of ODD Taxonomy in BSI 1883 / ISO34503*

4 Matching Use Cases to Vehicle Capabilities

Upon the definition of the final use cases and needs, the next step has been to match the vehicle requirements to the use cases, according to their needs and always keeping the focus on the optimal user experience.

4.1 Methodology

As specified in the previous chapters (Chapter 2 in particular), for each use case there have been a series of Elementary Usage Blocks (EUBs) and related Needs identified. The latter include:

- T: Technology Needs
- S: Service Needs
- V: Vehicle Capability Needs
- P: Policy Needs

Among these, and in order to specify the vehicle capabilities necessary for each Use Case, the Vehicle needs were the ones used for this clustering. Consecutively, all Use Cases were listed along with the corresponding EUBs that addressed vehicle needs and the specific needs. Using this list, along with the list of vehicle capabilities (defined in T2.2, see Annex B) the work was performed in two axes:

- Perform an overall Vehicle Capabilities clustering, i.e. Identify the Vehicle Capabilities that are necessary for all Use Cases (and any possible Use Case in general); thus the ones that an AV should absolutely have in order to operate in a DRT system, along with those that are needed by the fleet orchestrators in order to select the appropriate vehicle.
- Perform Use Case clustering of Vehicle Capabilities, i.e. specify the ones that would be necessary for each of the ULTIMO Use Cases (according to their Vehicle Needs).

In addition, for each Use Case, critical points that address the Fleet Orchestrators, the vehicle manufacturers, policy issues or the (complementary) use of ULTIMO services were also identified and indicated. These would serve as valuable input for the work in other ULTIMO Work Packages.

To do this, a template was used in table format, in order to guide the analysis of each Vehicle need per Use Case *(see table below).*

Table 3. List of Use Cases with corresponding EUBs and Vehicle Capabilities needs (extract)

Use Case	EUB	Vehicle Need	Vehicle capability/ Service	Fleet Orchestrator/ Manufacturer	Comments

UC-01 **Normal trip**	**EUB-01-05**	**V-01-05-01**: External display synchronised with the app information			
	EUB-01-06	**V-01-06-01**: Button placement ensuring accessibility and usability for all passengers. (external button to open the door)			
		V-01-06-02: Optional: Passenger detection system			
	EUB-01-08	**V-01-08-01-B**: Accessible button design to ensure ease of use for all passengers. (door operation)			
……	**……**	**……**	……	……	**…..**
UC-05 **Vehicle doors stay opened**	**EUB-01-05**	**V-01-05-01**: External display synchronised with the app information			
	EUB-05-06	**V-05-06-01**: Vehicle capability to **override standard boarding time in special cases**.			
	EUB-05-08	**V-05-08-01**: Vehicle capability to **override standard disembarking time in special cases**.			

.....	.....	.....	.....	.....	.....
UC-20 **Vehicle loses internet connection**	**EUB-94-06**	**V-20-07-01**: Vehicle system to **detect internet connectivity issues and initiate safe stopping procedures**.			
		V-94-06-01: Autonomous systems for safely halting and securing the vehicle in case of disabling incidents.			
		V-94-06-02: Automated **vehicle diagnostics and malfunction alerts**.			
		V-90-06-01: Vehicle capability to **self-diagnose and report failures**.			
.....	.....	.....	.....	.....	.....

The template was originally presented to the ULTIMO partners and the process for filling it in explained in a dedicated online session. Then the partners, comprising different expertise and – thus points of view (i.e. orchestrators, developers, researchers, operators, etc.) were asked to provide input and comments to the list according to their view. This was done through an online document accessible to the whole ULTIMO Consortium (through ULTIMO SharePoint).

Upon completing this step and performing a preliminary compilation of the provided inputs, a dedicated Workshop took place during the ULTIMO GA in Herford, in June 2025. The aim of the workshop was to finalise the matching of the vehicle capabilities with the ULTIMO Use Cases, discuss any conflicting issues and complete the inputs for all use cases.

Figure 6. Snapshot of the workshop on vehicle capabilities matching with Use Cases in Herford

During the session, the participants were split into 6 groups, each aiming to analyse a different set of Use Cases and finalise the working document, while one of the groups was dedicated to finalise the list of commonly necessary vehicle capabilities (overall clustering). The inputs were followed up after the workshop, for final compilation, integration and preparation to be included in the present Deliverable.

4.2 Results

The results of this work, based on the above-described methodology, are presented in detail in the tables of Annexes C and D. In this section, the main outcomes are highlighted regarding both the overall vehicle capabilities clustering and the vehicle capabilities clustering per Use Case, i.e. those that have been recognized as necessary for each of the ULTIMO Use Cases.

4.2.1 Overall clustering

Starting from the overall vehicle capabilities clustering, this has been done by identifying the capabilities in two groups:

- The ones that are necessary regardless of the Use Case, thus any AV performing on-demand mobility services should have;
- The ones that are needed by the fleet orchestrators in order to select the appropriate vehicle for the ride.

Moreover, for each of these capabilities their importance level was specified (i.e. whether obligatory, optional or blocking). The detailed results are included in ANNEX C, while below a summary is presented.

Table 4. Standard Vehicle Capabilities (to be present regardless of Use Case)

Importance level	Vehicle Capability
Obligatory	• Emergency stop button • Ability to contact remote operator (No safety driver on board) • SOS mechanism • Seatbelts • First aid kit • Emergency windows • Data transfer to back office: video, audio, other • Steering wheel / controller (For safety operator) • Operation temperature min/max • Radar • Camera • Infrared camera • 4G • 5G • IMU • RTK-GNSS • Computer • Protection level of vehicle computer hardware (ease of access) • V2V • V2X • Passenger information system • Loudspeaker • Screen(s)/Other to indicate line number
Optional	• V2Passenger • Integration of roadside sensors • Charging port for passengers (USB type and amount)

	• Indoor CO2 sensor
Optional (*pending local legislation*)	• Automated External Defibrillator (resuscitation device)

Table 5. Vehicle selection features (capabilities the fleet orchestrator will use to select the right vehicle for the passenger needs)

Importance level	Vehicle selection features
Blocking	• Wheelchair capabilities • Vehicle passenger capacity – available capacity • Status of Battery • Range (Km) • Space for extra items • Height • Length • Width • Weight • Height off the ground of the vehicle with respect to the road • Maximum slope
Non-blocking	• Speed authorization (km/h)

4.2.2 Clustering per Use Case

To cluster the Vehicle Capabilities per Use Case, there was one question to be answered: which are the capabilities needed to satisfy the vehicle needs of this use case?

The structure of the ULTIMO Use Cases, which identifies the needs into Technology (T), Vehicle (V), Service (S) and Policy (P) allows to focus on the specific needs to be catered by vehicle capabilities. In some cases, complementary to the vehicle capabilities, there are also ULTIMO services that contribute to these needs. In the course of specifying this matching, the role of the fleet orchestrator, the operator or the manufacturer is also very important and it was identified and indicated per case, where relevant. The latter, will serve as input also for WP3 and especially T3.5, to specify policies needed for optimal deployment.

The detailed clustering is included in ANNEX D, where the complete tables are included for each of the ULTIMO Use Cases. In this section, we are summarizing and highlighting certain features per Use Case.

Table 6. Summary of results per Use Case (detailed results in Annex D)

Use Case	Summary of results
UC-01: Normal trip **Same for:** **UC-02: Service abuse by passenger** **UC-04: On-board aggression** **UC-07: No show** **UC-08: Excess luggage** **UC-09: Forgotten belongings** **UC-10: Public transport at night** **UC-12: Using on-demand services without the app** **UC-16: Vehicle meets a roadblock**	UC-01 is the basic Use Case, which also forms the basis for many of the next ones. In the "Normal trip" case, apart from the standard vehicle capabilities (as per Table 2) the following ones have been recognized as necessary: • Screens to indicate line number • Door opening/closing control • Passenger counting system • Ticket verification system In terms of services, the ones that would complement the above vehicle capabilities are: • Vehicle identification • In-vehicle monitoring Regarding the roles of the manufacturer and the fleet orchestrator, the following were commented: • Manufacturer: o Provide screen o Provide via API control of messages to be shown on screen o Design according to accessibility standards (for buttons) • Orchestrator: o Synchronize screen with app information

UC-21: Deaf user **UC-22: No available vehicle for the passenger needs**	○ Detection of actual number of passengers on board Finally, the following policy needs were identified: • Policy on vehicle identification (bus number, ride number, real time location, time of arrival, free seats) • Policy for person entering the vehicle • Policy on door opening time slot
UC-03: Health incident during transportation	In UC-03, in addition to the requirements of UC-01, the following vehicle capabilities are considered necessary: • Emergency stop button • Ability to contact the remote operator (No safety driver on board) • Automated External Defibrillator (resuscitation device) • SOS mechanism Moreover: • The operator ○ must have the possibility to control the doors from the remote supervision center, if the automated process fails. ○ must have the possibility to remotely take control of the vehicle upon its safe stop • The manufacturer: ○ should provide APIs for accessing location information, executing emergency missions (deviation), and controlling door opening. • The fleet orchestrator: ○ should provide information about the location of the vehicle and the next accessible PUDO for passengers to disembark
UC-05: Vehicle doors stay opened	In this use case, it is worth noting some comments about the role of different stakeholders: • Safety operator should be able to take remote control • Fleet orchestrator: ○ Door opening/closing control ○ Assignment of a customized boarding/disembarkation time for certain profiles via the back-office ○ plan B for the upcoming rides of this vehicle. (e.g. send a different vehicle
UC-06: Missing bus stop	In this Use Case, apart from the UC-01 vehicle specifications, it is also suggested a camera which can detect passengers on board who are waiting to disembark, while a relevant notification (upcoming drop-off point) should be provided via the app (operator).

UC-11: Visual impairment	In the case where there are passengers with visual impairment, as essential vehicle capabilities are the existence of microphone and loudspeaker, audio guidance to the doors as well as door opening and closing control.
UC-13: User in a wheelchair	In the case where there are passengers in wheelchair, as essential vehicle capabilities are the existence of appropriate room and securing means, access capabilities (such as ramps/lifts) and the capability for embarking/disembarking with or without assistance. Moreover, in terms of policies, fixing points for wheelchairs should be available, according to regulatory standards, along with the necessary equipment for ingress/egress (ramp/lift).
UC-14: Passenger unbuckles seatbelt while vehicle is in motion	For this use case, in addition to the vehicle capabilities included in UC-01, there should also exist a system for detecting whether the seatbelt is buckled. Along with this, there should be a policy set on what should be the decision of the fleet orchestrator (i.e. whether there should be information to the FO about unbuckled seatbelts, whether there should be consecutive actions, etc.)
UC-15: Vehicle breaks down	In the case of a vehicle break down, the vehicle capabilities that are especially needed are: • State of sensors • State of autonomous system Moreover, the fleet orchestrator would need: • Video feed (internal/external) and • GNSS location
UC-17: Yield to an emergency vehicle	In this case, apart from UC-01 capabilities, V2X and V2V communication are needed (already included in the standard capabilities) along with integration of roadside sensors and camera. The fleet orchestrator's role here lies in receiving and using V2X information to the ADS.
UC-19: Object under the vehicle	For this use case, the vehicle capabilities that would be necessary are: • Passenger information system • SOS mechanism • Communication with passengers • Data transfer to back office (video, audio, other) • State of autonomous system Regarding the fleet orchestrator: • Intervention team should be available • Process for halting and securing the vehicle should be defined by policies

	While for the manufacturer it is considered useful that the vehicle should have an offline/internal procedure for guiding passengers, e.g. to the exit. Also, safety diagnostic functions should be in place.
UC-20: Vehicle loses internet connection	In the case of loss of internet connection, it is important that the following vehicle capabilities are in place: • State of autonomous system • Communication with passengers • Mission modification (*during mission*) • V2X • V2V • Ability to contact remote operator • Data transfer to back office (video, audio, other) • State of sensors • State of autonomous system In addition, the fleet orchestrator should be able to monitor the state of the autonomous system (including the status of vehicle connectivity), have an intervention team in place and have appropriate processes define at the site. From the manufacturer side, the autonomous driving system should be able to safety stop with internet connection. Finally, there should also be specific policies defined regarding what should be done with the passengers (i.e. whether there should be another vehicle picking them up, waiting times, etc.)
UC-23: Misuse and Use of emergency stop button	The vehicle capabilities matched with this use case (in addition to the ones from UC-01) are: • SOS mechanism • Emergency stop button • Communication with passengers • State of autonomous system • Video feed • Remote navigation control In addition, the manufacturer should provide the emergency button and the fleet orchestrator/operator should have penalties set in the case of misuse
UC-24: Extra passengers	In the case of extra passengers on board (extra to the ones that have booked and paid for the service), apart from some of the UC-01 vehicle capabilities, a camera is needed in order to detect how many passengers are on board. It is also suggested a functionality in the app (or the website) of the operator to report such behaviour.

	It is noted that this use case implies several issues that need policy regulation and immediate action, such as punishment of intruders, security of passengers, need for police intervention, etc.
UC-30: Mobile nano-hubs **UC-31 Automatic pick-up (Producer to Warehouse)**	This use case is dealing with freight mobility and logistics. The vehicle capabilities that were matched are: • Goods ramp. • Max cargo weight. • Max cargo dimensions. • Fixing to secure the cargo. • Door width. • Door height. • Operation temperature min/max. • Heating / Cooling /Air conditioning • App Door opening / closing control. In terms of operation, it is noted that a logistics orchestrator is needed who will be responsible for handling incidents and, in the case of incident, there should be plans on returning the goods to the logistic warehouse.
UC-96: Vehicle interaction with infrastructure	This is a horizontal use case dealing with the interaction of the vehicle with the infrastructure. Necessary vehicle capabilities in this case are V2X and Integration of roadside sensors, while it is suggested that the operator shall regularly analyse these interactions and their status (successful or not) as well as the reasons of possible failure, for the improvement of performance.
Non-service	Apart from the above-mentioned Use Cases, there are also a number of vehicle needs not directly linked to the service. These relate to detection battery levels, the compatibility with charging infrastructure, maintenance issues, etc. For these, there is mainly the need for action by the fleet orchestrator, the manufacturer or the operator, which can be found in the related table in the Annex.

4.3 Discussion

The work performed for matching the vehicle capabilities with the use cases aims at highlighting the characteristics of the vehicles which would be necessary in order to provide the optimal service in each use case. Having the adequate vehicle capabilities listed per case, the fleet orchestrator would be able to assign the appropriate vehicle for each requested route. Moreover, issues and requirements that are not possible to be catered by the

corresponding vehicle capabilities shall be catered – where relevant – by appropriate ULTIMO services, complementing the vehicle's own potential. In addition, critical issues that should be tackled by the fleet orchestrator, the manufacturer or the operator are highlighted to be taken into consideration, along with decision-making topics that require or are depended on policies.

Furthermore, these results are useful input to ULTIMO work in the course of other Work packages, i.e. for WP3 (especially T3.5 specifying policies needed for optimal deployment), for WP5 (allowing the pilot sites to identify the appropriate use cases according to their vehicles and vice-versa and/or necessary improvements/policies/interventions) and beyond.

Providing the appropriate vehicle according to the needs in each Use Case, not only allows for optimal orchestration and thus DRT service provision but also increases the satisfaction and acceptance of the users, as their perceived (and actual) safety, comfort and level of service is higher. As a result, the effectiveness of deployment is enhanced, and the demand for the service is more likely to increase.

5 Conclusion

In conclusion, Deliverable 2.2 lays a strong foundation for the ULTIMO project's pursuit of automated mobility. It has enriched all 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, vehicle capabilities identification, and PTO's ODD, is guiding our path forward.

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

- Prioritization of Requirements: Sections 2 and 4 outlines our commitment to continually prioritize requirements, ensuring alignment with the evolving needs of passengers and stakeholders.

- Persona Development: The development of personas throughout the ULTIMO project has deepen our insight into user diversity and preferences, enabling us to tailor our services more effectively.
- Tailored Pilot Sites: Taking into consideration the unique characteristics of each ULTIMO pilot site, use cases have been developed to anticipate the needs and requirements from a variety of users. These use cases also provide help determining the composition of an autonomous vehicle fleet. Conventional statistics fall short in accounting for variations in disability distributions across locations and the benefits of accessibility features for all passengers. Use cases help finding the needed features, like low-floor buses or sound and visual information system, to not only enhance accessibility but also improve efficiency, benefiting PTOs and PTAs.

Annex A Personas

Personas

The personas created for the ULTIMO project are listed below.

Hanna, 14

Picture of Hanna[4]

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

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

Baggage/Equipment: School backpack, outdated mobile phone

Experience

Mobile app **Public transport** **Area**

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.

Helena, 74

Picture of Helena[5]

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

Mobile app **Public transport** **Area**

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

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

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

Picture of Mary[6]

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.

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

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

Mobile app **Public transport** **Area**

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 can 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

Picture of Carlo[7]

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

Specific Needs: Visual impairment, white cane user

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

Pains: Noisy or disruptive passengers, lack of passenger announcements

Gains: Independence, social interactions, well-timed connections

Baggage/Equipment: White cane, smartphone, monocular

Mobile app **Public transport** **Area**

Scenario: Scenario: Carlo, 62, lives in a medium-sized town and is partially sighted. He uses a white cane for navigation and relies on the bus for work. He prefers to travel early to avoid crowds and loud passengers.

Carlo likes to sit near the driver to chat about city news. Most drivers know him well. He must switch buses once to reach work and uses his smartphone to track travel time. Some drivers call ahead to his connecting bus to ensure it waits for him.

Once, the bus's passenger information system crashed, causing Carlo to lose orientation. With the help of a live traffic app and other passengers, he managed to get off at the right stop. Carlo has used a self-driving tram but is wary of fully automated buses, fearing job losses for his driver friends.

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

Chloe, 32

Picture of Chloe[8]

I would like to be perceived like any other person, but the wheelchair makes me the centre 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

Mobile app **Public transport** **Area**

[8] Source: https://pixabay.com/photos/woman-beauty-face-portrait-facial-3289372/

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.

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

Picture of Ned[9]

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

Mobile app **Public transport** **Area**

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.

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

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 highjack a driverless vehicle.

Fabio, 19

Picture of Fabio[10]

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

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

Specific Needs: dependent on public transport at night

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

Mobile app **Public transport** **Area**

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.

Carolin & John, 77 & 82

Picture of Carolin and John[11]

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

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

Mobile app **Public transport** **Area**

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.

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

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

Picture of Lilly and Lou[12]

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

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

Specific Needs: no hand free and 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

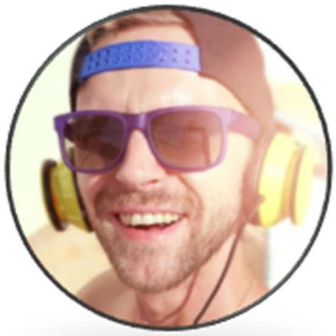
Mobile app **Public transport** **Area**

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.

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



Picture of Philippe[13]

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

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

Mobile app **Public transport** **Area**

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

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

Picture of Katie[14]

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

Mobile app **Public transport** **Area**

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

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 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.

Antony, 30

Picture of Antony[15]

I only use public transport to keep working if I need to.

Specific Needs: No time to be stuck in the traffic.

Desires: efficient and hassle-free mobility in the city with no need to worry about the next connection.

Pains: time on the road, number of connections to take

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, work bags

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[15] Source: https://www.freepik.com/free-photo/vertical-shot-blonde-caucasian-man-with-beard-wearing-cap_20386273.htm#fromView=search&page=1&position=4&uuid=aecec3e7-ba74-4280-b25c-0250e6c20520&query=white+man+with+tatoos+and+cap+

Mobile app **Public transport** **Area**

Scenario: Antony, 30 years uses regularly the ULTIMO service to go to work. He is a very active individual and is regularly stressed while going to work. He takes work at home and brings it back the next day. Aware of automated cars, he's surprised by existing automated buses. Curious and exited, he envisions a future with fully automated vehicles and more time for his work.

Eva, 42

Picture of Eva[16]

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.

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16 Source: https://www.freepik.com/free-photo/front-view-smiley-woman-posing-indoors_34598284.htm#query=40%20years%20old%20woman&position=2&from_view=keyword&track=ais_hybrid&uuid=6c7e03c2-ef38-4582-9538-4e18e9cba92d

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 pain, lack of parking and rush hour delays, weather too bad to cycle

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.

Mobile app **Public transport** **Area**

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.

Mikhail, Anna, Katarina, Igor, 22-25

Picture of students group[17]

New city, new experiences, new ways to travel.

Specific Needs: Affordable and reliable transportation, multilingual support, student discounts, additional information about the surroundings during the journey

Desires: Easy access to city attractions, cost-effective commuting

Pains: Navigating an unfamiliar city, language barriers, and managing a tight budget

Gains: Independence, cultural exploration, Conversations with locals

Baggage/Equipment: Backpacks, smartphones with translation apps, student IDs

Mobile app **Public transport** **Area**

Scenario: Anna, Mikhail, Katarina and Igor are a group of international students visiting a city that's famous for its autonomous buses. They've heard about the innovative technology and are excited to experience it firsthand. During their visit, they plan to explore several key attractions, including museums and cultural sites, where they have pre-booked tickets for specific time slots. They need to rely on the autonomous buses to navigate the city efficiently

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17 Source: https://de.freepik.com/fotos-kostenlos/freunde-die-selfie-in-der-strasse-nehmen_2483348.htm#fromView=search&page=1&position=0&uuid=f1e7fa9e-d3a4-4209-95c0-c084efe8e440

and reach their destinations on time. While they are curious about how the technology works, they are also concerned about its reliability, especially since they are unfamiliar with the city's layout and public transport system. The group hopes the buses are easy to use, timely, and provide real-time information in a language they understand to make their trip smooth and enjoyable.

Peter, 68

Picture of Peter[18]

I used to drive everywhere, now I'm learning to take the bus.

Specific Needs: Clear and accessible information about routes and schedules, convenient transportation for grocery shopping, doctor's appointments and meeting friends

Desires: Easy transition from car to public transport, with more flexibility than conventional buses, staying active, social and independent without being dependent on the car

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[18] Source: https://de.freepik.com/fotos-kostenlos/close-up-im-ruhestand-mann-laechelnd_904454.htm#fromView=search&page=1&position=19&uuid=c4e8f1a8-26d4-43ee-89cb-50d63241e1ba

Pains: Difficulty understanding bus schedules, feeling out of place among younger passengers, and missing the convenience of a personal vehicle

Gains: save money on car maintenance and reduce environmental impact, no more searching for a parking space

Baggage/Equipment: Reading glasses, a shopping bag

Mobile app **Public transport** **Area**

Scenario: **Scenario**: Peter is a recently retired man who still owns his car but rarely drives it anymore. He's starting to feel uneasy behind the wheel and knows this discomfort will likely increase as he ages. To prepare for a future where driving might not be an option, Peter is just beginning to explore public transport as an alternative. This is entirely new to him; he's unfamiliar with bus routes, schedules, and the overall experience of using public transport. The transition is daunting—he finds it difficult to understand the schedules and feels out of place among the younger passengers. However, Peter is motivated by the potential benefits, such as saving money on car maintenance and avoiding the stress of parking. He's determined to learn the ropes, starting with short trips for grocery shopping and doctor's appointments, hoping to eventually make public transport his primary way of getting around.

Olivia, 29

Picture of Olivia[19]

After my last experience, I'm cautious but curious about new transport options.

Specific Needs: Safe and stress-free commuting, safety when traffic is light or at dusk/night

Desires: regaining confidence in using public transport, a reliable and easy-to-use way to complete everyday tasks and maintaining independence

Pains: Fears due to previous negative experiences with public transport, such as feeling unsafe in the dark

Gains: Increased self-confidence, regaining independence and autonomy

Baggage/Equipment: Pepper spray, a bag and a smartphone

Mobile app **Public transport** **Area**

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[19] Source: https://de.freepik.com/fotos-kostenlos/smiley-frau-der-vorderansicht-die-leckeren-tee-haelt_35022601.htm#fromView=search&page=1&position=9&uuid=4eafaf7d-a94a-4192-a08b-ef8b7fad21bb

Scenario: Olivia's previous experience with public transport was unsettling; she had a stressful situation on a bus late in the evening that left her feeling vulnerable and anxious. Despite this, Olivia is open to trying new transport solutions that promise greater safety and ease. She's particularly interested in autonomous door-to-door shuttle buses that could offer a more controlled and secure environment. Olivia is starting to use these shuttles for short trips, focusing on low-traffic times and routes she feels comfortable with. The clear instructions and personalized service of the autonomous shuttles help her gradually overcome her past fears and regain confidence in public transport. Each successful journey reinforces her sense of security and independence.

Markus, 55

Picture of Markus[20]

I know I should take the bus, but driving is just so convenient.

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[20] Source: https://de.freepik.com/fotos-kostenlos/latino-geschaeftsmann-mittleren-alters_94949104.htm#fromView=search&page=1&position=14&uuid=ba190c3c-ef12-4c25-a6c4-ba9d14bb4080

Specific Needs: Reliable and convenient public transport, integration with his usual routine, and incentives for choosing public transport

Desires: To balance his love for driving with a more sustainable lifestyle sacrificing convenience (and making his daughter and girlfriend happy)

Pains: Struggles with the habit of driving everywhere, the time it takes to adjust to using public transport, and the pressure from others to make more eco-conscious choices

Gains: Satisfaction from contributing to environmental sustainability, saving money on fuel and parking

Baggage/Equipment: Car keys, smartphone

Mobile app **Public transport** **Area**

Scenario: Markus has been driving for decades and loves the freedom and convenience his car provides. However, his daughter and new girlfriend have been nudging him to adopt a more sustainable lifestyle, suggesting he use public transport more often. His workplace also started a friendly challenge to see who could reduce their carbon footprint the most, and Markus is reluctantly participating. Although he sees the benefits of using public transport, Markus finds it hard to give up his car. Each time he needs to go somewhere, he debates whether to drive or take the bus. He's slowly getting used to public transport but still feels the pull of his car's convenience.

Elena, 34

Picture of Elena[21]

Safety is my right; communication is my challenge.

Specific Needs: Clear visual and text-based communication, emergency support, safety assurances.

Desires: To travel independently and safely, to feel secure and understood even without verbal communication.

Pains: Fear of being vulnerable due to her disability, past experiences of feeling unsafe

Gains: Confidence in using AVs without relying on others, a sense of security from knowing help is available if needed

Baggage/Equipment: Smartphone with a translation and emergency app

Mobile app **Public transport** **Area**

Scenario: Elena is a 34-year-old woman who was born deaf and she is unable to communicate verbally. Although she values her independence, she often feels defenceless when using public

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[21] Source: https://de.freepik.com/fotos-kostenlos/latino-geschaeftsmann-mittleren-alters_94949104.htm#fromView=search&page=1&position=14&uuid=ba190c3c-ef12-4c25-a6c4-ba9d14bb4080

transport or AV services as she is unable to communicate verbally. She recently experienced an unsettling situation where she felt threatened while travelling in an autonomous vehicle. Now she is cautious but still relies on these services to maintain her independence. Elena needs a transport service that not only addresses her communication needs with clear visual and text-based instructions but also provides immediately accessible safety features. She appreciates AVs for their technological advances, but she needs reassurance that she is safe.

Annex B Use cases & Needs associated

Use cases

These use cases follow a flow of 9 parts as describe in the list below and based on the PTOs experience with DRT service. These stages, also described as User Journey, contain information about how a person interacts with the service and it helps us to better understand the touchpoints that need to be considered during the creation of the ULTIMO services. Among the elements that can benefit from this categorization are service design, user experience design, or even interface design.

1. **Inform**: all actions taken to share information related to the service.
2. **Book**: all actions taken to book a trip.
3. **Get to pick-up point**: all actions taken for a user to get to pick-up point.
4. **Wait**: all actions occurring during the waiting phase.
5. **Connect**: all actions taken for a user to connect with the AV.
6. **Board**: all actions taken for a user to board the AV.
7. **Travel**: all actions taken while traveling on board the AV.
8. **Disembark**: all actions taken for a user to disembark from the AV.
9. **Review**: all actions taken to review the service/trip.

UC-01: A normal trip of a person

Actor(s)

Markus, 55 years old.

User background

Markus has been driving for decades and loves the freedom and convenience his car provides. However, his daughter and new girlfriend have been nudging him to adopt a more sustainable lifestyle, suggesting he use public transport more often.

Goal

Markus would like to go to see some friends who live in the countryside.

Preconditions

Markus doesn't know about ULTIMO service.

Flow:

1. Markus looks for a transfer service as it is the first time he visits his friends' house, and he knows it is not close to any public transport station/stop and he does not want to walk far. He finds the ULTIMO app and downloads it to his mobile. The ULTIMO app informs Markus that it proposes an on-demand automated public transport available day and night. Markus creates his profile entering his information (first name, last name, phone number and email).
2. Once Markus has created his profile, he starts the booking process and sets information about his departure and arrival point. The app shows Markus all available points and he selects the one he wants. Markus indicates the number of passengers. He can also set the number of passengers in a wheelchair. Then he chooses the desired time of departure or arrival. The app shows him the immediate availabilities or allows him to book for a later day. Markus picks a trip and, after confirming his booking, the app informs him about the expected pick-up time and arrival time.
3. The app is informing Markus when and where he needs to go to be picked up. When he leaves home, the app is guiding him there through a map and a voice guidance and informs him when he has reached the PUDO. The PUDO are all clearly indicated through the DRT app.
4. While waiting at the PUDO, Markus receives information on the remaining time until the shuttle arrives, and – if any – on delays.
5. When the shuttle is approaching the PUDO, Markus receives an alert from the app. The app also informs Markus of the vehicle name for him to easily identify the vehicle. The name of the vehicle is displayed on a screen outside the vehicle.
6. When the vehicle has reached the PUDO it stops and opens the doors for Markus to board. The doors can also be opened with a button. Markus enters the vehicle, validate his trip with a code or QR code or his ULTIMO app and looks for a seat. Once Markus is inside the vehicle, the doors close. And once he is seated with his seat belt fastened, the vehicle departs. The in-vehicle display and sound information systems announce the vehicle departure.
7. During Markus' trip, the vehicle may make stops to pick up and disembark other passengers. The in-vehicle display and sound information systems provide details on

the upcoming stops as well as information to connections to other lines (bus, trams, trains, airports, ...). The app is dynamically displaying the same info, along with the remaining number of stops to his destination.

8. When arriving at the destination, Markus receives a notification through the app that the next stop is his and the vehicle stops at the defined drop off point. When the vehicle stops, Markus goes to the door, the door opens, and he disembarks. As soon as he is safely out the vehicle, the doors close and the vehicle departs for its next mission. The app is then guiding him on foot until he reaches his friends' house.
9. Finally, Markus decides to review his trip using the app review feature.

UC-02: Service abuse by a passenger

Actor(s)

Philippe 24 years old.

User background

Philippe listens to loud music, wants to be as fast to work as possible and be with less passengers as possible.

Goal

Going to work using on-demand transport, Philippe wants to be alone in the vehicle. To do that, he abuses of the system by booking as a group even if he is alone.

Preconditions

Philippe booked a trip for a group of the maximum size. Philippe is waiting for the vehicle to arrive at the pick-up point.

Flow:

1-5 UC-01: A normal trip of a person

6. The vehicle arrives at the pick-up point. Philippe enters the shuttle and must validate his trip. Philippe booked for a group and so the vehicle is waiting for all group members to enter, but these members do not exist and won't enter. And therefore,

the vehicle closes its doors and drives off. The vehicle's available space is updated, and new bookings can be placed on this vehicle.

7. The vehicle travels to destination. In the meantime, the UTLIMO system informs the supervision centre, and a supervisor contacts Philippe to warn him about the possible abuse. The supervisor comments and marks the event as resolved.

8-9 UC-01: A normal trip of a person

UC-03: Health incident during transport

Actor(s)

Eva 42 years old.

User background

Eva rarely uses public transport or on-demand service; the exception is when she knows she might want to have a drink.

Goal

Eva is using the service to go to a birthday but during her travel she has an epileptic crisis.

Preconditions

Eva is using the on-demand service and currently traveling.

Basic flow

1-6 UC-01: A normal trip of a person

7. Eva uses on-demand service. She is alone inside the shuttle. She has an epileptic attack, starts convulsing and collapses on her seat. The onboard passengers monitoring system detects the incident and sends a notification to the supervision centre. The supervisor visually assesses the situation and tries to communicate with Eva. Eva is not responding so the supervisor calls for emergency services and stops the vehicle at the nearest safe place.

Once the emergency services arrive and take in charge Eva, Eva's booking is cancelled by the supervisor, the vehicle leaves and goes back in service.

8-9 UC-01: A normal trip of a person

Alternative flow

7. Eva uses on-demand service. She and other passengers are inside the shuttle. Eva has an epileptic attack, starts convulsing and collapses on her seat. The onboard passengers monitoring system detects the incident and sends a notification to the supervision centre. The supervisor visually assesses the situation and tries to communicate with Eva. Eva is not responding so the supervisor asks other passengers to give him feedback. The supervisor calls for emergency services and stops the vehicle at the nearest safe place.

   The supervisor informs passengers that he called for emergency services and connect emergency first responder with them. Passengers can then do the first aid procedures as instructed by the emergency services.

   Once the emergency services arrive and take in charge Eva, Eva's booking is cancelled by the supervisor, the vehicle leaves and goes back in service.

UC-04: On-board aggression

Actor(s)

Hanna, 14 years old.

User background

Hanna takes the bus every day to go to school.

Goal

Hanna is being harassed inside the vehicle by a group of older students.

Preconditions

Hanna has booked a trip and is traveling inside the vehicle. The vehicle is full.

Flow:

1-6 Same comment as above

7. Hanna is being physically and verbally harassed by a group of older students. The ULTIMO system detects signs of physical aggression and bullying due to actions like pushing, hitting or taking away personal belongings. It then plays an audio cue inside the shuttle reminding all passengers to behave themself and informing them of any misbehaviours' consequences.

   In the meantime, the system alerts the supervision centre. A supervisor investigates the situation and communicates with the passengers to clear any issue and to warn them not to have any misbehaviours. If passengers continue to have any aggressive behaviour, then the supervisor stops the vehicle, informs emergency services and wait for them to arrive and take care of any troublemakers.

   After the situation is clarified, the vehicle resumes its journey if it had stopped and the supervisor comments and marks the event as resolved.

8-9 Same comment as above

Alternative flow 1

7. Hanna is being physically and verbally harassed by a group of older students.

   The vehicle has a possibility for passengers to call the customer service and inform them of any issue. A passenger witnessing the aggression could use the onboard touch screen to contact the customer service and inform them of the current situation. A supervisor would then take charge of the situation.

   After the situation is clarified, the vehicle resumes its journey if it had stopped and the supervisor comments and marks the event as resolved.

UC-05: Vehicle doors stay opened

Actor(s)

Ned, 58 years old, reduced mobility.

User background

Ned lives in the countryside, has difficulty walking and cannot stand up for too long or sit on the pavement because he could not get back up. He uses a cane to help his injured leg. He has difficulty entering and exiting a vehicle.

Goal

Ned would like to visit his family as he does once a week and he wants to use ULTIMO service.

Preconditions

Ned has the ULTIMO app. He has booked a trip and is waiting for a ULTIMO vehicle.

Flow:

2. Ned has pain in his leg and has difficulty moving but, when booking a trip, the ULTIMO app only allows Ned to say if he is in a wheelchair. Ned can't inform ULTIMO service about his injured leg. And therefore, ULTIMO system views Ned as a normal passenger (not a passenger with special needs) and sends him a vehicle without needed equipment or groom service.
6. The vehicle arrives at the pick-up point and Ned enters the vehicle. Ned has trouble entering the vehicle because of his leg and it takes him a long time to board the vehicle. The ULTIMO system detects an anomaly because the doors stay opened for too long. The system then plays an audio cue asking passengers to free the doors and since the doors are not freed on time, the system informs the supervision centre. A supervisor receives the alarm and investigates the situation. He sees Ned slowly boarding the vehicle because of his leg and therefore decides to stop any audio cue inside the shuttle and lets Ned calmly come aboard, seat and fastened his seat belt. The supervisor comments and marks the event as resolved.
7. In the meantime, the vehicle drives off to its next destination.
8. Once the vehicle arrives at the drop off point, Ned needs to exit the vehicle. It takes him a long time to get up from his seat and to get off the shuttle. The ULTIMO system knows that Ned must leave the vehicle and therefore waits for him to do so. If Ned takes too much time, then, as for the boarding, the vehicle plays an audio cue and if Ned still haven't left the vehicle, the supervision centre is informed. A supervisor then investigates the situation, sees Ned slowly disembark the vehicle because of his leg and therefore decides to stop any audio cue inside the shuttle and lets Ned calmly get off. The supervisor comments and marks the event as resolved. In the meantime, the vehicle drives off to its next destination.

UC-06: Missing bus stop

Actor(s)

Hanna, 14 years old.

User background

Hanna, 14 years old is looking forward to the bus ride every morning because she always meets her friends there. The ride takes quite a while and so they watch videos on their mobile phones or play games.

Goal

Hanna is using ULTIMO service. She is traveling in a ULTIMO vehicle and is going to miss her drop off point.

Preconditions

Hanna has booked a trip and is currently travelling inside a ULTIMO vehicle.

Flow:

7. Hanna is currently traveling inside a ULTIMO vehicle, and she is scheduled to get off at the next stop. The in-vehicle display and sound information systems inform passengers of the next stop.
8. The vehicle reaches the next stop, stops, opens its door, and the in-vehicle display and sound information systems inform passengers of the current stop. Hanna is so immersed in her game with her friends that she doesn't realize that she needs to get off the vehicle. As no passengers are getting off, the ULTIMO system knows it must wait and plays again an audio cue informing passengers of the current stop. Hanna being very absorbed, does not realize that it is her bus stop. Once the defined regulatory delays for bus stops have expired the bus closes the doors and continues the trip for the next customer. At some point Hanna realizes that she has missed her bus stop. She must wait to exit in the next bus top and from there she reschedules, if not too far from her destination, a new trip.

Alternative flow 1:

8. After the bus has closed the doors to the bus stop where Hanna was supposed to exit, it is scheduled to go back to the depot (recharging, maintenance, end of daily service etc.). For this last trip the bus is supposed to be empty, but the in-vehicle services' system identifies the presence of a passenger. An incident is raised to the back-office operator who activates the in-vehicle communication system and interrogates the passenger. Hanna responds to the operator, realizing that she has missed her stop. The back-office operator instructs the vehicle to stop to next closer PUDO, where Hanna can disembark. After Hanna has disembarked and reschedules a new trip, while the vehicle resumes it trip to the depot, this time empty.

Alternative flow 2:

8. After the bus has closed the doors to the bus stop where Hanna was supposed to exit, it is scheduled to go back to the depot (recharging, maintenance, end of daily service etc.). For this last trip the bus is supposed to be empty, but the in-vehicle services' system identifies the presence of a passenger. An incident is raised to the back-office operator who activates the in-vehicle communication system and interrogates the passenger. Hanna has actually fallen asleep, and she does not reply to the operator call. The back-office operator immediately raises a medical incident alarm: we apply the Use Case 03: Health incident during transportation.

UC-07: No show

Actor(s)

Fabio, 19 years old.

User background

Fabio works in a shop at the centre of the city, and he goes to work each morning. As it is very complicated to use car due to lack of easily accessible parking places, he always uses public transport.

Goal

Fabio uses ULTIMO transportation service for his trips, reserving the trips one hour in advance.

Preconditions

None.

Flow:

1. UC-01: A normal trip of a person
2. At the end of the day Fabio has reserved the ULTIMO service for a trip at 19:10, just after the closing hour of the shop.

3-4 UC-01: A normal trip of a person

6. However, at 19:00 some customers are still in the shop delaying him to close the shop. Being over occupied with the customers he forgot to cancel his 19:10 reservation. At 19:10 the customers are leaving the shop and Fabio remembers his reservation, but it is too late to catch the trip. He cancels his reserved trip in the app (penalties might apply based on when the trip was cancelled by users – if they forget to cancel their trip, then the full cost will be charged) and will need to make a new reservation. In the meanwhile, the vehicle he had ordered arrived at the PUDO, waited the regulatory time and left without him, raising an incident to the supervisor (No-Show). The system cancels automatically the trip and reschedules the vehicle.

7-9 UC-01: A normal trip of a person

UC-08: Excess luggage

Actor(s)

Lily and Lou, 33 and 2 years old.

User background

Lilly has a great two-year-old daughter with blond curly hair. As it is very complicated to use a private car with stroller and due to lack of suitable and easily accessible parking places, she and her daughter always use public transport.

Goal

Lily and Lou want to use ULTIMO transportation service with a stroller.

Preconditions

None.

Flow:

2. Lily has a stroller for Lou. Lily needs to book a trip and to inform the system that she has extra luggage, a stroller. She books for a stroller in the app and (according to the local regulations) an extra passenger, a 2-year-old kid.
6. Boarding with a stroller (or extra luggage) is not an issue, as ULTIMO system sees Lily and Lou get on and waits for them to do so.
7. Traveling with a stroller or extra luggage is not an issue since Lily and Lou have inform the system through the app when booking the trip. The fleet orchestrator is taking into account the extra space used by the stroller for the assignment of other trips.
8. Disembarking with a stroller (or extra luggage) is not an issue, as ULTIMO system sees Lily and Lou get off and waits for them to do so.

Alternative flow 1 – Not reserving for the stroller:

6. Lily and Lou want to use ULTIMO service with a stroller, but they have booked a trip without informing the system about this stroller. When the vehicle arrives, there is enough space for the stroller, so Lily and Lou are able to board with the stroller.
7. When the trip starts, the ULTIMO system detect that they are using extra space and update the booking availabilities. At the same time the supervisor is informed about the excess use of space, but according to the policies no action is taken.

Alternative flow 2 – Not reserving for the stroller and no available space:

2. Lily and Lou want to use ULTIMO service with a stroller, but they have booked a trip without informing the system about this stroller.
6. When the vehicle arrives, there is no space for the stroller, so Lily and Lou are not able to board the vehicle. The vehicle waits the predefined time, and then considers a No-Show, closes the doors and leaves.
2. In the meantime, Lily cancels the reservation on the fly and reserves a new trip declaring the stroller.

UC-09: Forgotten luggage

Actor(s)

Carolin & John, 77 & 82 years old.

User background

Carolin 77 years old and John 82 years old live 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.

Goal

Carolin and John are using ULTIMO service. They are traveling in a ULTIMO vehicle and are going to forget some belongings when getting off the vehicle.

Preconditions

Carolin and John have booked a trip and are currently travelling inside a ULTIMO vehicle.

Flow:

8. Carolin and John's drop off point is there. The vehicle stops and informs passengers to get off and not to forget any belongings. Carolin and John are talking about their connection and Carolin forget her bag inside the vehicle. The ULTIMO system identifies that an item was forgotten in the vehicle. It informs the supervisor, sending an image of the identified item. The supervision, based on the type of object and according to the PTO policies sends an intervention team to recover the item. The ULTIMO system sends to all passengers that used the vehicle before a message informing them that an item was found, its identification, and where they can recover it.

Alternative flow 1:

8. Carolin and John are talking, and Carolin forgets her backpack inside the vehicle despite the ULTIMO services warning her inside the vehicle through an audio cue and a notification in the ULTIMO app not to forget any belongings.
   After the vehicle has left, Carolin remembers that she has forgotten her bag in the vehicle. She sends a message to the supervisor via the ULTIMO app informing that she has forgotten here bag. The system has not yet identified the forgotten object (which can be done only when there are no more passengers in the vehicle). The supervisor, based on the vehicle occupancy and schedule will decide to turn the vehicle back so that Carolin can pick her bag, or send an intervention team to pick it and inform Carolin and John that they must contact customer service to ask where to pick up their lost item.

UC-10: Public transport at night

Actor(s)

Fabio, 19 years old.

User background

Fabio lives in the city.

Goal

Fabio went to a festival in the countryside. It is late at night, and he wants to go home using public transport. Fabio uses ULTIMO transportation service.

Preconditions

None.

Flow:

2. Fabio wants to go home but it is late at night and classic public transport are scarce. Fabio knows about ULTIMO transportation service and decides to book a trip to go home. The ULTIMO vehicles are automated vehicles available day and night. The ULTIMO app proposes a vehicle to Fabio in the shortest time possible. Fabio can book a trip and go home faster than if he had to wait for the classic public transport.

7. Fabio has booked a trip, boarded his vehicle and is currently traveling to his set destination. The ULTIMO system is detecting any misbehaviours inside the vehicle so that Fabio and other passengers can travel safely. In case of an incident, the ULTIMO system automatically detects it and informs the supervision centre. Then a supervisor assesses the situation and takes the necessary measures.

UC-11: Blind user

Actor(s)

Mary 29 years old.

User background

Mary, 29 years, old became blind after an accident. She wants to be as independent as possible thus she does not accept unrequested help by others.

Goal

Mary wants to use public transportation like anybody else.

Preconditions

The mobile app is implemented following the accessibility guidelines such as WCAG 2.2 for iOS and Android.

Flow:

1. Mary is blind and she wants to book a trip with ULTIMO transportation service. ULTIMO app offers accessibility for visually impaired user and so Mary can use the app.
2. Mary has entered in her profile the fact that she is blind and she books a trip.
3. Mary receives information about her pick-up point location and the vehicle arrival time through the app. The app provides the exact Geo localisation of the PUDO and via link to an external navigation app Mary can be guided to exact location.
5. At the pick-up point, when the vehicle arrives and stops at the designated PUDO, it emits a sound to help Mary locate it. If the PUDO is a formal bus stop, markings on the ground guide her toward the vehicle entrance. In cases where the vehicle must stop a

few meters away from the official PUDO—due to various reasons—the sound serves to direct Mary to its actual position. At the same time Mary's app, via audio and vibration cue informs her that her vehicle is stopped at the PUDO location. This is done via a tight synchronisation of the vehicle position and the app.

6.. Since the door-opening buttons are placed in a standard, clearly marked location, Mary can easily press the button to open the door and board the vehicle. The fleet orchestrator, being aware of Mary's disability, allocates additional waiting time to ensure she can embark comfortably.

7. During travel, the vehicle is informing passengers of the current and next stop through an onboard display and audio cues. The ULTIMO app is also informing Mary when her stop is next, and it also gives her information on connections.

8. Again, when arriving to her destination, the fleet orchestrator, being aware of Mary's disability, allocates additional waiting time to ensure she can disembark comfortably.

9. As the ULTIMO app is accessible, Mary can give a review of ULTIMO service if she wishes to.

UC-12: Using on-demand services without the app

Actor(s)

Katie, 31 years old.

User background

Katie 31 years old lives in a city resident, swaps her car for public transit in the bustling city centre.

Goal

Katie would like to use ULTIMO transport service without the app.

Preconditions

None.

Flow:

1. Katie wants to use ULTIMO transport service, but she does not have the ULTIMO smartphone app. Katie can still book a trip by calling the customer service or using the ULTIMO web app.
2. Katie books a trip. Katie needs to print the code or QR code to validate her trip once she boards the vehicle. Katie can also validate her trip by entering her code on the in-vehicle touchscreen.
3. Katie won't receive any in-app notifications, but she has seen all booking information when she received the booking confirmation so she can go to the pickup point.
4. Katie can go to the pick-up point on time, but she won't be informed of delays.
5. Katie can't recognize the vehicle since the vehicle's name is not known at the time of the booking confirmation but only later, when the vehicle is en route.
6. Katie must make sure she boards the right vehicle by validating his trip inside the shuttle. The onboard display would then inform Katie if she were in the right vehicle.

Alternative flow 1:

1. Katie doesn't have a phone or access to the web app, but the ULTIMO services have installed at selected bus stops interactive terminals where passengers can reserve their trip.
2. As Katie does not have a mobile phone or web access, she simply goes to the nearest terminal equipped PUDO, where she makes her reservation.

UC-13: User in a wheelchair

Actor(s)

Chloe, 32 years old.

User background

Chloe 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.

Goal

Chloe wants to use ULTIMO on-demand transportation service with her being in a wheelchair.

Preconditions

Chloe knows how the ULTIMO service work.

Flow:

1. Chloe wants to use ULTIMO transportation service while being in a wheelchair. She books a trip and tells the system that she is a passenger in a wheelchair. The ULTIMO system automatically chooses a vehicle with all needed equipment and/or a groom service.
2. Chloe is informed through the ULTIMO app that her vehicle is adapted to her needs.
6. A groom can assist Chloe to embark.
7. A groom can assist Chloe during her trip.
8. A groom can assist Chloe to disembark.

UC-14: Passenger unbuckles his seatbelt while vehicle is in motion

Actor(s)

Helena, 74 years old.

User background

Helena struggles with the challenges of her limited mobility and hearing impairment.

Goal

Helena wants to go to an appointment using ULTIMO transportation service.

Preconditions

Helena has booked a trip, and she is currently traveling in a ULTIMO vehicle.

Flow:

7. Helena is traveling in a ULTIMO vehicle. During the ride, she decides to unbuckle her seatbelt. The ULTIMO system detects that a passenger does not have his seatbelt on and so the in-vehicle display and sound information systems play a cue asking passengers to remain seated and with their seatbelts on while the vehicle is in motion. The system also informs the supervision centre. A supervisor assesses the situation and intervenes if needed. Helena buckles her seatbelt. The supervisor comments and marks the event as resolved.

Alternative flow 1:

7. The ULTIMO system detects that Helena doesn't have her seatbelt on. The in-vehicle display and sound information systems play a cue asking passengers to remain seated and with their seatbelts on while the vehicle is in motion. The system also informs the supervision centre, and a supervisor assesses the situation and intervenes. The supervisor warns Helena that she needs to remain seated and with her seatbelt on for her own safety. Helena refuses to buckle her seatbelt. No further actions are taken. The vehicle continues its trip. The supervisor comments and marks the event as resolved.

UC-15: Vehicle breaks down

Actor(s)

Olivia, 29 years old.

User background

Olivia is open to trying new transport solutions that promise greater safety and ease of use.

Goal

Olivia has booked a trip, and the vehicle sent breaks down before reaching the pick-up point

Preconditions

Olivia has booked a trip and is waiting at the pick-up point.

Flow:

1. Olivia has booked a trip through the ULTIMO app. She received information on the vehicle arrival time through the ULTIMO app and is waiting at the pick-up point.

   The vehicle sent to Olivia due to an incident, can no longer operate. The ULTIMO vehicles can identify failures and other incidents through their sensors.

   The supervision centre is informed about the incident and informs the passengers on the vehicle of the incident and that a new vehicle is dispatched and when it will arrive. The information, if possible (still functioning) is also displayed via the in-vehicle display and sound information systems, and send to the passengers via their app, along with information on how to proceed (disembark and wait for a new vehicle that will be automatically rescheduled). At the same time Olivia is informed of an unexpected delay through the ULTIMO app.

   If needed, the supervisor calls for an intervention team and possibly emergency services, depending on the type of incident.

   After emergency services took in charge the passengers or the new vehicle arrived, the supervisor comments and marks the event as resolved.

UC-16: Vehicle meets a roadblock

Actor(s)

Mikhail, Anna, Katarina, Igor, 22-25 years old.

User background

Anna, Mikhail, Katarina and Igor are a group of international students visiting a city that's famous for its autonomous buses. They've heard about the innovative technology and are excited to experience it first-hand.

Goal

Passengers must safely reach their destination.

Preconditions

Anna, Mikhail, Katarina and Igor have booked a trip and are currently traveling in a ULTIMO vehicle.

Flow:

7. Anna, Mikhail, Katarina and Igor are currently traveling in a ULTIMO vehicle when it detects a roadblock and stops.

   The vehicle informs (incident alert) the supervisor, providing all available information (video and possibly reading from the ADS). The supervisor assesses the situation and informs the passengers that the road is blocked, and that the vehicle will make a detour.

   Passengers receive information on the delay and new arrival time through the in-vehicle information systems and their ULTIMO app.

   The supervisor comments and marks the event as resolved and updates the city map marking this point of the road as blocked. The fleet orchestrator updates all itineraries of all vehicles to take into account the closed road.

Alternative flow 1 – Manual take over by supervisor:

7. Anna, Mikhail, Katarina and Igor are currently traveling in a ULTIMO vehicle when it detects a roadblock and stops.

   The vehicle informs (incident alert) the supervisor, providing all available information (video and possibly reading from the ADS).

The supervisor assesses the situation and informs the passengers that the road is partially blocked, and that he will take control of the vehicle to pass the obstacle.

Passengers receive information on the delay and new arrival time through the in-vehicle information systems and their ULTIMO app.

The supervisor comments and marks the event as resolved.

Alternative flow 2 – Automatic re-routing:

7. Anna, Mikhail, Katarina and Igor are currently traveling in a ULTIMO vehicle.

   The vehicle receives a V2X communication from a nearby infrastructure informing it of a roadblock.

   The information is passed to the fleet orchestrator who reschedules the itinerary.

   As there are no delays, no information is provided to the passengers.

Alternative flow 3 – Dynamic map update:

7. Anna, Mikhail, Katarina and Igor are currently traveling in a ULTIMO vehicle.

   The supervision centre receives a city map live update from a third party informing it of a roadblock on this vehicle path.

   The supervisor approves it, and the information is passed to the fleet orchestrator who reschedules the itinerary.

   As there are no delays, no information is provided to the passengers.

UC-17: Yield to an emergency vehicle

Actor(s)

Eva, 42 years old.

User background

Eva 42 years old lives with her partner and two children in the suburbs and has an office job in the city centre.

Goal

Eva is travelling in a ULTIMO vehicle. The vehicle must stop its trip and yield to allow an emergency service vehicle (ambulance, firefighting, police …) to pass.

Preconditions

Eva booked a trip with the ULTIMO app and is currently travelling inside a ULTIMO vehicle.

Flow:

7. Eva is travelling in a ULTIMO vehicle when an emergency vehicle (ambulance, police, firefighter) approaches from behind and requires overtaking the ULTIMO vehicle.

   The ULTIMO system detects the emergency vehicle, sees the lights and sirens on, and /or receives a V2V signal, and, as it blocks and prevents the emergency vehicle from moving forward, pulls over to the right and comes to a complete stop yielding to the emergency vehicle.

   The in-vehicle display and sound information systems inform passengers of the situation and to remain seated with their seatbelt on.

   The vehicle communicates to the supervisor the issue (as an information and the supervisor takes the actions, if any, as specified by the standing procedures), and an information is send to the fleet orchestrator regarding the possible additional delay (the vehicle informs when stopped and again when it resumes operation).

   Once the emergency vehicle has passed, the ULTIMO vehicle resumes its course.

UC-18: Vehicle stopped by the police

Actor(s)

Eva, 42 years old.

User background

Eva 42 years old lives with her partner and two children in the suburbs and has an office job in the city centre.

Goal

Eva is travelling in a ULTIMO vehicle. The vehicle must stop its trip to allow an emergency service vehicle (ambulance, firefighting, police …) to pass.

Preconditions

Eva booked a trip with the ULTIMO app and is currently travelling inside a ULTIMO vehicle.

Flow:

7. Eva is travelling in a ULTIMO vehicle when a police vehicle tries to pull over the ULTIMO vehicle.

   The police vehicle is in front of the ULTIMO vehicle, stopped and with blue lights and siren on.

   The ULTIMO system detects the police car and stops (or rather stops due to a detected obstacle – Use Case16) and informs the supervision centre.

   A supervisor assesses the situation, informs passengers and contacts the police services to resolve the situation. Depending on the duration the police intervention might take, a rescheduling of the reservations and vehicles might be necessary by the fleet orchestrator. The Supervisor decides based on standing procedures and policies.

   Once the situation is resolved, the ULTIMO vehicle resumes its course and informs passengers of the new arrival time through the in-vehicle display and audio systems. Passengers are also informed through their ULTIMO app.

   The supervisor comments and marks the event as resolved.

Alternative flow 1:

7. Eva is travelling in a ULTIMO vehicle when a police vehicle tries to pull over the ULTIMO vehicle.

   The police have contacted the supervision centre, and a supervisor has ordered the vehicle to stop at the nearest PUDO. The police vehicle can safely reach the ULTIMO vehicle and do their job.

   Depending on the duration the police intervention might take, a rescheduling of the reservations and vehicles might be necessary by the fleet orchestrator. The Supervisor decides based on standing procedures and policies.

   Passengers are informed of the sudden stop and delay through the in-vehicle display and audio systems and the ULTIMO app.

   The supervisor comments and marks the event as resolved.

UC-19: Object under the vehicle

Actor(s)

The ULTIMO vehicle.

User background

The ULTIMO vehicle is an autonomous vehicle.

Goal

The ULTIMO vehicle needs to be aware of its surroundings.

Preconditions

The ULTIMO vehicle is in operation.

Flow:

7. The ULTIMO vehicle is in operation, transporting passengers from one point to another. The vehicle drives over an object, and the object gets stuck under the vehicle. The ULTIMO system detects an object under itself, informs the

supervision centre and stops the vehicle. (Same situation as EUB-94-05: Malfunction, where the sensors and L4 capabilities detect an issue)

A supervisor assesses the situation. If the situation requires that the vehicle must be stopped, then the supervisor sends a new vehicle. If the vehicle can continue driving, then the supervisor simply informs the maintenance service.

The supervisor informs passengers. The supervisor comments and marks the event as resolved.

UC-20: Vehicle loses internet connection

Actor(s)

Peter, 68 years old.

User background

Peter is a recently retired man who still owns his car but rarely drives it anymore. He's starting to feel uneasy behind the wheel and is just beginning to explore public transport as an alternative.

Goal

Peter wants to travel using ULTIMO transportation service and to be able to rely on it.

Preconditions

Peter has booked a trip and is currently travelling inside a ULTIMO vehicle.

Flow:

7. Peter is travelling inside a ULTIMO vehicle when the vehicle loses internet connection and, as a safety measure, stops at the nearest safe spot.

   The in-vehicle display and sound information systems inform passengers of the issue.

The supervision centre is notified of the loss of connection with the vehicle.

A supervisor assesses the situation, sends a new vehicle, and informs passengers through the ULTIMO app. (Special Case of EUB-94-06: Malfunction)

UC-21: Deaf user

Actor(s)

Elena, 34 years old.

User background

Elena was born deaf and she is unable to communicate verbally. She often feels defenceless when using public transport or AV services as she is unable to communicate verbally.

Goal

Elena wants to use ULTIMO transportation service.

Preconditions

None.

Flow:

2. Elena is deaf and she is unable to communicate verbally, and she wants to book a trip with ULTIMO transportation service. Elena can easily book her trip through the ULTIMO app.
3. Elena receives information about her pick-up point location and the vehicle arrival time through the app.
5. At the pick-up point, Elena can identify the vehicle because its name is displayed on a screen outside the vehicle.

7. During travel, the vehicle is informing Elena of the current and next stop through the in-vehicle display information system. The ULTIMO app is also informing Elena when her stop is next, and it also gives her information on connections.

Alternative flow 1:

7. Elena is deaf and she is unable to communicate verbally, and she is currently traveling with ULTIMO transportation service. An issue arises and Elena must contact the customer service. She uses the in-vehicle touchscreen to access the customer service and can communicate with them by chat messages.

UC-22: No vehicle available

Actor(s)

Chloe, 32 years old.

User background

Chloe 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.

Goal

Chloe wants to use ULTIMO on-demand transportation service with her being in a wheelchair.

Preconditions

Chloe knows how the ULTIMO service work.

Flow:

2. Chloe wants to book a trip in a wheelchair. Chloe uses the booking app, where she has inserted in her profile the use of wheelchair, and defines her trip. However, at this

moment there are no available vehicles fulfilling the special needs of Chloe. The ULTIMO service replies that there are no vehicles available at this moment but there will be at a later time (1 hour later).

Chloe can reserve for a future time or abandon the reservation.

9. After having abandoned the reservation, Chloe uses the feedback form of the app to complain of the lack of service to the PTO.

UC-23: Use and Misuse of emergency stop button

Actor(s)

Antony, 30 years old.

User background

Antony, 30 years uses regularly the ULTIMO service to go to work. He is a very active individual and is regularly stressed while going to work. He takes work at home and brings it back the next day.

Goal

Arrive in time at his work.

Preconditions

Antony has booked a trip and is currently travelling inside a ULTIMO vehicle.

Flow:

7. Antony took the AV this morning and is currently traveling inside a ULTIMO vehicle towards his work. He suddenly realises that he as forgotten an important document he needs to bring to work. Antony panics and presses the emergency stop button, forcing the bus to stop. Antony was expecting to exit the bus, run home to pick up the documents.

The emergency button forces the vehicle to stop in place. Since it has stopped in the middle of the road, the doors remain closed. An emergency alert incident is raised to the back-office operator, who connects to the vehicle audiovisual system to evaluate the situation.

The back-office operator sees no emergency and thus interrogates the passengers.

Antony explains the situation. The back-office operator informs Antony that the emergency stop button is to be pressed only for emergency (and having forgotten a document is not one), and that there is a penalty for this. The back-office operator makes a note to the system which will be send to the customer management to issue (if decided so) the penalty.

8. Despite the request from Antony, the operator does not open the doors, cancels the emergency stop, puts the vehicle back in operation, and informs Antony that he can get off at the next official stop.

Alternative flow 1 - Legitimate use of emergency stop button:

7. Antony took the AV this morning and is currently traveling inside a ULTIMO vehicle towards his work. During the trip, due to an incident in the vehicle Antony presses the emergency stop button. (The incident can be an aggression, a medical emergency, etc.)

   The emergency button forces the vehicle to stop in place. Since it has stopped in the middle of the road, the doors remain closed. An emergency alert incident is raised to the back-office operator, who connects to the vehicle audiovisual system to evaluate the situation. The back-office operator communicates with the passengers and identifies the incident nature. Based on the identified incident the back-office operator engages the related procedures (as defined in the different use cases: in case of medical emergency the health incident procedure UC-3 is activated, in case of on-board aggression UC-04 is activated, in case of vehicle failure UC-15 is activated, etc.).

   Since the vehicle has been stopped in the middle of the road, the back-office operator requests a remote takeover of the vehicle to drive it to the roadside. A special operator in the back-office receives the request and remotely drives the vehicle to the roadside.

UC-24: Extra passengers

Actor(s)

Carlo, 62 years old.

User background

Carlo lives in a medium-sized town and is partially sighted. He uses a white cane for navigation and relies on the bus to go to work.

Goal

Carlo wants to use ULTIMO transportation service. He booked a trip for himself and wants to take two friends with him, but they did not book a trip.

Preconditions

Carlo already booked a trip. It is too late for his friends to book the same trip. His friends did not book a trip.

Flow:

6. Carlo is waiting for his ULTIMO vehicle to arrive at the pick-up point. There, Carlo meets two friends, talks with them. When the vehicle arrives, Carlo's friends decide to board the vehicle together with Carlo since there are free seats, but they don't have a booking. The ULTIMO system detects that extra passengers have boarded the vehicle. The information is passed to the back-office operator and the fleet orchestrator. The back-office operator, based on standard procedures and policies can either contact the passengers or simply ignore the situation or inform the intervention team to perform a ticket control in the specific vehicle. The fleet orchestrator can consider adapting the scheduled trips to accommodate the presence of extra passengers.

Needs associated

The preceding parts describe the use cases and the numbering system. These use cases associated elementary usage blocks and needs (Technology (T), Service (S), Vehicle Capability (V), or Policy (P)) are identified and listed here.

UC-01: A normal trip of a person

EUB-01-01: Mobile App Download and Configuration

T-01-01-01: Support for Android/iOS platforms.

P-01-01-01: Policy defining supported OS versions.

T-01-01-02: Secure profile storage (on-device or in PTO database).

S-01-01-01: Option to specify permanent special needs in the profile.

P-01-01-02: GDPR compliance for data storage and handling.

S-01-01-02: Confirmation message for successful setup.

EUB-01-02: Reserving a Trip

T-01-02-01: Integration of city maps with PUDO locations.

S-01-02-01: Accurate identification of PUDOs within proximity.

T-01-02-02: Search capabilities for locations by name or map.

T-01-02-03: Provide the different options, with related time delays and possible cost differentiation.

P-01-02-01: Policy defining maximum response time (e.g., 5 seconds).

T-01-02-04: Delivery of trip confirmation, vehicle identification and ETA.

P-01-02-02: Policy defining acceptable delays in trip confirmation.

EUB-01-03: Guidance to PUDO

T-01-03-01: Real-time navigation with location tracking.

S-01-03-01: Notifications to guide the passenger to the PUDO.

S-01-03-02: Confirmation of arrival at PUDO.

EUB-01-04: Waiting for the Ride

T-01-04-01: Real-time updates on ETA and vehicle identification.

S-01-04-01: Reliable notifications for any delays.

EUB-01-05: Connecting to the vehicle

T-01-05-01: External vehicle identification display.

T-01-05-02: Real-time updates of the vehicle ID in the app.

V-01-05-01: External display synchronised with the app information.

EUB-01-06: Boarding the Vehicle

P-01-06-01: Policy defining if the door opens automatically or requires a button press.

T-01-06-01-A: Automated door opening system triggered upon arrival at the PUDO.

P-01-06-01-A: Policy defining under what conditions the door opens automatically (e.g., detection of a confirmed passenger in proximity).

T-01-06-01-B: External button mechanism for manual door operation.

V-01-06-01-B: Button placement ensuring accessibility and usability for all passengers.

P-01-06-01-B: Policy defining how long the door remains unlocked for boarding after the button press.

T-01-06-02: Identification if the passenger has been seated.

P-01-06-02: Policy defining if seating is mandatory before departure.

T-01-06-03: Automated door closing mechanism.

V-01-06-02: Optional: Passenger detection system to confirm boarding.

P-01-06-03: Optional: Time duration that the door stays open.

EUB-01-07: Travel to Destination

T-01-07-01: Fleet orchestrator to dynamically adjust routes.

V-01-07-01: In-vehicle display and sound system.

T-01-07-02: In-vehicle display system synchronized with app updates (touch screen enable).

P-01-07-01: Policy defining required information for stop announcements.

T-01-07-03: App updates with route, stops and ETA.

EUB-01-08: Disembarking

T-01-08-01: Vehicle notification system for approaching stops (display/audio).

T-01-08-03: Passenger detection system to confirm disembarking.

S-01-08-01: Reliable alerts for passenger readiness.

P-01-08-01: Policy defining acceptable door opening and closing times.

T-01-08-02-A: Automated door opening system triggered upon arrival at the PUDO.

P-01-08-02-A: Policy defining conditions for automatic door opening.

T-01-08-02-B: Internal button mechanism for manual door operation.

V-01-08-01-B: Accessible button design to ensure ease of use for all passengers.

P-01-08-02-B: Policy defining how long the door remains unlocked after the button press.

EUB-01-09: Post-Trip Feedback and Guidance

T-01-09-01: Trip completion information and Feedback submission interface (if required).

S-01-09-01: Clear and simple feedback mechanism.

T-01-09-02: Navigation support for walking to the destination.

UC-02: Service abuse by a passenger

The following EUB and corresponding needs remain unchanged:

EUB-01-01: Mobile App Download and Configuration

EUB-01-02: Reserving a Trip

EUB-01-03: Guidance to PUDO

EUB-01-04: Waiting for the Ride

EUB-01-05: Connecting to the Vehicle

EUB-01-06: Boarding the Vehicle

EUB-02-07: Travel to Destination (Includes Service Abuse Handling)

EUB-01-08: Disembarking

EUB-01-09: Post-Trip Feedback and Guidance

The following EUB and corresponding needs are new or modified:

EUB-02-07: Travel to Destination (Includes Service Abuse Handling)

T-02-07-01: System detection of group booking without corresponding passengers.

T-02-07-02: Automated timeout for waiting on non-existent group members.

T-02-07-03: Real-time vehicle capacity update when group members fail to show up.

S-02-07-01: Notification to the supervision centre for manual intervention.

S-02-07-02: Supervisor protocol for warning passengers about abuse.

P-02-07-01: Policy defining maximum wait time for missing group members.

P-02-07-02: Policy on penalties for repeated service abuse (warnings, fines, or temporary bans).

UC-03: Health incident during transport

The following EUB and corresponding needs remain unchanged:

EUB-01-01: Mobile App Download and Configuration

EUB-01-02: Reserving a Trip

EUB-01-03: Guidance to PUDO

EUB-01-04: Waiting for the Ride

EUB-01-05: Connecting to the Vehicle

EUB-01-06: Boarding the Vehicle

EUB-02-07: Travel to Destination (adjusted to include incident management steps)

EUB-01-08: Disembarking - Step cancelled

EUB-01-09: Post-Trip Feedback and Guidance

The following EUB and corresponding needs are new or modified:

EUB-03-07: Travel to Destination (Includes Health Incident Management)

T-03-07-01: In-vehicle monitoring system for detecting anomalies in passenger behaviour.

T-03-07-02: Real-time data transmission from the vehicle to the supervision centre.

T-03-07-03: Remote video and audio feed access for supervisors.

T-03-07-04: Vehicle control system to enable safe emergency stops.

S-03-07-01: Supervisor training for handling medical emergencies.

S-03-07-02: Clear communication protocol between supervisors and passengers in emergencies.

P-03-07-01: Policy defining thresholds for detecting medical distress.

P-03-07-02: Policy defining safe locations for stopping in medical emergencies.

P-03-07-03: Privacy policy on the use of in-vehicle monitoring systems.

V-03-07-01: Automated door unlocking mechanism for emergency access.

UC-04: On-board aggression

The following EUB and corresponding needs remain unchanged:

EUB-01-01: Mobile App Download and Configuration

EUB-01-02: Reserving a Trip

EUB-01-03: Guidance to PUDO

EUB-01-04: Waiting for the Ride

EUB-01-05: Connecting to the Vehicle

EUB-01-06: Boarding the Vehicle

EUB-02-07: Travel to Destination (Includes Aggression Incident Handling)

EUB-01-08: Disembarking

EUB-01-09: Post-Trip Feedback and Guidance

The following EUB and corresponding needs are new or modified:

EUB-04-07: Travel to Destination (Includes Aggression Incident Handling)

T-04-07-01: AI-powered monitoring system to detect physical aggression and bullying.

T-04-07-02: Automated audio warnings inside the vehicle.

T-04-07-03: Real-time video/audio feed access for the supervision centre.

T-04-07-04: Passenger interface for manual incident reporting (touchscreen or app).

S-04-07-01: Supervisor protocol for intervening in passenger disputes.

S-04-07-02: Passenger awareness campaign on reporting misconduct.

P-04-07-01: Policy defining thresholds for detecting aggression via AI.

P-04-07-02: Policy defining acceptable intervention steps (warnings, stops, police intervention).

P-04-07-03: **Privacy policy** on monitoring passengers inside the vehicle.

UC-05: Vehicle doors stay opened

The following EUB and corresponding needs remain unchanged:

EUB-01-01: Mobile App Download and Configuration

EUB-01-02: Reserving a Trip

EUB-01-03: Guidance to PUDO

EUB-01-04: Waiting for the Ride

EUB-01-05: Connecting to the Vehicle

EUB-05-06: Boarding the Vehicle (Includes Extended Boarding Handling)

EUB-01-07: Travel to Destination

EUB-05-08: Disembarking (Includes Extended Disembarking Handling)

EUB-01-09: Post-Trip Feedback and Guidance

The following EUB and corresponding needs are new or modified:

EUB-05-06: Boarding the Vehicle (Includes Extended Boarding Handling)

T-05-06-01: System detection of extended door opening time.

T-05-06-02: Automated audio cue to remind passengers to clear the doors.

T-05-06-03: Real-time video feed access for supervisor intervention.

S-05-06-01: Supervisor training for assisting passengers with reduced mobility.

P-05-06-01: Policy defining maximum wait time before an alert is triggered.

V-05-06-01: Vehicle capabilit**y to override standard boarding time in special cases.**

EUB-05-08: Disembarking (Includes Extended Disembarking Handling)

T-05-08-01: System detection of delayed passenger exit.

T-05-08-02: Automated audio cue reminding passengers to exit quickly.

T-05-08-03: Supervisor video access for real-time assessment.

S-05-08-01: Supervisor training for handling accessibility-related delays.

P-05-08-01: Policy defining acceptable exit time before an alert is triggered.

V-05-08-01: Vehicle capability to override standard disembarking time in special cases.

UC-06: Missing bus stop

The following EUB and corresponding needs remain unchanged:

EUB-01-01: Mobile App Download and Configuration

EUB-01-02: Reserving a Trip

EUB-01-03: Guidance to PUDO

EUB-01-04: Waiting for the Ride

EUB-01-05: Connecting to the Vehicle

EUB-01-06: Boarding the Vehicle

EUB-01-07: Travel to Destination

EUB-01-08: Disembarking

EUB-01-09: Post-Trip Feedback and Guidance

The following EUB and corresponding needs are new or modified:

EUB-06-07A: Unexpected Passenger Detected During Non-Passenger Return to Depot (Responsive)

V-01-06-02: Passenger detection system in the vehicle

T-03-07-03: Remote video and audio feed access for supervisors (2 way).

S-06-07A-01: Supervisor dashboard to trigger communication, next stop and rerouting.

P-06-09A-01: Policy to allow depot rerouting in case of passenger detected.

EUB-06-07B: Unexpected Passenger Detected During Non-Passenger Return to Depot (Unresponsive)

V-01-06-02: Passenger detection system in the vehicle

T-03-07-03: Remote video and audio feed access for supervisors (2 way).

S-06-07A-01: Supervisor dashboard to switch to medical emergency.

UC-07: No show

The following EUB and corresponding needs remain unchanged:

EUB-01-01: Mobile App Download and Configuration

EUB-07-02: Reserving a Trip (modified for cancelation)

EUB-01-03: Guidance to PUDO

EUB-01-04: Waiting for the Ride

EUB-01-05: Connecting to the Vehicle

EUB-07-06: Boarding the Vehicle (No-Show Handling) (Modified)

EUB-01-07: Travel to Destination

EUB-01-09: Post-Trip Feedback and Guidance

The following EUB and corresponding needs are new or modified:

EUB-07-06: Boarding the Vehicle (No-Show Handling)

T-07-06-01: System detection of passenger no-show and automatic trip cancellation.

T-07-06-02: System-generated incident report to the supervision centre.

P-07-06-01: Policy defining maximum wait time before vehicle departs and trip is cancelled.

EUB-07-02: Trip Cancellation, No-Show, Penalties

P-07-02-01: Policy defining cancellation windows and penalties:

Cancellation before pickup window → No penalty.

Cancellation within 10 minutes of pickup → Partial charge.

Failure to cancel and no-show → Full charge.

T-07-02-01: Automated trip cancellation by fleet orchestrator

S-07-02-01: Penalty enforcement system, and notification system to inform passengers of no-show penalties/consequences/feedback.

UC-08: Excess luggage

The following EUB and corresponding needs remain unchanged:

EUB-01-01: Mobile App Download and Configuration

EUB-08-02: Reserving a Trip (Includes Stroller Selection) (Modified)

EUB-01-03: Guidance to PUDO

EUB-01-04: Waiting for the Ride

EUB-01-05: Connecting to the Vehicle

EUB-08-06: Boarding the Vehicle (Includes Excess Luggage Handling) (Modified)

EUB-01-07: Travel to Destination

EUB-08-08: Disembarking (Includes Excess Luggage Handling) (Modified)

EUB-01-09: Post-Trip Feedback and Guidance

The following EUB and corresponding needs are new or modified:

EUB-08-02: Reserving a Trip (Includes Stroller Selection)

T-08-02-01: Booking system to prompt passengers to specify extra luggage (stroller, suitcase, etc.).

T-08-02-02: Automated space allocation update based on stroller selection.

T-08-02-03: Fleet orchestrator adaptation for reallocating space dynamically.

P-08-02-01: Policy enforcing extra seat booking for strollers per local regulations.

EUB-08-06: Boarding the Vehicle (Includes Excess Luggage Handling)

T-08-06-01: System detection of excess luggage or space usage.

T-08-06-02: Real-time update of vehicle capacity after detecting excess luggage.

P-08-06-01: Policy defining boarding priority when extra luggage is present.

P-08-06-02: Policy defining time limit for passenger entry before vehicle departs.

EUB-08-08: Disembarking (Includes Excess Luggage Handling)

T-08-08-01: System detection of delayed passenger exit due to luggage.

T-08-08-02: Audio cue to remind passengers to clear the exit.

P-08-08-01: Policy defining acceptable disembarking time based on luggage type.

UC-09: Forgotten luggage

The following EUB and corresponding needs remain unchanged:

EUB-01-01: Mobile App Download and Configuration

EUB-01-02: Reserving a Trip

EUB-01-03: Guidance to PUDO

EUB-01-04: Waiting for the Ride

EUB-01-05: Connecting to the Vehicle

EUB-01-06: Boarding the Vehicle

EUB-01-07: Travel to Destination

EUB-09-08: Disembarking (Includes Forgotten Item Handling) (Modified)

EUB-09-09: Post-Trip Forgotten Item Notification and Recovery (New)

The following EUB and corresponding needs are new or modified:

EUB-09-08: Disembarking (Includes Forgotten Item Handling)

T-09-08-01: AI-based detection of unattended belongings after passenger exit.

T-09-08-02: System-triggered audio cue reminding passengers to check for personal items.

S-09-08-01: Supervisor intervention process for item retrieval.

P-09-08-01: Policy defining how forgotten items are classified and handled (urgent vs. non-urgent recovery).

P-09-08-02: Policy defining to handle forgotten items reported by the passengers (urgent vs. non-urgent recovery).

EUB-09-09: Post-Trip Forgotten Item Notification and Recovery

T-09-09-01: Automated notification system to inform passengers of found items.

S-09-09-01: Defined collection points for lost items based on PTO guidelines.

P-09-09-01: Policy defining timelines for keeping and disposing of lost items.

UC-10: Public transport at night

The following EUB and corresponding needs remain unchanged:

EUB-01-01: Mobile App Download and Configuration

EUB-01-02: Reserving a Trip

EUB-01-03: Guidance to PUDO

EUB-01-04: Waiting for the Ride

EUB-01-05: Connecting to the Vehicle

EUB-01-06: Boarding the Vehicle

EUB-01-07: Travel to Destination

EUB-01-08: Disembarking (Includes Forgotten Item Handling)

EUB-01-09: Post-Trip Forgotten Item Notification and Recovery

UC-11: Blind user

The following EUB and corresponding needs remain unchanged:

EUB-01-04: Waiting for the Ride

The following EUB and corresponding needs are new or modified:

EUB-01-01: Mobile App Download and Configuration

T-11-01-01: Full support for Android/iOS accessibility APIs (screen readers, voice-over, text resizing, contrast modes).

S-11-01-01: User profile allows for the declaration of blind or low vision.

EUB-01-02: Reserving a Trip

T-11-02-01: Booking workflow must be navigable using a screen reader or voice commands.

S-11-02-01: Confirmation includes verbal and haptic feedback.

EUB-01-03: Guidance to PUDO

T-11-03-01: App provides geo-coordinates of PUDO and external navigation app linking (e.g., Google Maps or pedestrian-focused apps).

T-11-03-02: Audio and haptic cues guide user to the exact PUDO.

EUB-01-05: Connecting

V-11-05-01: Vehicle emits external sound signals when it arrives, localized to the correct PUDO or to its adjusted location (within a few meters).

T-11-05-01: App provides sound and vibration alert upon vehicle arrival, synchronized with vehicle positioning.

P-11-05-01: How from the designed PUDO location the vehicle is allowed to stop.

EUB-01-06: Boarding the Vehicle

V-11-06-01: Door-opening button placed in a standard, clearly marked, tactile-accessible location.

S-11-06-01: Fleet orchestrator assigns extended door-opening and boarding time for blind or low vision passengers.

P-11-06-01: PTO policy defining minimum allocated extra time for boarding blind or low vision passengers.

EUB-01-07: Travel to Destination

T-11-07-01: ULTIMO app announces upcoming stop and connections via audio and/or haptic alerts.

S-11-07-01: Blind or low vision passengers can opt-in to connection info and accessibility assistance.

EUB-01-08: Disembarking

T-11-08-01: App and vehicle notify user (via audio and haptics) that the vehicle has arrived at the destination stop.

S-11-08-01: Fleet orchestrator ensures door remains open longer to allow safe disembarkation.

P-11-08-01: PTO policy requiring extended disembarkation time for registered blind or low vision users.

EUB-01-09: Post-Trip Feedback and Guidance

T-11-09-01: Feedback and rating features accessible via screen readers and voice input.

S-11-09-01: User can review the trip independently without external assistance.

UC-12: Using on-demand services without the app

The following EUB and corresponding needs remain unchanged:

EUB-01-01: Mobile App Download and Configuration (Skipped, since the app is not used)

EUB-12-02: Reserving a Trip (Without the Smartphone App) (Modified)

EUB-01-03: Guidance to PUDO

EUB-01-04: Waiting for the Ride (Limited, no app-based notifications)

EUB-12-05: Connecting to the Vehicle (Trip Validation Without App) (Modified)

EUB-01-06: Boarding the Vehicle

EUB-01-07: Travel to Destination

EUB-01-08: Disembarking

EUB-01-09: Post-Trip Feedback and Guidance (Skipped if no digital access is available)

The following EUB and corresponding needs are new or modified:

EUB-12-02: Reserving a Trip (Without the Smartphone App)

T-12-02-01: Support for booking via web app and phone call.

T-12-02-02: Generation of printable/email-based QR codes or validation numbers.

S-12-02-01: Customer service assistance for phone-based bookings.

P-12-02-01: Policy defining locations and procedures for booking via physical terminals.

T-12-02-03: Installation of interactive terminals at selected PUDOs.

EUB-12-05: Connecting to the Vehicle (Trip Validation Without App)

T-12-05-01: Onboard QR code scanner and manual validation entry system.

S-12-05-01: User-friendly interface for validating trips without the app.

P-12-05-01: Policy defining how non-app users verify their trip upon entry.

UC-13: User in a wheelchair

The following EUB and corresponding needs remain unchanged:

EUB-01-01: Mobile App Download and Configuration

EUB-13-02: Reserving a Trip (Wheelchair Passenger Adaptations) (Modified)

EUB-01-03: Guidance to PUDO

EUB-01-04: Waiting for the Ride

EUB-01-05: Connecting to the Vehicle

EUB-13-06: Boarding the Vehicle (Includes Accessibility Features and Groom Assistance) (Modified)

EUB-01-07: Travel to Destination (Assistance available during trip if needed)

EUB-13-08: Disembarking (Includes Accessibility Features and Groom Assistance) (Modified)

EUB-01-09: Post-Trip Feedback and Guidance

The following EUB and corresponding needs are new or modified:

EUB-13-02: Reserving a Trip (Wheelchair Passenger Adaptations)

T-13-02-01: Booking system to **prompt passengers for accessibility needs (wheelchair selection, groom service request)**.

T-13-02-02: Automated **matching of accessible vehicles to wheelchair users**.

P-13-02-01: Policy ensuring **PTO provides specialized vehicles for multiple wheelchair users**.

S-13-02-01: Customer **support for accessibility service reservations**.

P-13-02-02: Policy ensuring **that the users declaring special needs are eligible (abuse protection –** possibly simply by having mobile ticket control teams- other options can be post analysis of passenger reservations (once has a broken leg, once is pregnant, once is wheelchair ...).

EUB-13-06: Boarding the Vehicle (Includes Accessibility Features and Groom Assistance)

S-13-06-01: Groom service availability for boarding assistance if requested.

P-13-06-01: Policy ensuring priority access for passengers with mobility needs.

V-13-06-01: Vehicle capability to secure wheelchairs safely.

V-13-06-02: Automated ramp/lift deployment for wheelchair access.

EUB-13-08: Disembarking (Includes Accessibility Features and Groom Assistance)

S-13-08-01: Groom service availability for disembarking assistance if requested.

P-13-08-01: Policy ensuring safe and accessible disembarking procedures.

V-13-08-01: Vehicle capability to secure and release wheelchairs safely.

V-13-06-02: Automated ramp/lift deployment for wheelchair access.

UC-14: Passenger unbuckles his seatbelt while vehicle is in motion

The following EUB and corresponding needs remain unchanged:

EUB-01-01: Mobile App Download and Configuration

EUB-01-02: Reserving a Trip

EUB-01-03: Guidance to PUDO

EUB-01-04: Waiting for the Ride

EUB-01-05: Connecting to the Vehicle

EUB-01-06: Boarding the Vehicle (Includes seatbelt requirement before departure)

EUB-14-07: Travel to Destination (Seatbelt Monitoring and Safety Intervention) (Modified)

EUB-01-08: Disembarking

EUB-01-09: Post-Trip Feedback and Guidance

The following EUB and corresponding needs are new or modified:

EUB-14-07: Travel to Destination (Seatbelt Monitoring and Safety Intervention)

T-14-07-01: System detection of seatbelt status in real-time.

T-14-07-02: Automated in-vehicle display and audio warnings for unbuckled seatbelts (need to define how long the alarm sounds and if the supervisor can cancel it).

S-14-07-01: Supervision centre notification when a passenger unbuckles a seatbelt.

P-14-07-01: Policy defining whether a trip can continue if a passenger refuses to buckle their seatbelt.

P-14-07-02: Policy defining supervisor intervention protocol for seatbelt violations.

UC-15: Vehicle breaks down

The following EUB and corresponding needs remain unchanged:

EUB-01-01: Mobile App Download and Configuration

EUB-01-02: Reserving a Trip

EUB-01-03: Guidance to PUDO

EUB-15-04: Waiting for the Ride (Vehicle Breakdown Handling Before Pickup) (Modified)

EUB-01-05: Connecting to the Vehicle (If replacement vehicle arrives, connection process remains standard.)

EUB-15-07: Travel to Destination (Vehicle Breakdown Handling During Travel) (Modified)

EUB-01-08: Disembarking (For passengers who transfer to a new vehicle.)

EUB-90-05: Vehicle Malfunction Handling (System Detection, Supervision, and Intervention) (New - Vehicle Service Block)

The following EUB and corresponding needs are new or modified:

EUB-15-04: Waiting for the Ride (Vehicle Breakdown Handling Before Pickup)

V-15-07-01: System detection of vehicle failures and breakdowns via sensors.

T-15-04-01: Automated trip rescheduling and passenger notifications.

P-15-04-01: Policy defining maximum delay tolerance before passengers must be rebooked.

S-15-04-01: Customer support for delay handling and passenger assistance.

EUB-15-07: Travel to Destination (Vehicle Breakdown Handling During Travel)

V-15-07-01: System detection of vehicle failures and breakdowns via sensors.

T-15-07-01: Automated rescheduling and passenger notifications.

P-15-07-01: Policy defining passenger handling in case of breakdowns (waiting vs. disembarking).

S-15-07-01: Supervisor intervention and communication process.

UC-16: Vehicle meets a roadblock

The following EUB and corresponding needs remain unchanged:

EUB-01-01: Mobile App Download and Configuration

EUB-01-02: Reserving a Trip

EUB-01-03: Guidance to PUDO

EUB-01-04: Waiting for the Ride

EUB-01-05: Connecting to the Vehicle

EUB-01-06: Boarding the Vehicle

EUB-16-07: Travel to Destination (Roadblock Detection and Response) (Modified)

EUB-01-08: Disembarking

EUB-90-06: Roadblock Detection and Fleet Adaptation (System and Supervisor Intervention) (New - Vehicle Service Block)

The following EUB and corresponding needs are new or modified:

EUB-16-07: Travel to Destination (Roadblock Detection and Response)

T-16-07-01: System detection of roadblocks using ADS and onboard sensors.

T-16-07-02: Incident alert to the supervision centre with live video feed.

T-16-07-03: Integration of V2X communications for real-time rerouting.

P-16-07-01: Policy defining when manual takeover is required.

P-16-07-02: Policy for passenger notifications based on delay severity.

S-16-07-01: Fleet orchestrator capability for real-time detour planning.

EUB-90-06: Roadblock Detection and Fleet Adaptation (System and Supervisor Intervention)

T-90-06-01: System capability to detect roadblocks and communicate with the fleet orchestrator.

T-90-06-02: Live video and ADS data transmission to the supervision centre.

T-90-06-03: Integration of third-party dynamic map updates into the fleet management system.

S-90-06-01: Automated detour and fleet rescheduling.

P-90-06-01: Policy defining supervisor intervention and when manual takeover is required.

UC-17: Yield to an emergency vehicle

The following EUB and corresponding needs remain unchanged:

EUB-01-01: Mobile App Download and Configuration

EUB-01-02: Reserving a Trip

EUB-01-03: Guidance to PUDO

EUB-01-04: Waiting for the Ride

EUB-01-05: Connecting to the Vehicle

EUB-01-06: Boarding the Vehicle

EUB-17-07: Travel to Destination (Yielding to an Emergency Vehicle) (Modified)

EUB-01-08: Disembarking

The following EUB and corresponding needs are new or modified:

EUB-17-07: Travel to Destination (Yielding to an Emergency Vehicle)

V-17-07-01: Vehicle capability to detect emergency vehicles using V2V communication and visual sensors.

T-17-07-01: Automated hazard light activation and safe yielding behaviour.

T-01-07-02: In-vehicle display system synchronized with app updates.

T-17-07-03: System capability to log and communicate emergency stops to the fleet orchestrator.

P-17-07-01: Policy defining when a supervisor should intervene beyond the automated yielding response.

S-17-07-01: Supervisor decision-making process for handling fleet-wide emergency interactions.

UC-18: Vehicle stopped by the police

The following EUB and corresponding needs remain unchanged:

EUB-01-01: Mobile App Download and Configuration

EUB-01-02: Reserving a Trip

EUB-01-03: Guidance to PUDO

EUB-01-04: Waiting for the Ride

EUB-01-05: Connecting to the Vehicle

EUB-01-06: Boarding the Vehicle

The following EUB and corresponding needs are new or modified:

EUB-18-07: Travel to Destination (Police Intervention and Supervisor Coordination)

V-17-07-01: Vehicle capability to detect emergency vehicles using V2V communication and visual sensors.

T-17-07-01: Automated hazard light activation and safe yielding behaviour.

T T-01-07-02: In-vehicle display system synchronized with app updates.

T-18-07-04: System capability to log and communicate police stops to the fleet orchestrator.

P-18-07-01: Policy defining supervisor intervention and when fleet rescheduling should occur.

S-18-07-01: Supervisor decision-making process for handling fleet-wide police interventions.

UC-19: Object under the vehicle

The following EUB and corresponding needs remain unchanged:

EUB-01-07: Travel to Destination (Vehicle in normal operation)

EUB-94-06: Malfunction (Vehicle Stops Due to an Object Underneath) (Reused)

EUB-90-02: Fleet Rescheduling (If the Vehicle is Removed from Service) (Reused)

The following EUB and corresponding needs are new or modified:

EUB-94-06: Malfunction (Vehicle Stops Due to an Object Underneath)

T-94-06-01: Incident detection system to classify disabling malfunctions or accidents (L4 capabilities)

T-94-06-01: Real-time communication with the fleet orchestrator to report the vehicle's condition and location.

T-94-06-03: Supervisor dashboard for incident handling and intervention coordination.

S-94-06-01: Notifications for fleet operators and recovery teams about the incident and required actions.

S-94-06-02: Real-time updates for the recovery team to locate and retrieve the vehicle.

S-94-06-03: Dynamic fleet updates to account for vehicle removal and re-booking of passengers by the fleet orchestrator

V-94-06-01: Autonomous systems for safely halting and securing the vehicle in case of disabling incidents.

V-94-06-02: Automated vehicle diagnostics and malfunction alerts.

V-90-06-01: Vehicle capability to self-diagnose and report failures.

P-94-06-01: Protocols for immediate vehicle removal and recovery team dispatch.

P-94-06-02: Incident classification guidelines for determining disabling malfunctions.

P-90-06-03: Policy defining when a vehicle should be pulled from service.

EUB-90-02: Fleet Rescheduling (If the Vehicle is Removed from Service)

T-90-02-01: Automated fleet orchestrator capability to reschedule affected trips.

S-90-02-01: Passenger communication regarding delays, alternative routes, and new ETAs.

P-90-02-01: Policy defining thresholds for removing a vehicle from service due to operational issues.

UC-20: Vehicle loses internet connection

The following EUB and corresponding needs remain unchanged:

EUB-01-07: Travel to Destination (Vehicle in normal operation)

EUB-94-06: Malfunction (Vehicle Stops Due to Internet Loss) (Reused and Adjusted for Connectivity Issues)

EUB-90-02: Fleet Rescheduling (If the Vehicle is Removed from Service) (Reused if Necessary)

The following EUB and corresponding needs are new or modified:

EUB-94-06: Malfunction (Vehicle Stops Due to Internet Loss)

V-20-07-01: Vehicle system to detect internet connectivity issues and initiate safe stopping procedures.

T-20-07-01: Backup communication protocol for emergency alerts to the supervision centre.

T-20-07-02: Ability of the vehicle to autonomously display information in cases of loss of connectivity to the Passenger notification system (in-vehicle displays and audio cues).

S-20-07-01: Supervisor-led recovery process, including potential remote troubleshooting.

P-20-07-01: Policy defining acceptable downtime before a vehicle must be removed from service in case of loss of connectivity.

UC-21: Deaf user

The following EUB and corresponding needs remain unchanged:

EUB-01-01: Mobile App Download and Configuration

EUB-01-02: Reserving a Trip (Modified: Accessibility Selection)

EUB-01-03: Guidance to PUDO

EUB-01-04: Waiting for the Ride

EUB-01-05: Connecting to the Vehicle

EUB-01-06: Boarding the Vehicle

EUB-21-07: Travel to Destination (Visual Communication and Customer Service Chat Support) (Modified for Accessibility)

EUB-01-08: Disembarking

The following EUB and corresponding needs are new or modified:

EUB-01-02: Reserving a Trip (Accessibility Selection)

T-21-02-01: App feature to store and apply accessibility preferences for deaf users.

S-21-02-01: System ensures trip assignment prioritizes vehicles with enhanced accessibility features.

EUB-21-07: Travel to Destination (Visual Communication and Customer Service Chat Support)

T-01-07-02: In-vehicle display system synchronized with app updates.

T-21-07-01: Integrated chat function to the app connecting passengers to customer service.

T-21-07-02: Integrated chat function to the in-vehicle communication system to passengers to supervisor or customer service.

S-21-07-01: Supervisor protocol for handling non-verbal support requests.

UC-22: No vehicle available

The following EUB and corresponding needs remain unchanged:

EUB-01-01: Mobile App Download and Configuration

EUB-22-02: Reserving a Trip (Service Unavailable Handling) (Modified)

EUB-01-03: Guidance to PUDO (If Antoine successfully reserves a later trip.)

EUB-01-04: Waiting for the Ride (If Antoine successfully reserves a later trip.)

EUB-01-05: Connecting to the Vehicle (If Antoine successfully reserves a later trip.)

EUB-01-06: Boarding the Vehicle (If Antoine successfully reserves a later trip.)

EUB-01-07: Travel to Destination (If Antoine successfully reserves a later trip.)

EUB-01-08: Disembarking (If Antoine successfully reserves a later trip.)

EUB-22-09: Post-Trip Feedback and Complaint Submission (Modified)

The following EUB and corresponding needs are new or modified:

EUB-22-02: Reserving a Trip (Service Unavailable Handling)

T-22-02-01: System capability to recognize accessibility needs and check vehicle availability accordingly.

T-22-02-02: Automated alternative trip suggestions if no vehicles are available.

S-22-02-01: Customer service support for passengers requiring special vehicle accommodations.

P-22-02-01: Policy defining maximum acceptable wait time before a passenger is considered unable to book a trip.

EUB-22-09: Post-Trip Feedback and Complaint Submission

T-22-09-01: System capability to log and process service interactions and complaints via the app.

T-22-09-02: Integrate in passenger review information about the reported incident (possibly the failed reservation attempt, and/or time and place of the request (so the system can identify why it was rejected).

S-22-09-01: Feedback submission interface for reporting accessibility issues.

P-22-09-01: PTO policy on handling complaints related to unavailable services.

UC-23: Use and Misuse of emergency stop button

The following EUB and corresponding needs remain unchanged:

EUB-01-01 to EUB-01-06: Standard trip stages including boarding and traveling

EUB-01-07 and EUB-01-08: To be resumed after handling the incident

The following EUB and corresponding needs are new or modified:

EUB-23-07: Emergency Stop Button Pressed (Misuse or Legitimate)

V-23-07-01: In-vehicle emergency stop button.

T-23-07-01: Emergency stop signal sent to vehicle control and supervision centre.

P-23-07-01: Policy defining valid reasons for using emergency stop.

T-23-07-02: System rule: doors remain locked if vehicle is not at a safe stop

P-23-07-02: Safety policy for door locking in non-authorized locations

S-23-07-01: Automatic incident alert to back-office operator

T-03-07-02: Real-time data transmission from the vehicle to the supervision centre

T-03-07-03: Passenger communication interface

P-23-07-03: Supervisor decision tree for classifying misuse

P-23-07-04: Policy defining sanctions for inappropriate use of emergency stop

T-23-07-05: Supervisor log interface for flagging misuse to customer management

S-23-07-02: back-office action: suppress the emergency stop and reactivate the vehicle

T-23-07-06: Remote driving interface to move vehicle to safe location

P-23-07-05: Policy for remote takeover procedures following emergency stops

UC-24: Extra passengers

The following EUB and corresponding needs remain unchanged:

EUB-01-01: Mobile App Download and Configuration

EUB-01-02: Reserving a Trip (Carlo books alone)

EUB-01-03: Guidance to PUDO

EUB-01-04: Waiting for the Ride

EUB-01-05: Connecting to the vehicle

EUB-01-06: Boarding the Vehicle

EUB-01-07: Travel to Destination

EUB-01-08: Disembarking

EUB-01-09: Post-Trip Feedback and Guidance

The following EUB and corresponding needs are new or modified:

EUB-24-06: Unauthorized Passengers Detected During Boarding or Travel

V-24-06-01: Sensors to detect number of passengers onboard.

T-24-06-01: Passenger count verification system against reservation data.

T-24-06-02: Real-time alert system to supervision and orchestrator.

S-24-06-01: Integration between vehicle, supervision, and fleet orchestrator for anomaly management.

P-24-06-01: Policy defining how to handle unauthorized boarding.

S-24-06-02: Supervisor notification and decision-making interface.

T-24-06-03: Fleet orchestrator trip adjustment logic.

P-24-06-02: Policy defining when and how fleet adjustments are triggered by extra passengers.

Annex C Vehicle Capabilities

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 D Vehicle capabilities Overall Clustering

Generic capabilities

Vehicle Capability	Importance level	Comments
Emergency stop button	Obligatory	Same as SOS mechanism?
Ability to contact remote operator (No safety driver on board)		
SOS mechanism		
Seatbelts		Depending on regulations
First aid kit		Add on service / not part of the vehicles
Emergency windows		
Data transfer to back office: video, audio, other		Depending on local regulations on what data need to be send back / locally stored
Steering wheel / controller (For safety operator)		Need to evolve / nothing in the vehicle / Passengers shouldn't have access
Operation temperature min/max		
Radar		
Camera		

Infrared camera		
4G		
5G		
IMU		
RTK-GNSS		
Computer		
Protection level of vehicle computer hardware (ease of access)		
V2V		
V2X		
Passenger information system		
Loudspeaker		For passenger information provision
Screen(s)/Other to indicate line number		
V2Passenger	Optional	
Integration of roadside sensors		For smoother operations of the vehicle and safety
Charging port for passengers (USB type and amount)		Nice to have for passenger comfort. Issues on cybersecurity need to be addressed.
Indoor CO2 sensor		

Automated External Defibrillator (resuscitation device)	Optional (pending local legislation)	Not part of the vehicle itself. Add-on device to be installed by the PTO

Vehicle selection features

Vehicle selection features	Importance level	Comments
Wheelchair capabilities	Blocking	Cannot send a vehicle that does not support wheelchair transfer
Vehicle passenger capacity – available capacity		If vehicle is full (or to capacity) cannot send it for the trip
Status of Battery		
Range (Km)		We cannot send a vehicle to a route for which its range will not be enough
Space for extra items		
Height		Depending on ODD
Length		Depending on ODD
Width		Depending on ODD
Weight		Depending on ODD
Height off the ground of the vehicle with respect to the road		Depending on ODD
Maximum slope		Depending on ODD
Speed authorization (km/h)	Non-blocking	We can send a slower vehicle to a fast road (with limits) or a fast

		vehicle to slow road (reducing its speed)

Annex E Vehicle Capabilities per Use Case

Use Case	EUB	Vehicle Need	Vehicle capability/ Service	Fleet Orchestrator/ Manufacturer / Operator	Comments
UC-01 **Normal trip**	**EUB-01-05**	**V-01-05-01**: External display synchronised with the app information	VC: Screen(s)/Other to indicate line number Service: Veh.ID	**Manufacturer**: • provide screen • provide via API control of messages to be shown on screen **Fleet Orchestr.**: Synchronise with app info **Operator**: Policy on vehicle identification (bus number, Ride number, real time location, time of arrival, free seats)	Depends of service model (feeder, free floating etc.). Policy to be added. Apply standard
	EUB-01-06	**V-01-06-01**: Button placement ensuring accessibility and usability for all	VC: Door opening / closing control	**Man**: provide button at appropriate position and type (acc.to accessib. std) **Operator**: Ensure the button is locatable for blind	**Apply standard** TSI PRM 5.3.2.1. Interface of the door control device

		passengers. (external button to open the door)		persons and wheelchair users.	
		V-01-06-02: Optional: Passenger detection system	VC: • Passenger counting system • Ticket verification system Service: • In vehicle monitoring • Vehicle identification service: Used to match a reservation for a certain number of passengers with the vehicle assigned via the app.	Information about the number of people who should be on the reservation. Third-party system: Detection of actual number of passengers + alert in case of mismatch. + waiting time per profile Need for policy/Operator: • control if the person who enters the vehicle has booked a ride. • control number of passengers to specify capacity • Door open time Slot.	The FO needs to identify how many people are currently on board.
	EUB-01-08	**V-01-08-01-B**: Accessible button design	VC: Door opening / closing control	Manufacturer: design according to accessibility standards (type of button,	**Apply standard** TSI PRM

		to ensure ease of use for all passengers. (door operation)		force to operate, tactile, etc.)	5.3.2.1. Interface of the door control device
UC-02 **Service abuse by passenger**	**EUB-01-05**	See UC1	See UC1	See UC1	
	EUB-01-06	See UC1	See UC1	See UC1	
	EUB-01-08	See UC1	See UC1	See UC1	
UC-03 **Health incident during transportation**	**EUB-01-05**	See UC1	See UC1	See UC1	
	EUB-01-06	See UC1	See UC1	See UC1	
	EUB-01-08	See UC1	See UC1	See UC1	
	EUB-03-07	**V-03-07-01**: Automated door unlocking mechanism for emergency access.	VC: • Emergency stop button • Ability to contact the remote operator (No	Operator: Must have the possibility to control the doors from the remote supervision center, if the automated process failed.	

			safety driver on board) • Automated External Defibrillator (resuscitation device) • SOS mechanism Service: • Two-way communication tool (pax report operator) • In-Vehicle Monitoring (Operator gets the alert)	Stop safely and Operator Remotely can take control of the vehicle Manufacturer: APIs for accessing location information, executing emergency missions (deviation), and controlling door opening. FO: Information about the location of the vehicle and the next accessible PUDO for passengers to disembark.	
UC-04 **On-board aggression**	**EUB-01-05**	See UC1	See UC1	See UC1	
	EUB-01-06	See UC1	See UC1	See UC1	
	EUB-01-08	See UC1	See UC1	See UC1	
UC-05	**EUB-01-05**	See UC1	See UC1	See UC1	

Vehicle doors stay opened					
	EUB-05-06	**V-05-06-01**: Vehicle capability to **override standard boarding time in special cases**.		Safety operator: Remote control	These two depend on how the door opening and closing is override and by who. So, if they are fully fleet orchestrator controlled, then this becomes a service. If they are hardwired to the vehicle, then we need the to be able to override.
	EUB-05-08	**V-05-08-01**: Vehicle capability to **override standard disembarking time in special cases**.	VC: 4G/5G	**FO**: • Door opening / closing control • Assignment of a customized boarding/disembarkation time for certain profiles via the back-office • in worst case must also have a plan B for the upcoming rides of this vehicle. (e.g. send a different Vehicle)	
UC-06 **Missing bus stop**	**EUB-01-05**	See UC1	See UC1	See UC1 Notification to the user before the stop via the app	

	EUB-01-06	See UC1	See UC1	See UC1	
	EUB-06-07A/B	**V-01-06-02:** Passenger detection system in the vehicle	Camera can detect and count people (pose estimation) the vehicle wait until the passenger is dropped		
	EUB-01-08	See UC1	See UC1	See UC1	
UC-07 No show	**EUB-01-05**	See UC1	See UC1 Detection of no show via the pax counting system	See UC1	The shuttle should inform the FO about passenger no show
UC-08 Excess luggage	**EUB-01-05**	See UC1	See UC1	See UC1	Most likely too constrained for users
UC-09 Forgotten belongings	**EUB-01-05**	See UC1	See UC1	See UC1	
	EUB-01-06	See UC1	See UC1	See UC1	

UC-10 **Public transport at night**	**EUB-01-05**	See UC1	See UC1	See UC1	
	EUB-01-06	See UC1	See UC1	See UC1	
	EUB-01-08	See UC1	See UC1	See UC1	
UC-11 **Visual impairment**	**EUB-01-05**	**V-11-05-01:** Vehicle emits external sound signal when it arrives, localized to the correct PUDO or to its adjusted location (within a few meters).	VC: • Loudspeaker • Audio guidance to doors • Microphone		
	EUB-01-06	**V-11-06-01**: Door-opening button placed in standard, clearly marked, tactile-accessible location.	VC: • Audio guidance to doors • Door opening / closing control • Stop button	**Apply standard** TSI PRM	Share info with blind people association or municipalities to disseminate this capability and service

UC-12 **Using on-demand services without the app**	**EUB-01-06**	See UC1	See UC1	See UC1	
	EUB-01-08	See UC1	See UC1	See UC1	
UC-13 **User in a wheelchair**	**EUB-01-05**	See UC1	See UC1	See UC1	
	EUB-13-06	**V-13-06-01**: Vehicle capability to **secure wheelchairs safely**.	VC: Room for wheelchair, walker, stroller	**Manufacturer**: fixing points for wheelchairs, according to regulatory standards.	
		V-13-06-02: Automated **ramp/lift deployment for wheelchair access**	VC: • Wheelchair ramp • Wheelchair access- No assistance • Wheelchair access – with assistance	**Manufacturer**: provide automated ramp/lift	Included in UC1 via the app

	EUB-13-08	**V-13-08-01**: Vehicle capability to **secure and release wheelchairs safely**.	VC: Room for wheelchair, walker, stroller	**Manufacturer**: fixing points for wheelchairs, according to regulatory standards.	Should be accessible to the user in the wheelchair to fix the points ==> follow existing standards
		V-13-06-02: Automated **ramp/lift deployment for wheelchair access**	VC: • Wheelchair ramp • Wheelchair access- No assistance • Wheelchair access – with assistance		
UC-14 **Passenger unbuckles seatbelt while vehicle is in motion.**	**EUB-01-05**	See UC1	See UC1	See UC1	
	EUB-01-06	*Seatbelt requirement before departure*	VC: Seatbelts (and detection if buckle or not)	Policy: Fleet Orchestrator informed (or not) about seatbelt status and related actions (start or not the vehicle/provide warning/other)	
	EUB-01-08	See UC1	See UC1	See UC1	

UC-15 **Vehicle breaks down**	**EUB-15-04**	**V-15-07-01**: System **detection of vehicle failures and breakdowns** via sensors.	VC: • State of sensors • State of autonomous system	**FO**: Video feed (internal / external) **FO**: GNSS location	
	EUB-01-05	See UC1	See UC1	See UC1	
	EUB-15-07	**V-15-07-01**: System **detection of vehicle failures and breakdowns** via sensors.	VC: • State of sensors • State of autonomous system	**FO**: Video feed (internal / external) and GNSS location	
	EUB-01-08	See UC1	See UC1	See UC1	
UC-16 **Vehicle meets a roadblock**	**EUB-01-05**	See UC1	See UC1	See UC1	
	EUB-01-06	See UC1	See UC1	See UC1	
	EUB-01-08	See UC1	See UC1	See UC1	
UC-17	**EUB-01-05**	See UC1	See UC1	See UC1	

Yield to an emergency vehicle	**EUB-01-06**	See UC1	See UC1	See UC1	
	EUB-17-07	**V-17-07-01**: Vehicle capability to detect emergency vehicles using V2V communication and visual sensors.	VC: • V2V • V2X • Integration of roadside sensors • Camera	**FO**: receiving and using V2X information to the ADS.	
	EUB-01-08	See UC1	See UC1	See UC1	
UC-18 Stopped by police	**EUB-01-05**	See UC1	See UC1	See UC1	
	EUB-01-06	See UC1	See UC1	See UC1	
	EUB-18-07	**V-17-07-01**: Vehicle capability to detect emergency vehicles using V2V communication and visual sensors.	VC: • V2V • V2X • Integration of roadside sensors • Camera • Microphone	**FO**: receiving and using V2X information to the ADS.	

	EUB-01-08	See UC1	See UC1	See UC1	
UC-19 **Object under the vehicle**	**EUB-94-06**	**V-94-06-01**: Autonomous systems for safely halting and securing the vehicle in case of disabling incidents.	VC: • Loudspeaker • Passenger Information System • SOS mechanism • Communication with passengers	Intervention team : Processes defined per site in the policies. **Manufacturer:** the vehicle could have an offline/internal procedure played to help passengers (how to exit the vehicle, what to do in case of fire, ...)	
		V-94-06-02: Automated vehicle diagnostics and malfunction alerts.	VC: • Data transfer to back office: video, audio, other • State of sensors • State of autonomous system	**Manufacturer**: implement safety diagnostics functions	
		V-90-06-01: Vehicle capability to	VC: • Data transfer to back	**Manufacturer**: implement safety diagnostics functions	

		self-diagnose and report failures.	office: video, audio, other • State of sensors • State of autonomous system		
UC-20 **Vehicle loses internet connection**	**EUB-94-06**	**V-20-07-01**: Vehicle system to detect internet connectivity issues and initiate safe stopping procedures.	• State of autonomous system • Communication with passengers • Mission modification (during the mission) • V2V, V2X	**FO:** State of autonomous system (including vehicle connectivity state) **Manufacturer:** Autonomous Driving System capable to do a safety stop without internet connection	There should also be a policy for what to do with the passengers
		V-94-06-01: Autonomous systems for safely halting and securing the vehicle in case of disabling incidents.	Ability to contact remote operator	Intervention team : Processes defined per site	
		V-94-06-02: Automated	VC:		

		vehicle diagnostics and malfunction alerts.	• Data transfer to back office: video, audio, other • State of sensors • State of autonomous system		
		V-90-06-01: Vehicle capability to self-diagnose and report failures.	VC: • Data transfer to back office: video, audio, other • State of sensors • State of autonomous system		
UC-21 **Deaf user**	**EUB-01-05**	See UC1	See UC1	See UC1	
	EUB-01-06	See UC1	See UC1	See UC1	
	EUB-01-08	See UC1	See UC1	See UC1	

UC-22 **No available vehicle for the passenger needs**	**EUB-01-05**	See UC1	See UC1	See UC1	
	EUB-01-06	See UC1	See UC1	See UC1	
	EUB-01-08	See UC1	See UC1	See UC1	
UC-23 **Misuse and Use of emergency stop button**	**EUB-01-05**	See UC1	See UC1	See UC1	
	EUB-01-06	See UC1	See UC1	See UC1	
	EUB-23-07	**V-23-07-01:** In-vehicle emergency stop button	VC: • SOS mechanism • Emergency stop button • Communication with passengers • State of autonomous system • Video feed • Remote navigation control	**Manufacturer**: provide emergency stop button *__Operator__: Penalties of misuse in the General Conditions of Carriage	

UC-24 Extra passengers	**EUB-01-08**	See UC1	See UC1	See UC1	
	EUB-01-05	See UC1	See UC1	See UC1	
	EUB-01-06	**V-24-06-01**: Sensors to detect number of passengers onboard	Camera can detect and count people (pose estimation) the vehicle wait until the passenger is dropped	A way in the app and web site for the other passenger to report that and weird behaviour	This opens to a much broader issue which is rogue use and weird behaviours by users in relation with the service. How to socially control people into behaving in a socially acceptable way? Or alternatively to punish them (e.g. rating). Also there is the issue immediate danger, which cannot be easily addressed remotely, and intervention matters a lot.
	EUB-01-08	See UC1	See UC1	See UC1	

UC-30 **Mobile nano-hubs**	-	Door lock controller (Bluetooth – NFC compatible).	Goods ramp. Max cargo weight. Max cargo dimensions. Fixing to secure the cargo. Door width. Door height. Operation temperature min/max. Heating / Cooling /Air conditioning Door opening / closing control.	Incident: Plan time to bring back the goods to a logistic warehouse (pre-defined pound warehouse)	Need to have a Logistic Orchestrator responsible for incidents
UC-31 Automatic pick-up (Producer to Warehouse)	-	Door lock controller (Bluetooth – NFC compatible).	goods ramp. Max cargo weight. Max cargo dimensions. Fixing to secure the cargo. Door width. Door height.	Incident: Plan time to bring back the goods to a logistic warehouse (pre-defined pound warehouse)	Need to have a Logistic Orchestrator responsible for incidents

			Operation temperature min/max. Heating / Cooling /Air conditioning Door opening / closing control.		
UC-96 **Vehicle interaction with infrastructure**	**EUB-96-07**	**V-96-07-01** : V2X installation on the vehicle, allowing communication with the infrastructure	VC: • V2X • Integration of roadside sensors	Operator: a monthly analysis of these interactions and their status (successful, failure) as well as reasons for failure would be good to have!	
Non-service	**EUB-91-02**	**V-91-02-01**: Configurable systems for seamless transition between LaaS and MaaS modes (e.g., cabin layout adaptation, sensor		Not to be tackled at the moment	

		reconfiguration).			
	EUB-92-03	**V-92-03-01**: Battery monitoring system to detect and report low battery levels.		Manufacturer: R100 standard Info for F.O., so when battery low send vehicle to charging station	
		V-92-03-02: Compatibility with charging infrastructure for seamless docking and charging.		F.O. to send vehicle to compatible charging station Intervention team/permanent charging person might be needed to plug/unplug	
	EUB-93-04	**V-93-04-02**: Internal systems for detecting and logging maintenance issues.		Via VPN access for internal tech team. To be extended with the remote-control centre PTO responsibility	
	EUB-94-05	**V-94-05-01**: Autonomous systems for safely halting		Intervention team : Processes defined per site	

		and securing the vehicle in case of disabling incidents.			

Annex F Complete Service Blueprint

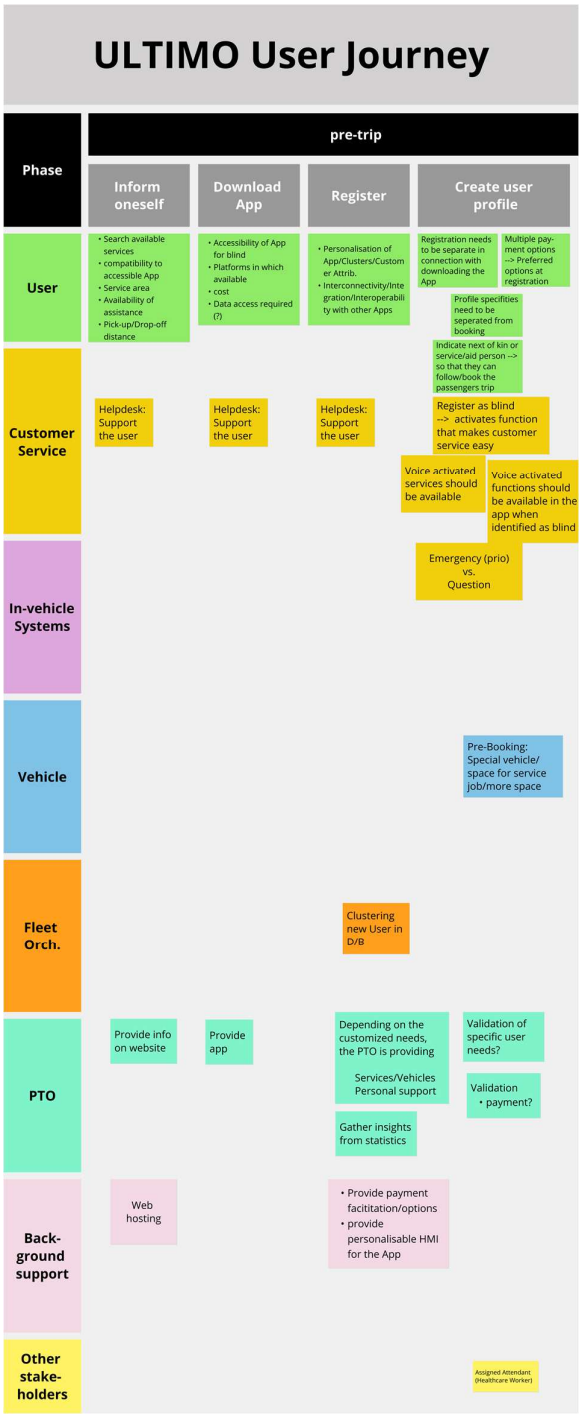

Figure 7: Service Blueprint - Part 1

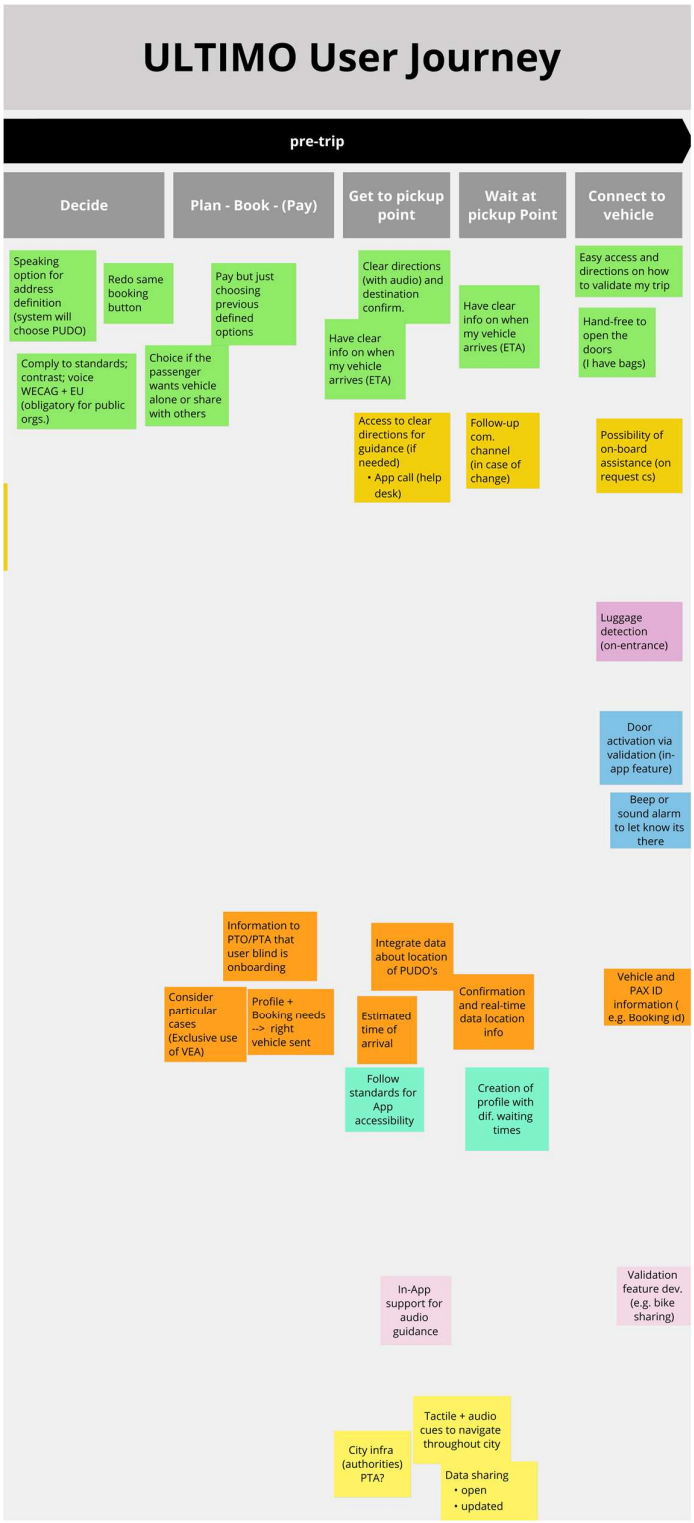

Figure 8: Service Blueprint - Part 2

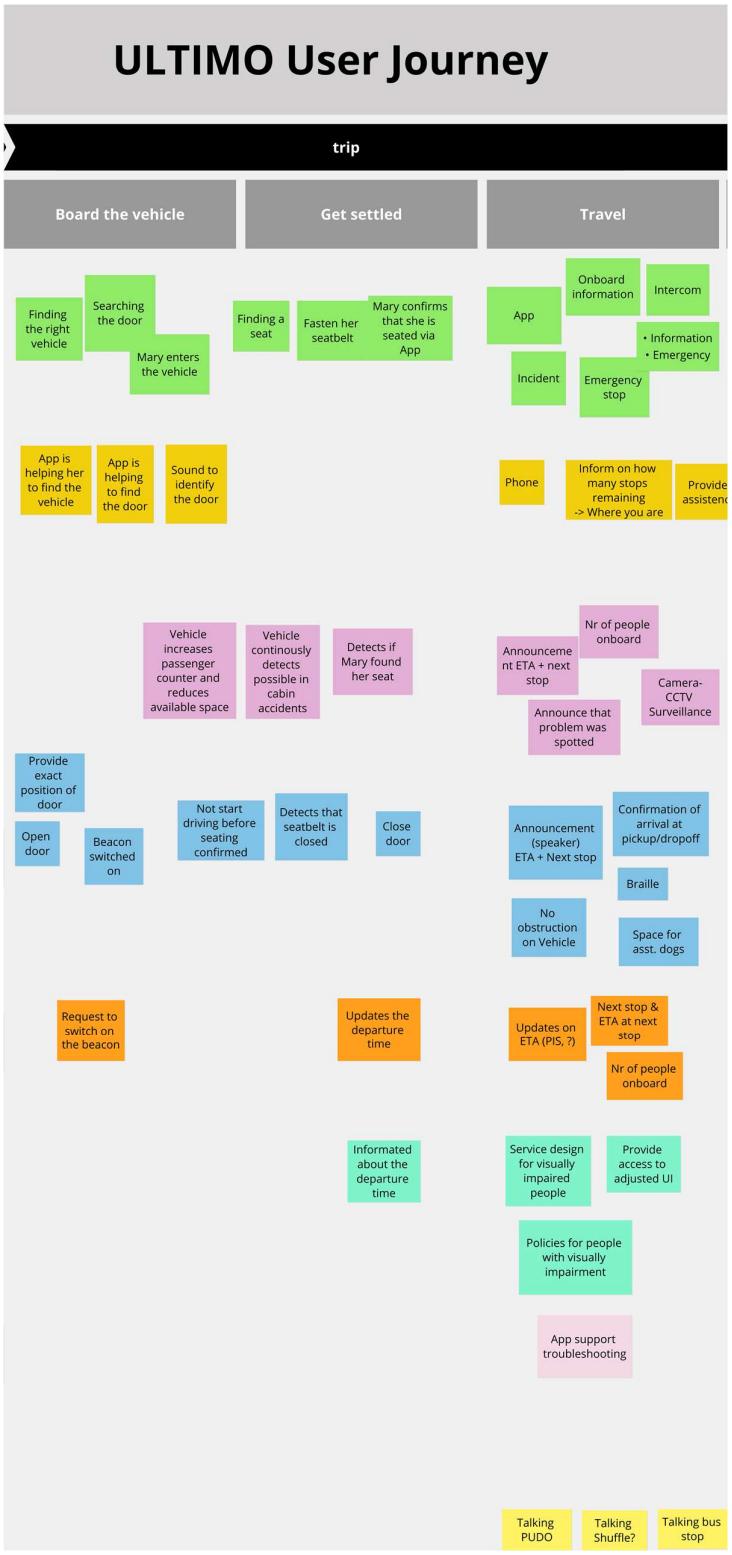

Figure 9: Service Blueprint - Part 3

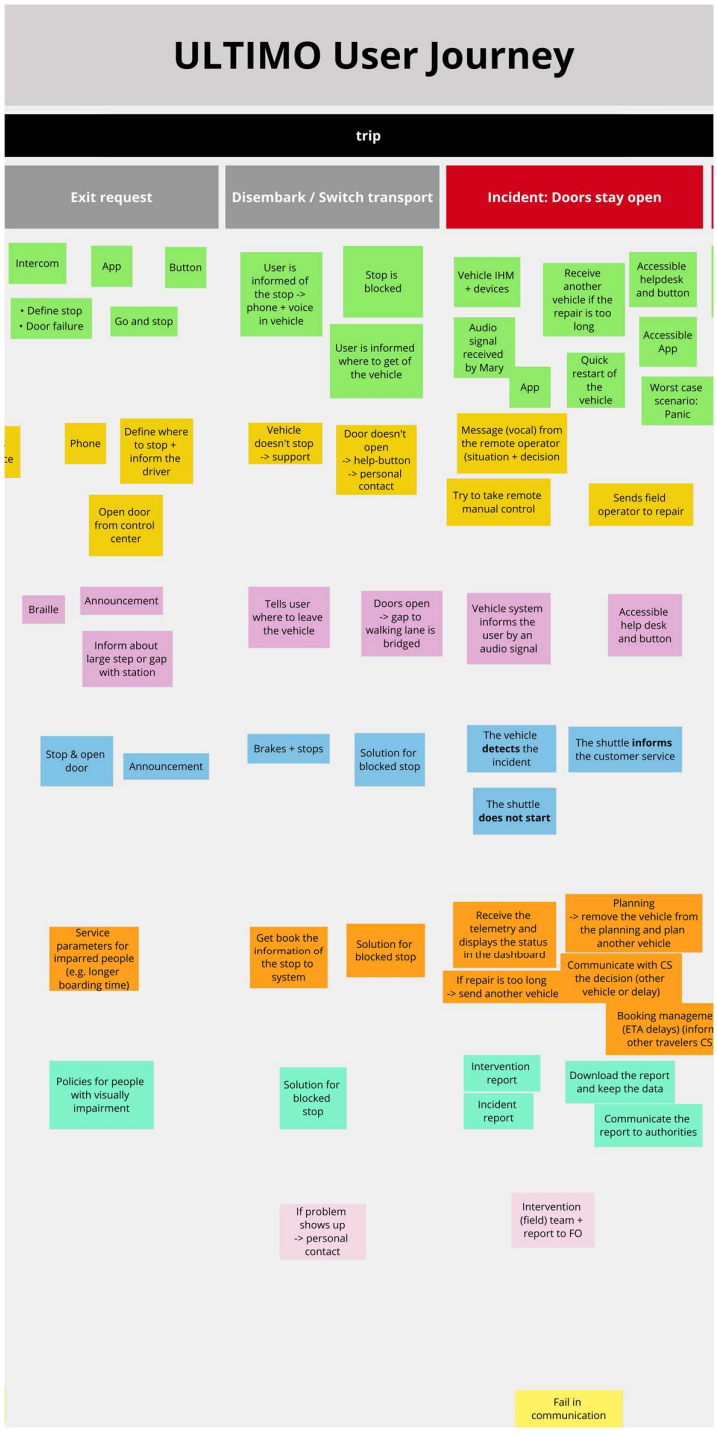

Figure 10: Service Blueprint - Part 4

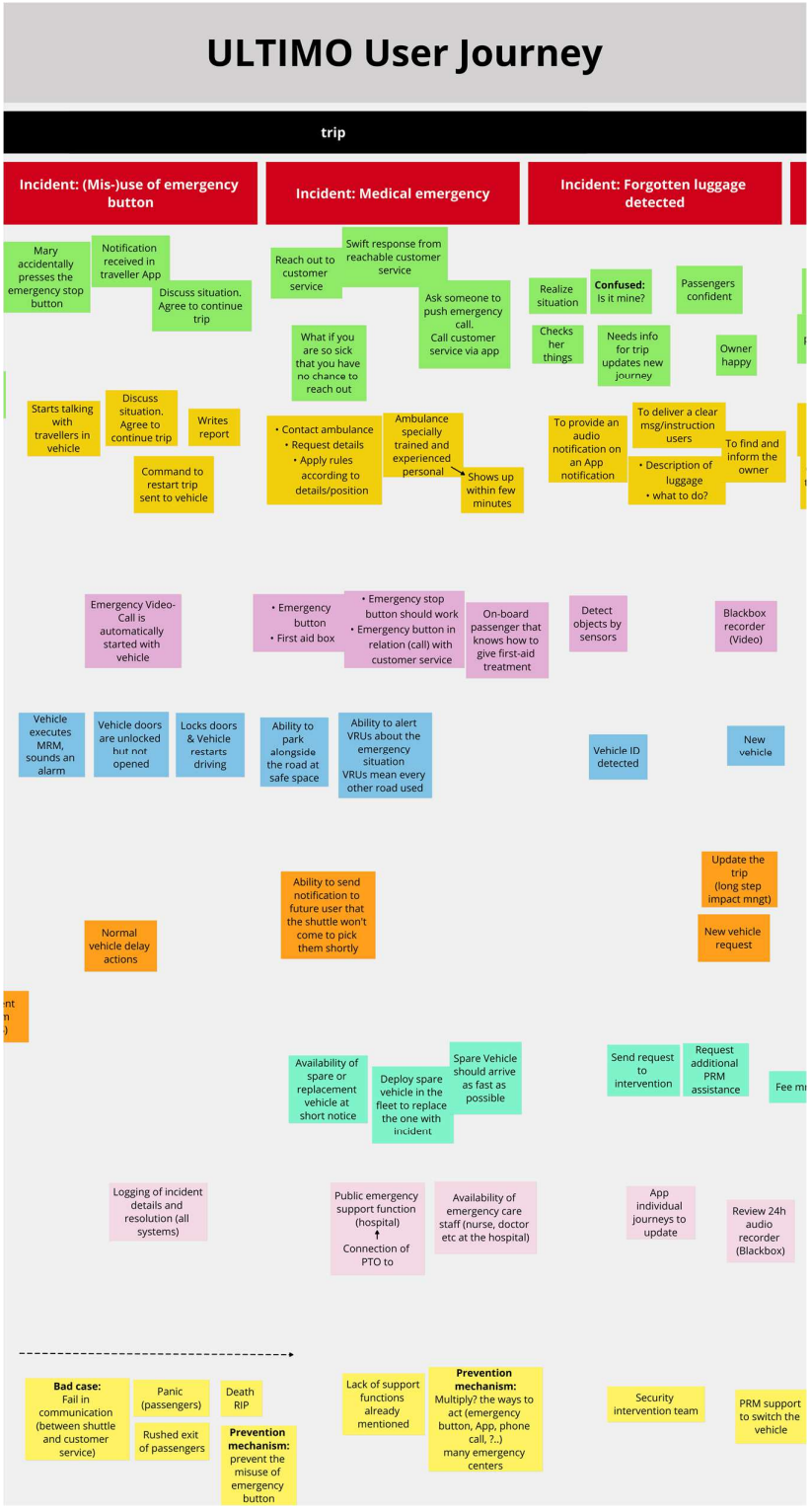

Figure 11: Service Blueprint - Part 5

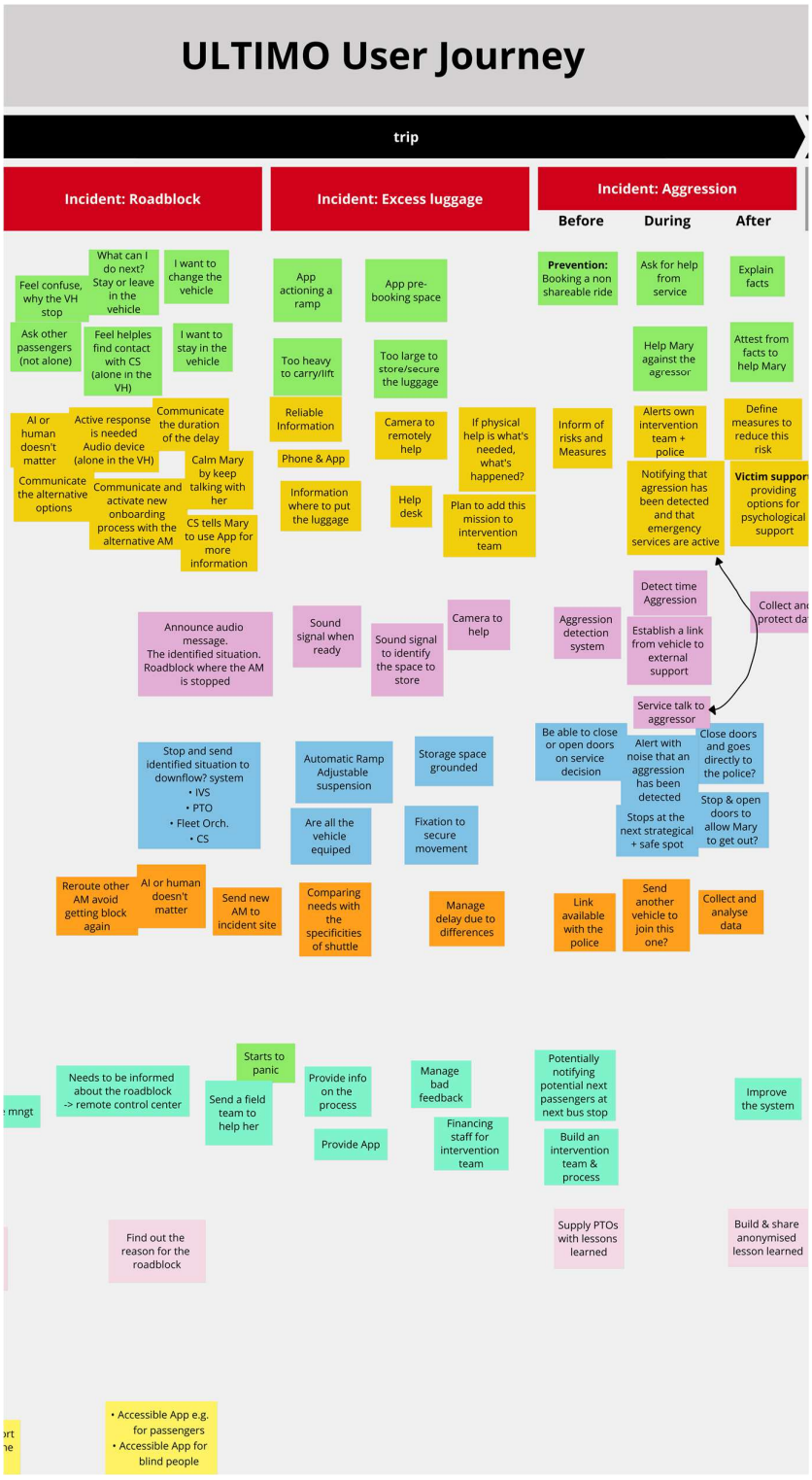

Figure 12: Service Blueprint - Part 6

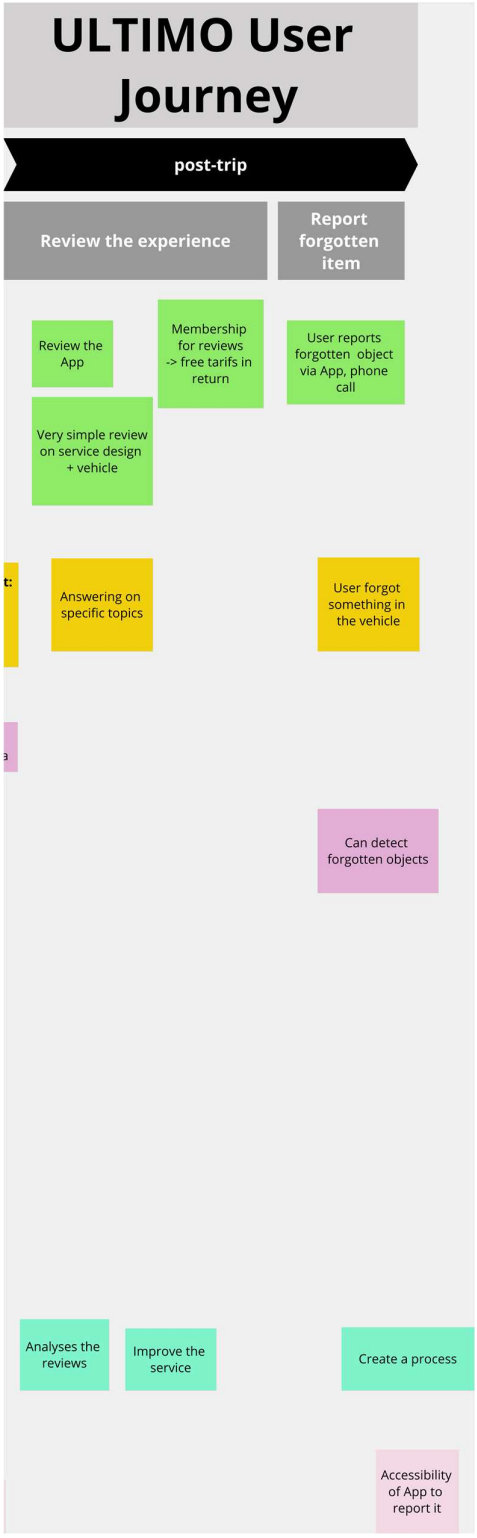

Figure 13: Service Blueprint - Part 7

Annex G Vehicle capabilities list

Vehicle									
Vehicle name	**Golden Dragon**	**EVO 3**	**EZ10**	**ZF ATS - discontinued**	**NIO ES8 SUV**			**Toyota Sienna Autono-MaaS (S-AM)**	**ZF - Eversum Prototype**
Vehicle manufacturer	KingLong	Navya mobility	EasyMile	ZF	NIO	Waymo	nuTonomy	Toyota + Pony.ai	Eversum
Automation software provider	WeRide	navya Lacroix for V2X	EasyMile	Oxbotica	Mobileye			Pony.ai	ZF Mobility Solutions
Country	China	France	France	Germany	China / Israel	USA	USA	China/USA	Germany
Launch Date Europe		Mar-25	2015		2023			N/A	2024
Launch Date USA						2018	2018	N/A	-
Hardware specifications									

Vehicle dimensions									
Height (mm)	2850	2667	2871mm	2900	1756	1566	1562	1,780 mm	3100
Length (mm)	5330	4776	4050mm	6700	5022	4682	4087	5,180 mm	6900
Width (mm)	2280	2098	1892mm	2400	1963	2139	1782	1,990 mm	2400
Weight (kg)	N/A	2682	Net vehicle weight : 2130kg Gross vehicle weight : 3130kg	5000	2425	2670	1988	2182	9200
Height off the ground of the vehicle with respect to the road (Adaptability) (mm)	N/A	170	~150 mm	340; with kneeling: 270	N/A	174	120	162.56	
Technical specifications									
Top speed (km/h)	69 km/h	25 km/h and 30km/h from ealry 2026	45 km/h, electronically limited to 25 km/h	40	200	180	135		80

Range (km)	≥ 200		The EZ10 generally has an autonomy of 10 to 15 hours, depending on conditions like battery usage, terrain, and climate	> 100km	485	470	395		>100
Turning diameter (m)	7.5	9	5m	20m; with co-steering rear axle: 13m	N/A	12.4	10.56		19
Steering (Two wheel - all wheel)	N/A	Two wheel	The vehicle operates with four-wheel steering, with options to select only front or rear wheel steering as required	4-wheel steering + crab walk	4WD Electric	2 wheel	2 wheel		2 wheel
Steering wheel / controller (For safety operator)	detachable	controller	Remote controller	Controller		yes	yes		Steering Wheel
Driving direction or directions	N/A	bidirectional	4 steering wheels	undirectional		forward-backward	forward-backward		Forward-backward
Maximum slope	≥ 20 %	15%	15%	16% -18%	20 degrees				-
Ground clearance	110 mm	170/270 Min/Raised			161-170 mm	174	120		
Fuel capacity (Petrol/diesel /etc) (liter)	N/A	N/A	N/A (100% electric)	N/A	-				-

Battery capacity (kWh)	CATL 89.16 kWh	33 kWh	The EZ10 operates on 48V lithium-iron phosphate batteries, with configurations of two, three, or four batteries depending on the specific setup	50/80/100	84	90	52	1.9 kWh	80
Battery health	N/A		Batteries provide operations for up to 15 hours	??		yes	yes	10 years/150 '000 miles	-
Battery charger	N/A	- 230V, 10A - 230V, 16A - 230V, 32A		AC 11/22 - DC 50/150	N/A	yes	yes	Hybrid car	-
Battery charging time (0 to 100%) (minutes)	N/A	- 230V, 10A - 19 Hours - 230V, 16A - 12 Hours - 230V, 32A - 6 Hours	Electric (Battery type LiFePo4) 6 hours	AC 60 to 180		40 (80%)	47 (80%)		60
Charger type, inductive charging, other type	N/A		USB Chargers, Optional wireless charger	charging plug CCS type 2	N/A	CCS combo 2	CCS combo 2		Type 2

Number of doors	1	1	The EZ10 typically has two doors equipped with safety features like force sensors to prevent accidental closing on objects	1	5	5	5		1
Door width	N/A			1200	N/A				-
Door height	N/A			1970	N/A				-
Operation temperature min/max	0°C~40° C	-10°C to 45°C	heavy rain, snow, fog, temperature from -15°C to 45 °C	-25° to +50°	N/A				-15 to +40
Bluetooth low energy (Angle of Arrival/Departure services)	N/A	No	No	under investigation	N/A				-
Spare wheel	N/A	No	No	none	N/A				-
Carrying capacity									
Passenger									
Passenger capacity		15	12 (900kg max.)	22	6	5	5		23
Number of seating positions	8 or 10 (without driver)	11	6	15	6	5	5		9
Number of standing positions	N/A	4	6	6	0	0	0		14

Seating positions (in direction of travel, against direction of travel, across direction of travel?)	8 or 10 in direction of travel	4	3 in, 3 against direction of travel	all	front direction	5	5		all in direction of travel
Cargo									
Max cargo weight	N/A	N/A			639 kg				-
Max cargo dimensions	N/A	N/A			310 l with third seat row, 871 without	505	338		-
Fixing to secure the cargo	N/A	N/A			N/A				-
Specific space for baggage	N/A	No	The vehicle is passenger-focused with no specific cargo space, although some configurations may allow minimal luggage if permitted by weight limits		N/A				-
Other									

Room for wheelchair, walker, stroller	N/A	1 wheelchair	1 wheelchair	1	Yes, folded in the trunk				Yes, 1
Passenger services									
Stop request button	No	No	Yes	Y	Makeshift solution				Yes
Passenger counting system	No	No	Yes	Y	No				Yes
Ticket verification system	No	No	No	under investigation	No				No
Loudspeaker	Yes	Yes	Yes	Y	Makeshift solution				Yes
Charging port for passengers (USB type and amount)	N/A	No	Yes	Y	No				Yes
Accessibility and comfort									

Screen(s)/Other to indicate line number	Yes	Yes	Additionally, the passenger screen can be updated in real-time to provide geolocalized information, emergency procedures, next stops, estimated time of arrival, etc	Y	None				Yes
Passenger information system (Number of units and placement)	Yes	Yes	A screen within the vehicle provides real-time information on line number, estimated arrival time, and stops	Y	2 screens	1	1		Yes, 2
Audio guidance to doors	No	No	The EZ10 does not have specialized audio guidance but includes general guidance and stop request options	under investigation	none				No
Wheelchair / baby carriage ramp	No	Yes	Integrated automated electric access ramp	Yes	none				Yes
Wheelchair / baby carriage access - No assistance	No	Optional electric ramp		Yes	none				No
Wheelchair / baby carriage access - With assistance	No	No	Passengers in wheelchairs or with mobility limitations can press the clearly labeled accessibility ramp button to extend the ramp and lower the vehicle.	automatic	none				Yes

Accessibility seats spots (Elderly, pregnant etc)	No	No	Dedicated seating for elderly, pregnant passengers, and wheelchair users.	Yes	None				Yes
Tinted or darkened windows	No	No	Not specified; standard configurations likely vary	Yes	No data yet				Yes
Heating / Cooling /Air conditioning	Yes	Yes	The EZ10 shuttle vehicle is equipped with both air conditioning and heating systems to offer passengers optimal comfort in all operating conditions. Air conditioning and heating may be adjusted using a touch screen inside the vehicle	Yes	Yes				Yes
Indoor CO2 sensor	N/A	No	No	N	No				No
Passenger Safety									
Assistance systems for visually and/or hearing impaired	No	No	The vehicle does not specifically support systems for visually or hearing-impaired passengers	Yes	Via app				Yes
Seatbelts	Yes	Yes	Yes	Yes	Yes	Yes	Yes		No
Emergency stop button	Yes	Yes	Yes	Yes	Yes				No

Ability to contact remote operator (No safety driver on board)	Yes	Yes	If a passenger has a question or concern, a clearly labeled button opens a two-way communication between them and a remote fleet manager	Yes	Yes				Yes
Automated External Defibrillator (resuscitation device)	No	No	No	Yes	No				No
First aid kit	N/A	Yes	Fire extinguishers and a first aid kit are also available within the EZ10	Yes	No				Yes
Emergency windows	N/A	No	Yes	Yes	No				Yes
SOS mechanism	N/A	No	Instructions visible inside, Audio call, Manually opening doors	Yes	Yes				Yes
Autonomous driving hardware									
Sensors									
LiDARs	5	10 Lidars	The EZ10 uses a variety of different LIDAR sensors, some of which are tuned for obstacle detection and others that are better suited for landmark recognition and localization.	Yes	3 long-range 6 short-range	Yes	Yes		Yes

Radar	No	No	Yes	Yes	6	Yes	Yes		Yes
Camera	13	2 external cameras, 1 interior camera	Yes	Yes	13	Yes	Yes		Yes
Infrared camera	N/A	No	No	No	No				No
4G	Yes	Yes	Yes	Yes	Yes				Yes
5G	Yes	No	Yes	Yes	Yes				Yes
IMU	Yes	Yes	Yes	Yes	Yes	Yes	Yes		Yes
RTK-GNSS	Yes	2 antennas	Yes	Yes	Yes	Yes	Yes		Yes
Computer									
Size, location	N/A			sensitive info	N/A				Yes
Protection level of vehicle computer hardware (ease of access)	N/A	Protected, Only authorized individuals have access to this	In order to prevent malicious or unauthorized access to the components, all physical ports (such as USB or Ethernet, etc.) are physically protected or disabled.	sensitive info	Rudimentary				Yes

Software specifications									
Operational design domain, autonomous driving system									
Traffic lights	Yes	Yes	Yes	Yes	Yes	Yes	Yes		Yes
Roundabouts	Yes	Yes	Yes	Yes	Yes	Yes	Yes		Yes
Pedestrian crossings	Yes	Yes	Yes	Yes	Yes	Yes	Yes		Yes
Speed signs	Yes	Respected but no recognition needed	Yes	Yes	Yes	Yes	Yes		Yes
Pedestrians	Yes	Yes	Yes	Yes	Yes	Yes	Yes		Yes
Low visibility conditions (Rain, snow, fog, dust, night etc)	N/A	Yes	Optional	Yes	Yes				Yes
Other road users	Yes	Yes	Yes	Yes	Yes	Yes	Yes		Yes
Road blocking obstacles	Yes	Yes	Yes	Yes	Yes	Yes	Yes		Yes

Road conditions (Icy road, holes)	Yes	No	Yes	No	Yes				No
Tunnels	Yes	No	Yes	Yes	Yes				Yes
Highway	N/A	No	No	No	Yes				No
Remote capabilities									
Safety operator									
Remote driving/steering	Yes	No	Yes	No	No data yet				No
Tire pressure	N/A	No	Yes	Yes	No data yet				No
State of sensors	N/A	Yes	Yes	Yes	No data yet				Yes
State of autonomous system	N/A	Yes	Yes	Yes	No data yet				Yes
Battery level (Electric vehicle)	N/A	Yes	Yes	Yes	No data yet				Yes
Fuel level (Petrol/Diesel/etc)	N/A	NA	N/A		No data yet				-
Passengers counter	No	No	Yes with camera inside the vehicle	Yes	No data yet				Yes

Video feed (Internal / External)	Yes	Yes		Yes	No data yet				Yes
Audio feed	Yes	No		Yes	No data yet				Yes
Indoor temperature	Yes	No	Yes	Yes	No data yet				Yes
Indoor co2 level	N/A	No	No	No	No data yet				No
GNSS location	Yes	Yes	Yes	Yes	No data yet				Yes
Remote navigation control	Yes	No	Yes	you mean teleoperation??	No data yet				No
Door opening / closing control	Yes	No	Yes	Yes	No data yet				Yes
Communication with passengers	Yes	No	Yes	Yes	No data yet				Yes
Fleet management									
Multi routing	N/A	No	Yes - EZFleet CONTROL CENTER	Yes	No data yet				Yes

Mission cancellation	N/A	Yes	EZ Maestro allows mission management, including cancellations and modifications during operation	Yes	No data yet				Yes
Mission modification (During the mission)	N/A	No	EZ Maestro allows mission management, including cancellations and modifications during operation	Yes	No data yet				Yes
Connectivity									
V2V	N/A	No		under investigation	No data yet				No
V2X	N/A	Yes	Optional	Yes	No				Only traffic lights at the moment
V2Passenger	N/A	No		Yes	No data yet				no
Integration of roadside sensors	N/A	No		under investigation	No				no
Other specifications									
Legal and regulatory									

Type of licence of the safety operator	To be defined			under investigation	Formal: Category B driver license Internal: specific certification required.				Bus Driver with training from ZF
Speed authorisation (km/h)	To be defined			50	60 km/h				60
Data transfer to back office: video, audio, other	To be defined		EZFleet provides useful data which can be used to improve overall operations. Information is gathered from the vehicle, site, and operations, and the system automatically creates monthly operating reports.	Yes	No data yet				Yes
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