SHared automation Operating models for Worldwide adoption

SHOW

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D12.4: Austrian CCAV demonstrators

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Executive Summary

This document, *D12.4: Austrian CCAV demonstrators*, provides a comprehensive overview of the objectives and achievements of the three Austrian SHOW pilot sites - Graz, Salzburg and Carinthia. The overall vision of the Austrian Triplet Mega Pilot was to connect peri-urban regions to intermodal mobility hubs in mixed traffic. This goal was achieved in all pilot sites. In total, seven automated vehicles (AVs) were deployed, and more than 11,000 passengers were transported.

The Graz pilot site focused on complementing public transport with automated vehicles. Two retrofitted vehicles, a Ford Fusion and a Kia e-Soul, were used to transport passengers between a public transport hub and a shopping centre, a distance of approximately 1.5 km. The vehicles operated on a dedicated bus road and in a public transport terminal, encountering buses, trams and pedestrians. While the vehicles were equipped for V2X and V2N communication, enabling data exchange with the infrastructure and the Internet, their journeys were designed to be feasible without these features. Nevertheless, infrastructure such as the 'awareAI camera system' was used to increase safety and reliability, particularly at the bus terminal, by providing real-time information on available bus bays for the automated vehicles to pass through. The Graz pilot successfully transported 520 public passengers, including commuters, visitors and students. Passenger feedback was positive, with few instances requiring safety driver interventions. Challenges encountered included cases where all bus bays were occupied, requiring the automated vehicle to wait briefly. A number of technical issues were successfully addressed during the pilot phase, including improvements to the processing of LIDAR data for dealing with adverse weather conditions such as rain or fog. The experience gained will contribute to the further development of automated driving technology and its integration into existing mobility services.

The Salzburg pilot site focused on connecting the village of Koppl to the city centre of Salzburg via an intermodal mobility hub. Two scenarios were implemented, one using a dedicated 1.4km pilot route in the village of Koppl and the other involving an 8km C-ITS enhanced corridor to Salzburg. Scenario 1 used two automated vehicles, a prototype shuttle (HEAT-shuttle) and a retrofitted electric minivan (eVAN), to provide a first/last mile service between the Koppl centre and the mobility hub. The service complemented existing public transport and reduced the cycle time from one hour to 30 minutes. Scenario 2 focused on using cooperative intelligent transport systems (C-ITS) along an 8 km corridor between Koppl and Salzburg. The eVAN, equipped with an on-board unit (OBU), interacted with roadside units (RSUs) to test use cases such as hazard location notification and traffic light prioritisation. The Salzburg pilot faced several challenges. Technical issues, particularly with localisation and positioning accuracy, affected both automated vehicles. The eVAN was taken out of service after a minor accident during a test run without public passengers. Despite the technical difficulties, the pilot successfully carried 689 passengers during the public pilot phase with the HEAT shuttle. Passenger feedback was largely positive, with many expressing a wish for higher speeds and a wider operating area. In conclusion, the Salzburg pilot shows the potential of integrating automated vehicles into existing transport systems, but also highlights the technical and operational challenges that must be addressed to achieve this integration successfully.

The pilot site in Carinthia involved the deployment of automated shuttles into urban environments for first and last mile public transport. The pilot site used Navya Arma DL4 shuttles, with one in the tourist town of Pörtschach and a fleet of three in the capital city of Klagenfurt. This two-site approach allowed the evaluation of automated mobility in different environments with different traffic complexities and user groups. Pörtschach mainly served tourists and residents, linking the station with the lake,

hotels, shops and town centre. The route followed narrow streets with mixed traffic, including pedestrians and cyclists, especially during the tourist season. The Klagenfurt pilot targeted commuters, students and residents and covered a more complex route that included several signalised intersections and a roundabout. Additionally, Klagenfurt used C-ITS infrastructure, allowing shuttles to communicate with traffic lights to improve traffic flow and safety. While both sites offered scheduled services, Klagenfurt also implemented an on-demand booking option via the smart:MOBIL application in cooperation with IOKI. In addition, Klagenfurt implemented a cargo transport use case, using a custom-built transport box within the shuttle to deliver medicines, office supplies and groceries. Challenges included the complexity of the route in Klagenfurt and some negative reactions from other drivers due to the low speed of the shuttle. Overall, passenger feedback was positive at both sites in Carinthia, with users appreciating the convenience and accessibility of the service. With 9,272 public passengers and 203 package deliveries, the Carinthia pilot successfully demonstrated the feasibility of integrating automated shuttle services into existing transport networks.

Overall, the Austrian Triplet Mega Pilot demonstrated the potential of automated mobility in a range of use cases and environments across Austria. The successful integration into the existing public transport system, support through C-ITS infrastructure and the integration into an on-demand application were key achievements. Deployment in urban, peri-urban and mixed traffic environments provided valuable insights into vehicle performance and passenger interest, with high levels of engagement observed in all locations. However, the pilots also highlighted the necessity for further technological development.

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Abbreviation List

Abbreviation	Definition
AD	Automated driving
ADAS	Advanced Driver Assistance System
APOS	Austrian Positioning Service
AV	Automated Vehicle
CCAM	Cooperative, Connected, and Automated Mobility
CCAV	Cooperative Connected Automated Vehicle
C-ITS	Cooperative Intelligent Transport Systems
DENM	Decentralized Environmental Notification Message
DMP	Data Management Portal
DRT	Demand Responsive Transport
GNSS	Global Navigation Satellite System
GNSS-RTK	Global Navigation Satellite System - Real-Time Kinematic
HD-Map	High-Definition Map
HLN-PTVC	Hazardous Location Notification- Public Transport Vehicle Crossing
HLN-PTVS	Hazardous Location Notification - Public Transport Vehicle at a Stop
HMI	Human-Machine Interface
JSON	JavaScript Object Notation
LDMP	Local Data Management Platform
LIDAR	Light Detection and Ranging
MAMCA	Multi-Actor Multi-Criteria Analysis
MQTT	Message Queuing Telemetry Transport
OBU	On-Board Unit
ODD	Operational Design Domain
PT	Public Transport
PTO	Public Transport Operator
RSU	Roadside Unit
SI-TLP	Signalized Intersection - Traffic Light Prioritization
SW	Software
TMC	Traffic Management Center
UHD-Map	Ultra-High-Definition Map
V2N	Vehicle-to-Network
V2X	Vehicle-to-Everything
VRU	Vulnerable Road User

1 Introduction

1.1 Purpose and structure of the document

The objective of this deliverable is to provide a comprehensive overview of the pilots conducted at the Austrian Megasite. The document provides descriptions of the three pilot sites in Graz, Salzburg, and Carinthia. A summary of the operations conducted at the three sites can be found in Chapter 3. A detailed description of the activities conducted at the sites is provided in Chapters 4, 5, and 6 of the document. Each chapter, following a uniform structure, offers an overview of the site's ecosystem, operation settings, use cases, fleet, infrastructure, and passengers. Additionally, the chapters detail the operations, data collection processes, and key findings from the pilots, including key local pilot events, key challenges and impacts as well as lessons learnt and a roadmap that extends beyond the SHOW project. The document concludes with a joint conclusion for the Austrian Megasite (chapter 7).

1.2 Intended Audience

Deliverable D12.4: Austrian CCAV Demonstrators is a publicly accessible document that provides an overview of the large-scale pilot conducted at the Austrian Megasite. Its objective is to disseminate insights and lessons learned from the operations at the three Austrian SHOW pilot sites to individuals external to the project consortium. The primary audience includes experts in the field of automated mobility, public transport operators, and other key stakeholders in the transport sector.

1.3 Interrelations

Deliverable D12.4: Austrian CCAV Demonstrators is closely linked to other pilot site deliverables, allowing the exchange of key findings from different operations and use cases. In addition, D12.4 builds on *D1.2: SHOW Use Cases* [1], which focused on identifying and detailing the project's priority urban automated mobility use cases, as well as stakeholder interests and public acceptance. *Deliverable 9.3: Pilot Experimental Plans, KPI Definition and Impact Assessment Framework for the Final Demonstration Round* outlines the common evaluation framework and methodological approach for the final pilot evaluations. In Appendix I of D9.3, each site presents its experimental plans for the final pilot phase of SHOW [2].

Further discussion of these and other deliverables from the pilot sites can be found in *Deliverable 12.9: Real-Life Demonstrations, Pilot Data Collection and Results Consolidation* [3], and *Deliverable 13.5: SHOW Impact Assessment on User Experience, Awareness and Acceptance* [4]. In addition, the deliverables of WP13 and WP10 include the impact assessment and simulation studies based on the results, findings and data collected from the Austrian and other pilot sites.

2 High level vision of Austrian Sites and joint goals

The overall vision of the Austrian Triplet Mega Pilot was to connect peri-urban regions to intermodal mobility hubs in mixed traffic. This vision has been achieved in all pilot sites. In Graz, a public transport hub and a shopping centre were connected with two automated vehicles; in Salzburg, the first/last mile in the village of Koppl was covered with an automated shuttle and an automated minibus; and in Carinthia, flexible mobility services were offered with three automated shuttles in its two different sites.

The three Austrian pilot sites addressed the following Use Cases:

	UC	Comment
Automated traffic in real city environment	*1.1; 1.2; 1.3; 1.5, 1.6*	All sites ran vehicles/shuttles on public roads, offering public transport services in mixed traffic flows
Automated mixed spatial mobility	*2.1*	Specific transport boxes were used to transport medicine, office supplies and groceries in the shuttle
Automated services at bus stops and COVID-19 safe DRT	*3.1; 3.4; 3.6*	Including a busy bus terminal with six bus bays, on-demand app by IOKI and tests with air filter systems, antibacterial and antiviral coatings

All Use Cases have been successfully implemented, except UC3.1 (Self-learning Demand Response Passengers/Cargo mobility), since there was no possibility to add this functionality to the automated shuttles.

3 Overview of contributing sites

Table 1: Overview of contributing sites

Pilot site	Duration of operation	Leader	Vehicles	Use Cases (by ID and name)	Number of passengers transported
Graz	12 months	VIF	1 automated Ford Fusion 1 automated Kia e-Soul	UC1.2: Automated passengers/cargo mobility in Cities under complex traffic & environmental conditions UC1.3: Interfacing non automated vehicles and travellers (including VRUs) UC3.4: Automated services at bus stops	610 (90 pre-demo, 520 public operation)
Salzburg	2 months	SRFG	1 HEAT-Shuttle 1 Digitrans eVan	UC1.2: Automated passengers/cargo mobility in Cities under complex traffic & environmental conditions UC1.3: Interfacing non automated vehicles and travellers (including VRUs) UC1.5: Actual integration to city TMC UC1.6: Mixed traffic flows UC3.1: Self-learning Demand Response Passengers/Cargo mobility (has not been implemented, see chapter 5.4)	720 (31 pre-demo, 689 public operation)
Carinthia - Pörtschach	12 months	PDCP	1 Navya Arma DL4	UC1.1: Automated passenger/cargo mobility in cities under normal traffic & environmental conditions (including semi-automated DRT) UC1.2: Automated passenger/cargo mobility in cities under complex traffic & environmental conditions (including semi-automated DRT) UC1.6: Mixed traffic flows UC2.1: Automated mixed spatial mobility (mixed mobility of cargo/passenger at the same time) UC3.6: COVID-19 safe DRT	6600 (564 pre-demo, 6036 public operation)
Carinthia - Klagenfurt	3 months	PDCP	3 Navya Arma DL4	UC1.1: Automated passenger/cargo mobility in cities under normal traffic & environmental conditions (including semi-automated DRT)	3300 (64 pre-demo, 3236 public operation)

Pilot site	Duration of operation	Leader	Vehicles	Use Cases (by ID and name)	Number of passengers transported
				UC1.2: Automated passenger/cargo mobility in cities under complex traffic & environmental conditions (including semi-automated DRT) UC1.6: Mixed traffic flows UC2.1: Automated mixed spatial mobility (mixed mobility of cargo/passenger at the same time) UC3.6: COVID-19 safe DRT	
All Sites in total					**11230 (749 pre-demo, 10481 public operation)**

4 Graz test site

4.1 The ecosystem

Virtual Vehicle and AVL are the developers of retrofitted automated research vehicles. They also perform the operation for each vehicle in the SHOW pilot. Yunex Traffic provides infrastructure equipment like smart cameras and C-ITS for the Graz site. Holding Graz is the local public transport operator that also owns the public transport hub and is responsible for all buses and trams at that location. AustriaTech is the Mega Site Leader for SHOW in Austria; the contact point for automated mobility at AustriaTech also acts as the interface to the Austrian Ministry for the issue of automated driving permits.

Table 2: Pilot site ecosystem at Graz

Participating Entity	Internal to the Consortium	External to the Consortium	Role
Virtual Vehicle Research GmbH	√		Operator and developer of pilot vehicle 1, pilot site leader
AVL List GmbH	√		Operator and developer of pilot vehicle 2
Yunex Traffic Austria GmbH	√		Infrastructure provider for Graz site
Holding Graz - Kommunale Dienstleistungen GmbH		√	Public Transport Authority Graz
AustriaTech – Gesellschaft des Bundes für technologiepolitische Maßnahmen GmbH	√		Mega site leader Austria & Contact Point for Automated Mobility

4.2 Operation setting

The Graz pilot site is located in the southern outskirts of the city, approximately 4 km from the city center.

Figure 1: SHOW pilot site within the local public transport system (Source: GVB)

The driving route targets to transfer pedestrians from a bus terminal to a shopping center (Figure 2). The focus of the research is the transfer station (A, see circle). See the following picture for the whole route. The route covers areas A - B - C - D - E - F. Area G is optional for alternative routes.

Figure 2: Route in Graz divided into sections (Source: VIF)

On the whole route, the automated vehicle can encounter pedestrians and buses. Sometimes there are also company vehicles from the city Graz, and the trams cross the street at the transfer station. After traversing the tunnel in C, there is a long street D, where the automated vehicle might stop at a traffic light. In area A there the AV reaches a public street with a high frequent intersection and a street with many curves. It might be difficult for the vehicle to get a full overview of the traffic situation. At the center West (E and F), there are generally many pedestrians with parked vehicles.

Table 3 shows the segments in tabular form. In general, the speed limit for driving is 30 km/h in those areas as the city of Graz has a general speed limit of 30 km/h excluding priority roads. An exception is the bus terminal (A), where a self-defined maximum speed of 10 km/h was chosen due to safety reasons and the larger number of pedestrians. Driving on other segments (E, F, G) is performed in manual mode with a maximum speed of 30 km/h.

Table 3: Route segments in Graz

Segment	Route description	Length	Driving mode	Maximum speed of vehicle
A	Public Transport Terminal	200 m	Automated	10 km/h
B	Dedicated Bus Road, East Part	100 m	Automated	30 km/h
C	Tunnel	50 m	Automated	30 km/h
D	Dedicated Bus Road, West Part	550 m + optional route 100 m (Western Part)	Automated	30 km/h
E	Public Traffic Area	200 - 400 m depending on local route	Manual	30 km/h
F	Car Park Shopping Center West	500 - 700 m depending on local route	Manual	30 km/h
G	Car Park IKEA (Future Extension)	200 - 500 m depending on local route	Manual	30 km/h

The automated vehicle drove through a public transport terminal with several bus bays. Depending on availability, a different route (i.e. bay) would be chosen. The speed was limited to 10 km/h in this area in the vehicle, which results in a stopping distance of about 3.8 m, which is a bit less than the length of the car. Figure 3 and Figure 4 give some impression of the public transport terminal.

Figure 3: Segment A - Public Transport Terminal with buses (left) and tram (right). (Source: VIF)

Figure 4: Segment A - Automated Vehicle in mixed traffic with public buses. (Source: VIF)

Figure 5 shows the driving route of the automated vehicle at the bus terminal. In this area, driving is prohibited except for public buses. For the operation of the automated vehicle, an exception has been applied for at the road department of the City of Graz. To increase safety, yellow warning lights were installed on the tram crossing when leaving the terminal, which signal the approach of a tram and are clearly visible when crossing the tracks in a westerly direction. The warning light indicates the approach of a tram at an acute angle from the right rear and is therefore very useful for the buses operating there (due to blind spot on the side facing away from the driver). The automated vehicle can easily detect an approaching tram directly at any time with its sensors (Lidar) due to its large size and therefore does not need this warning light in general. However, this information is provided via C-ITS and used in our cars as redundant information source.

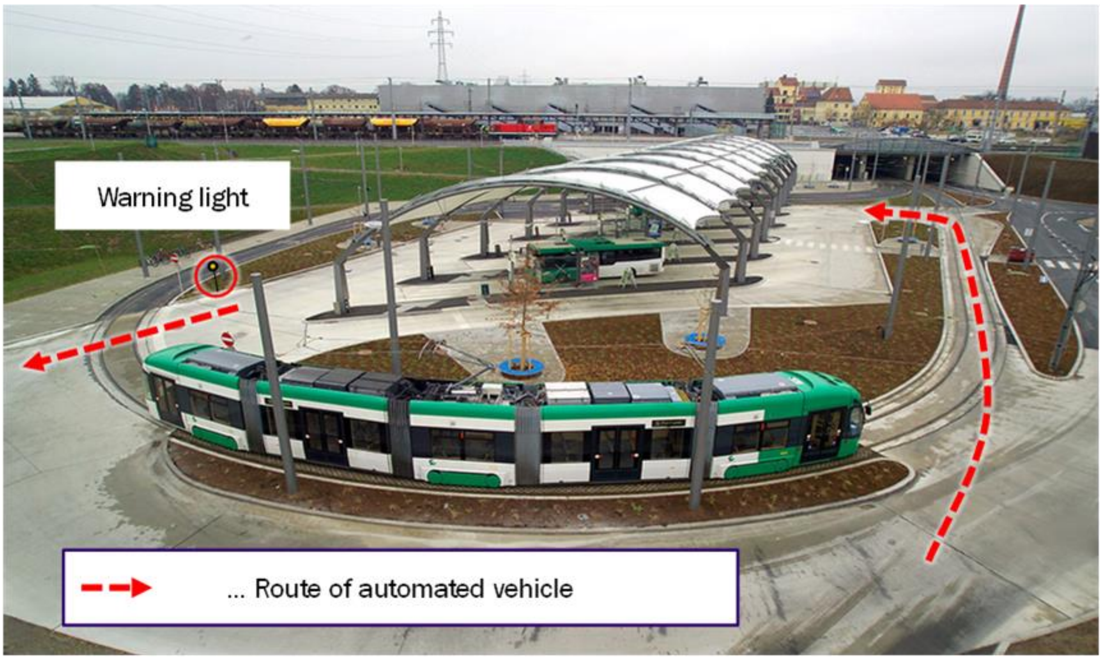


Figure 5: Segment A with route of automated vehicle. (Source: VIF)

Figure 6 and Figure 7 show the intermediate roads between the bus terminal and the shopping center. In this area there is only bus traffic once every 10 minutes per direction and no other traffic. Pedestrians are typically not present in these segments, but have already been observed in rare cases.

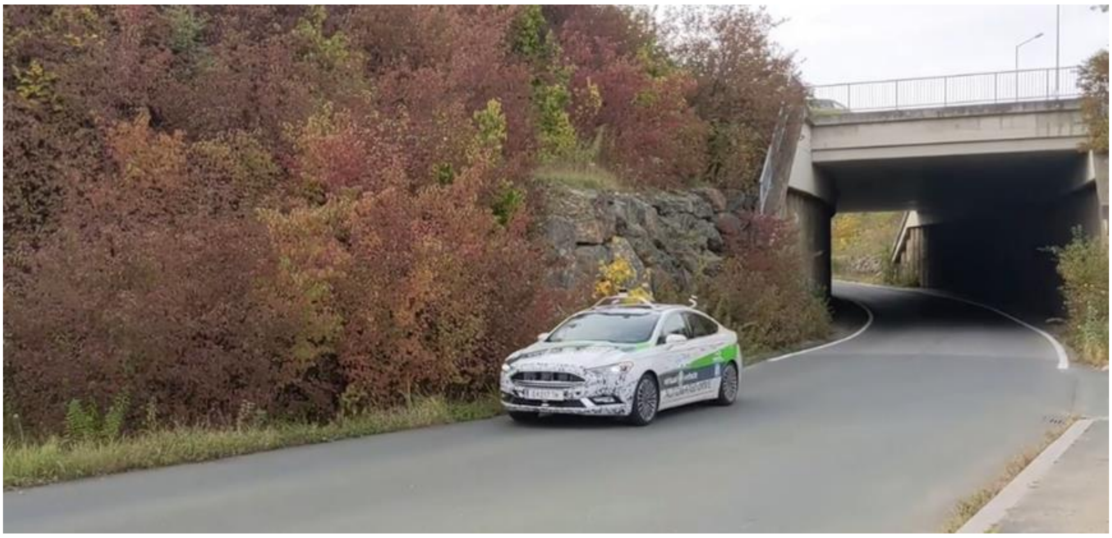


Figure 6: Segment B (dedicated road; front) and C (tunnel; behind). (Source: VIF)

Figure 7: Segment D - dedicated bus road. (Source: VIF)

The western part of the pilot site consists of a rather complex traffic layout with many lanes and curves, roundabouts and high traffic volumes, especially during shopping hours. Therefore, is has been decided that in these parts (segments E, F, G) a change from automated to manual driving will be performed to consider the higher risks. Nevertheless, data has been collected here (sensors, driving data, etc.) to prepare for automated driving in future.

The set up in Graz involves a handover from automated driving in section D to manual driving in section E, this was triggered by the safety driver. Figure 8 shows the position when a handover from automated driving to manual driving is performed when driving in Western direction, it is located at coordinates 47°01'56.5"N 15°25'16.4"E.

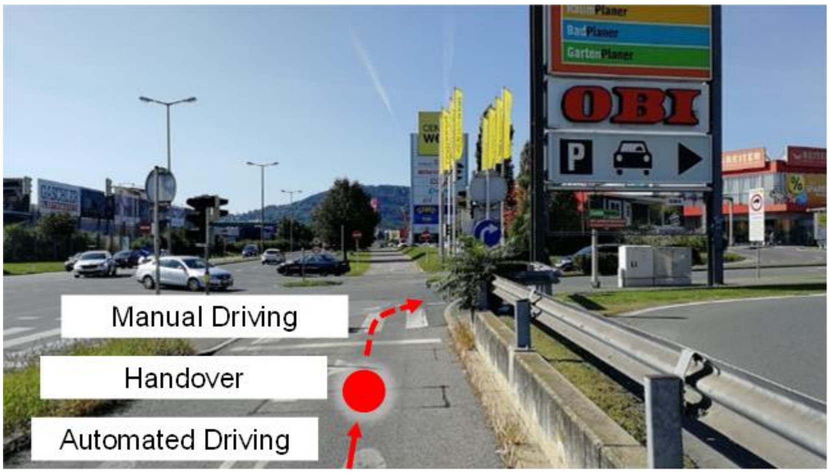


Figure 8: Handover Point Section D --> E. (Source: Google, VIF)

Figure 9 shows the position when a handover from manual driving to automated driving is performed when driving in Eastern direction, it is located at coordinates 47°01'57.6"N 15°25'10.2"E.

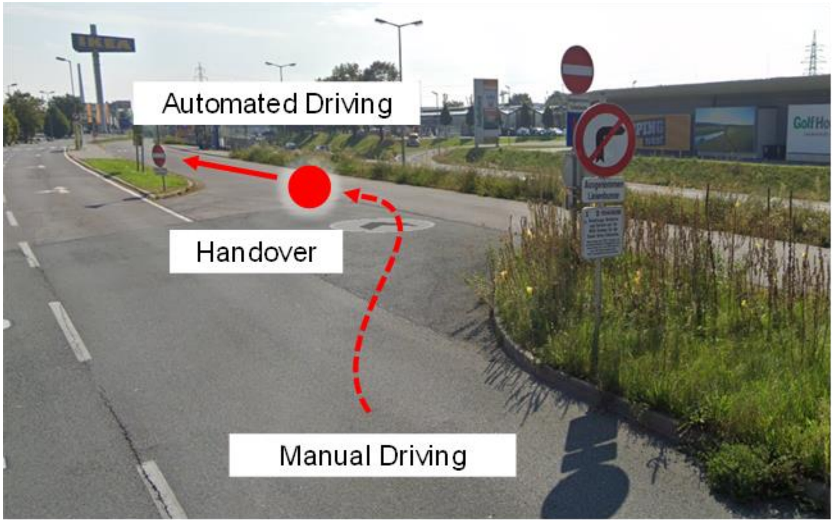


Figure 9: Handover Point Section E --> D. (Source: Google, VIF)

Table 4 provides an overview of road, traffic and weather conditions for the Graz pilot site.

Table 4: Road, traffic and weather conditions at Graz pilot site

Variable	Graz
Area type (In- or outside built-up area)	• Outside built-up area
Weather	• Most of the year quite favourable conditions • Fog is fairly common in the winter months (from October to February), in particular in the morning hours. • Snow has become less frequent in Graz in recent decades. There are years in which no snow falls at all and years in which a snow cover remains for 2 months. • Heavy rain is possible in the summer months with thunderstorms
Sight conditions	• Restricted conditions due to rain, snow, fog
Road type(s)	• Urban roads with 30 km/h speed limits on route

Variable	Graz
	• Number of intersections on route: no typical intersection (tram crossing; bus terminal lanes; junctions in shopping center area) • No. of roundabouts: 1 • No. traffic lights on route: 2 (1 crossing tram track; 1 junction in western part of area) • No dedicated lanes for automated vehicles, mixed traffic roads only with bus traffic
Road works	• In case of road works on any part of the incoming tram line, a replacement bus service is provided. This bus service interferes with the stopping place of the automated vehicle in such cases.
Incidents	• Even though the area around the public transport hub is only dedicated for buses, rare cases of commercial and emergency vehicles could be observed. However, they did not pose any risk for incidents.
Traffic conditions	• The traffic volume of buses is particular high at rush hours, in particular in the morning. Therefore, there are cases where all bus bays are occupied at the same time and the automated vehicle cannot find a way through. However, this typically does not take long and after an average waiting time of 1-2 minutes, a bus bay becomes available.
Traffic composition	• Mostly buses on the eastern part of the area with some trams operating as well.

4.3 Services and use cases

The key objectives of the pilot site in Graz were the following:

- Integrate automated and connected shuttles into existing mobility services.
- Enable automated vehicles to enter highly frequented public transport bus stops.
- Perform safe detection of pedestrians and shuttle passengers at bus stops.
- Construction of an automated shuttle line demonstrator linked to a bus stop.

At typical day of field trials for the site looked as follows (routine of operation):

The operation begins at the defined vehicle stop in front of the public transport terminal. In very rare cases, all bus bays are occupied. If this is the case, the safety driver has to delay the drive for about 1 minute until a bus bay becomes available. Afterwards an automated selection of the first free bus bay available is done with support by a C-ITS based smart-camera and the round is started. Automated driving is performed through the bus terminal, and crossing of tram tracks, what is also supported by a C-ITS based traffic light. Then the track goes along the dedicated bus road, through the tunnel to the intermediate stop at IKEA. If passengers exit at this place, according to actions like stopping and starting again are taken. In the further course, the vehicle approaches the western part of the area, where the safety driver changes the driving mode to planned manual mode due to the performed risk analysis mentioned before. On the way back, the vehicle changes back to automated mode initiated by the safety driver shortly before arriving at the intermediate stop at IKEA. After serving this stop, the vehicle drives back towards the public transport terminal. Before reaching it, in needs to stop at a stop line, drive along a tram road and *finally turn into the defined vehicle stop at the front of the public transport terminal. In this way, one round is finished that covers all three use cases (UC1.2, UC1.3, UC3.4).*

After the final route of the day, the safety driver drives the vehicle manually to the garage for charging and maintenance.

4.4 Site-specific test cases

In Graz, the following test cases were deployed and evaluated:

Automated passenger mobility in Cities under complex traffic & environmental conditions (responding to UC1.2)

The automated vehicle successfully and deterministically drives on the predefined track. Because of missing road markings, an HD map is used for precise localization and for planning the vehicle movement. Additionally, this map includes speed limits, lane- and road-boundaries as well as stopping lines.

Interfacing non automated vehicles and travellers (responding to UC1.3)

The area of train-, tram- and bus station is probably the most demanding section of the site. Here buses, trams, pedestrians and cyclists roam around in various directions. Using 360° sensor coverage and limiting the cruising speed to walking speed, the automated vehicle can traverse this station safely along the predefined paths.

Automated services at bus stops (responding to UC3.4)

The vehicle stops only if the passenger has selected the bus stop as target. At the tram- and bus station the existing bus bays are not used because this could interfere with the bus schedule, which must be avoided. Thus, a temporary stop is set up at the driveway at times when the shuttle service is available.

4.5 The fleet

The utilized vehicles are passenger cars equipped with automated driving functionality. This is a Ford Fusion (Partner VIF, Figure 10) and a Kia e-Soul (Partner AVL, Figure 11).

Figure 10: Graz pilot vehicle 1 - Ford Fusion (Source: VIF)

Figure 11: Graz pilot vehicle 2 - Kia e-Soul (Source: AVL)

Figure 12 shows a simplified overview, how automated driving functionality is deployed in the vehicles. The vehicles are normal passenger cars registered for traffic and do not need an extra permit for manual driving on any roads.

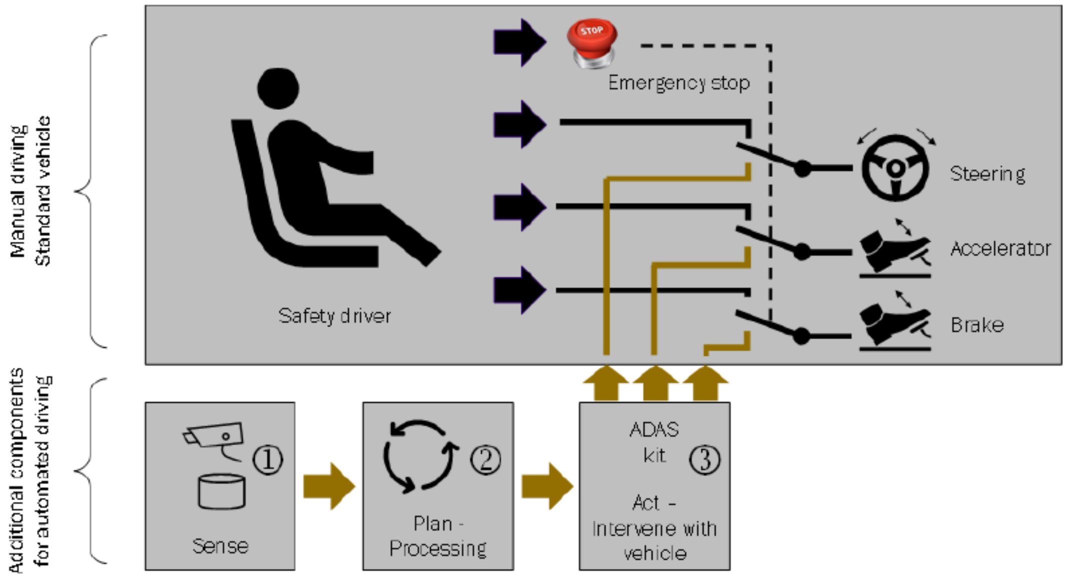


Figure 12: Basic operation of automated driving in deployed vehicles (simplified). (Source: VIF)

The vehicles are retrofitted with three components implementing the “Sense – Plan (Think) – Act” paradigm that enables automated driving.

1. Sense: Environmental sensors like LiDAR and camera (latter is not used in SHOW)

2. Plan (Think): Intelligent automated driving functions that process input from sensors and plan the vehicle's next steps in the current position. This is implemented as dedicated hardware and software in the vehicle.

3. Act: ADAS Kit: This is a complete automotive-grade hardware and software solution that allows seamless electronic control of a vehicle’s brake, throttle and steering. It is the functionality that intervenes on the vehicle and is also responsible for switching between manual driving and automated driving.

Table 5: Automated driving components in the deployed vehicles.

Components for automated driving	Ford Fusion	Kia e-Soul
(1) Sense	Lidar	Lidar
(2) Plan (Processing)	The exact same automated driving algorithm will be used in both cars (based on Autoware)	
(3) Act (ADAS Kit)	DataSpeed ADAS Kit	AVL DRICON Drive-by-wire kit
(4) Overriding instance in the event of any error	Safety driver	Safety driver

Figure 13 illustrates what the automated driving software of a vehicles senses, when it is in front of the public transport terminal. The red points are points from the Lidar point cloud showing the surface of the road and any other objects in the 3D space. The green cubes and cylinders are recognized objects like buses and pedestrians.

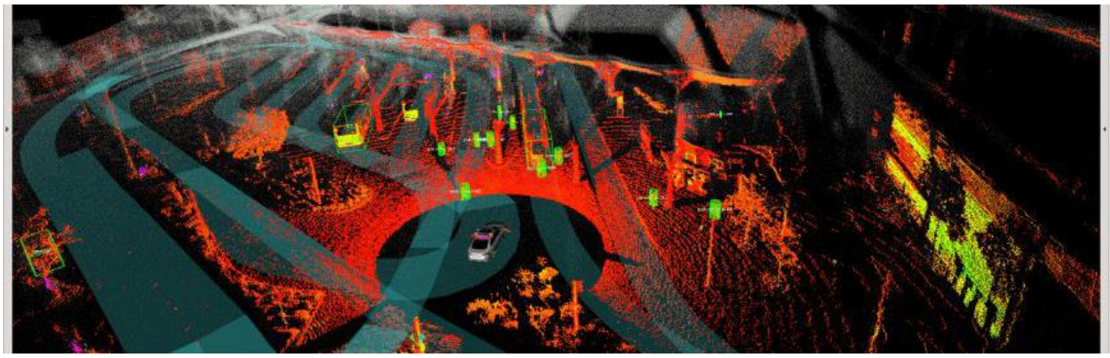


Figure 13: Sensor view from the vehicle when crossing the public transport terminal. (Source: VIF)

This illustration is also constantly shown on a front display in the vehicle during driving. This makes it relatively easy to explain to passengers what the vehicle recognises at each stage of the journey. Our public test drive experience has also shown that the presence of this display increases passengers' confidence in the technology because they see that a large number of objects are reliably detected. In addition, the vehicle was equipped with a tablet as HMI (human-machine-interface) for the selection of the desired stop of the passenger (see Figure 14). The tablet was connected via a local, secure WiFi network to the vehicle.

Figure 14: Safety driver (left) and passenger (right) selecting destination on tablet. (Source: VIF)

Table 6: Graz fleet characteristics.

Test/Use Case	Deployed fleet characteristics								
	Vehicle brand & model	**Vehicle type (shuttle, …)**	**SAE Level reached for the field trials [1-5]**	**TRL level reached for the field trials [1-9]**	**Summary of upgrades held during the project (in consistency with D7.2)**	**HMI and Hand-over strategies (in consistency with D7.2)**	**Maximum speed reached during the trials (km/h)[1]**	**Average speed during the trials (km/h)**	**Maximum capacity of vehicle**
Same for all UCs: UC1.2, UC1.3, UC3.4	Ford Fusion	Passenger car	4	6	Upgrade of automated driving SW Measurement of the route as HD map and storage in the vehicle	Handover is always initiated by safety driver with any intervention (steering, accelerate, braking, emergency stop)	30 km/h	approx. 15 km/h	1 safety driver + 4 passengers

[1] Maximum and average speed calculations might show slight deviations in the analysis followed in WP13 Deliverables as well as in the final Dashboard values.

Test/Use Case	Deployed fleet characteristics								
	Vehicle brand & model	**Vehicle type (shuttle, …)**	**SAE Level reached for the field trials [1-5]**	**TRL level reached for the field trials [1-9]**	**Summary of upgrades held during the project (in consistency with D7.2)**	**HMI and Hand-over strategies (in consistency with D7.2)**	**Maximum speed reached during the trials (km/h)[1]**	**Average speed during the trials (km/h)**	**Maximum capacity of vehicle**
	Kia e-Soul	Passenger car	4	6	Upgrade of automated driving SW Measurement of the route as HD map and storage in the vehicle	Safety driver initiates handover with any intervention (steering, accelerate, braking, emergency stop). Any failures also result in fallback to safety driver with auditive warning.	30 km/h	approx. 15 km/h	1 safety driver + 4 passengers

4.6 The infrastructure

A very important feature in Graz is that the vehicles' journeys are in principle independent of the additional digital infrastructure and can also be carried out without infrastructure. With the infrastructure, however, there are improvements when driving through the bus terminal, as objects are detected more reliably. This does not mean that the journeys without infrastructure are unreliable, as the conservative approach means that the vehicles stop in the event of ambiguities. Figure 15 gives an overview of the infrastructure components in Graz, which is also explained in SHOW Deliverable 4.4. The vehicles technically have 2 ways to communicate with the outside world, firstly traditional short range V2X for the local environment and secondly cellular V2N (4G/5G) to connect to the internet.

An essential task of the automated journey is to drive through a bus terminal. Here, it must be determined which bus bay is available, i.e. free of buses, and where few VRUs are at risk. For this reason, the bus terminal digital infrastructure must allow to detect presence of buses and acquire information of buses arriving soon. The bus terminal is monitored via a smart camera system. It detects the bounding boxes of the objects in its view, classifies them and provides corresponding information locally to the C-ITS Road Side Unit (RSU). The RSU continuously sends out C-ITS messages about the status of each bus bay to inform whether it is free or occupied. In addition, AVs need to cross a tram track after leaving and before entering the bus terminal. This information is also conveyed via C-ITS to the vehicles.

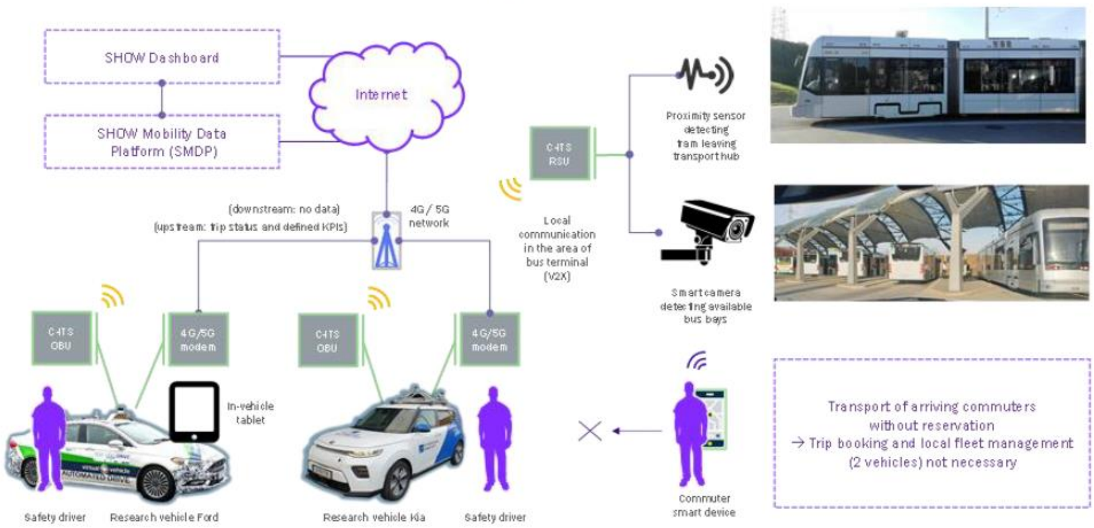


Figure 15: SHOW pilot architecture in Graz (as described in SHOW D4.4). (Source: SHOW)

The implementation of infrastructure in Graz has been carried out in 2 phases:

Phase 1 (Part of Pre-Demo): Provision of real-time data from the vehicle to the SHOW Data Management Portal (DMP). In the pre-demo phase, the software implementation and testing of real-time data via MQTT has been performed. This included reading of values from the vehicle (e.g. GNSS position, speed, mileage etc.), converting them to a standardized format (JSON), sending it via a defined protocol (MQTT) and a 4G router within the vehicle to the SHOW DMP.

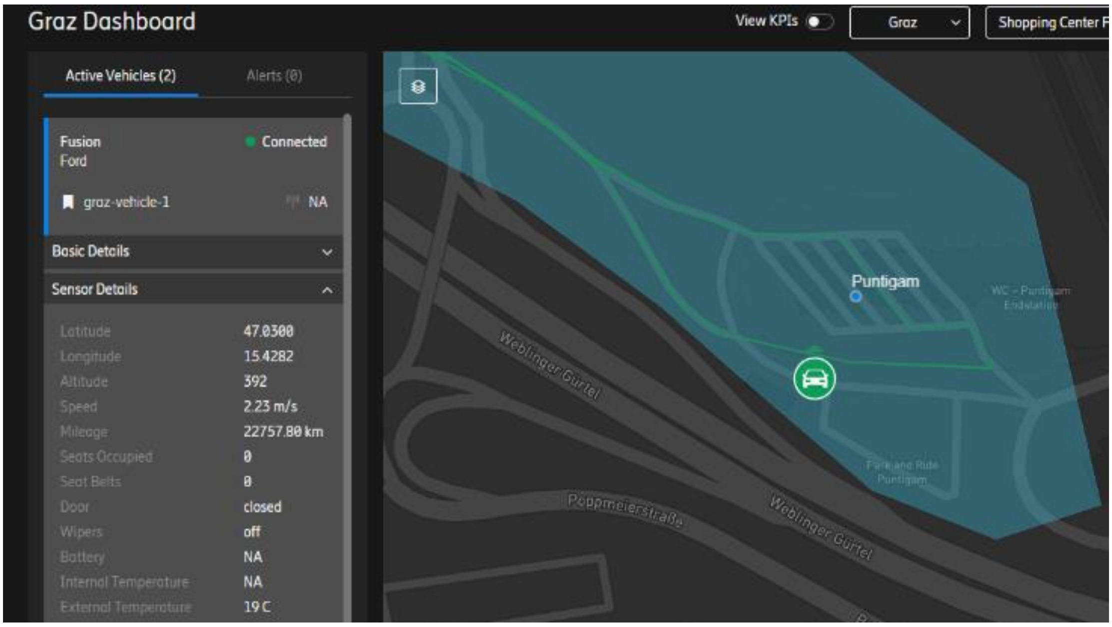


Figure 16: Display of live streaming data and position of Graz vehicle on the SHOW dashboard. (Source: VIF)

Phase 2 (implemented during pilot phase): A camera system with on edge AI processing (“awareAI camera system”) has been deployed on top of an existing light pole. The local implemented awareAI core, functioning in real-time, undertakes the processing of incoming video stream data. Throughout the implementation process, five specific detection zones were established, each covering an individual bus bays of the bus-terminal to determine the drive-through status (free or occupied). Based on the detected information, the awareAI core system generates the respective C-ITS information which is updated and triggered per second to the connected C-ITS Road Side Unit (RSU). The RSU continuously encapsulates the C-ITS information to a standardized ISO “In-Vehicle Information” message, including the detected drive-through status dynamically as a project-defined bit-string. The RSU broadcasts the C-ITS message per second via the ITS-G5 communication channel. Figure 17 gives an impression of the implemented awareAI camera system.

Figure 17: AwareAI camera detecting available bus bays for passage of automated vehicles. (Source: YUNEX Traffic)

4.7 Passengers

The primary types of passengers targeted in Graz were commuters, visitors of the shopping centre, and individuals with an interest in automated mobility. In order to appeal to a wider audience, Graz's public transport company employed the use of advertising monitors on their trains and buses throughout the city, thereby raising awareness of the SHOW service. Additionally, the SHOW shuttle service has been promoted within the academic community. As a consequence of these activities, the potential of the technology has been demonstrated to a number of students and school classes. Furthermore, the possibility of an automated journey from the PT hub to the shopping centre has been promoted at various events with relation to mobility around the city of Graz (such as MotionExpo).

Figure 18: Passenger with baby seat boarding an AV in Graz (source: AustriaTech/ Schallauer)

4.8 Total number of passengers

During the public operation between October 2022 and October 2023, 520 passengers were transported. In addition, around 90 passengers were included in the pre-demo phase running from August to September 2022. The operation was carried out in blocked events, for one week in each season and during special events such as the 'Supertester' day.

These 520 passengers were roughly distributed as follows: Approximately 60 students from 3 school classes, approx. 30 supertesters, approx. 30 VIPs such as politicians, media representatives and stakeholders and around 400 ordinary citizens in the age range 16 – 75; including both men and women and individuals from a wide range of educational backgrounds and professions.

4.9 Data Collection

Throughout the operation and test period, important vehicle data was collected and sent to a cloud system using the Message Queuing Telemetry Transport (MQTT) protocol. The data was then used to calculate the KPIs and displayed on the project dashboard (Figure 19).

In addition, the online survey questions were printed on paper and given to passengers to complete after their journey. Experience showed that very few passengers wanted to click through the online questions themselves. This step involved some extra work, as the questionnaires had to be transferred to the online survey afterwards. However, we were able to get feedback from almost 100% of our passengers.

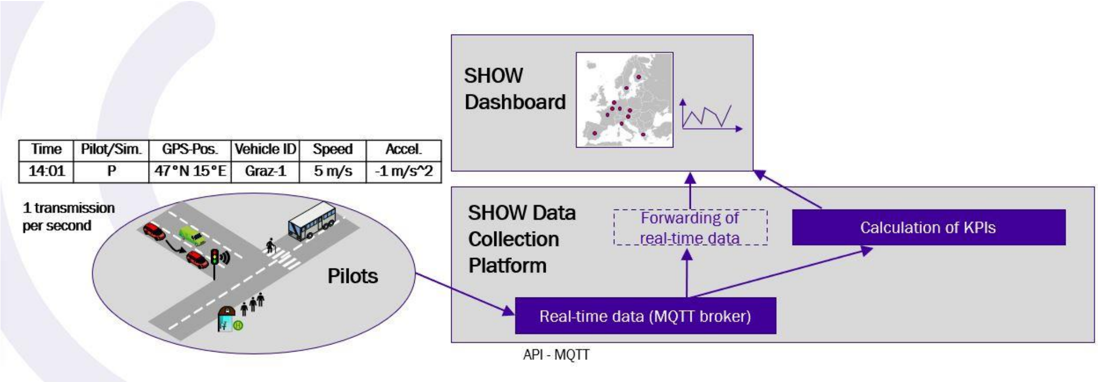


Figure 19: Connection to SHOW DMP and Dashboard

4.10 Pilot operation key findings

During almost 400 test drives with the VIF-robotaxis, there were few non-critical individual situations, in which the safety driver intervened in the operation and had to take over and drive manually. Besides these few events and the turning manoeuvres around 99% of the operation was automated. We did not have clearance to perform these turning manoeuvres autonomous mode. Within the next subsections those challenges, incidents and impacts will be described.

4.10.1 Key findings per Use Case

High level findings per Use Case		
Use Cases	Overall qualitative performance score (1-3[2])	Justification
UC1.2: Automated passengers/cargo mobility in cities under complex traffic & environmental conditions	3	The automated vehicle successfully and deterministically drives on the predefined track. An HD map is used for highly accurate localization and for planning the vehicle movement. Interventions of the test driver were hardly ever needed.
UC1.3: Interfacing non automated vehicles and travellers (including VRUs)	3	The area of train-, tram- and bus station is probably the most demanding section of the site. Here buses, trams, pedestrians and cyclists roam around in various directions. By using 360° Lidar sensor and limiting the cruising speed to walking speed, the automated vehicles traversed this station safely along the predefined paths without human interventions.
UC3.2 Big data/AI based added value services for passengers	3	During the public operation the dynamic vehicle parameters were made available via MQTT every second for further evaluation within the project consortium.
UC3.4 Automated services at bus stops	2	The vehicle stops only if the passenger has selected the bus stop as target. Most passengers using our service were so impressed by the service that they took a complete trip from bus terminal to the shopping centre and back again.

[2] 1 [Low] – 2 [Medium] – 3 [High]; success qualitative score, considering all aspects (technical, user acceptance).

4.10.2 Key challenges and mitigation outcomes

There were different challenges to overcome during the pilot phase at the pilot site Graz, Table 7 shows a list of them.

Table 7: Key challenges

Challenge	Type (Operational, Technical, Business, Other)	Mitigation	Mitigation outcome
There is a need to accelerate users' adaptation time to use automated vehicles, who sometimes still prefer to use conventional buses, even if they have to wait longer.	Business	Increased advertising about the service, creating awareness and intensification of users engagement to increase user experience.	More users came to our pilot-site in the second half of the testing-period
At times, all bus bays were occupied, and our automated vehicles had to wait until they were freed.	Operational	With six bus bays and short standing times of buses.	Since the waiting time was relatively short (max of 1 or 2 minutes) no action was taken.
The automated vehicle recognised an unplanned object (police vehicle) and stopped behind it in a lane used by public buses, blocking its operations.	Operational	The safety driver took over the vehicle and steered to an adjacent spot to pick up passengers.	In future, remote operators could take control in such rare cases.

4.10.3 Key incidents and impacts

One key incident occurred when a police vehicle occupied the robotaxi's stop. Although the robotaxi recognized the unexpected object and stopped behind it, the robotaxi blocked the bus lane and impaired bus operations.

Another key incident happened when the robotaxi confronted with a situation, in which a bus travelled against a one-way bus lane for reaching a parking lot. The bus drove towards the robotaxi since no one gave the bus any instructions. These cases point out that AVs need to be able to perform more flexible manoeuvres, e.g. driving in the opposite direction away from another object, instead of just stopping or deviating from the predetermined lane/path, since unexpected situations can occur anytime in a complex traffic environment.

The above issues imply that there is room for improvement to draw other road users' attention to moving AVs, and to enhance reaction alternatives and decision-making of AVs. The capability to better handle more critical weather and pavement conditions, e.g. heavy rain and snow and icy roads, should also be further addressed.

4.10.4 The passengers' point of view

From the passengers' point of view, we got overall positive feedback. At first, people hesitated to go in an automated vehicle but were positively impressed and felt safe after being transported. - "Very good idea, great implementation! Would love to use it in future." Younger people in particular were generally positive and said that it was fine for them to pay for such a service. Older passengers were often a little hesitant before using our shuttle service, but once they had taken a ride, the feedback was also very positive. The most important result was always that they would use the service without hesitation if the safety was at least at the same level as with manually operated vehicles.

Figure 20: Pilot operation on 04th October 2023 in Graz (Source: Virtual Vehicle)

More detailed feedback was provided by "supertesters". The "supertesters" (see Chapter 4.11, Key local demonstration events) consisted of 21 participants who tested the automated vehicles and provided feedback on their experiences during a workshop. The group represented a wide age range, from about 10 to 70 years old. After driving the automated vehicles, they rated various aspects of the experience and made suggestions for improvement.

Overall, the feedback was positive, with the service receiving an average satisfaction score of 88.7 out of 100. Participants rated reliability at 6.9 out of 10, usefulness at 7.8, speed at 7.9, comfort at 8 and perceived safety at 8. However, the Ford Fusion vehicle was generally rated as smoother, while the Kia was described as sometimes jerky, with slow and overly cautious driving. Despite these issues, most testers still felt safe in the cars. Participants also suggested improvements, including better communication to explain vehicle stops or delays during journeys, the addition of an emergency call system and clearer communication in abnormal situations. They also recommended a voice module to increase interaction and improve the overall passenger experience. For further user acceptance results, please refer to D13.5 [4].

Figure 21: Supertesters on site and during the workshop in Graz (Source: AustriaTech)

4.10.5 The safety drivers´ point of view

A total of 4 safety driver were involved in the Graz pilot site operation – two from AVL and two from ViF.

The feedback from the safety drivers was very positive overall, as there were only a few situations in which they had to take control due to special events. As already described, there was one situation where a police car blocked the road and the safety driver had to take control as the automatic function would have waited until the car (obstacle) was gone. As we didn't want to wait that long, the safety driver drove past the obstacle manually and the automatic drive was able to continue.

The handover procedure in the test vehicles used is intuitive: a grip on the steering wheel or a press on the brake immediately deactivates the autonomous driving functions - this is necessary for safety reasons as well. The system can be reactivated just as easily by pressing two buttons on the steering wheel - provided, of course, that the vehicle is located on a known route.

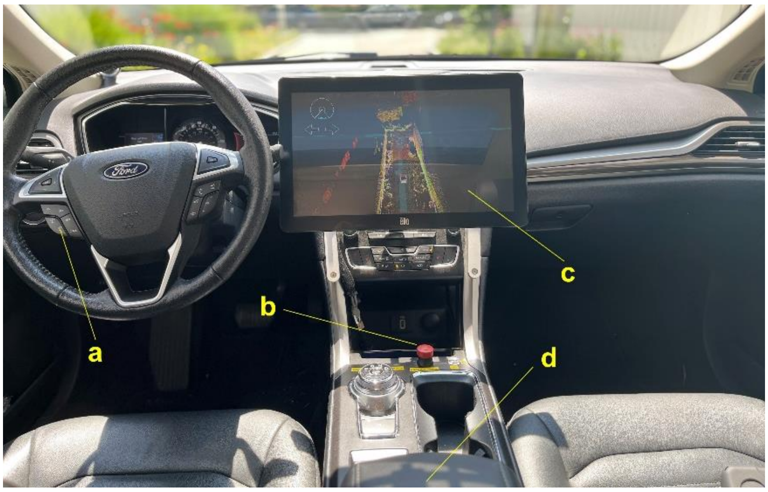


Figure 22: Buttons for activation of automated driving, (b) emergency stop button, (c) screen for test driver and (d) tablet for passenger (Source: Virtual Vehicle)

In conversations with passers-by and people transferring at the local transport hub, it was noticeable that some people were hesitant and afraid of riding in an automated vehicle. However, after riding along in the vehicle, these people were consistently impressed and felt safe. The result of the offered test drives was indeed that the acceptance of automated driving is increased when people experience it in real life and thus possible prejudices can be dispelled. For further user acceptance results, please refer to D13.5 [4].

The questions asked by our passengers during the test drives varied greatly depending on their level of knowledge. Many simply enjoyed the ride while other wanted to discuss things – both technical and organisational – at length with our safety drivers. As our safety drivers had all been involved in the project to a greater or lesser extent, they were able to provide competent answers.

4.10.6 The other road users´ point of view

We had personal interaction with three groups of road users during the tests: pedestrians, bus drivers and cab drivers.

Some people at the bus stop - mostly waiting for a bus - were definitely interested in our vehicle and our project in general. We were able to persuade some of them to travel with our AVs during a brief personal conversation. Others said they didn't want to come along due to time constraints. Still other groups were very sceptical about the topic and even had derogatory words for it.

We also got talking to taxi drivers. They were interested out of concern for their profession when and if this service were to become available throughout the city. We were able to persuade them to take a test drive. Once they had experienced the service, they were convinced that their job will probably change in the medium term but will not be eliminated (retraining as a safety driver).

Another initially sceptical group were the city bus drivers. Their concern was primarily whether the AV could interfere with their work and timetable. But after some discussions and a test drive, they were reassured, as they did not know that there is currently always a safety driver in the vehicle who can intervene at any time in the event of malfunctions or unforeseen situations. Furthermore, should the legal situation in Austria change (safety driver is no longer mandatory), a remote operator will still be available to assist in challenging traffic situations.

4.10.7 The stakeholders´ point of view

Even in the initial phase, the stakeholders - including the public transport company - were very interested and supported the project from the very start. In addition to the prestige of having such a project in their city, they also wanted to gain insights into the extent to which autonomous driving is already capable for series production and what requirements need to be considered when building new transport services and lines to make them fit for the future. The hope that fewer bus drivers will soon be needed - who are not available on the labour market but are urgently needed for the further expansion of their network - was likely another reason for their interest in project SHOW.

Now that the project has been completed, we got the following message from our stakeholder: The current situation, where a safety driver must always be in the vehicle, means that this technology is not beneficial for them. A remote driving approach would probably be acceptable, where the AV normally drives itself but in unforeseen situations a remote driver in a call center temporarily takes control of the vehicle and brings it back into a defined state. Further information can be found in D1.3 [5].

Figure 23: Site visit by the Graz road construction office, who supported obtaining a permission to use the bus only lanes in Puntigam (Source: SHOW)

4.11 Key local demonstration events

What: Supertester day Graz

Who: organised by ATE, VIF and AVL

When: 30 June 2023

Objective: Inviting a diverse group of the same users to experience the Austrian pilot sites. The first test day of this event series was held in Graz.

Outcome: 21 participants were taking several rides in the vehicles and actively participating in the workshop afterwards.

Figure 24: Supertesters at the pilot site and during the workshop in Graz (Source: AustriaTech)

What: Forum Alpbach (showcase Wörgl)

Who: organised by VIF

When: 29 August 2023

Outcome: During the Forum Alpbach, ViF held a demonstration in a cordoned-off zone in the area of Wörgl train station. People participating at the Forum Alpbach could go to Wörgl and take a short trip with our automated vehicle.

Figure 25: Picture showing the train-station in Wörgl (Source: VIF)

What: Students from “"HTL-Kaindorf" are testing the pilot-site Graz

Who: organised by VIF

When: 4 October 2023

Objective: Inviting around 60 students to visit the pilot site and take a ride

Outcome: 60 people could take a ride and give feedback on how it feels to use such a service.

Figure 26: Students of HTL-Kaindorf at the pilot site (Source: VIF)

What: MotionExpo 2024 in Graz

Who: organised by VIF

When: 8-10 March 2024

Outcome: Between 8-10 of March 2024 ViF showcased the robotaxi at an event called Motion Expo. At this public event with thousands of visitors, the test vehicle was exhibited at the event booth. The software was demonstrated by emulating a test drive and showing the data on a screen.

Figure 27: Picture of the event pooth at the MotionExpo 2024 (Source: VIF)

4.12 Lessons learned

Overall, the automated vehicles performed well during the demonstration and evaluation periods and have presented several novel approaches and their practicability for future shared automated mobility. No critical issues have arisen. Challenges still persist, particularly when interacting with other road users and at intersections that are difficult to overlook. In order to start fully automated operation, many small technical hurdles still need to be overcome over the next few years and the flexibility in action taking needs to be further enhanced to make sophisticated decisions for driving safety and efficiency.

Overall, no fatal situations occurred during the drives on the pilot-site. In situations where the system reached its limit, the safety driver had to intervene and resolve the situation. Examples for this scenario are the following: (1) In a single case, a police vehicle drove to the defined stop place of the automated vehicle and blocked it. The automated vehicle recognized this unplanned object and stopped in front of it. However, in this situation, the automated vehicle was now blocking the public buses due to space constraints. In this case, the safety driver took over the vehicle and steered to an adjacent spot to pick up passengers. (2) In another single case, an empty public bus reversed on the bus lane against the one-way in a section to get to a parking lot (length about 100 m). In this case, the automated vehicle stopped automatically, but the safety driver had to immediately take over the vehicle and bring it to a stop so that the bus could pass the automated vehicle. Once the route was cleared, the automated drive continued.

Figure 28: Automated driving on public roads in rainy conditions. Left: Handling of oncoming buses on the road. Right: Passage through a tunnel on the pilot-site. (Source:VIF)

Furthermore, other experiences were gathered during the pilot phase. At certain times, all of the bus bays in the bus terminal were occupied and there was no way for the automated vehicle to pass. In these cases, the vehicle was forced to wait until a bus bay became available. However, the waiting time was relatively short with a maximum of 1-2 minutes, since with 6 bus bays and short standing times of the buses, a bus bay becomes available relatively quickly.

It should be mentioned at this point that we have never before brought our technology closer to normal citizens to this extent but have mostly only dealt with an expert audience.

Some of the technical problems we faced in the SHOW project, and which were solved during the project will continue to improve our vehicle in the future. One of these challenges was initially the evaluation of the LIDAR data when rain or fog was present on the track. Before SHOW, we only carried out test drives in clear weather. But for SHOW, we had to dig deeper into this domain and improve the LIDAR data processing pipeline to deal with such weather conditions. An outlier filter has been added to remove single measurements (rain, fog) and a crop box filter has been applied to remove spray behind the vehicle and spray from the chassis in heavy rain to avoid obstacle detection in the near field of the ego vehicle. The proven algorithms for localization and object detection were then applied on top of this pre-processed point cloud.

Another thing that initially caused concern were bushes and scrubs that were close to the track in places and even grew in. This problem was alleviated by modifying the map and reducing the width of the lane at the critical sections. Since we position our vehicle on the HD map using a SLAM algorithm, another concern was whether we could locate our vehicle well enough near the bushes at all four seasons. During the show pilot operation, it turned out that this concern was unfounded; the vehicle can localize itself accurately in all seasons, regardless of the foliage of the bushes and the height of the surrounding grass. Even harsh winter conditions with snow all around did not influence the localization accuracy significantly.

Another lesson-learnt concerns C-ITS communication. Although basic knowledge was available before SHOW, this interface was only integrated into the AVs as part of SHOW and will likely continue to be used long after SHOW is completed. This integration involved the entire signal flow, from receiving the messages and decoding them and reacting appropriately, had been integrated into the autonomous driving software.

4.13 Roadmap beyond SHOW and replicability

Virtual Vehicle has already set up another demo site in Wörgl in Tyrol with funding and cooperation with the local municipal government. The aim of this pilot system is to demonstrate automated passenger transportation between the train station and an industrial area in Wörgl. We were able to transfer our knowledge from the SHOW pilot site to the new site, so that we were able to move from the preparation phase to the demo phase in a very short time. As the focus of Virtual Vehicle Research GmbH is on research and innovation, the main aim of this project is to further develop our software and hardware solutions in the field of automated driving.

Furthermore, it is planned in upcoming research projects to extend the existing route of the pilot site of the SHOW project in Puntigam to include a connection to the nearby highway, so that we can enhance our knowledge in terms of automated driving to the highway and back to the urban area.

For AVL the SHOW project was a great opportunity to test a L4 demonstrator vehicle on public roads that was built-up starting from a non-automated series production car (retro-fittig). The lessons learned shall be used to streamline the process of retro-fitting non-automated vehicles and deploying automated vehicles for testing purposes in Austria to future customers of AVL. Additionally, the analysed and identified modifications to both the vehicle and the target area in terms of V2I (vehicle to infrastructure) communication to enhance the safety of the driving operation will be subject of further investigations. Another next step is to establish a virtual validation workflow once a digital twin of the target area Graz Puntigam is available.

5 Salzburg test site

5.1 The Ecosystem

The Salzburg pilot site ecosystem consists of three stakeholders within the SHOW consortium and three external stakeholders. The participating entities, their role and whether they are internal or external to the consortium is listed in Table 8.

Table 8: Salzburg Pilot site – the ecosystem

Participating Entity	Internal to the Consortium	External to the Consortium	Role
Salzburg Research	✓		Local site leader responsible for the pilot in Salzburg
AustriaTech	✓		Mega site leader - coordinator of common aspects of Austrian pilot sites
Kapsch TrafficCom	✓		responsible for the C-ITS-infrastructure/equipment and the implementation of the C-ITS UC's HLN-PTVS and HLN-PTVC at the pilot Salzburg
Municipality of Koppl		✓	provide support for the pilot activities; location of the pilot track
Salzburger Verkehrsverbund		✓	Local public transport authority.
DigiTrans GmbH		✓	Lender of the HEAT-shuttle and the eVAN

5.2 Operation setting

The pilot track for automated shuttles is situated in a peri-urban environment within the municipality of Koppl / Salzburg / Austria. The length of the autonomous route is approximately 1.4 km one-way. It is a slightly curved asphalt road with a maximum of 8 % incline. The whole route has driving lanes for both directions. Including start and terminus stops, the route serves four bus stops in each direction. It is fully equipped with ETSI-ITS-G5-enabled Roadside Stations (#5). A HD-map of the whole test route has been created and optimized for the pilot (see Figure 29).

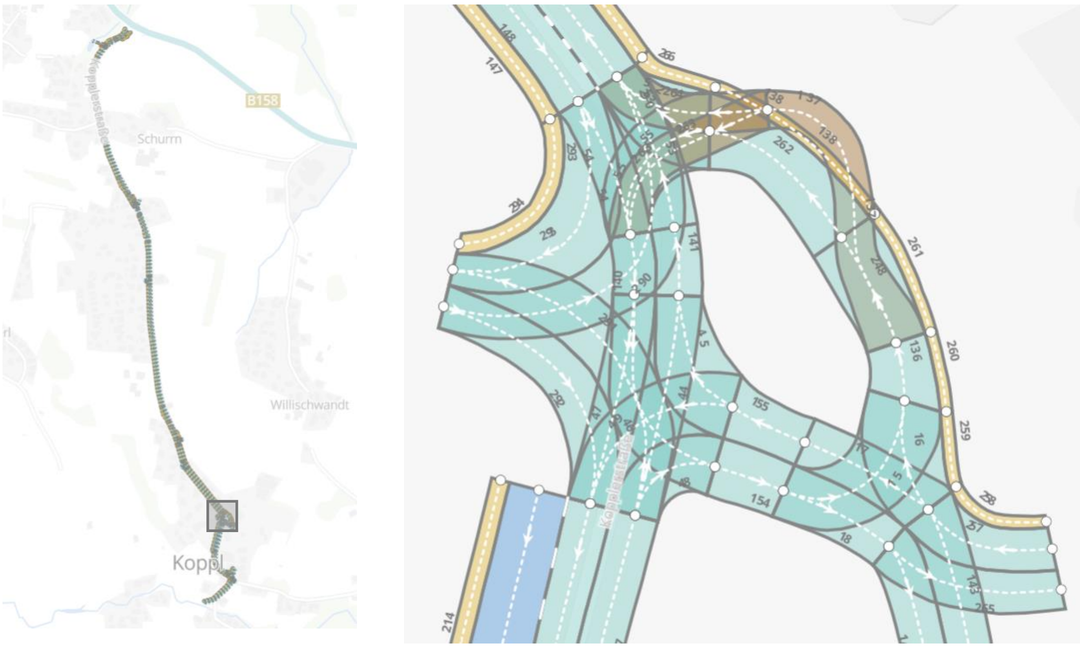


Figure 29: HD-Map of the pilot track in Koppl © HD-Graphen Digibus® Austria and Joanneum Research

To be granted a test application by the Austrian Federal Ministry of Climate Action, Environment, Energy, Mobility, Innovation and Technology a detailed risk analysis including the identification of risk mitigation measures for the pilot track was performed. Figure 30 shows impressions of the pilot track in Koppl. Figure 31 visualizes the map of the pilot track including the locations of the stops (green squares). In addition, the location of Koppl in proximity to the city of Salzburg is shown as well as a part of the pilot track (orange dot-line) in the photograph of the municipality of Koppl.

Figure 30: Impressions of the pilot track (Source: Kapsch TrafficCom; Salzburg Research)

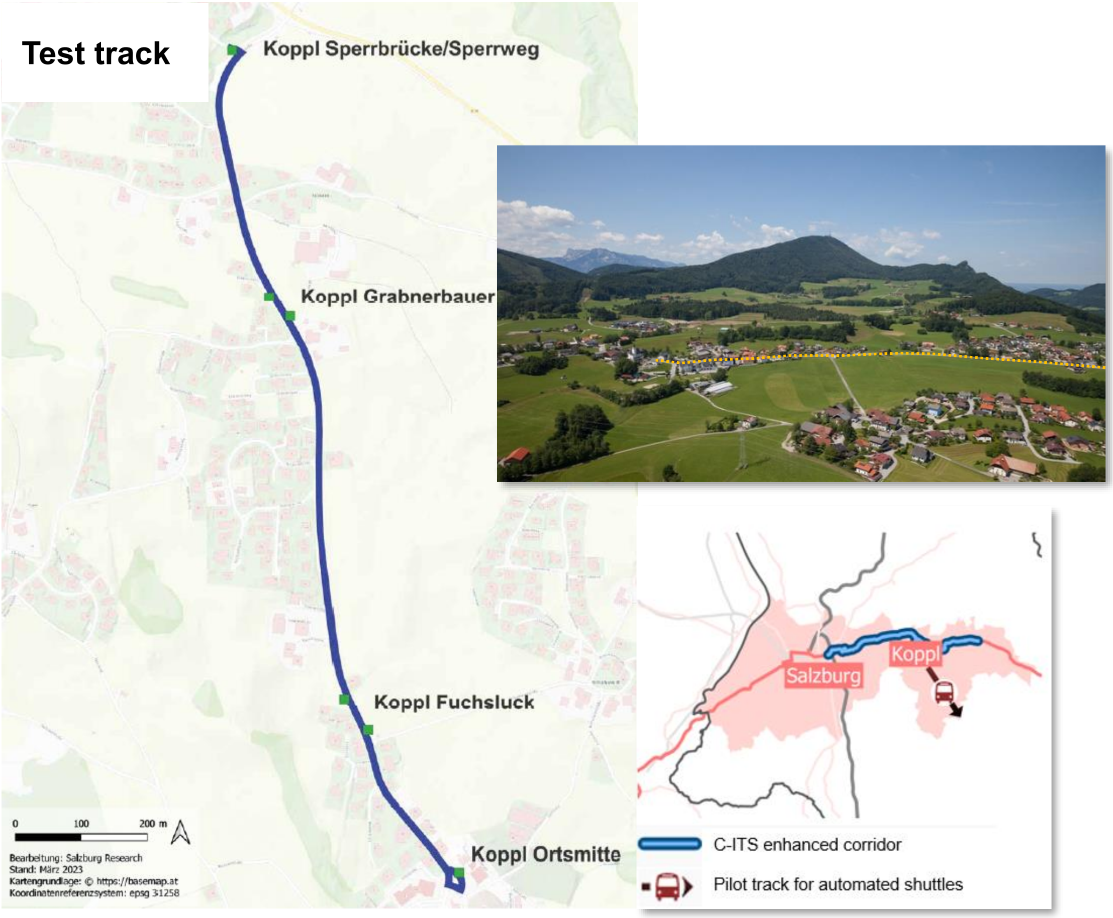


Figure 31: Pilot track in Koppl (Source: Salzburg Research)

The C-ITS enhanced corridor runs along the B158 Wolfgangsee Bundesstraße in a peri-urban environment from the public transport stop “Koppl Sperrbrücke” westwards on one of the major commuter connections into the city of Salzburg. It is an asphalted, 2-way-lane and slightly curvy road with a length of approximately 8 km (one-way).

In Figure 32 the locations of the four RSU’s (white) on the C-ITS enabled bus corridor into the city of Salzburg and the 5 RSU’s (yellow) on the pilot track for automated vehicles in Koppl are visualized.

Figure 32: Road site units on the pilot track for automated vehicles in Koppl (yellow) and on the C-ITS enabled bus corridor (blue line) into the city of Salzburg (Source: Kapsch TrafficCom; adapted by Salzburg Research)

Table 9: Road, traffic, and weather conditions at Salzburg Pilot Site.

Variable	Salzburg
Weather	General description: Salzburg is located in the transition zone between the Atlantic maritime and continental climate, which is characterized by moderately cold winters and warm summers with year-round precipitation (mainly in the summer months). Compared to other major Austrian cities, the city has higher levels of precipitation and more frequent strong winds due to its location on the northern edge of the Alps. Foggy conditions are rare. During the pilot: sunny, cloudy, rainy / dry, wet; typical temperature range for May/June.
Sight conditions	sight conditions during the pilot within AD-system boundaries.
Road type	Suburban roads. Two-way street, speed limit of 50 km/h and 30 km/h.
Roadworks	No roadworks during the pilot
Incidents	one incident / one accident (see 5.10.3)
Traffic conditions	The traffic density varies depending on the time of day, with higher densities in the morning and evening hours (commuter traffic). No major congestion.
Traffic composition	All types of vehicles are allowed and occurring including VRUs.
Traffic control	No traffic control
Area type (in- or outside built-up area)	Suburban, inside and outside built-up area.

5.3 Services and use cases

The key objectives of the pilot site Salzburg in SHOW were the following:

- Enable and provide safe, sustainable, and integrated transport.
- Build upon existing trials, tests and learning environments in Austria.
- Integrate automated and connected shuttle(s) into the existing mobility services.
- Deployment of C-ITS infrastructure along pilot corridors in Salzburg.
- Enhance MaaS platforms & frameworks and make use of existing steering groups e.g., ITS Austria.

The Salzburg pilot site was in operation between May and June 2023 (scenario 1) as well as between October and December 2023 and in April 2024 (scenario 2).

Four safety operators were responsible for the daily operations of the automated first-/last-mile service. The service was integrated into their App (https://salzburg-verkehr.at/en/timetables/salzburg-verkehr-app/), which facilitated the trip planning with the automated vehicles for the passengers as they were able to access information about arrival/departure time and connections. Passenger real-time information within the automated vehicles was not implemented.), which facilitated the trip planning with the automated vehicles for the passengers as they were able to access information about arrival/departure time and connections. Passenger real-time information within the automated vehicles was not implemented.

The process of operation for automated vehicles is carried out as follows: passengers disembark from bus line 150/155, arriving from Salzburg city center, at the intermodal mobility hub "Koppl Sperrbrücke." From there, they board an automated vehicle for the final stretch to their destination, "Koppl centre." Once seated and secured with seatbelts, a safety operator on board greets them and initiates the automated service from "Koppl Sperrbrücke" to "Koppl centre." The vehicle autonomously covers the 1.4 km route, making stops at two stations, giving passengers the opportunity to exit or enter the shuttle. Upon reaching the terminal stop at "Koppl centre," all remaining passengers disembark. The vehicle then resumes service, heading back to the intermodal mobility hub.

Minors were permitted to travel in the automated vehicle only if accompanied by their legal guardians. Due to the lack of suitable safety equipment, baby carriages and wheelchairs could not be accommodated. Additionally, animals were not allowed on board. Transporting objects such as large parcels was also prohibited, as the vehicles did not have the necessary securing devices.

Figure 33: Impressions of the first- / last-mile-service in Koppl with the two automated vehicles; left column: eVAN, right column: HEAT-shuttle (Source: Salzburg Research)

5.4 Site-specific test cases

The Salzburg pilot site implemented two scenarios. With these scenarios, Salzburg realized and evaluated the UC's 1.2, 1.3, 1.5, 1.6 in compliance with the Use cases according to Amendment #3 of the Grant Agreement. Functionality for planning, routing, operation self-learning services for passengers based upon AI enabled algorithms that optimize DRT operations was not implemented in the automated shuttle by the manufacturer. There was no possibility to add this functionality to the shuttles. Hence, UC 3.1 was not piloted.

- Scenario 1: (UCs 1.2, 1.3, 1.6): Testing automated demand responsive transport (DRT) for connecting a peri-urban area to a city centre via an intermodal mobility hub. Two automated shuttles were used to bridge the first/last mile on the pilot track for automated vehicles in Koppl.

- Scenario 2 (UC 1.5):
  - Testing C-ITS UCs and functionalities with the “eVAN” on the pilot track for automated vehicles in Koppl and on the C-ITS enabled bus corridor, connecting an intermodal mobility hub in Koppl to the city of Salzburg.
  - The following UCs were tested:
    - Use Case 1: Automated Public Transport Vehicle in a Stop - HLN-PTVS
    - Use Case 2: Automated Public Transport Vehicle Crossing - HLN-PTVC
    - Use Case 3: Traffic light prioritisation for automated public transport vehicles - SI-TLP

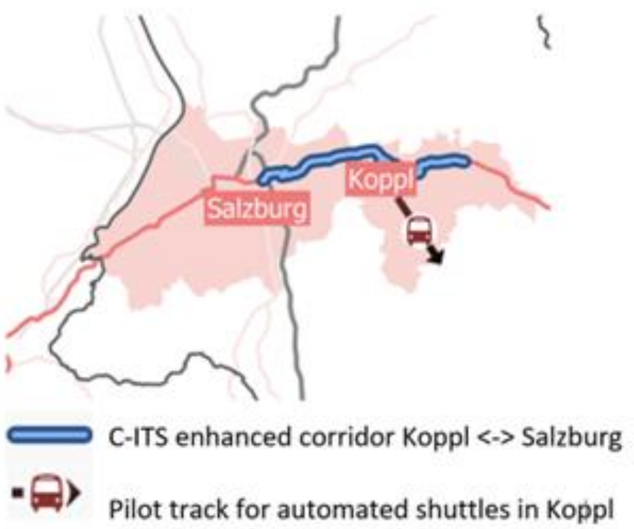


Figure 34: Visualization of pilot track for automated vehicles in Koppl (scenario 1) and the C-ITS enhanced corridor between Koppl and Salzburg (scenario 2) (Source: Salzburg Research)

Within *scenario 1*, one prototype L4 shuttle (HEAT-shuttle IS 2, TSP-Demonstrator C-AV 42) and one retrofitted automated electric passenger minivan L4 (“eVAN”) connected the centre of Koppl (village in a rural environment) to an intermodal interchange (“Koppl Sperrbrücke”).

During the pilot, the use of the automated passenger vehicles was free of charge, complementing existing public transport services five days a week, from Monday to Friday. The typical cycle time was reduced from one hour to half an hour. Table 10 shows the timetable during the pilot phase in Koppl with the HEAT-shuttle and Table 11 shows the timetable for the eVAN.

Table 10: Timetable for the pilot phase with the HEAT-shuttle

Stop	Departure time				
Koppl Ortsmitte	13:24	14:24	14:54	16:24	16:54
Koppl Fuchsluck	13:27	14:27	14:57	16:27	16:57
Koppl Grabnerbauer	13:31	14:31	15:01	16:31	17:01
Koppl Sperrbrücke/Sperrweg	**13:34**	**14:34**	**15:04**	**16:34**	**17:04**
Koppl Sperrbrücke/Sperrweg	**13:42**	**14:42**	**15:12**	**16:42**	**17:12**
Koppl Grabnerbauer	13:45	14:45	15:15	16:45	17:15
Koppl Fuchsluck	13:49	14:49	15:19	16:49	17:19
Koppl Ortsmitte	13:52	14:52	15:22	16:52	17:22

Table 11: Timetable for the pilot phase with the eVAN

Stop	Departure time									
Koppl Ortsmitte	**12:24**	**12:54**	**13:24**	**13:54**	**14:24**	**14:54**	**15:24**	**15:54**	**16:24**	**16:54**
Koppl Fuchsluck	12:26	12:56	13:26	13:56	14:26	14:56	15:26	15:56	16:26	16:56
Koppl Grabnerbauer	12:28	12:58	13:28	13:58	14:28	14:58	15:28	15:58	16:28	16:58
Koppl Sperrbrücke (D)	12:30	13:00	13:30	14:00	14:30	15:00	15:30	16:00	16:30	17:00
Koppl Sperrbrücke (C)	12:42	13:12	13:42	14:12	14:42	15:12	15:42	16:12	16:42	17:12
Koppl Grabnerbauer	12:44	13:14	13:44	14:14	14:44	15:14	15:44	16:14	16:44	17:14
Koppl Fuchsluck	12:46	13:16	13:46	14:16	14:46	15:16	15:46	16:16	16:46	17:16
Koppl Ortsmitte	**12:48**	**13:18**	**13:48**	**14:18**	**14:48**	**15:18**	**15:48**	**16:18**	**16:48**	**17:18**

A trained safety operator, responsible for the vehicle's integrity and the passengers' safety while ensuring the shuttle operated according to the predefined schedule, provided human assistance to passengers throughout the pilot. According to "§3 Driver" in the Austrian Federal Ordinance on Automated Driving[3] of May 13th, 2022, on Automated Driving, §3 Driver, a safety operator is mandatory. The safety operators were obliged to keep a logbook of every journey with the automated shuttles. An operational checklist prepared by Salzburg Research needed to be reviewed by the safety operators before, during and after operation on each day of operation and confirmed with their signature. Detailed instructions for the preparations, the test run before operation without passengers, the regular runs and the decommissioning were available to the safety operators.

Within *scenario 2* (UC 1.5) C-ITS Use cases were piloted with the eVAN in manual mode on the C-ITS enhanced corridor (UC1, UC2, UC3) connecting an intermodal mobility hub in Koppl to the city center as well as on the pilot track for automated vehicles (UC1, UC2) between October and December 2023 and in April 2024.

- The following UCs were tested:
  - Use Case 1: Automated Public Transport Vehicle in a Stop - HLN-PTVS) - (Decentralized Environmental Notification Message - DENM)
  - Use Case 2: Automated Public Transport Vehicle Crossing - HLN-PTVC) - (Decentralized Environmental Notification Message - DENM)
  - Use Case 3: Traffic light prioritisation for public transport automated vehicles - SI-TLP (Signal Status Request Message – SSEM / Signal Status Extended Message - SSEM)

[3] An English translation of the Ordinance for information purposes can be obtained here: https://www.austriatech.at/assets/Uploads/Fokusseiten/Kontaktstelle-Automatisierte-Mobilitaet/Dokumente/68cd019e8d/Automated-Driving-Regulation-Austria-EN_05_2022.pdf

The primary goal of cooperative intelligent transport systems (C-ITS) is to deliver information to drivers of road vehicles via V2X communications. This information can originate from the infrastructure (V2I), including Traffic Management Centers (TMC), or directly from other vehicles (V2V). Within the pilot in Salzburg, the messages are created by the onboard unit in the eVAN and broadcasted directly to other road users or via the installed RSU's.

Description of the Use cases

- *Use case 1: HLN-PTVS: Hazardous Location Notification – automated public transport vehicle at a stop*

Automated public transport vehicle halting at specific types of stops may obstruct the roadway, particularly at stops situated within traffic lanes or where passengers disembark directly onto the road or cross the road in front of the stopped vehicle. In these scenarios, there is an increased risk of collision between approaching vehicles and either the stationary automated vehicle or passengers, with the risk exacerbated under adverse weather conditions. To mitigate this hazard, drivers receive in-vehicle notifications and warnings regarding the presence of an automated public transport vehicle at these stops, enhancing their situational awareness. This system allows drivers to anticipate and react to unpredictable actions of pedestrians.

<u>Scenario:</u>

  - Vehicle is approaching a public transport stop where the automated vehicle is standing
  - locations are known, pre-selected and saved in the database
  - database of the locations and their trigger areas are saved in the automated vehicle's OBU
  - automated vehicle enters the trigger area of this location in the appropriate direction
  - automated vehicle at the PTVS location generates and transmits specific warning messages about "Public transport at bus stop"
  - these messages are received by the vehicle passing by and forwarded by an ITS G5 RSU nearby to the central system

- *Use case 2: Hazardous Location Notification – automated public transport vehicle crossing*

A vehicle is approaching a high-risk area for potential collisions with the automated public transport vehicle. The driver is alerted through in-car information and warnings, which is especially crucial when an automated vehicle is turning at an unsignalized intersection, merging from a lower-ranking to a higher-ranking road or leaving a stop. Due to the lower speed of automated vehicles, these manoeuvres take longer than those of standard passenger cars, and drivers may not anticipate the turn or merge. Additional high-risk areas include locations where automated public transport vehicles merge from dedicated lanes into mixed traffic lanes. While public transport vehicles have priority, many drivers fail to yield, increasing the likelihood of accidents. The driver receives warnings at such locations, to enhance situational awareness and reinforce the need to yield when required. The system aims to improve driver attention and promote safer driving behaviour in these scenarios.

<u>Scenario:</u>

  - Vehicle is approaching a location with a high risk of collision with automated vehicle
  - locations are known, pre-selected and saved in the database

- database of the locations and their trigger areas are saved in the automated vehicle’s OBU
- the automated vehicle enters the trigger area of this location in the appropriate direction
- automated vehicle at the PTVC location generates and transmits specific warning messages about “PT lane crossing”
- These messages are received by the vehicle passing by and forwarded by an ITS G5 RSU nearby to the central system

- Use case 3: Signalized Intersection – Traffic Light Prioritization for automated public transport vehicle

This Use case is designed to prioritize the automated public transport vehicle at signalized intersections to help reduce travel times, enhance the reliability, and improve road safety. Relevant message types are SREM/SSEM (Signal Request/Signal Status Messages). These messages convey detailed information for handling priority requests and responses. SREM messages contain vehicle data, such as vehicle position, speed, type of vehicle etc. Meanwhile, SSEM messages from the infrastructure deliver prioritization status and traffic signal state.

Scenario:

- A V2X equipped priority eligible automated vehicle approaches a signalized intersection
- The designated automated vehicle transmits a prioritization request
- The prioritization system processes the request and either accepts or rejects the request, then gives feedback to the designated automated vehicle.
- If the request is accepted, e.g. "red phases" may be shortened and "green phases" extended, thus the automated vehicle gets "green light" with minimum delay at the stop line.
- After the automated vehicle has successfully driven through the intersection, the traffic light controller switches back to normal operation.

5.5 The fleet

Table 12: Fleet characteristics at site

Test/ Use Case	Deployed fleet characteristics								
	Vehicle brand & model	**Vehicle type (shuttle, …)**	**SAE Level reached for the field trials [1-5]**	**TRL level reached for the field trials [1-9]**	**Summary of upgrades held during the project (in consistency with D7.2)**	**HMI and Hand-over strategies (in consistency with D7.2)**	**Maximum speed reached during the trials (km/h)**	**Average speed during the trials (km/h)**	**Maximum capacity of vehicle**
UC1.2; UC1.3; UC1.6;	HEAT-shuttle / developer and owner: IAV GmbH	Shuttle	4	6	No upgrades during project	Operating and display elements (HMI) are installed in the safety operators' field of vision towards the front. The operating elements are illuminated and display the current status of the individual functions. An additional immediate stop switch is integrated there. The elements are identified by symbols and labels. The safety operator can intervene at any time, by pressing the overtake button, steering the vehicle manually with the 4-way PARAVAN joystick and reacting appropriately to the given situation.	20[4]	10.86	4 passengers plus 1 safety operator

Test/ Use Case	Deployed fleet characteristics								
	Vehicle brand & model	**Vehicle type (shuttle, …)**	**SAE Level reached for the field trials [1-5]**	**TRL level reached for the field trials [1-9]**	**Summary of upgrades held during the project (in consistency with D7.2)**	**HMI and Hand-over strategies (in consistency with D7.2)**	**Maximum speed reached during the trials (km/h)**	**Average speed during the trials (km/h)**	**Maximum capacity of vehicle**
UC1.2; UC1.3; UC1.5; UC1.6;	VW e-Crafter; owner/lender: DigiTrans GmbH	Retrofitted passenger mini-van	4	6	No upgrades during project	The safety operator must constantly monitor the automated drive. Both hands must be on the steering wheel and the right foot over the brake pedal. If the situation requires it, the safety operator must take control. The following options are available: • Pressing the brake pedal • Actuating the gas pedal • Intervention in the steering (override of the turning movement performed by the vehicle) • Actuation of the "AD release" key switch	50	19.7	6 passengers plus 1 safety operator

[4] Maximum and average speed calculations might show slight deviations in the analysis followed in WP13 Deliverables as well as in the final Dashboard values.

Test/ Use Case	Deployed fleet characteristics								
	Vehicle brand & model	**Vehicle type (shuttle, …)**	**SAE Level reached for the field trials [1-5]**	**TRL level reached for the field trials [1-9]**	**Summary of upgrades held during the project (in consistency with D7.2)**	**HMI and Hand-over strategies (in consistency with D7.2)**	**Maximum speed reached during the trials (km/h)**	**Average speed during the trials (km/h)**	**Maximum capacity of vehicle**
						• Actuating the "On/Off" steering wheel button • Actuating the emergency stop			
Additional information regarding VW e-Crafter eVAN *The pilot phase without passengers started on the 1st of August 2023. The public pilot phase was planned to start on the 7th of August 2023. All necessary preparations for this phase were conducted. On the 2nd of August 2023, the eVAN was involved in an accident and consequently the piloting with the automated research vehicle on the pilot track in Koppl was suspended. The test permit was revoked and pilot operations with the eVAN could not resume before the project's end (see 5.10.2 Key incidents and impacts).*									

The first phase of the pilot in Salzburg was carried out with a prototype automated shuttle. It is called HEAT-shuttle, designed, developed and manufactured by IAV (https://www.iav.com/).

The second phase of the public pilot was planned to be carried out with a retrofitted automated electric passenger minivan L4 (“eVAN”) equipped with an automated driving system provided by IAV.

To enable autonomous driving on the desired pilot track in Koppl the pilot leader (Salzburg Research) provided advance information about the pilot track in the form of a high-precision map (HD map). The automated vehicles can only drive independently on routes which have been mapped manually beforehand. This customization was performed in the form of a deployment process. The pilot track was mapped in such a way that it is first driven slowly in automated driving mode and then at the desired speed. Employees of the owner/developer of the vehicles / AD-system (IAV) were on board. A trained and authorized expert from IAV checked the correctness of the automated driving maneuver, including longitudinal control, lateral control, acceleration behavior, shearing-off target driving and shearing-in target driving as well as entry and exit into and out of stop bays. A second expert from IAV simultaneously checked the data sent by the vehicles. The automated driving maneuvers were thus checked and adjusted if necessary. Only after a successful deployment piloting the automated vehicles in Koppl was permitted by the owner/developer.

Vehicle No.1 – HEAT-shuttle

The HEAT-shuttle is equipped with a drive-by-wire system called “Space Drive 2”. It consists of a steering control unit, a steering motor, an acceleration/brake control unit, a brake motor, a display unit and an input device unit. This system is intended for the manual control of the vehicle and for the transportation mode.

The automated driving functions of the HEAT-shuttle have already been tested on public roads in several projects such as “HEAT-Shuttle Hamburg” (https://verkehrsforschung.dlr.de/de/projekte/heat), “FLASH Shuttle Rackwitz” (https://www.mdv.de/projekte/nordsachsen-bewegt/flash/) and project “Absolut” (https://www.absolut-project.com/de/arbeitspakete/fahrzeug/). The functions have also been assessed by DEKRA Germany.

Figure 35: SHOW Digibus 2.0, HEAT-shuttle on a test drive at the Pilot site Salzburg (Source: Salzburg Research)

Before the automated shuttle is released for public transport, the functions are tested internally by IAV at module, sub-function and overall function level in various automated test procedures (from module test level to closed-loop simulation of the overall function).

The vehicle is designed and approved for a maximum speed of 25 km/h. Operation above this speed is prohibited. According to §7 under the AutomatFahrV (Federal Ordinance on Automated Driving) the system may be tested up to a maximum speed of 20 km/h. The actual permitted speed when testing was in any case based on the route analysis and risk assessment results.

The maximum capacity of the HEAT-shuttle is four passengers plus one safety operator. Passengers may only be transported in a seated position. The safety operator must always face the direction of travel and keep a close eye on the traffic situation. The safety operator must always be ready to intervene and have one hand on the joystick or over the takeover button.

Table 13 lists the different types of sensors, their number and purpose, which are in use in the HEAT-shuttle.

Table 13: HEAT-shuttle: types of sensors, number and purpose

Sensors	Number	Purpose
LIDAR	7	Object recognition, path planning and self-localization.
Radar	8	Object recognition and path planning. The data is merged with the LiDAR data in the sensor fusion.
Cameras	4	Environment and obstacle detection
Cameras virtual rear-view mirror	2	Environment and obstacle detection for the safety operator
GPS-Antenna	2	Self-localization

Figure 36: SHOW Digibus 2.0, HEAT-shuttle on the pilot track in Koppl (Source: Salzburg Research)

The HEAT-shuttle can be operated in autonomous mode as well as manually. The safety operator can start the autonomous mode at every bus stop and can intervene and take over manually any time. The shuttle can be steered manually via a 4-way PARAVAN joystick. In this Joystick-Mode the safety operator can accelerate, steer or brake.

The safety operator can activate the autonomous driving mode (AD-mode) at every bus stop by pressing the “AD LaunchRequest” Button. After a required check of the joystick functionalities, the vehicle is driving in AD-mode according to its programmed strategic plan.

During a drive in AD-mode, the safety operator can intervene at any time, by pressing the overtake button and steering the vehicle manually with the 4-way PARAVAN joystick, reacting appropriately to the given situation. If the situation allows, the safety operator continues the drive until the next bus stop manually, where he/she can switch to AD-state if desired. Besides overtaking the steering of the shuttle from AD to manual mode by the described method, the shuttle can be decelerated in a controlled manner with an average deceleration of approx. -3 m/s² by pressing one of the three stop buttons located in the vehicle. The shuttle will then decelerate and stop safely. In case the vehicle needs to be stopped immediately, a radio instant stop control element is part of the vehicle equipment. It must be placed within reach of the safety operator.

The manual of the HEAT-shuttle states the following safety instructions:

- No operation below 2°C or above 35°C.
- No operation in rain: There is no precise definition for this. According to the lender of the automated vehicle, the following should be noted: The vehicle can be used without restrictions in light or drizzle rain. In heavy rain or a combination of heavy rain and strong wind, the shuttle's operation should not begin or should be stopped. Operations on continuously water-covered roads (2 mm of water on the road surface) or driving through large or deep puddles must be avoided to prevent water ingress from below.

For orientation, refer to Figure 37, Figure 38 and Figure 39. If the situation is similar to the photos depicted, on any given section, the operation must be paused or terminated.

Figure 37: Standing water at the edge of the road and on uneven surfaces (Source: Salzburg Research)

Figure 38: deep puddles at the stop “Koppl town centre” (Source: Salzburg Research)

Figure 39: Standing water in the ruts (Source: Salzburg Research)

Vehicle No.2 – eVAN

The automated vehicle (the e-Kombi VAN - "eVAN"), which was used at the Pilot Site Salzburg within the SHOW project, serves as a platform for companies and research organizations to implement research and use case projects (deployments) in the field of automated mobility.

Based on an existing, road-approved vehicle platform, a VW e-Crafter (fully electrified), a research platform was built upon that enables manual or automated driving. For this purpose, the vehicle was converted for operations as a passenger shuttle. Sensors, computing power and public transport equipment were installed. A tried and tested white-box-drive-pilot system was installed, which allows open interfaces and a high degree of design freedom for the research partners.

Figure 40: The Digitrans eVAN as "Digibus 2.0" in the Salzburg municipality of Koppl as part of the European research project SHOW; owner DigiTrans eVAN: DigiTrans GmbH, © Salzburg Research, wildbild

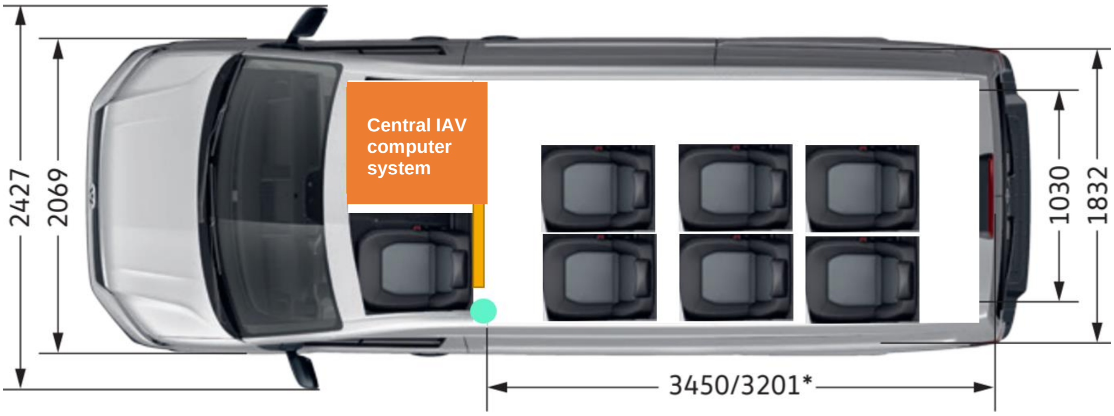


Figure 41: View of the EVAN interior with safety operator's seat, central IAV computer system and seats for six passengers (Source: DigiTrans GmbH)

The "IAV Automated Driving System" has been integrated into the eVAN. The vehicle therefore has a so-called hybrid control concept, which enables two operating modes:

a. manual driving: conventional control by the safety operator
b. automated driving: the vehicle performs automated driving maneuvers that can be monitored and overridden by the operator at any time.

When the AD system is deactivated and the emergency stop button is pressed, the vehicle is in manual driving mode, i.e. all functionalities correspond to the standard vehicle. Automated driving is made possible by extensive sensor technology attached to the outside of the vehicle. Various sensor types are used to ensure a robust and redundant system design. The following Figure 42 and Figure 43 show the positions of the sensors on the vehicle.

Figure 42: Front view ©IAV GmbH

Figure 43: Rear view ©IAV GmbH

The sensor data is processed in the central IAV computer system (see Figure 44), which is located in the front-passenger area of the vehicle (the front passenger seat was removed).

Figure 44: central IAV computer system ©IAV GmbH

Figure 45: IAV operating and display panel for commissioning and decommissioning the measurement technology and the AD system ©DigiTrans GmbH

The "IAV AD system" consists of various subsystems, the central IAV computer system in the front passenger area, the IAV operating display panel for commissioning and decommissioning the measurement technology and the AD system (see Figure 45), the sensors and the safety gateway (vehicle layer). The sensor system records the environment and forwards the recorded data to the central IAV computer system, which is responsible for processing the incoming data. This includes the recorded sensor data as well as vehicle data, V2X data or driver input. This data is used for the following purposes:

- the vehicle's position is determined using a highly accurate digital map (UHD map),
- detecting vehicles, people and obstacles and
- planning the future movement of the vehicle, considering the detected environment.

This data processing delivers target values (acceleration value and steering wheel angle) for the vehicle. These are sent to the vehicle layer, which then activates the corresponding control interfaces for steering, braking or accelerating the vehicle. The vehicle layer also monitors the permissibility of the requested target values and enables the safety operator to intervene at any time.

In addition to the functions mentioned, the AD system is also responsible for many other tasks, such as providing status information for the operator and the passenger monitor, communicating with the infrastructure if necessary or planning and executing the automated stop approach.

Table 14: eVAN: types of sensors, number and purpose / technical components

Sensors	Number	Purpose
LIDAR	6	Object recognition, path planning and self-localization.
Radar	8	Object recognition and path planning. The data is merged with the lidar data in the sensor fusion.
Cameras	5	Front camera: is used to recognize traffic signs and guidelines (lane). The additional 4 cameras were not yet used in the version of the eVAN piloted in Salzburg. The use of these cameras is planned for the eVAN v2 extension. For all cameras, no data is stored. Only live images are processed (VW standard)
GNSS-system	1	The GNSS system is used for rough localization at the stops.
Drive by Wire interface	1	As the vehicle does not have a redundant "Drive by Wire" interface as standard, it was retrofitted with additional actuators. These components for steering, braking and acceleration were purchased from Bozzio AG.

Basic operating instructions

The following points must be observed when using the AD system of the eVAN:

- Any steering, braking or acceleration intervention by the safety operator will deactivate the AD system. The safety operator is then responsible for controlling the vehicle.
- The AD system can only be activated at stops. In the event of a takeover by the safety operator the vehicle must be driven manually to the next stop.
- The AD system drives to every stop along the defined route. No stops are skipped. A stop request button has not been implemented in the version of the eVAN used at the pilot site Salzburg. There is a minimum waiting time at each stop to allow passengers to get on and off.
- The departure times at stops are not dynamically adjusted.
- At stops, the AD system signals the start intention to the safety operator by means of interaction in the safety operator display. The vehicle starts to flash on the left. The vehicle only leaves the stop after the safety operator has given the clearance by pressing the safety-operator-clearance button located on the right side of the steering wheel.
- At junctions where the AD system must give way to other road users, additional clearance by the safety operator is required.
- There is no automated lane change. Should such a lane change be necessary this must be done manually by the safety operator.
- No trips with the eVAN are permitted, when the following conditions apply:
    - Heavy rain
    - Snow or ice on the track
    - Heavy fog
    - Storm

5.6 The infrastructure

In this chapter the physical and digital infrastructure of the pilot track for automated vehicles as well as the C-ITS enhanced corridor are described.

Physical infrastructure features of the pilot track for automated vehicles:

There are in total seven stops served along the pilot track in Koppl. They can be identified as such:

1. Koppl Sperrbrücke – direction of travel Koppl town center
2. Koppl Grabnerbauer – direction of travel Koppl town center
3. Koppl Fuchsluck – direction of travel Koppl town center
4. Koppl town center
5. Koppl Fuchsluck – direction of travel B158 Wolfgangsee Bundesstraße
6. Koppl Grabnerbauer – direction of travel B158 Wolfgangsee Bundesstraße
7. Koppl Sperrbrücke – direction of travel B158 Wolfgangsee Bundesstraße

- Asphalted, 2-lane and slightly curvy road; 1.4 km length (one-way), no constant line-markings, slight damages to the road reducing comfort
- Traffic signs with the indication "Test track automated vehicle".
- Reduction of the speed limit from 100 km/h to 50 km/h on the L226 from km 0.00 + 80 m to km 0.2 to increase safety during the pilot phase
- Connection to public transport (Postbus stop bus line 152, Koppl Ortsmitte as well as Postbus stop Sperrbrücke, bus line 150/155) is given
- Garage with SCHUKO socket for parking and charging the shuttles
- Public charging facility owned by the local energy provider for charging the shuttles

Figure 46: Traffic signs with the indication "Test track automated vehicle" and maximum Speed of 50 km/h; Connection to public transport in the direction of Salzburg and Bad Ischl (Source: Salzburg Research)

Figure 47: Garage with SCHUKO socket for parking and charging the shuttles, public charging facility (Source: Salzburg Research)

Digital infrastructure equipment of the pilot track for automated vehicles in Koppl:

- Internet-based service for GNSS correction data (APOS) (provided by Salzburg Research but not used for the HEAT-shuttle).
- Vectorized UHD map with a verified accuracy <10 cm used for localization; referencing (map matching) of trajectories that show the lanes of other vehicles or bicycles; prediction of intentions of other road users; planning / prediction of own behavior; simulation
- Mobile data connection (LTE)
- 5x Roadside Units (RSU) for C-ITS communication

Figure 48: Pilot track automated vehicles; RSU locations (Source: Salzburg Research)

Figure 49: Pilot track automated vehicles public transport stops; (Source: Salzburg Research)

Figure 50: C-ITS installation on the pilot track for automated vehicles

Figure 51: Impression of the pilot track for automated vehicles (Source: Salzburg Research; Kapsch TrafficCom)

Physical infrastructure features of the C-ITS enhanced corridor between Koppl and the city of Salzburg

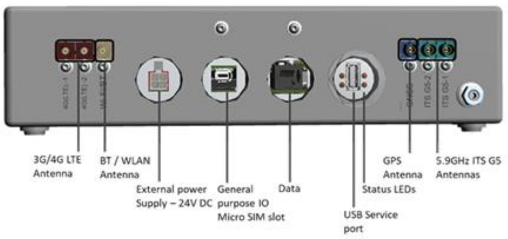
The C-ITS enhanced corridor between Koppl and the city of Salzburg is an asphalted, 2-lane and slightly curvy road with a length of approximately 8 km (one-way), with constant line-marking and no damage to the road. It is one of the six main commuter corridors leading into the city of Salzburg.

Digital infrastructure equipment of the C-ITS enhanced corridor between Koppl and the city of Salzburg

- 1x OBU (Onboard-Unit) in the eVAN
- 3x Roadside Units (RSU) for C-ITS communication
- Kapsch V2X-App

Kapsch TrafficCom supported the piloting of the C-ITS Use cases by providing the following C-ITS products:

OBU: CBX-9x60



Kapsch V2X App

RSU: RIS-9x60

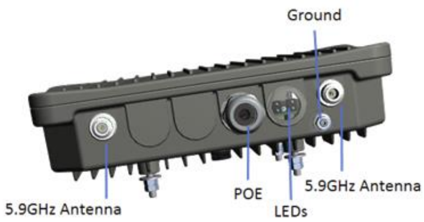


Figure 52: Kapsch C-ITS products in SHOW used at the pilot site Salzburg (Source: Kapsch TrafficCom)

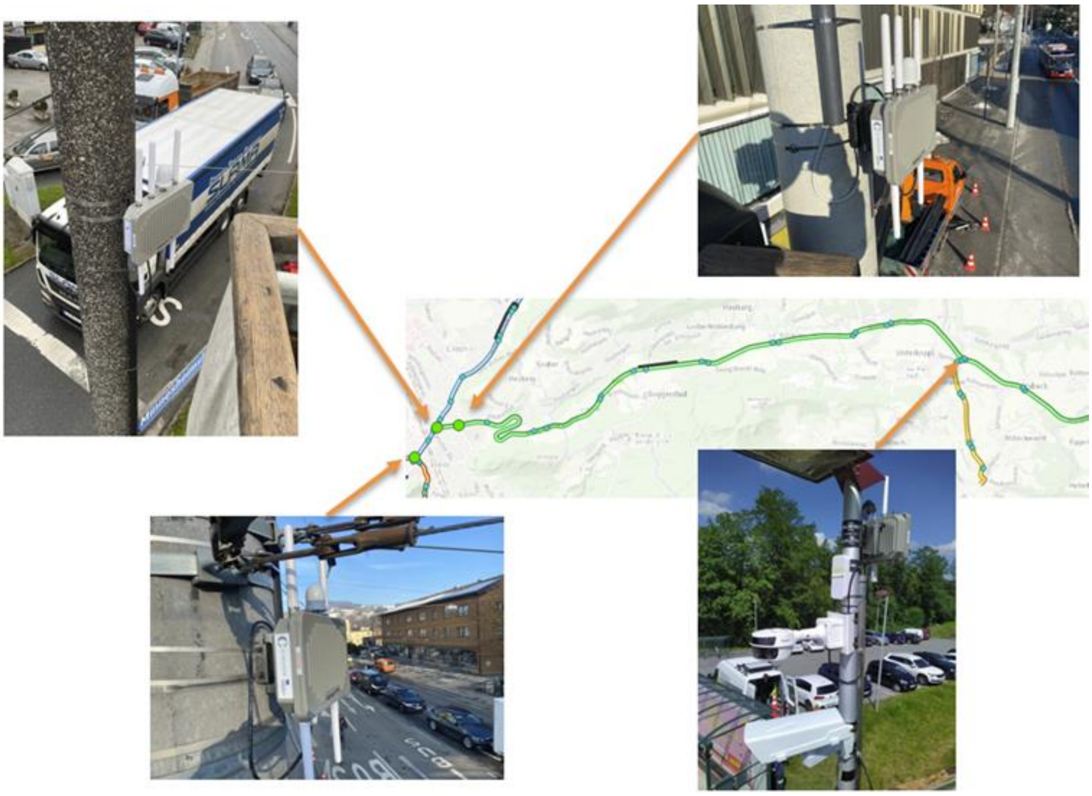


Figure 53: Visualisation of the pilot tracks and installed RSU's (Source: Salzburg Research)

5.7 Passengers

The Salzburg pilot site targeted pedestrians in the role of commuters, peri-urban residents and tourists with the need to cover the first-/last-mile. The majority of passengers used the service for their daily transportation needs, primarily to cover the first or last mile between Koppl town center and the intermodal mobility hub, where they transferred to /from public buses traveling to and from Salzburg. Observations indicate that service usage peaked between 13:00 and 14:00, as well as between 15:30 and 17:00. The usage rate remained consistent across all service days (Monday to Friday), while the intermediate stops between the start and terminus were rarely utilized. Minors, accompanied by their legal guardians, as well as elderly showed particular interest in automated driving technology, citing it as their primary reason for visiting the site and trying out the service.

5.8 Total number of passengers

During the pilot with the HEAT shuttle, 689 passengers were transported. 9 passengers were transported during the pre-demo with the HEAT shuttle. Due to the involvement of the Digibus® 2.0 (eVAN) in an accident on the 2nd of August 2023 (see 5.10.3) and the consecutive revocation of the test permit by the Austrian Federal Ministry of Climate Action, Environment, Energy, Mobility, Innovation and Technology (issuer of the test permit) the piloting with the automated research vehicle on the pilot track in Koppl was suspended after two days and could not be resumed until the end of the project. During the pilot phase without public passengers, 22 internal passengers were transported with the eVan.

5.9 Data collection

The integration of the Salzburg Local Data Management platform (S-LDMP) into the SHOW Mobility Data Platform (SDMP) has been described in *D4.4 Open modular system architecture – third version*. [6]

The internal data platform to connect the automated shuttle and submit data has been set up. In a micro-service-based architecture, clearly separated components have been deployed to connect the AV Data to the streaming platform, process and bridge the data to the SDMP and forward the data to a database-based storage solution for historical storage of the stream data. With this approach, data from the AV is internally connected to a streaming platform and in addition historicized.

The bridge component to the SDMP is processing the online data stream (locations and speed) and converting the data into the JSON based SHOW DMP MQTT message format.

As no access to the driving data of the HEAT-shuttle has been granted by the owner/developer (IAV) the already set up architecture, described in D4.4 Open modular system architecture – third version could not be used. KPI's (Average speed, maximum operational speed, kilometers travelled, number of passengers, road accidents, hard breaking events, conflicts/near misses, number of trips) could be delivered based on our own records. For this purpose, Salzburg Research created an internal protocol in the form of a "Lime survey" to collect information regarding each day of pilot operation from the safety operators. At the end of each pilot day, the safety operators were required to provide information regarding:

- Name of the Safety operator
- Test route (Koppl town centre -> Koppl Sperrbrücke; Koppl Sperrbrücke -> Koppl town centre)
- Day of pilot operation
- Test purpose (pilot run; deployment; 1st run without passengers before pilot run; technical test)
- KM level at the beginning and end of the pilot day
- Electrical range at the beginning and end of the pilot day
- Number of trips
- Number of passengers per trip
- Type of passenger (internal / external)
- Weather, temperature, road conditions
- Difficulties / complications / error messages and their frequency before the start of the pilot operation
- Difficulties / complications / error messages and their frequency during the pilot operation
- Other comments

The logs were transmitted online and stored for analysis. The average speed was calculated based on a mobile GPS-tracker located in the shuttle.

The pre-acceptance survey has been distributed through social networks (LinkedIn, Facebook), the Salzburg Research Homepage as well as the Salzburg Research Newsletter in print (distributed within the Salzburg Research network, including a QR-code with the link to the survey). In total, Salzburg Research received 52 answers on the pre-acceptance survey.

For the 1-question satisfaction survey Salzburg Research rented a tablet ("Satisfaction-type" response terminal") with installed Webropol-App. The tablet was positioned in the HEAT-shuttle and every passenger was asked to press the button according to her/his satisfaction. In total, 244 passengers answered the 1-question satisfaction survey for the HEAT-shuttle. 88 % of the passengers categorized their experience as very positive or positive (see Figure 54).

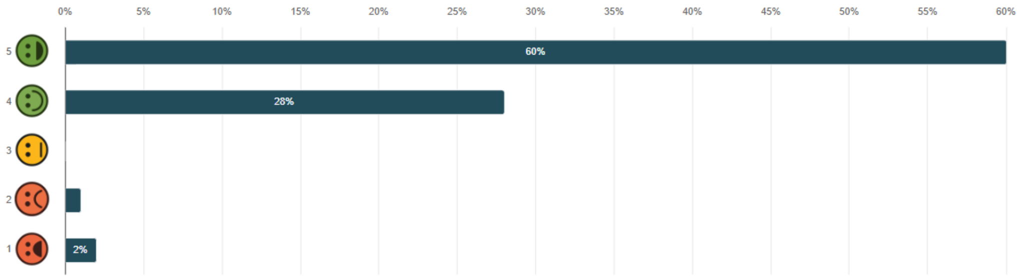


Figure 54: results of the 1-question satisfaction survey

It was planned to use the same setup for the pilot with the eVAN. Due to the involvement of the automated vehicle in an accident on the 2nd of August (see 5.10.3) the test permit had been revoked and pilot operation with the eVAN could not be resumed until the end of the project. Hence no data regarding the 1-question satisfaction survey could be retrieved.

Stakeholder interviews regarding "needs, wants and acceptance" were conducted with two stakeholders in June 2024 using the prepared interview guideline presented in D9.2: Pilot experimental plans, KPIs definition & impact assessment framework for final demonstration round, Appendix III: Interview with stakeholders [2].

Feedback from four safety operators regarding the pilot operation was collected via the provided questionnaire on Netigate at the end of the pilot.

The implementation of the C-ITS use cases

- HLN-PTVS: Hazardous Location Notification – automated public transport vehicle at a stop
- HLN-PTVC: Hazardous Location Notification – automated public transport vehicle crossing

was simulated in the lab environment utilizing real equipment and software implementation before approaching the proof of concept in the field.

Figure 55: Screenshots from the lab-environment simulating the UC's HLN-PTVS and HLN-PTVC (Source: Kapsch TrafficCom)

ITS G5 road-side units receive CAM messages from ITS-G5 equipped automated vehicles in regular case including vehicles position, speed, direction etc. Irregular events are exchanged applying DENM message when they occur.

The automated vehicle at the bus stop generates a DENM indicating this status with the message “PT at bus stop”. When leaving the bus stop to continue the journey, the automated vehicle generates a new DENM indicating this status as “PT lane crossing”.

The data from the tested C-ITS use cases was recorded, stored and analysed. In Figure 56, Figure 57 and Figure 58 the DENM’s “PT at bus stop”, generated by the OBU of the automated vehicle at chosen public transport stops along the C-ITS enhanced corridor, are visualized in red whereas the DENM’s “PT lane crossing” are shown in blue. All DENM’s have been generated reliably in the pre-defined geofences. The size of the dots reflects the duration of the latency, whereas the latency refers to the time required to construct a C-ITS message, encode it, transmit it, and decode it at the receiver's end, making it available at the application layer for C-ITS applications.

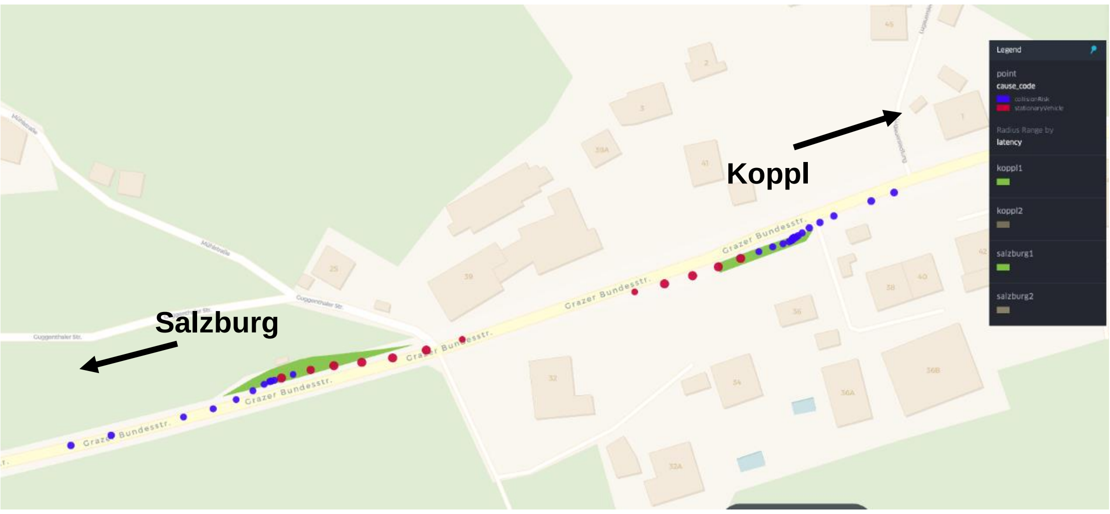


Figure 56: Visualisation DENM’s; stops “Salzburg Kühberg” direction Salzburg and Koppl (Source: Salzburg Research)

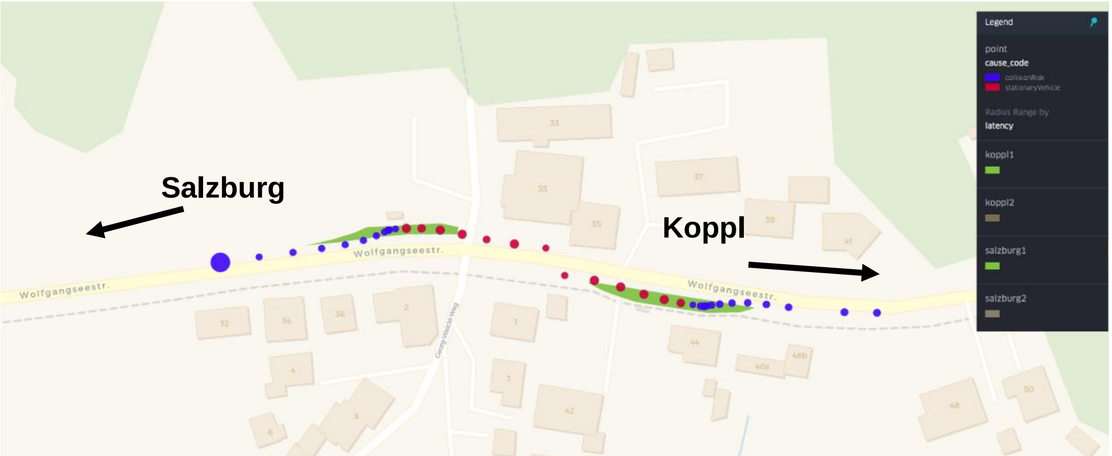


Figure 57: Visualisation DENM’s; stops “Koppl Guggenthal” in direction Salzburg and Koppl (Source: Salzburg Research)

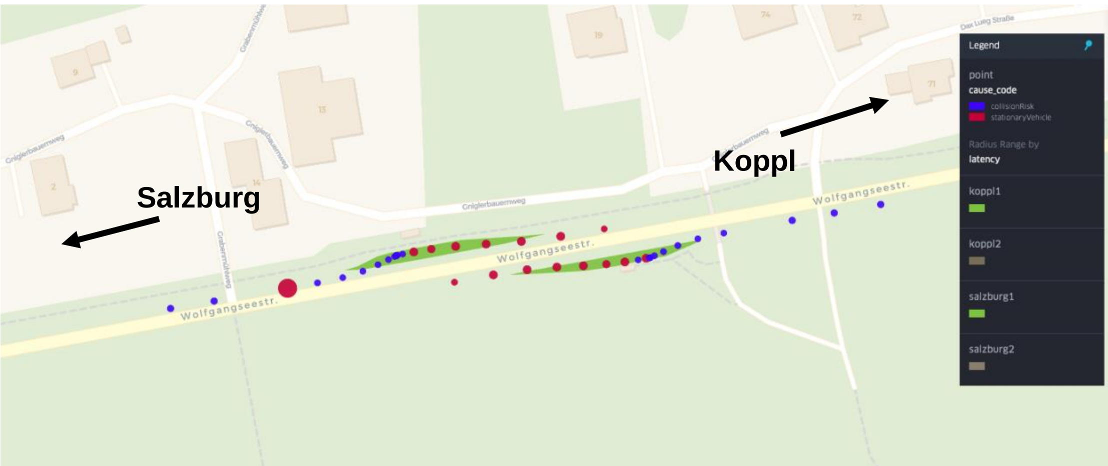


Figure 58: Visualisation DENM's; stops "Koppl Gniglerbauer" in direction Salzburg and Koppl (Source: Salzburg Research)

The boxplot in **Error! Reference source not found.** depicts the latency in ms (milliseconds) of all generated messages. In general, latency over the ITS-G5 interface is minimal. The mean latency is 37 milliseconds, with 95% of messages processed within 48 milliseconds. 98% of the messages exhibited a latency of 69 milliseconds or less, which is considered highly efficient. Only 1% of the messages experienced a latency of 82 milliseconds or greater. The maximum observed latency was 1039 milliseconds, with only 17 messages exceeding a duration of one second.

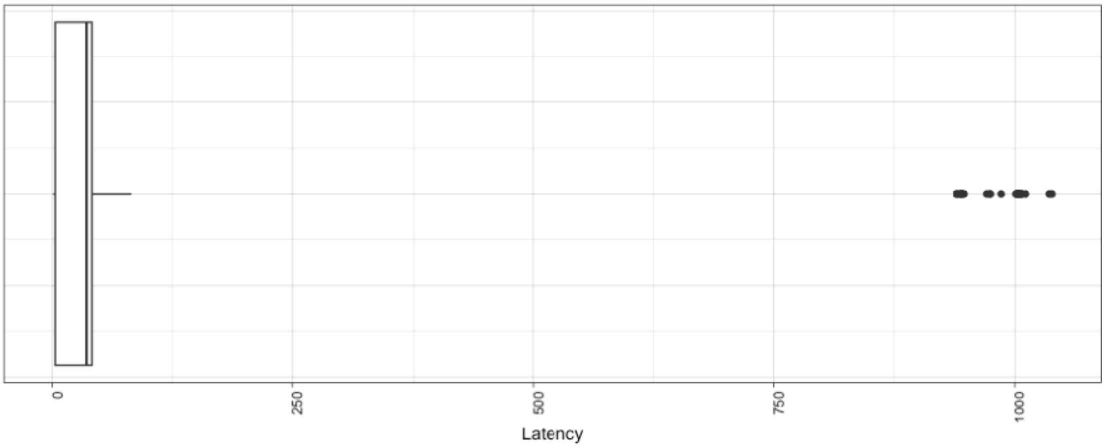


Figure 59: Boxplot of all generated C-ITS messages (Source: Salzburg Research)

The field tests for Use Case 3: Traffic light prioritisation for public transport automated vehicles - SI-TLP were carried out with the automated vehicle eVAN. The automated vehicle, equipped with an OBU, approaches the intersection, entering a pre-defined geofence, which is detected by the OBU via GNSS. It transmits a request via an SREM, specifying the current lane in use. An SSEM confirms or denies the request. The traffic light controller, responsible for signal changes, has been simulated in our setup, as direct access to the actual traffic light system was not granted. Exemplary, Figure 60 and Figure 61 visualize that SREM's have been sent and SSEM's have been received reliably using this setup.

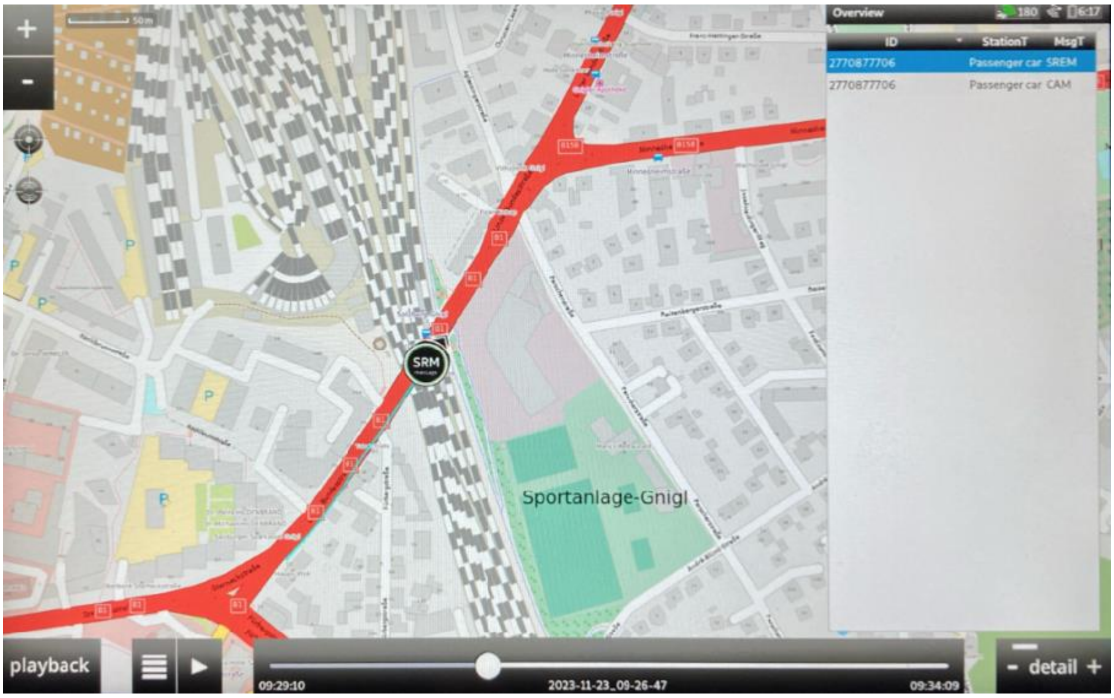


Figure 60: SREM sent by OBU in eVAN

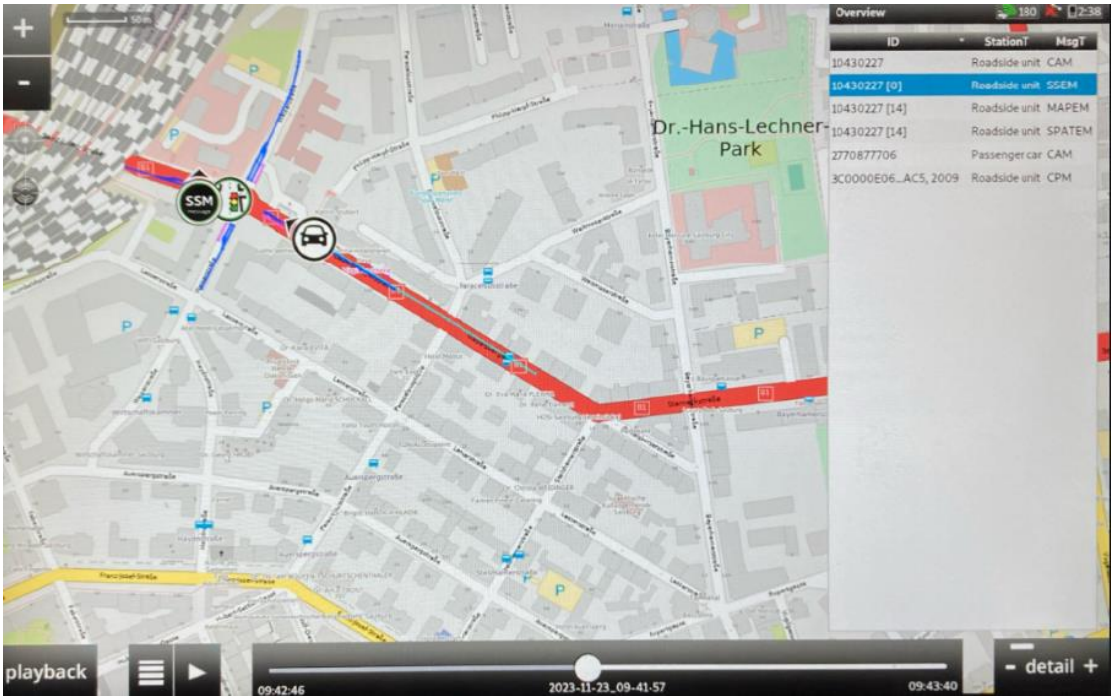


Figure 61: SSEM received by OBU in eVAN

5.10 Pilot operation key findings

5.10.1 Key findings per Use Case

High level findings per Use Case		
Use Cases	Overall qualitative performance score (1-3[5])	Justification
UC1.2: Automated passengers/cargo mobility in Cities under complex traffic & environmental conditions	2	In general, the automated first-/last-mile service was successfully piloted as part of the public transportation system, operating alongside existing services five days a week, from Monday to Friday. The standard cycle time was reduced from one hour to 30 minutes. To enhance passenger convenience, trip planning for the automated vehicle was made easier by integrating the service into the local public transport provider's app. The highly automated, electrified HEAT shuttle at the Salzburg site faced several technical, operational, and organizational challenges, including localization and positioning issues. Disruptions hindered schedule adherence. Only two test days were completed with the eVAN, resulting in too few trips to draw concrete and reliable conclusions. From these limited test drives, it can be observed that the highly automated, electrified eVAN used at the Salzburg pilot site faced safety-critical technical challenges. Issues with reliability, particularly in

[5] 1 [Low] – 2 [Medium] – 3 [High]; success qualitative score, considering all aspects (technical, user acceptance).

High level findings per Use Case		
Use Cases	Overall qualitative performance score (1-3[5])	Justification
		localization and positioning, rendered the vehicle unsuitable for reliably and safely connecting the municipality of Koppl to an intermodal mobility hub and effectively supporting first- and last-mile public transport. One critical situation and one accident with the eVAN in autonomous mode without public passengers occurred. As a result of the accident, piloting the automated research vehicle on the Koppl track was suspended and the test permit was revoked. Pilot operations could not be resumed for the remainder of the project. It should be noted that both vehicles are prototypes and require further development before they can operate fully autonomously. Currently, a safety operator must continuously monitor the automated trip and be ready to intervene if necessary.
UC1.3: Interfacing non automated vehicles and travellers (including VRUs)	3	The pilot track in Koppl is a public road with challenging topography and presence of other road users. Those include non-automated vehicles (passenger cars, buses, trucks, agricultural vehicles etc.) and VRUs (bicycle/pedestrians). The residents of Koppl were informed about the Digibus® 2.0 pilot through the municipal newspaper, raising awareness of the automated vehicle trials. Vulnerable road users present were mainly people on bicycles.

High level findings per Use Case		
Use Cases	Overall qualitative performance score (1-3[5])	Justification
		Most vulnerable road users (VRUs) encountered were cyclists. The automated vehicle's sensors detected the VRUs reliably, prompting the AD system to adapt the planning of movement accordingly. Interfacing VRU's did not affect road safety during the pilot. One section of the pilot track features an incline of approximately 8%. When interacting with a cyclist on this stretch, no overtaking occurred because the speed difference between the VRU and the HEAT shuttle (max. 20 km/h) was too small. Although the eVAN could have achieved the necessary speed difference, the AD system deemed an overtaking maneuver too risky and did not perform it. No incidents involving VRUs were recorded. The slow speed of an automated vehicle can be particularly problematic in certain situations, as it may lead to impatience from other road users, causing them to overtake in unsafe conditions, such as just before a curve or in areas with limited visibility. This reduced speed poses an additional challenge during peak hours, as it hinders the overall flow of traffic.
UC1.5 Actual integration to city TMC	2	The three defined Use cases have been tested successfully on the pilot track for automated vehicles and on the C-ITS enhanced corridor. Direct communication between the OBU and the AD-system of the vehicle was not allowed by the manufacturer. Consequently real-time-decision making within the AD-system of the automated vehicle could not be evaluated. Nonetheless, the

High level findings per Use Case		
Use Cases	Overall qualitative performance score (1-3[5])	Justification
		tested setup has the potential to reduce travel times by improving traffic flow at intersections, enhance the reliability of automated public transport services, and improve road safety.
UC1.6: Mixed traffic flows	2	Traffic signs displaying "Test track automated vehicle" alerted other road users, and the reduced speed limit on the pilot track enhanced safety during the pilot phase. Reactions from other road users varied. Most were positive, but some were uncertain, especially when the HEAT shuttle moved slowly. This slow speed occasionally led to impatience and unsafe overtaking, particularly in challenging sections. The slow pace also disrupted traffic flow during peak times. Reactions to the eVAN were similar to those for conventional public transport, likely due to its maximum speed of 50 km/h. While the right of way was sometimes respected when the eVAN pulled out of stops, it was occasionally ignored, necessitating increased attention from the operator. The automated vehicles shared the bus stops with public transport vehicles. The timetable of the automated vehicle has been optimized to avoid simultaneous stops of the automated vehicle and the public transport vehicles.
UC3.1: Self-learning Demand Response Passengers/Cargo mobility .	n.a.	Functionality for planning, routing, operation self-learning services for passengers based upon AI enabled algorithms that optimize DRT operations was not implemented by the

High level findings per Use Case		
Use Cases	Overall qualitative performance score (1-3[5])	Justification
		manufacturer/developer in the rented automated vehicles and hence could neither be validated nor piloted.

5.10.2 Key challenges and mitigation outcomes

Table 15: Key challenges at Salzburg pilot site - HEAT shuttle

Challenge	**Type** (Operational, Technical, Business, Other)	**Mitigation**	**Mitigation outcome**
Heavy rain may interfere with the operation of the automated shuttle HEAT (no impact on other road users)	Operational	In the event of heavy rain or a combination of heavy rain and strong wind, operation of the automated shuttle was not started or was stopped. Operation on continuously water-covered roads and driving through large or deep puddles of water was avoided to prevent the ingress of water from below. The automated shuttle must not be charged in the rain. Drizzle or light rain is not considered problematic. Safety operator ensured that the charging point on the vehicle was not directly sprinkled.	Damage on the automated shuttle was avoided.
The AD system can only be activated at stops.	operational	In the event of a takeover by the safety operator the vehicle must be driven manually to the next stop.	The challenge could not be overcome, since activation of the AD system only at stops was inherent to the setup (according to the shuttle

Challenge	Type (Operational, Technical, Business, Other)	Mitigation	Mitigation outcome
			manufacturer's specifications)
The HEAT-shuttle encountered difficulties due to the incline of max. 8 %. When driving uphill at the stops in AD mode, there were occasional technical difficulties. In addition, the incline could only be travelled at a maximum speed of 5 km/h in the case of manual control.	technical	Manual takeover and a restart of the AD system by the safety operator	The challenge could not be overcome due to the construction and functionality of the automated shuttle.
Several technical errors (e.g.: no acceptance of input commands via the joystick in manual mode, operating and display instruments malfunctioning, doors do not close, brake / parking brake error)	technical	Shut down and restart of the automated shuttle. Consultation of error-message documentation provided by shuttle manufacturer. Ensure availability of technical support team, in case error-message documentation could not help in solving the issue.	Error messages were not predictable. Solution for error message could sometimes be overcome by consultation of the error-message documentation. Despite those interruptions, service could be continued. Adherence to planned timetable was impeded.
Localization / positioning inaccuracy (e.g. HEAT-Shuttle leaves the specified lane during AD drive; Incorrect positioning at the stop after entering in AD mode; No exit from the stop despite correctly activated AD mode; crossing the stop line without clearance from the safety operator)	technical	Manual takeover by the safety operator and restart of the AD-system at the next stop. Increased awareness of the safety operator	Challenge can be attributed to localization / positioning inaccuracy. Despite those interruptions, service could be continued. Adherence to planned timetable was impeded. Shuttle manufacturer was contacted but no

Challenge	Type (Operational, Technical, Business, Other)	Mitigation	Mitigation outcome
			solution was presented.
Object detection failures (e.g. HEAT-Shuttle stops without recognizable obstacle; obstacles not recognized; unpredictable emergency braking without obstacle; risky exit from the stop)	technical	Manual takeover by the safety operator; manual repositioning by the safety operator; restart of the AD system at the next stop.	Challenge can be attributed to object detection algorithm. Despite those interruptions, service could be continued. Adherence to planned timetable was impeded. Shuttle manufacturer was contacted but no solution was presented.
Low-voltage battery discharge	technical	External jump-starting aid necessary.	Stop of the service for the day. Starting of automated vehicle was possible after the external jump-starting aid.
The battery of the HEAT-Shuttle must not be charged unattended in public areas or enclosed spaces. In addition, the test operation showed that the energy demand of the HEAT-Shuttle is high on the route in Koppl (up to 10 % per course = 2.8 km).	operational	Safety operator always present during charging. Reduction in the number of trips per day and a planned intermediate charge of 1 h during operating hours.	No incidents during charging. High energy demand can be attributed to the incline of the test track (max. 8 %).

Table 16: Key challenges at Salzburg pilot site – eVAN

Challenge	Type (Operational, Technical, Business, Other)	Mitigation	Mitigation outcome
eVAN leaves the specified lane during AD-drive; incorrect positioning at the	technical	Immediate safety operator intervention	Challenge can be attributed to localization /

Challenge	Type (Operational, Technical, Business, Other)	Mitigation	Mitigation outcome
Koppl Ortsmitte stop after entering in AD mode			positioning inaccuracy. Shuttle manufacturer was contacted but no solution was presented.
eVAN does not recognize static obstacle	technical	Immediate safety operator intervention	Challenge can be attributed to object detection algorithm. Shuttle manufacturer was contacted but no solution was presented.

5.10.3 Key incidents and impacts

During the pilot with the HEAT-shuttle there were no key incidents.

Accident eVAN: The pilot phase without passengers started on the 1st of August 2023. The public pilot phase was planned to start on the 7th of August 2023. All necessary preparations for this phase were conducted. On the 2nd of August 2023, the eVAN was driving in automated mode during a test drive without public passengers on the pilot track in Koppl under supervision of a safety driver on the L226 Koppler Landesstraße between the stops “Koppl Ortsmitte” and “Koppl Fuchsluck” towards the B158 Wolfgangsee Bundesstraße. At one point the automated vehicle steered unpredictably to the left in the direction of the oncoming lane. Despite immediate intervention by the safety driver, a collision with an oncoming vehicle on the exterior mirrors could not be prevented. This resulted in slight damage to the exterior mirrors of both vehicles. The accident has been logged by the police.

As obliged, the accident has been reported to AustriaTech and the Austrian Federal Ministry of Climate Action, Environment, Energy, Mobility, Innovation and Technolgy (issuer of the test permit) and consequently the piloting with the automated research vehicle on the pilot track in Koppl was suspended. The test permit was revoked. As a condition for resubmitting the application for a new test permit, the Ministry required measures to prevent the automated shuttle from deviating from its designated lane in the future. This involved modifications to the autonomous driving software, which could only be implemented by the vehicle's manufacturer. Since the necessary adjustments were not realized by the vehicle’s manufacturer, pilot operations with the eVAN could not resume before the project's end.

Critical situation eVAN: During a test drive with the eVAN in automated driving mode on 01.08.2023, a critical situation arose at the Koppl Grabnerbauer stop in the direction of the B158 Wolfgangsee Bundesstraße. The eVAN approached the stop automatically. At the end of the bus stop bay, a car was parked. There was no indication that the sensor system recognized the static obstacle and initiated a stop of the automated vehicle. Following his subjective perception, the safety operator on duty took over the eVAN and brought the vehicle to a standstill in good time before a collision.

5.10.4 The passengers' point of view

The eVAN was piloted for two days without public passengers due to the accident on the 2nd of August 2023 (see 5.10.3). Hence the passengers' point of view only refers to the pilot with the HEAT-shuttle. The insights have been drawn from conversations between the safety operators and the passengers.

During the pilot, passengers were asked about their satisfaction with the automated ride using a "one-question-user-acceptance-survey". 88% of passengers liked the ride "very much" or "well" (see Figure 62). In total, 244 passengers answered the 1-question satisfaction survey.

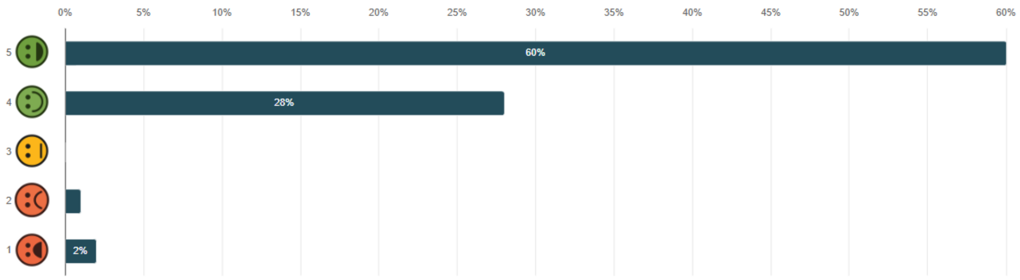


Figure 62: Rating of the one-question-user-acceptance survey for the pilot with the HEAT-shuttle

The service was appealing to the local community because it supplemented existing public transport five days a week, from Monday to Friday, and reduced the cycle time from one hour to thirty minutes. Additionally, the service was offered free of charge.

Salzburg Research has piloted various types of automated vehicles on the pilot track in Koppl since 2017, hence the automated first-/last-mile service was already familiar for some passengers. Their impression was mostly positive, and they showed interest in the new developments within the field of automated driving. Nonetheless differentiated attitudes towards the automated vehicles prevail: From negative and partly skeptical, to neutral and expectant. However, hardly any fears were expressed and almost all passengers had confidence in the technical capabilities of the automated vehicles. The willingness to use automated vehicles in the future was high. The fear that the use of automated vehicles could lead to job losses was frequently mentioned. However, many passengers expressed the hope that automated shuttles would improve public transport provision in rural / sub-urban regions and that the service would also be more environmentally friendly and flexible than the present public transport options. The pilot track in Koppl is a public road with challenging topography and presence of other road users. Hence, the deficits of the current technological state of automated vehicles (localization in open areas, interaction with other road users, low driving speed) became more apparent to the passengers. This led to somewhat more critical assessments. Especially higher driving speed and a wider and more flexible operating range were mentioned as the most important prerequisites for increasing the willingness to use automated shuttle services on a regular basis. More analytical results will follow in D13.5 [4].

5.10.5 The safety operators' point of view

According to the Federal Ordinance on Automated Driving[6] only trained safety operators who can provide proof of adequate training which corresponds to the respective application and the specific test project must be present in the automated vehicle. The safety driver is fully responsible for the safety of the passengers and the intactness of the automated vehicle. The training courses are provided by the vehicle owner/lender specifically for the automated vehicle used and cover both theoretical and practical aspects, such as:

- Requirements for the safety driver
- Tasks of the safety driver
- Theoretical instruction on the automated vehicles
    - Technical principles of the vehicle, the AD-system and the sensors
    - Performance
    - Limits
    - General operation
    - potential incorrect behavior of the AD-system
- Practical instruction on the vehicle and its operation (manual and autonomous), with special focus und the autonomous mode
- Training in manual and autonomous mode and switching between modes
- Training in the handling of targeted incorrect behavior of the AD system
- Training and handling when several faults are superimposed (e.g. freezing the steering angle, faulty / uncontrolled acceleration; faulty / uncontrolled deceleration, faulty steering control signals)
- Increasing the criticality of incorrect behavior
- Countermeasures to reduce criticality

The training took place on a closed test track in Austria. In addition, each safety operator demonstrated their ability to safely handle the automated vehicles on the pilot track in Koppl.

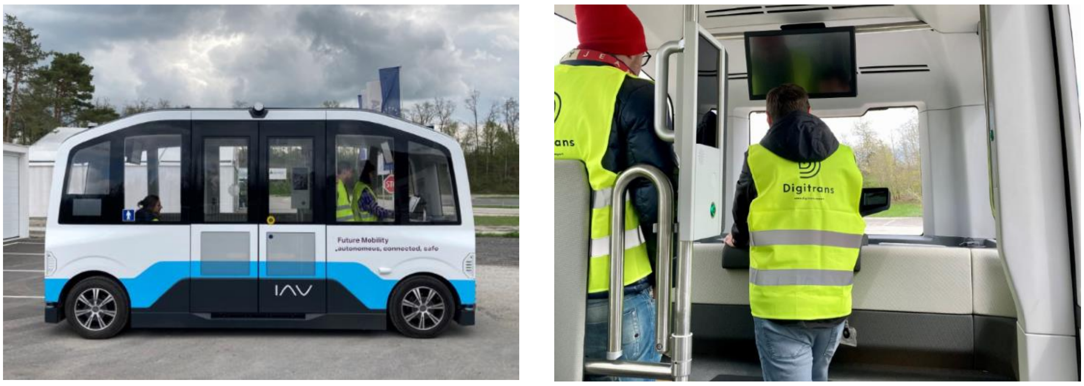


Figure 63: Impressions from the safety training on the closed test track (Source: Salzburg Research 2023)

[6] https://www.austriatech.at/assets/Uploads/Fokusseiten/Kontaktstelle-Automatisierte-Mobilitaet/Dokumente/68cd019e8d/Automated-Driving-Regulation-Austria-EN_05_2022.pdf (Englisch summary)

Since the automated vehicles are fully electrical it was mandatory for the safety operators to receive professional safety instruction for work on vehicles with hybrid or electric drives from an authorized institution.

To familiarize the safety operators with the specific test project, an operator manual was developed. It provides an overview of the necessary preparations for test drives with the automated vehicle, outlines potential driving and traffic scenarios, and identifies possible risk areas on the pilot track, along with recommended actions for the operators. The operator manual also contains emergency guidelines in which situations are defined that are to be classified as emergencies and how the safety operators must behave in an emergency.

The operator manual is structured as follows:

- Introduction (test project, use cases, pilot track incl. environmental conditions)
- Requirements for the safety operators
- Procedure for preparing the test drives
- Description of how to carry out a test drive before the start of the planned operation (without passengers)
- Description of the execution of a test drive with passengers
- Possible driving and traffic situations during the test drive incl. options for action for the safety operators
- Emergency guidelines (definition of emergency situations and safety operator behavior for each emergency situation)

An on-site inspection of the test track by the test management together with the safety operators was carried out before the start of the pilot, in which the peculiarities, danger spots as well as general and special risks per track section are discussed.

The exchange of experiences between the safety operators and the pilot management was ensured by the following measures:

- Operator survey, which must be carried out at the end of each pilot's day.
- Regular discussion of the results at a defined interval (operator and test management)
- Provision of all telephone numbers (operator / test management) for direct feedback.

The **four trained safety operators** perceived the theoretical and practical training, the availability of the operator manual as well as the on-site inspection of the test track as helpful in order to execute their tasks.

The work as a safety operator of an automated vehicle was described as highly challenging but also rewarding. The safety operators valued the opportunity to gain in-depth knowledge of automated driving technology and to test it in real-world conditions. Many different procedures must be memorized and followed step-by-step. Full responsibility for the intactness of the automated vehicle and the safety of the passengers as well as operating the automated shuttle according to the predefined timetable demands the highest level of attentiveness from the safety operator and was described as a psychological strain. The automated shuttles did not traverse the pilot track completely in AD-mode. Manual approval by the safety driver was required for the following driving maneuvers:

- Exit from the stop.
- Continue driving after the stop sign.
- Left turns could only be carried out in manual mode.

It was criticized that there is no visual or audio notification which would alarm the safety operator in order to prepare for taking over from the automated mode, i. e. the automated vehicles are not equipped with an output channel which informs the safety operator about the detection or planned steps of the collision detection system.

Within the HEAT-shuttle the safety operator had to take up the position behind the HMI-module with one hand on the joystick (kneeling on a wooden bench). Remaining in this position for a prolonged time was described as highly uncomfortable by the safety operators. More analytical results will follow in D13.5 [4].

Figure 64: Safety operators at work (Source: Salzburg Research)

5.10.6 The other road users' point of view

The reactions of other road users varied. The reactions were predominantly positive, but in some situations (e.g. when the HEAT shuttle was moving very slowly) they were unsure. In some cases, other road users showed consideration for the shuttle, in others they did not. The slow speed of the shuttle was particularly unfavorable in some cases, as other road users reacted with impatience and overtook in inappropriate situations, such as immediately before a bend or in a section of the route that was difficult to negotiate. The slow speed posed a particular challenge at peak times, as it slowed down the flow of traffic.

The reactions of other road users to eVAN were not noticeably different than if the automated vehicle was a conventional vehicle serving public transport. This can possibly be attributed to the speed of the eVAN (max. 50 km/h = highest permitted speed on the public road where the test track is located). In some instances, other road users respected the automated vehicle's right of way when it was pulling out of stops, but in other cases, the right of way for public transport was disregarded, even though this right of way is valid within village borders. This circumstance required increased attention on the part of the safety operator.

The residents of Koppl were generally informed about the Digibus® 2.0 test drives through the Koppl municipal newspaper. This helped raise awareness among the public that the vehicle was being operated as part of an automated driving test and that defensive driving behavior was appropriate.

5.10.7 The stakeholders' point of view

Two stakeholder interviews (county of Salzburg, Salzburg Transport Authority) were performed at the end of the pilot phase.

During the pilot phase, a delegation of the Federal Ministry for Climate Action, Environment, Energy, Mobility, Innovation and technology (BMK), together with AustriaTech (ATE) as the contact point and facilitator of the testing permit for automated mobility in Austria visited the Pilot site in Salzburg. During the visit the piloted use cases, scenarios and the automated vehicle were demonstrated live on the pilot track. An exchange on the process of applying for the test permit, on the cooperation between Salzburg Research, the Federal Ministry and AustriaTech and the gained experiences from the pilot was on the agenda. Planned dissemination as well as possible further activities relating to the demonstration of automated mobility were discussed.

The stakeholder Salzburg Transport authority was directly involved in the pilot since the automated first-/last-mile service was integrated into their App (https://salzburg-verkehr.at/en/timetables/salzburg-verkehr-app/), which facilitated the trip planning with the automated vehicles for the passengers as they were able to access information about arrival/departure time and connections. Passenger real-time information within the automated vehicles was not implemented.

Within the national project Innovationslabor Digitrans e-Kombi-VAN - "EVAN" (see https://projekte.ffg.at/projekt/4443983) it is planned to implement this service in the eVAN.
In the stakeholder interview with the Salzburg Transport Authority the following feedback was collected:

- Positively highlighted was experiencing the technology of automated driving (strategic planning, localization, sensor fusion) – despite technical challenges – in a real-time-environment (public road with other road users)
- A key negative was the heavy reliance on automated driving technology for passenger safety, combined with a general lack of trust in the system.
- It was stated that automated shuttles integrated as a first-/last mile service into the public transport system could prove beneficial in rural environments or parts of the city to increase service coverage and as a feeder into the established public transport system. It should not be in competition with the standard public transport options.
- The integration of automated vehicles in public transport as a first-/last-mile-service, might prove beneficial especially in night/early morning service and on weekends (especially in areas where the standard public transport options are not available).
- First-/Last-mile services could contribute to an overall reduction of vehicles and hence reduce local emissions (e.g. noise, exhaust gases). An expansion of the charging infrastructure would be a prerequisite.
- Salzburg Transport Authority intends to investigate options for integration of the first last-/ mile automated services in the future to increase the service coverage of public transport options.

- Especially for passengers with disabilities accessibility of automated vehicles needs to be ensured (especially when no safety operator is on board) and the design and technical equipment of stops must be regarded.

In addition, the county of Salzburg was directly involved in the pilot activities. An application for issue of an ordinance to mitigate the risk on the pilot track (reduction of speed limit, additional traffic signs) was granted and the governor of the county of Salzburg approved the pilot activities. The county of Salzburg confirmed that the pilot acitivities are strategically in line with Salzburg's provincial mobility concept "salzburg mobil 2025[7]" and correspond to Salzburg's positioning in terms of the Science and Innovation Strategy 2025 (WISS 2025[8]).

In the stakeholder interview with the county of Salzburg the following feedback was collected:

- A key positive aspect was the opportunity to experience automated driving technology in a real-time environment on public roads alongside other road users, despite the technical challenges involved.
- A key drawback was that the automated vehicles could only operate on a predefined route. Additionally, unexpected interventions by the safety operator due to technical issues disrupted the service experience.
- The technology of automated driving as experienced in the pilot Salzburg has not reached the desirable level of technological maturity in order ensure safety and reduce / prevent risk of injuries and damage.
- If the technology of automated driving reaches maturity (hence ensures safety) and automated shuttles can reliably feed into the public transport system, they could leverage a shift towards public transportation and reduce motorized individual traffic. Integration into the tariff models of public transport providers must be realized to ensure a seamless and effortless transportation experience.
- First-/last-mile public transport is an important topic in the county of Salzburg (especially rural areas). The learning from the SHOW project will be taken into consideration when investigating the option of automated public transport services.
- In the case of remote operation of automated vehicles in the future with no safety operator on board, there will be no physical assistance available. Accessibility for passengers with disabilities must be ensured.

Salzburg Research has piloted various types of automated vehicles on the pilot track in Koppl since 2017 and over the course of the years has established a solid cooperation with the municipality of Koppl (location of the pilot track for automated first-/last-mile service). The municipality was highly supportive in the preparatory and pilot phase. They were servicing the pilot track (cutting shrubs and greenery), provided a parking and charging facility for the automated vehicles and informed the residents on a regular basis about the pilot activities via their local newspaper which raised awareness among the population of Koppl and attracted them to use the automated first-/last-mile service.

5.11 Key local pilot events

Before the pre-demonstration Salzburg Research presented the open and modular vehicle concept of the Digibus 2.0 eVAN in the “The Austrian Mega Pilot” 1st Online-

[7] https://www.salzburg.gv.at/verkehr_/Documents/landesmobilitaetskonzept.pdf
[8] https://www.salzburg.gv.at/wirtschaft_/Documents/WISS-2025-english.pdf

Event on the 14th of October 2022 organised by AustriaTech. This event had more than 100 participants from all over the world including Australia and China. The aim of the Online-Event was to show a broader audience the capabilities of the Austrian Pilot Sites in SHOW. The presentations of the site included detailed information on the automated research vehicles, the Use-cases and the different approaches of implementation. (https://show-project.eu/event/insights-on-shows-austrian-mega-pilot/)

The following events have taken place during the Pilot phase:

- A site visit on the 20th of June 2023 by Michael Nikowitz, Coordinator Automated Driving at the Federal Ministry for Climate Action, Environment, Energy, Mobility, Innovation and technology (BMK), together with AustriaTech (ATE) as the contact point and facilitator of the testing permit for automated mobility in Austria. During the visit UCs, scenarios and automated vehicle were demonstrated live on the pilot track. An exchange on the process of applying for the test permit, on the cooperation between SRFG, BMK and ATE and the experiences during the pilot was on the agenda. Planned dissemination as well as possible further activities relating to the demonstration of automated mobility were discussed.
- MAMCA Workshop Austria on the 12th of May 2023
    - 40 participants from 6 stakeholder groups (vehicle users, authorities/regulators, PTO's, mobility service providers, public interest groups, R&D)
    - Outcome: Stakeholders exchanged their assessments and professional opinion on various scenarios of automated mobility services.

The following event has taken place after the Pilot phase:

- Austrian Mega Pilot Final event on the 23rd of July 2024 in Carinthia/Austria
    - Experience and lessons learned from pilot operations were presented and the future of CCAM services in Europe was discussed during a roundtable with various stakeholders.
    - The participants had the opportunity to experience a ride in the automated shuttles at the pilot site Klagenfurt.

5.12 Lessons learned & Recommendations

Technical:

- The highly automated electrified test vehicles at the Salzburg pilot site are prototypes that require further development to achieve full autonomy on public roads. Currently, it is essential for a safety operator to monitor the vehicle's systems and be prepared to intervene when necessary. While there are notable technical challenges, particularly with localization and positioning, operators demonstrate strong problem-solving skills and patience. The reliability of environment detection and positioning is generally higher in built-up areas with ample reference points for the sensors. In contrast, undeveloped areas adjacent to the test route present more challenges, leading to occasional orientation loss. To enhance GNSS positioning accuracy and reliability, utilizing a correction service (GNSS-RTK) is recommended. Additionally, incorporating a diverse array of sensors can further improve object detection and increase the system's overall robustness and redundancy.
- High-precision digital maps (UHD-Maps) are a vital component of the digital infrastructure for autonomous driving. Given that requirements for UHD-Maps can differ among vehicle manufacturers, it is advisable for manufacturers to clearly and comprehensively communicate these specifications in advance. Currently, the absence of uniform standards regarding map formats, quality

criteria for the modeled environment, and minimum landmark requirements presents an opportunity for improvement. Establishing standardized specifications would be beneficial in creating universally applicable quality standards and enhancing the usability of HD-Maps for automated driving.

- The behavior and sensitivity of actuator systems in automated vehicles present an area for exploration. These systems empower safety operators to transition the vehicle from autonomous driving (AD) mode to manual mode by turning the steering wheel or pressing the brake. At the Salzburg pilot site, one of the automated vehicles featured an actuator system that required more force than typical, particularly when operators took control by steering. The actuator's initial resistance can be notable, and there may be a brief delay before it responds. Similarly, the brake requires greater force than in standard passenger vehicles. To ensure effective handling of these unique characteristics, safety operators will benefit from specialized training tailored to these actuator systems.
- C-ITS technologies provide advanced capabilities for efficiently prioritizing automated vehicles at signalized intersections and increasing road safety. They enable precise control by leveraging detailed vehicle location data, authorization concepts, and driving trajectory mapping. Managing multiple, conflicting traffic-light prioritization requests from various vehicles (e.g., public transport or emergency vehicles) is complex. Balancing the reduction of schedule deviations while minimizing delays for all priority requests, and accounting for policies favoring specific modes of transport and emergency vehicles, adds to the difficulty.
- In decentralized C-ITS systems, where traffic-light prioritization decisions are made at the intersection level, the accuracy of real-time information is crucial. Unexpected changes, such as road work or timetable adjustments, can negatively impact decision-making and reliability.

Operational:

- Gaining operational experience with automated shuttles in real-world traffic environments is essential for understanding their true capabilities and identifying technical limitations. Numerous aspects, such as dynamic interactions with other road users and unpredictable traffic scenarios, cannot be fully evaluated through simulation alone. In addition, it is crucial for the public to engage with emerging technologies firsthand. Direct testing and experiential interaction with innovations enhance user acceptance, which is vital for the successful implementation of new technologies.
- Challenges with the operation of the shuttles might occur both at startup (e.g., insufficient positioning accuracy, software problems) and during the ride (e.g., shuttle stopped without a visible obstacle, shuttle lost orientation/positioning, shuttle did not continue after stopping, shuttle stopped without a visible obstacle). Most of these issues were related to orientation and positioning inaccuracies. If an automated shuttle is to be used as part of public transportation, reliability is a key factor. Passengers may find autonomous transportation services intriguing upon their introduction, but their primary focus shifts to reliability and safety over time. What truly matters is that the service operates consistently and safely, adhering to scheduled times or arriving promptly for on-demand requests. Therefore, prioritizing technical robustness and safety is essential to meet passenger expectations.
- A visual inspection of the pilot track should be conducted before each day of operation to ensure the safe and reliable functioning of the automated vehicle. This inspection allows for the identification of any changes on or near the track, enabling appropriate countermeasures to be implemented if necessary.

- A mandatory test run in AD mode should be conducted before each service launch to verify safety and reliability.
- The vehicle developer may impose operational restrictions on automated shuttles under certain weather and road conditions, such as heavy rain, snow or ice on the track, heavy fog, or storms. To enhance the functionality of these shuttles, it is advisable for manufacturers to focus on addressing and overcoming these limitations.
- The battery range of the automated vehicle may fall short of expectations. Factors such as terrain (inclines), weather conditions (use of AC/heating), and passenger load can necessitate intermittent charging of the shuttle during a pilot day. To accommodate this, charging facilities should be available on or near the pilot route, and there should be flexibility to adjust the planned schedule as needed.
- The role of a safety operator for an automated vehicle is both rewarding and challenging. It requires the operator to learn and follow a variety of procedures in a precise, step-by-step manner. The operator is responsible for ensuring the vehicle operates effectively and the safety of its passengers while adhering to the shuttle's schedule. This demands exceptional focus and attentiveness. Therefore, thorough technical and operational training for safety operators is vital to support their success in this important role.
- The automated shuttles at the Salzburg pilot site did not provide an output channel to inform safety operators about the collision detection system's actions or planned responses, lacking visual or audio alerts for potential takeovers. Consequently, operators relied solely on their subjective judgment. Operators expressed a desire for a notification system to indicate when a takeover might be necessary. However, the vehicle developer emphasizes that the safety operator is central to the vehicle's safety design, requiring independent monitoring of the autonomous drive without relying on vehicle data. This approach ensures that operators function as independent "control loops," minimizing distractions from monitoring traffic. While no definitive recommendations can be made at this stage, further exploration of this issue is encouraged.
- The deployment of automated vehicles on a pilot track presents an opportunity for learning and innovation and is a prerequisite for piloting, although it is a time-intensive and resource-demanding process which can only be carried out proprietarily by the manufacturer of the shuttle (AD-system) separately for each vehicle. Each deployment requires careful consideration of the driving environment, specific infrastructure needs, legal conditions, and planned driving maneuvers. Developing a standardized process for analyzing, evaluating, and digitalizing the driving environment—using a uniform toolchain for the (partially) automated creation of the digital driving environment—would greatly enhance efficiency and be highly beneficial for the industry, moving towards a more cohesive approach that is less reliant on individual manufacturers.

Business:

- Automated shuttles integrated as first/last-mile services in public transport can enhance service coverage in rural areas and certain city regions without competing with traditional transport options. They are particularly beneficial for night and early morning services, as well as weekends, in areas lacking standard public transport. Additionally, these services could help reduce the number of vehicles on the road and lower local emissions, though expanding the charging infrastructure would be necessary.

- Before public transport operators can be expected to incorporate automated shuttles into their vehicle fleets for first-/last-mile services, several issues need to be addressed:
    - Significant advancements in the maturity and safety of AD technology
    - Operating costs must be comparable to those of conventional vehicles
    - Reducing limitations related to gradients in topography
    - Seamless integration of these shuttles into the fare systems of public transport providers to ensure a smooth and convenient passenger experience.
- Maintaining a focus on passengers will remain crucial in the future. To encourage a high acceptance of autonomous mobility, the feelings and experiences of individuals in autonomous vehicles – such as their subjective perceptions of safety, comfort, and available services – will continue to be important.
- A successful business model must prioritise accessibility and equity. Ensuring that automated vehicles are accessible to passengers with disabilities is essential. As a result, the design and technical features of stops will be crucial for the acceptance of automated transport services.

5.13 Roadmap beyond SHOW and replicability

Participation in the SHOW project has enabled Salzburg Research to enhance its expertise in deploying autonomous vehicles and high-precision mapping. The collaboration within the consortium has facilitated valuable knowledge exchange and expanded the network for autonomous driving across Austria and Europe. This acquired expertise will support future projects related to autonomous driving and will be shared with national stakeholders, e.g. the county of Salzburg, allowing for its integration into upcoming strategies and mobility plans.

Salzburg Research will also share the insights and lessons learned from SHOW with to the Austrian Strategic Alliance for Automated Mobility. The Alliance was launched in 2023 as a pioneering cooperation initiative. It aims to connect relevant national stakeholders and facilitate knowledge transfer and exchange. The goal is to ensure the best possible deployment of automated mobility while simultaneously strengthening Austria's technological leadership.

A leading Austrian bus company is set to gradually introduce automated shuttles into public transport, with ambitious plans for significant expansion. These shuttles will function as on-demand vehicles in suburban and rural areas. The insights and recommendations from the Salzburg pilot will serve as a valuable foundation for this initiative.

Integrating automated shuttles as first-/last-mile services within the public transport network presents significant opportunities, particularly in rural areas and parts of Salzburg with limited transport options. This enhancement would improve service coverage and must connect to the existing system. Recognizing the importance of this initiative, the Salzburg Transport Authority plans to explore options for integrating automated services in the future. Insights from the SHOW project will play a crucial role in assessing the potential for these automated public transport solutions. It is vital that these services complement standard public transport options rather than compete with them.

Continuing test operations with automated shuttles in real-world environments is essential for providing the public with firsthand experience of automated vehicles, which helps to build awareness and confidence. These pilots educate the community and showcase that journeys with automated shuttles are already a reality on public roads. Furthermore, these pilots highlight the current technological limitations, paving the way for future advancements. As automated driving technology matures and safety is assured, automated shuttles can seamlessly integrate into public transport systems, encouraging a shift towards public transit and reducing reliance on individual motorized vehicles.

Moreover, first-/last-mile services can help reduce the overall number of vehicles on the road, contributing to lower local emissions, including noise and exhaust gases. To facilitate this transition, expanding charging infrastructure will be essential.

According to the ERTRAC Roadmap for "Connected, Cooperative, and Automated Mobility" from 2022 [7], the decade between 2030 and 2040 is expected to be the phase of technological maturity when automated driving will significantly advance with comprehensive infrastructural support. To effectively address specific research questions regarding automated driving in public transport, systematic testing must continue. This includes investigating aspects such as passenger safety during driverless operation and exploring methods for monitoring automated shuttles from a control center. The objective is to progressively enhance the SAE levels while also increasing the complexity of the Operational Design Domain (ODD) to advance towards the vision of unrestricted autonomous driving in mixed traffic environments. Additionally, it is essential to establish a supportive legal framework that facilitates these tests and is continuously updated to reflect the latest developments and advancements, such as permitting driverless operations on public roads.

6 Carinthia test sites

6.1 The Ecosystem

The region of Carinthia has two pilot sites, one in Pörtschach and the other in the capital city Klagenfurt, some of the participating entities are the same for both sites and some are specific to one site. Stakeholder meetings were held regularly in both Pörtschach and Klagenfurt. The operational setting is different from site to site.

Table 17: Pilot sites ecosystem in Carinthia

Participating Entity	Internal to the Consortium (√)	External to the Consortium (√)	Role
pdcp GmbH (SURAAA)	√		Pilot site leader and responsible for the planning, realization and evaluation of the pilots, events etc.
IAM - Institut für Technologie und alternative Mobilität		√	Owner of one shuttle, is renting the shuttle to pdcp GmbH
Navya (until 2023)	√		OEM of the shuttle
Gama (since 2023)		√	OEM of the shuttles, is renting the shuttles to pdcp GmbH
AustriaTech	√		Mega site leader Austria, contact point for automated driving permits in Austria
Land Kärnten		√	Government of Carinthia
Yunex Traffic Austria GmbH	√		Infrastructure provider
AIT	√		Responsible for traffic simulation
City of Klagenfurt		√	Capital city, responsible for infrastructure issues
Gemeinde Pörtschach		√	Community of Pörtschach, responsible for infrastructure issues
IOKI	√		On demand provider
Carinthian University of applied science		√	Cooperation in UC3
Kärntner Linien (VKG)		√	Public transport provider
KMG -Klagenfurt Mobil		√	Public transport provider

6.2 Operation setting

Both sites in Carinthia are popular tourist destinations with high density in the summer, allowing for an assessment of acceptance and interaction with other road users. The scheduled operation in Pörtschach started in 2021 with one shuttle on the road. After a successful implementation, the test site was extended to Klagenfurt in 2024, with three shuttles in fleet operation operating together on three different routes and additional challenges such as 5 traffic lights with C-ITS, motorway access road and a roundabout.

Pörtschach

Pörtschach is a recognised summer holiday resort about 14 km from the Carinthian capital Klagenfurt, the pilot site is a rural area with one main road, Hauptstraße, along which the shuttle operates going to the main railway station and the town promenade (a popular tourist area). The shuttle connects the train station (train, bus) with the lake, hotels, shops and the town centre. The route goes into a narrow street Elisabethstraße passing through residential buildings, hotels and two public car parking lots. A high number of road users especially cyclists and pedestrians use the same way. Part of Elisabethstraße was converted to a one-way street due its narrowness.

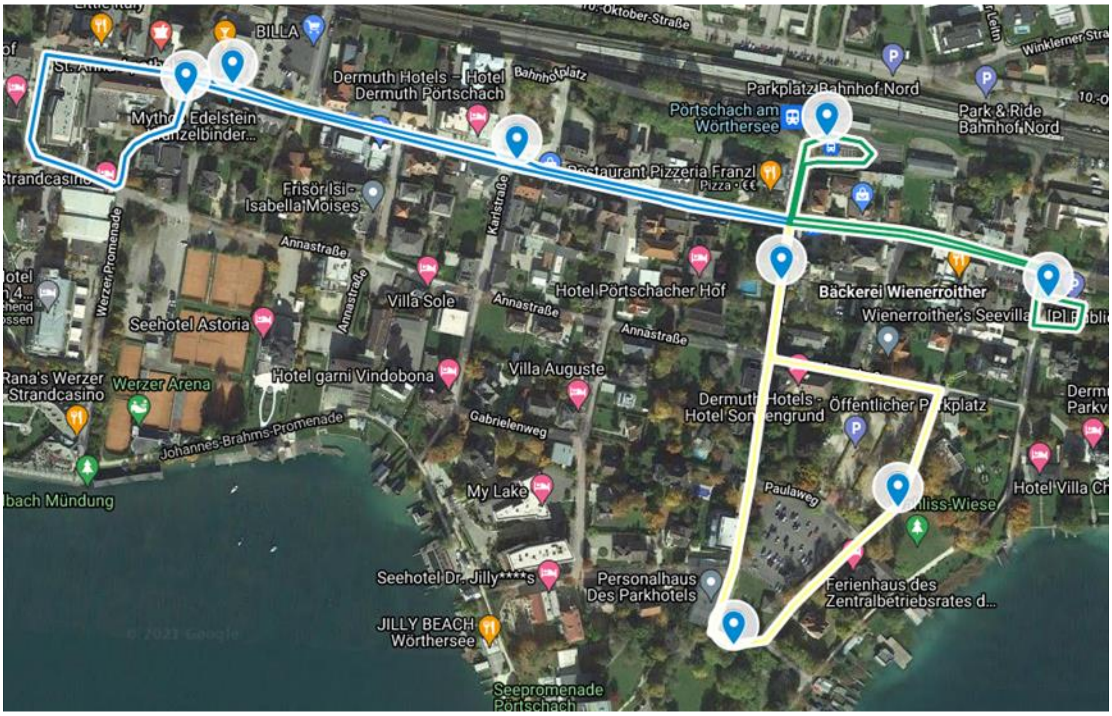


Figure 65: Route in Pörtschach including 8 bus stops. (Source: SURAAA)

The test route is approximately 2.7 km long with 8 stops (Figure 65), of which three are shared with PT and five were added for the purpose of the pilot. In addition, the shuttle also crosses 10 intersections, none of them are controlled by traffic lights. The shuttle operates in mixed traffic and the operating schedule is coordinated with the local public transport providers. There are several traffic signs along the route e.g. stop sign, pedestrian crossing sign.

Figure 66: Route sections for commissioning. (Source: SURAAA)

The route was divided into 4 sections for commissioning (Figure 66), in section 1 (Figure 67) the speed of the AV was adapted to the route and therefore reduced in Monte Carlo Place, which is a pedestrian area. To reassure pedestrians, the AV also reduces its speed just before a pedestrian crossing (Figure 68).

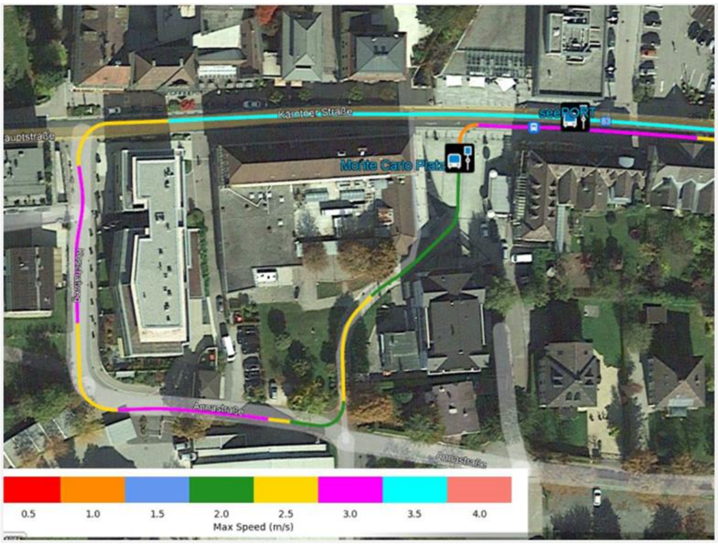


Figure 67: Section 1 (Monte-Carlo-Platz). (Source: SURAAA)

Figure 68: Section 2 (principal road B82). (Source: SURAAA)

In 2021, the conditions are set to allow the test route to expand on Kärntner Strasse eastwards to a new stop at the public car park after the Wienerroither bakery, which is accessed via Johannaweg (Figure 69). This section has been added to meet the needs of the population, particularly the elderly, who want to use the AV to get to the bakery.

Section 4 (Figure 70) has been in operation since 2018 and is characterised by narrow road conditions and feeder traffic (buses, goods deliveries), particularly in the morning, with heavy pedestrian and cycle traffic (Annastrasse is part of the local cycle network). Trees, fast-growing hedges and bushes can be challenging and cause occasional disruption (reduced GNSS signal reception).

Figure 69: Section 3 (Train station and Wienerroither). (Source: SURAAA)

Figure 70: Section 4 (Wahlliswiese and Parkhotel). (Source: SURAAA)

The use of an automated vehicle was tested on the first/last mile in a semi-urban environment, with changing conditions due to the location of the test route in a tourist-dominated infrastructure and with strong interaction of different road users.

The tests were carried out annually from May to September except in 2024, when the shuttle was operated between April to June and in September. During this period the weather is mostly mild, sometimes with a combination of sun, light rain, summer storms and temperatures ranging from 15°C to 33°C. As the Pörtschach site is located directly at the Lake Wörthersee, there is a chance of fog, especially in the morning hours. Detailed information on the environmental conditions of the test can be found in Table 18.

Table 18: Road, traffic and weather conditions at Pörtschach pilot site

Variable	Value for the Site
Weather	Temperature varied between 15°C to 33°C.
Sight conditions	Good. Possibly light fog in the morning.
Road type	Semi-urban roads with good infrastructure, shared with cyclists and in some places with pedestrians.
Road works	No road works during pilot test.
Incidents	One time the automated shuttle hit the curb at the Bahnhof (train) station. There was one instance of parking damage involving parked cars near the garage at the Bahnhof (train) station. No one was involved.
Traffic conditions	Heavy traffic between 7-8:30 CET and 16-18:00 CET, otherwise moderate traffic. Very busy area during the day, especially with cyclists and pedestrians.
Traffic composition	On the main road, traffic is mixed with a lot of interaction with cargo vehicles. There are single track roads off the main road

Variable	Value for the Site
	with a lot of pedestrians and cyclists. A small part of the test route is in a pedestrian zone.
Traffic control	No traffic control.
Area type	Peri-urban environment.

Klagenfurt

The Klagenfurt site provides an ideal area to evaluate the mobility service and the integration of AV in an urban context. It has a complex structure and contains many relevant situations for a good evaluation, e.g. traffic lights, roundabout, mixed use area between vehicles and pedestrians, dual carriageway with two lanes in each direction, single carriageway with cycle path and car park. The shuttles were upgraded with V2X OBUs for the traffic light communication.

The testing environment covers three main areas (Figure 71):

- The first area (in red) around Lakeside Science & Technology Park the automated shuttles are challenged with two scenarios. 1) navigating with other vehicles on the road including public transport buses, 2) navigating through the inner streets of the Lakeside Park with pedestrians and cyclists.
- The second area (in yellow) is around the University of Klagenfurt and connected to Lakeside Park, an innovation center with around 1,800 employees. It also includes a residential area, student dormitory, restaurants, shops, hotels, leisure facilities, a retirement home, nurseries and schools etc.
- The third area (in blue) is around the Klagenfurt West railway station, which also consists of a residential area, Leisure facilities, a large Park&Ride area and the dual carriageway with two lanes in each direction. Heavy traffic exists in both directions and the shuttles are turning left at the intersection.

Three different routes (Figure 72) have been implemented to test the first shuttle fleet in Austria, with different lengths of 2,3 and 4 km. The longest route connects the railway station with the university and the Lakeside Park via 5 traffic lights of which 5 were equipped with a C-ITS system (RSU) and one Aware AI camera and a roundabout and motorway access road.

Figure 71: Klagenfurt areas. (Source: SURAAA)

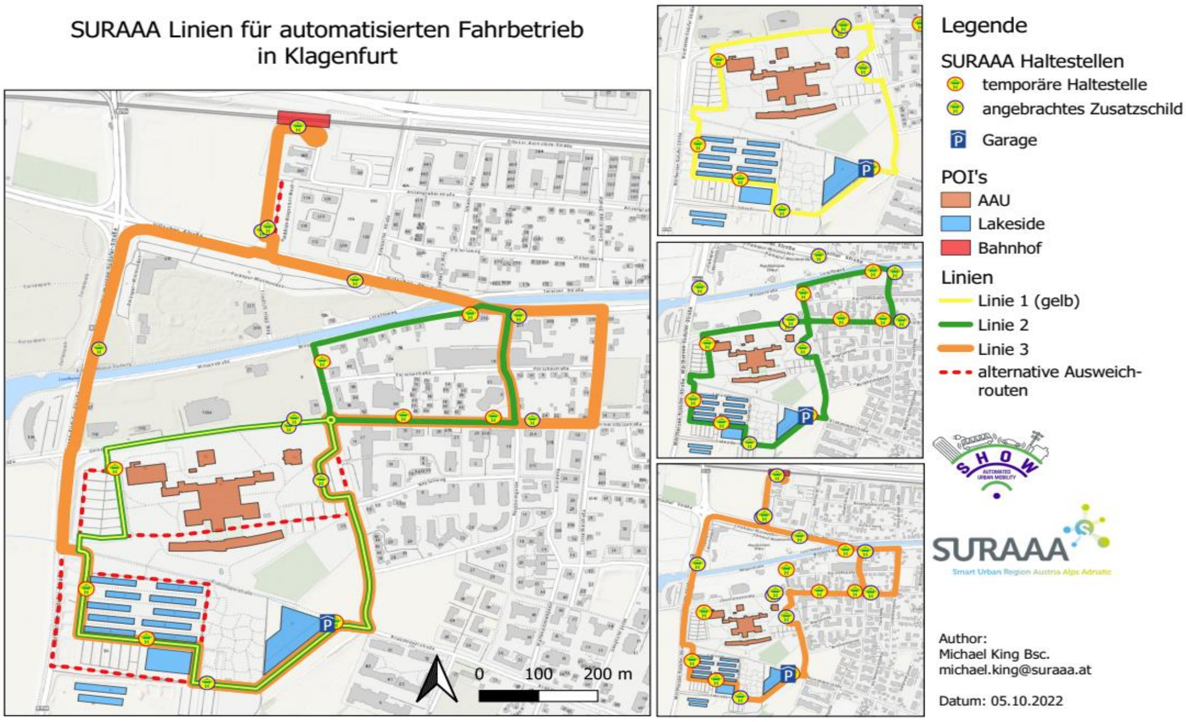


Figure 72: Klagenfurt route options. (Source: SURAAA)

The tests were carried out from June to September 2024, during which the weather was mostly mild with a few days of extreme hot temperatures and more rainy days in September. The shuttles were also operated once on a light rainy day with minor technical problems (lidar sensor communication), which were overcome by a hard reset or manually moving the shuttle forward a few metres. Detailed information on the environmental conditions of the test can be found in Table 19.

Table 19: Road, traffic and weather conditions at Klagenfurt pilot site

Variable	Value for the Site
Weather	Summer temperature varied between 15°C to 33°C.
Sight conditions	Clear sight.
Road type	The route runs along a four-lane main road with traffic lights and a speed limit of 50km/h. In addition to the main road, there are single lane roads with an integrated cycle path, a roundabout and mixed traffic including PT, with a speed limit of 30km/h. A part of the route is within the Innovation Park with a speed limit of 10km/h and mixed traffic including pedestrians.
Road works	No road works during pilot test.
Incidents	Fall of safety operators due to unexpected hard braking.
Traffic conditions	Heavy traffic between 7-9:00 CET and 16-18:00 CET, otherwise moderate traffic. The main road is always busy as it leads to the highway A2 Süd Autobahn.
Traffic composition	Mixed traffic, with interaction with cargo vehicles and PT. Near the university, there is a very high volume of pedestrians and cyclists and several crosswalks
Traffic control	5 traffic lights are equipped with C-ITS RSUs and one traffic light is equipped with an aware AI camera.
Area type	Urban environment.

6.3 Services and use cases

The key objectives of both Carinthian sites are the following:

- To enable and provide safe, sustainable, and integrated public transport (first/last mile).
- To build upon existing trial, test and learning environments in the regions of Carinthia.
- To integrate automated & connected fleets into the existing mobility systems (e.g., DRT, PT).
- To enable MaaS platforms & frameworks.
- Cooperation with existing support groups e.g., ITS Austria, local decision makers, local PT operators.
- To achieve efforts for legal enablers.

The typical test day procedure is as follows:

Table 20: Typical test day procedure in Klagenfurt and Pörtschach

Klagenfurt	Pörtschach
The operators of the 3 shuttles and a field operator (who monitors the operation from the control room) meet at 8:30 CET to discuss the events and status of the previous and recent test operation day.	The operator on duty start at 8:30 CET and reads the previous logs of the previous days to know about peculiarities on the route and in the shuttle.

Klagenfurt	Pörtschach
After the shuttles have been checked, they will be driven out of the garage, do a test run and arrive at their respective starting points (each route has a different starting point) at 9:30 CET	After that, the shuttle is inspected both inside and outside. Then the shuttle is started and driven out of the garage and do a test run and arrive at their respective starting points at 10:00 CET
The shuttles are operated according to the schedule with a short lunch break at 12:30 CET, during which the shuttles are charged (if the AC is used constantly the range of the shuttles decreases drastically), the test operation ends at 16:00 CET, the shuttles return autonomously until 16:30 CET to the garage and are parked manually, then they are cleaned and charged for the next operation day. Reports were written.	Check of the status of the dashboard (GNSS, hit ratio, battery, warning symbols). The automated test operation is started, and the route is operated according to the schedule from 10:00 to 16:00 CET with a break from 12:00 to 14:00 CET. After the test operation is completed, the vehicle is returned to the garage after a brief inspection and connected to the charging infrastructure. Reports were written.
Passengers board the shuttle at the designated stops (shared with PT or added for the test), the operator provides information about the project and the vehicle and collects relevant data. Passengers are asked to rate their journey and complete online surveys.	The main passenger on the route in Pörtschach are tourists, students and residents. The travellers board the shuttle at one of the bus stops. The passengers mainly get information about the test operation and the technology of the vehicle from the operator. The operator counts the participating passengers and refers to the online questionnaire if necessary.
The operators return to the office to fill in a report on the day's operation (driven route, number of passengers, problems, interventions, etc.). The shift ends at 5 p.m.	After the AV is back in the garage and charging, the operator compiles the reports. The reports include number of passengers, routes driven, number of hard resets, number of operator interventions and any issues that might have occurred during operations. The shift ends at 5 p.m.

To operate a Navya Arma DL4 shuttle in Austria, it is mandatory to have one operator/ safety driver on board during operations. In the event of a problem, the operator can contact the Navya Supervision team via the SIGNAL application for immediate assistance. The service is free of charge and has already been integrated into the public transport booking system. An operator is always on board and can answer any questions.

Figure 73: The automated shuttle on the route in Pörtschach. (Source: SURAAA)

Figure 74: The fleet of three automated shuttles in Klagenfurt. (Source: SURAAA)

Figure 75: Roundabout and signalised intersections in Klagenfurt. (Source: SURAAA)

6.4 Site-specific test cases

The specific test cases are built around three of the original use cases. The test cases are as follows:

- UC1.1: Automated passenger/cargo mobility in cities under normal traffic & environmental conditions (including semi-automated DRT)
- UC1.2: Automated passenger/cargo mobility in cities under complex traffic & environmental conditions (including semi-automated DRT)
- UC1.6: Mixed traffic flows
- UC2.1: Automated mixed spatial mobility (mixed mobility of cargo/passenger at the same time)
- UC3.6: COVID-19 safe DRT

Pilot Case 1: Automated Mobility in Cities (UC1.1, UC1.2, UC1.6)
Carinthia is offering a scheduled daily automated public transport service in an urban and peri-urban environment within all UCs. The traffic situation is different at the two pilot sites. In Pörtschach the main users are tourists and residents, in Klagenfurt commuters, residents and students.

An on-demand service was also tested in Pörtschach (since June 2024) and in Klagenfurt (since July 2024) in cooperation with IOKI (our on-demand provider), where passengers were able to book a ride via the smart:MOBIL application (Figure 77).

The on-demand service can be set up in an online control centre, where it is defined which shuttles will provide the service and in what timeframe, and the service is also monitored by the operator in the field (position of the shuttles, issues, ride bookings). At the start of the service, operators connect via a driver app to activate the service.

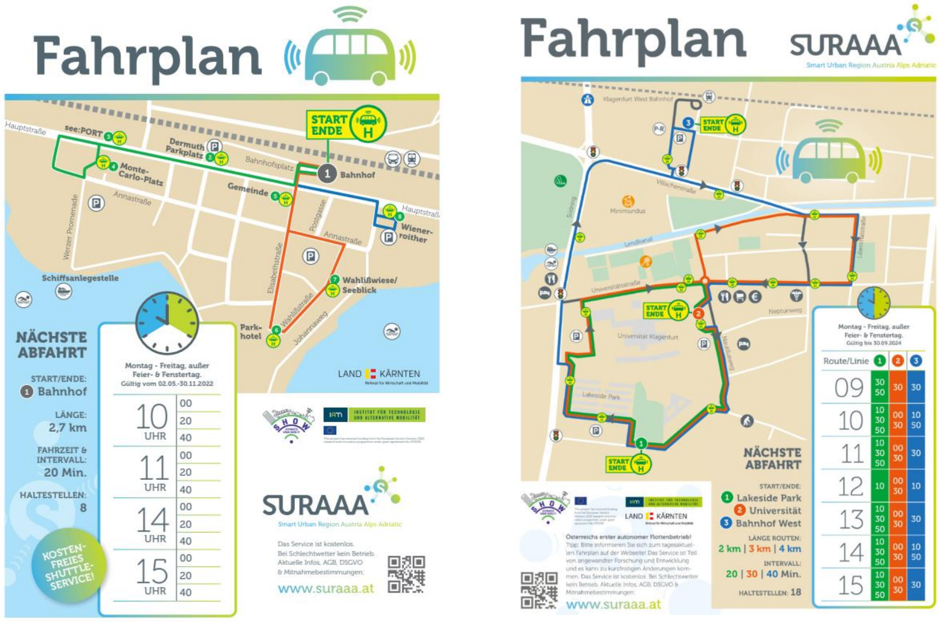


Figure 76: Pilot sites timetable. Left: Pörtschach   Right: Klagenfurt (Source: SURAAA)

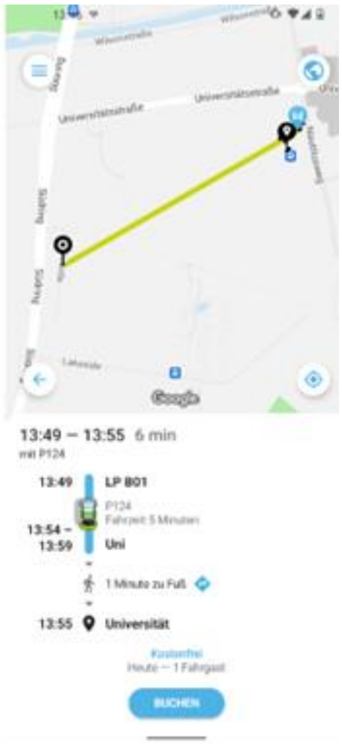


Figure 77: Screenshot of a booking for a journey from LP B01 to Uni station with an estimated travel time of 5 minutes. (Source: SURAAA)

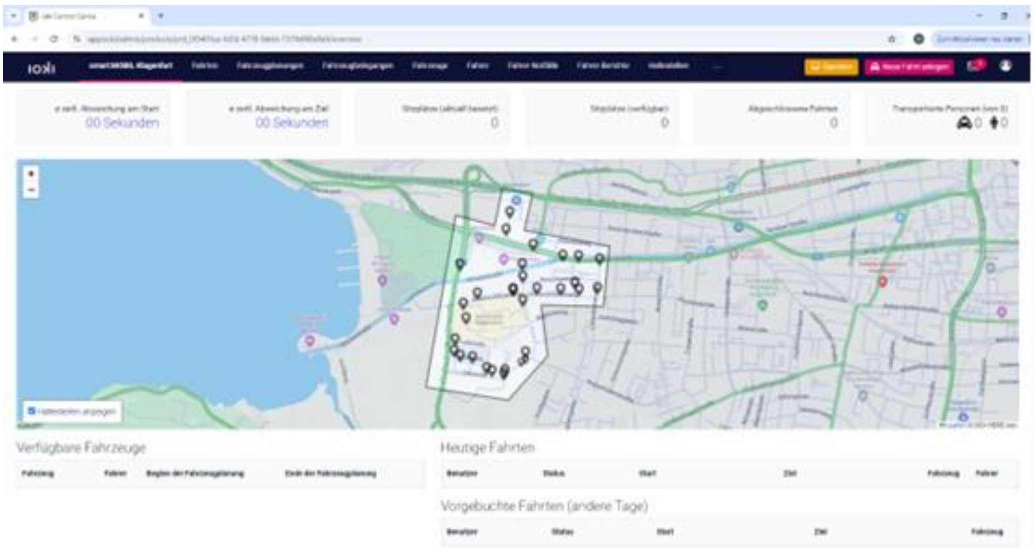


Figure 78: IOKI control centre to monitor the on-demand shuttle service. (Source: SURAAA)

Pilot Case 2: Automated Mixed Mobility in Cities (UC2.1)

UC1.1, UC1.2, UC1.6, UC2.1, UC3.6

The cargo use case is realized in Klagenfurt, which is the larger pilot site in Carinthia with complex traffic and environmental conditions. Small and medium-sized parcels using a custom-built transport box mounted inside the AV were transported with the shuttle. For the UC we delivered a medicine box from the *Uni Apotheke* Pharmacy to the *Wie Daham* a retirement home, the transport box is secured via a QR code opening system (Figure 79). Office supplies and goods from the nearby supermarket were also transported. A Q'Straint system is used on the ground to secure the transport box. This box is designed to fit in the space reserved for a wheelchair or a stroller.

Figure 79: Delivery of the medicine box to the retirement home using the shuttle. (Source: SURAAA)

In Pörtschach, a combination of passenger and goods transport was tested in cooperation with the ARTI delivery robot. The robot was transported by the shuttle close to the delivery address and autonomously completed the final metres to the recipient. By taking the delivery robot with the shuttle, the range of the robot can be extended and the delivery time shortened. Another advantage of the combined transport of passengers and goods is the efficient utilization of the automated shuttles.

Figure 80: Delivery robot ARTI being transported by shuttle to destination. (Source: SURAAA)

Pilot Case 3: Added Value Services for Cooperative and Connected Automated Mobility in Cities (UC3.6)

The goal of the Covid-19 UC is to find practical solutions to reduce the risk of infection when using public transport. The aim is to keep the virus load in the vehicle as low as possible during the operating hours by using various disinfection methods, one of which is air purification with HEPA filter systems for which the need has been assessed using an aerosol spectrometer. Another method is the use of antibacterial and antiviral coatings on the surfaces and the use of UV light disinfection. The effectiveness of these measures is evaluated by FH-Kärnten.

Figure 81: Automated shuttle at pilot site Pörtschach (Source: SURAAA)

6.5 The fleet

Table 21: Fleet characteristics at sites

Test/Use Case	Deployed fleet characteristics								
	Vehicle brand & model	Vehicle type (shuttle, …)	SAE Level reached for the field trials [1-5]	TRL level reached for the field trials [1-9]	Summary of upgrades held during the project (in consistency with D7.2)	HMI and Hand-over strategies (in consistency with D7.2)	Maximum speed reached during the trials (km/h)[9]	Average speed during the trials (km/h)	Maximum capacity of vehicle
Same for all UCs: 1.1, 1.2, 1.6, 2.1, 3.6	Navya	Arma DL4 (3 of them)	4	7	No	Manual driving via joystick	18	10	9 (includes operator)

At the Pörtschach pilot site, one Arma DL4 was in use. During the pilot in Klagenfurt a fleet of three Navya Arma DL4 shuttles was operated. The average maximum speed reached was 14,4 km/h in Pörtschach and 18 km/h in Klagenfurt.

Figure 82: Fleet of 3 Navya Arma DL4 shuttles in Klagenfurt. (Source: SURAAA)

[9] Maximum and average speed calculations might show slight deviations in the analysis followed in WP13 Deliverables as well as in the final Dashboard values.

6.6 The infrastructure

Information panels at the bus stops provide details about the project and automated driving. Passengers can also view the current timetable, the test route and contact information for the project, as well as a QR code to the SURAAA website, where the shuttles can be followed live (Figure 83). The tracking solution is possible by adding a device inside the shuttle.

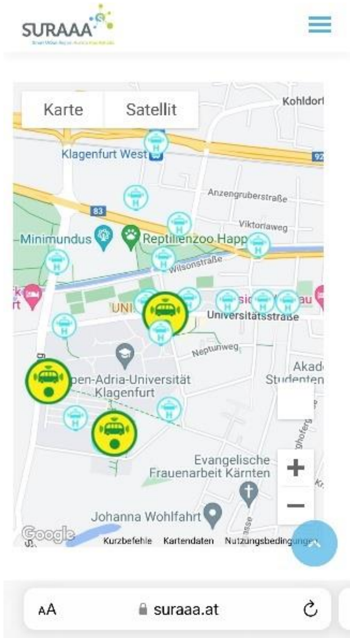


Figure 83: Live Tracking on the Website of the fleet of three shuttles in Klagenfurt. (Source: SURAAA)

Signs have been placed at all points where the road meets the test site to inform road users of the test region (Figure 84). A warning sign has also been placed along critical roads to alert to the presence of the AV including a clapping sign which limits the speed in case the shuttle is on the road (Figure 85).

Figure 84: Traffic signs along the route indicates the test region for automated driving in Pörtschach. (Source: SURAAA)

Figure 85: Temporary speed limit in Pörtschach. (Source: SURAAA)

The shuttles are programmed to stop at the stop signs or intersections. The operator gives permission to proceed with the GO button after double checking the road for approaching vehicles or other road users. The shuttle will stop automatically, if the operator misses a vehicle or an approaching pedestrian.

Pörtschach

At the Pörtschach site, storage, parking and charging facilities are provided by the local council, together with the charging possibility. 4G/LTE is currently used in Pörtschach, 5G is ready to be used, but the shuttle does require a suitable 5G router.

Figure 86 shows the general overview of the architecture of the site Pörtschach in Carinthia. C-ITS was removed from the architecture for Pörtschach because there is no possibility to test/use C-ITS.

Along the route, there is smart lighting infrastructure implemented. The data is not processed in the LDMP. Live tracking is possible over an external device inside the shuttle. Users can follow the location via the official website of SURAAA.

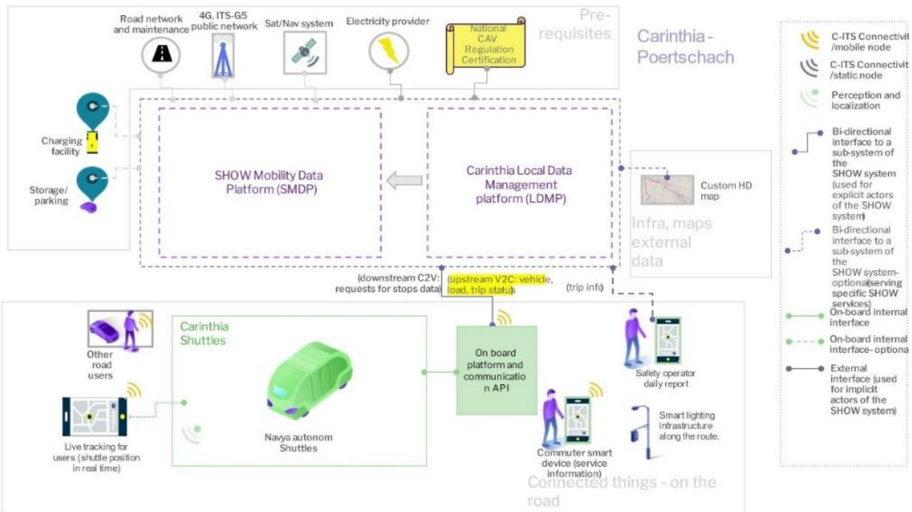


Figure 86: Data Management system Architecture for test site Pörtschach. (Source: SURAAA)

The shuttle was also listed in the official public service schedule proposed by external app providers (Figure 87).

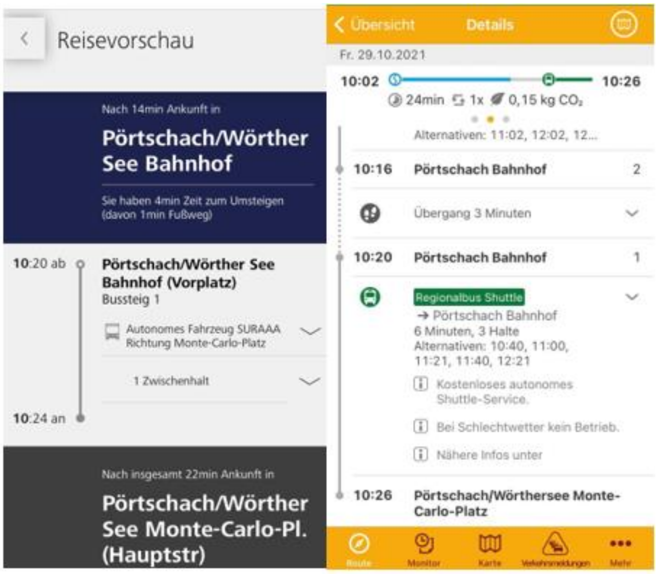


Figure 87: Public transport booking platforms OEBB and Kärntner Linien giving the shuttle as transport option. (Source: SURAAA)

Klagenfurt

At the Klagenfurt site, storage and parking of the shuttles is provided by the Lakeside Science & Technology Park. 5G/LTE is currently in use in Klagenfurt. There are several traffic signs and traffic lights along the route. All five traffic lights have been equipped with C-ITS, which provides the ability to communicate the signal phase to the shuttle. The shuttles can also register at the traffic lights to get priority. On the dual carriageway with two lanes in each direction, four additional warning signs with an orange flashing light option were installed (Figure 88); this was necessary because the speed limit on these roads is 50 km/h and the maximum shuttle speed is 20 km/h.

Figure 88: Warning sign "slow vehicle” (Source: SURAAA)

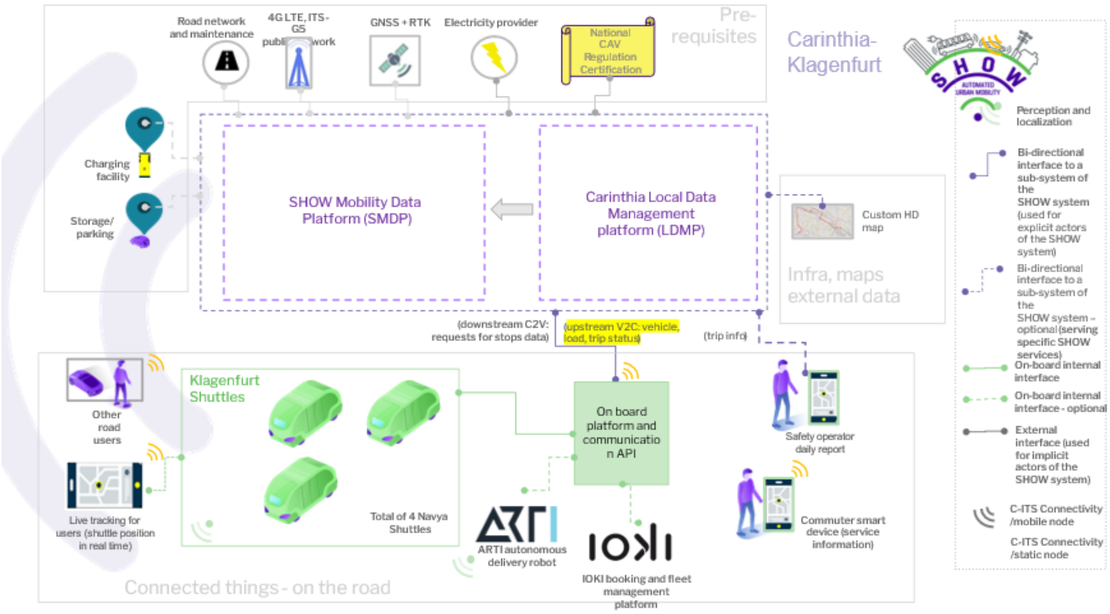


Figure 89: Data Management System Architecture for the Klagenfurt test site. (Source: SURAAA)

Figure 89 shows the general overview of the architecture of the Klagenfurt site. IOKI is used for on-demand booking of the automated shuttles as for the fleet management of the three deployed shuttles. The ARTI autonomous delivery robot was tested in Pörtschach.

Two additional screens were installed in all three shuttles for the pilot in Klagenfurt. One screen provides a visual overview of the C-ITS function and localization of the respective shuttle. This additional screen is connected to a specially installed additional OBU from Yunex. There is also a screen for passenger satisfaction surveys. They can rate their satisfaction with the ride using a smiley system. Also, in Klagenfurt passengers can see via our webpage the real time whereabouts of the three shuttles.

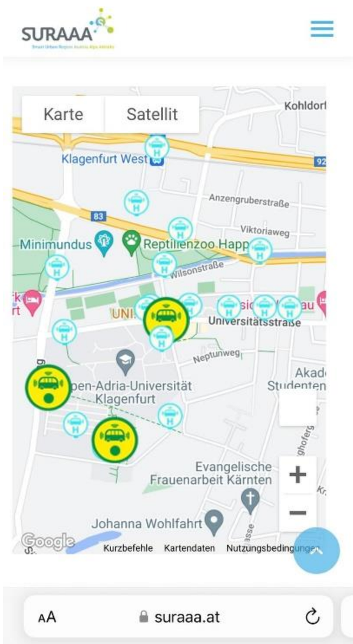


Figure 90: Live Tracking of the shuttles in Klagenfurt via SURAAA Webpage. (Source: SURAAA)

C-ITS infrastructure at pedestrian crossing in Klagenfurt

To ensure a safe passage through the pedestrian crossing, an infrastructure-based support was implemented. This infrastructure-based support is setup by a camera system with on edge AI processing (awareAI camera system) for detecting vulnerable road users (VRUs) on the crosswalk. The awareAI camera has been deployed on top of an existing traffic light pole at a height of approximately 6 meters. This installation expended the camera's field of view, thereby ensuring the acquisition of high-quality video data from the surveilled areas. The awareAI core, functioning in real-time, undertakes the processing of incoming video stream data. Throughout the implementation process, two specific detection zones were established, corresponding to the possible directions of travel. All detection tasks are performed within the local processing unit of the camera system, guaranteeing the highest level of data protection as only fully anonymized information is processed by external systems.

Figure 91 illustrates the detection zone configuration of the monitored area, highlighting the two segments of the crosswalk (represented as red layout) as well as the corresponding waiting areas (represented as yellow layout). In the event of a successful trigger activation, the awareAI core system generates the respective C-ITS information which is updated and triggered per second to a local C-ITS Roadside Unit (RSU). The RSU encapsulates the received information, as profiled by C-ROADS, to an ETSI standardised “DENM” warning message, and broadcasts this warning message as long as VRUs are detected within the detection zones of the awareAI system.

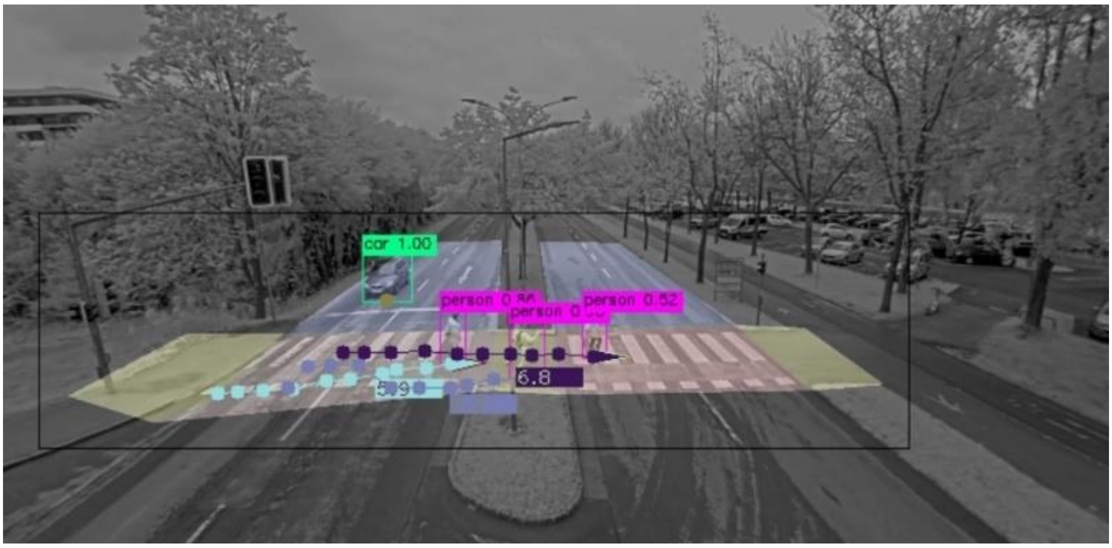


Figure 91: Illustration of the awareAI detection parameters. (Source: Yunex Traffic Austria GmbH)

The intersection was tested with the AustriaTech Mobile Lab, which is a testing and validation tool used to test C-ITS Messages in various settings. The tool uses the Vector CANoe Car2X functionality as a basis and allows for quick analysation of the most important C-ITS payload parameters. The Mobile Lab placed within a vehicle tested the situation statically while parked in a parking space close by, and also dynamically while driving towards the crosswalk.

The analysed C-ITS payload received by the testing tool is depicted in Figure 92. It shows as a red line the trace to an event and the event itself depending on the causeCode and subCauseCode as a specific traffic sign. In the case of the pedestrian on the road the tool only shows the general warning sign at the event position, as no specific traffic sign is implemented. The text in the figure is used during testing to provide additional information like the ActionID, which is the unique identifier of the event and also the causeCode in its written form in this example HumanPresenceOnTheRoad.

The event was triggered by people crossing the road and messages where recorded. Furthermore the SPATEM/MAPEM messages where analysed together with the DENM. It was observed that the warning messages where triggered with the correct traces while the traffic light signal was green for turning left. However also DENM with traces along the main road could be observed sometimes.

The conclusion of the test was very positive as every time a person walked across the crosswalk a DENM was sent out.

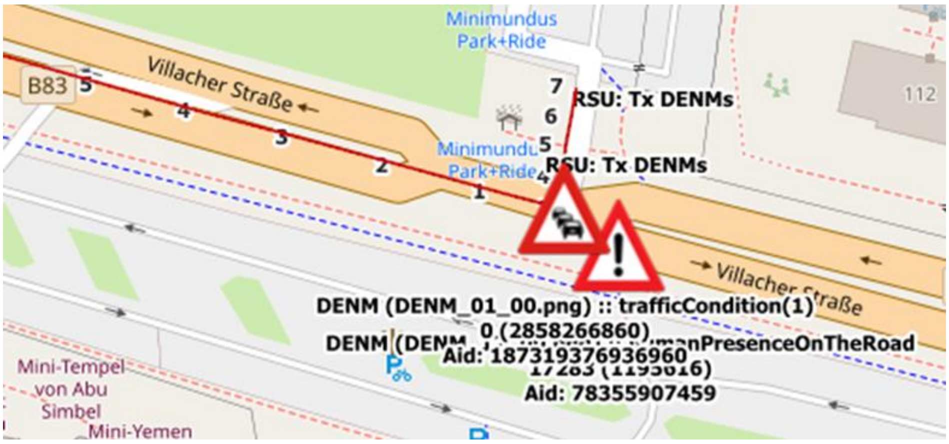


Figure 92: C-ITS payload received by AustriaTech Mobile Lab (Source: AustriaTech)

6.7 Passengers

The main target groups in Klagenfurt were commuters to/from the railway station, Minimundus visitors, students, residents, tourists, employees at Lakeside Park and people interested in automated mobility. Several activities were also carried out to understand the needs and wishes of children (see chapter 6.11, Kids DAY). In Pörtschach, the target passengers were tourists interested in automated mobility and residents (who are mainly seniors) who enjoyed the ride to the town's bakery.

6.8 Total number of passengers and cargo deliveries

The Pörtschach shuttle operated from May to November in 2022 (6 months), from May to August 2023 (3 months), and from April to June and in September (3 months) in 2024, with a timetable from Monday to Friday from 10:00 to 16:00 CET, excluding public holidays and bridging days, for this period excluding the pre-demo phase from September to November 2021 (3 months), the total number of passengers is 6036. During pre-demo phase 564 passengers have been transported which makes a total of 6600 passengers.

In Klagenfurt, the three shuttles went into service at the beginning of July and have run until the end of September 2024 (3 months) with a timetable from Monday to Friday from 9:30 to 16:00 CET, excluding the pre-demo phase in June (1 month) and an event in May, a total of 3236 were carried during this period. During pre-demo 64 passengers have been transported which sums up to 3300 passengers in total. Within the combined transport of passengers and goods 203 packages have been delivered.

6.9 Data collection

Data was collected concerning different aspects of the shuttle operation. Among these data are:

- The kind of service that was provided (regular service, event service, special service, on demand service)
    - The time during which the service was provided
    - Operator on duty
    - Which test was executed
    - Jira tickets opened
- Failure reports
- Outage of shuttle service
- Number of Hard Resets
- Number of Smart Resets
- Number of Key Resets
- Steering Wheel Issue
- Aborted missions
- Number of passengers (in the morning, in the afternoon)
- Number of routes completed
- Manually driven segments
- Number of error messages

The data is inserted into a spreadsheet and stored locally. The data is collected daily by the safety operator and at the end of the day inserted into the spreadsheet.

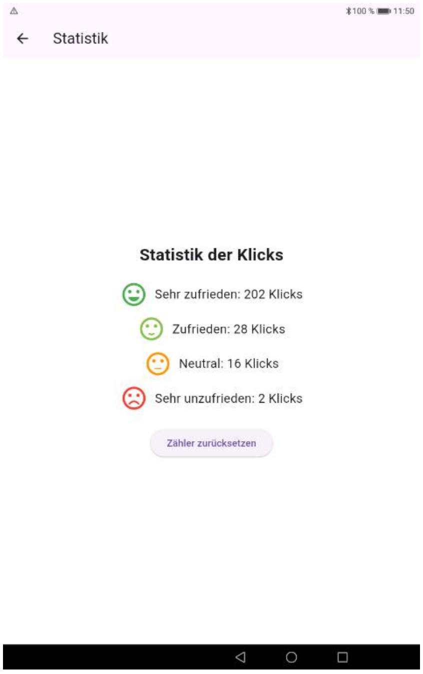


Figure 93: Statistic of the satisfaction clicks from one Shuttle. (Source: SURAAA)

Inside the shuttles, touch screens were installed for passengers to report their satisfaction using 4 smileys from happy to not happy (Figure 93). An overview of the number of participants and their level of satisfaction from 15 July to the 5 September at the Klagenfurt site is shown in Figure 94. A QR code for the acceptance survey has also been placed in the shuttles.

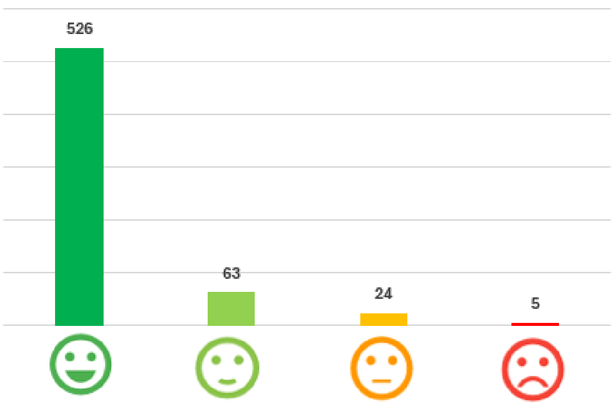


Figure 94: Evaluation of the satisfaction survey from all three shuttles in Klagenfurt as of 05 September 2024. (Source: SURAAA)

All necessary surveys and interviews within the project were carried out using either the Netigate tool or forms. The two LaaS surveys were carried out using Forms and later manually transferred to Netigate. A detailed analysis will follow in D1.3 [5] and D13.4 [8]. In order to be able to conduct more and also comparative surveys, special user events were held. Participants had the opportunity to test the automated shuttles and services, such as the on-demand service, and to complete a Netigate questionnaire before and after the journey.

AustriaTech held a supertester event at the Austrian pilot sites in summer 2023. The same user group was also able to test the automated shuttle in Carinthia and contribute their experiences to surveys, and workshops were also held with the testers to find out more information about the desired services.

In May 2023, the MAMCA workshop was held in Pörtschach for all three pilot sites in Austria. Stakeholders from the Carinthian pilot sites in particular were invited to attend.

6.10 Pilot operation key findings

Driving under complex traffic and environmental conditions does provide challenges for automated vehicles. Complex environmental conditions like heavy precipitation, snowfall, and fog cause technical complications with the LiDAR sensors. Complex traffic conditions are generally not an issue for the autonomous vehicles, but due to the low operating speed, it causes more unnecessary traffic jams and might lead to more risky driving manoeuvrers from other drivers. Overtaking manoeuvrers without sufficient safety distance and poorly parked cars can lead to abrupt braking, which can affect passenger comfort. This hard braking can cause minor injuries, even at low speeds.

Some real-life road situations require a gesture or a look between the people involved to decide how to overcome the situation, this type of communication is not yet achieved with automated shuttles because the other users can't understand what the shuttle's next step is, this situation leads to confusion between the shuttle and the other users.

6.10.1 Key findings per Use Case

High level findings per Use Case		
Use Cases	Overall qualitative performance score (1-3[10])	Justification
UC1.1: Automated passengers/cargo mobility in cities under normal traffic & environmental conditions *Carinthia specific: First & last mile public transportation in normal conditions*	3	Due to the fact that Pörtschach is a highly frequented tourist resort, traffic was normal in the early and late season, but during the high season there was a very high volume of traffic with many cyclists and pedestrians on the road. This led to more spontaneous hard breakings when there were too many obstacles on the road. The satisfaction of the passengers with the service was, however, very good.
UC1.2: Automated passengers/cargo mobility in cities under complex traffic & environmental conditions *Carinthia specific: First & last mile public transportation with passengers and cargo at the same time under complex traffic conditions*	2	The route in Klagenfurt was more complex due to its length and the challenging route, we had to cope with 5 C-ITS equipped traffic lights and longer stretches with shared space. Above all, setting up the route with the 5 traffic lights proved to be a challenge. Beyond the set-up time, we had to continue working on optimizing the communication between shuttles and traffic lights. It was only towards the end of the demonstrations that a good result of these efforts was achieved. Apart from that, we received good feedback from passengers and stakeholders.
UC1.6: Mixed traffic flows *Carinthia specific: First & last mile public transportation in mixed traffic and shared space with VRU*	3	At both demo sites (Pörtschach and Klagenfurt), the shuttles were used in public traffic with other road users (two-way traffic, 4-lane roads, narrow road conditions and shared space). In Pörtschach in particular, many pedestrians and cyclists were to be expected during

[10] 1 [Low] – 2 [Medium] – 3 [High]; success qualitative score, considering all aspects (technical, user acceptance).

High level findings per Use Case		
Use Cases	Overall qualitative performance score (1-3[10])	Justification
		the high season. In Klagenfurt, there were sections of the route with shared space, i.e. this section could be used by cyclists and cars. The situation was only problematic when cyclists came too close to the shuttle, which resulted in abrupt braking. No crash or incident happened. The speed of the shuttle was slow. This was seen as both good and bad. The good thing is that it will not attract those that can walk or cycle by them self, the bad thing is that it will not be attractive enough for car drivers. Another good thing is that if hard breaking happened the effect of it was not serious. The driver onboard could support and explain why it ran slow. This was very positive during the operation.
UC2.1: Automated mixed spatial mobility *Carinthia specific: First & last mile public transportation with passengers and cargo at the same time*	2	In the combined UC with passengers and cargo, deliveries were made from the local pharmacy to the retirement home. There it was important that the transport box was locked and only accessible by the person who picked up the packages. This could be guaranteed as the compartments of the transport box were only accessible by QR Code provided when the delivery was booked. Furthermore, it was important that the shuttle could be cooled as the medicine needs a certain temperature. Additional deliveries were made from the supermarket with office supply and grocery goods. Since there were not always bookings for deliveries it was necessary to bring the transport box in and out from the shuttle. Therefore, it is still necessary to have an operator on board.
UC 3.6 COVID-safe DRT	3	Tests with an air filter system have been conducted as well as antibacterial and antiviral coatings. The evaluations are carried out by

High level findings per Use Case		
Use Cases	Overall qualitative performance score (1-3[10])	Justification
Carinthia specific: First & last mile public transportation with specific preventive measures to avoid contamination		a research partner, the Carinthia University of Applied Sciences. No results are currently available.

6.10.2 Key challenges and mitigation outcomes

Table 22: Key challenges at Carinthia pilot sites

Challenge	**Type** (Operational, Technical, Business, Other)	**Mitigation**	**Mitigation outcome**
Navigation and positioning errors	Technical	Due to an ongoing problem with the GNNS positioning in the year 2022 we had to switch to Lidar Only Mode	The GNSS problem of course wasn't existing anymore, but also the Lidar Only Mode made at that time problems.
Slow speed	Technical	Warning signs along the street that says: Caution slow vehicle	Other road users were warned
Poorly parked cars	Operational, Technical	Advertisement and text in the community newspaper to make drivers aware of the correct parking regulations etc.	It certainly helped with locals, but not with tourists
Weather conditions	Technical, Operational	Announcement on our website and on the bus stops that the shuttle service is not in place at certain weather conditions like heavy rainfall or snow.	Locals knew already to take a look on our website, if the shuttle service is currently in operation.
Narrow overtaking	Technical, Operational	Warning at the rear end of the shuttle that says: Please keep a distance of at least 3 meters	Many road users, like cars followed this instruction

6.10.3 Key incidents and impacts

Our team uses an Internal Reporting Tool to log key data after each test drive, ensuring that any operational issues or incidents are thoroughly documented. All operators are required to fill out this report daily, providing crucial insights into vehicle performance and any challenges encountered during their shift. The tool covers the following categories:

1. **Failure Reports:** Details any mechanical or system failures that occurred during the test drive.
2. **Outage of Shuttle Service: Logs** any periods of service disruption where the shuttle was non-operational.
3. **Number of Hard Resets:** Tracks instances where a hard reset (full system reboot) was needed to restore functionality.

4. **Number of Smart Resets:** Counts smart resets, a less disruptive reset to restore the vehicle's operation.
5. **Number of Key Resets:** Records the use of key resets, typically when the ignition is turned off and on to resolve minor issues.
6. **Steering Wheel Issue:** Documents any malfunctions or irregularities related to the steering wheel.
7. **Aborted Missions:** Logs any test drives that had to be terminated prematurely due to unforeseen circumstances.
8. **Manually Driven Segments:** Notes portions of the route where manual driving was required, instead of autonomous operation.
9. **Number of Error Messages:** Tracks the total number of error messages generated by the vehicle's systems during the test drive.

This structured reporting allows us to quickly identify and address recurring issues, enhancing overall vehicle performance and safety. All operators must ensure accurate and timely completion of the report after each test drive.

For urgent issues, immediate communication with the manufacturer's operations and maintenance team is facilitated through a mobile device via a Signal chat group. If the problem cannot be resolved promptly, a JIRA ticket is created on the manufacturer's platform for further investigation. In cases where necessary, a log extraction is performed on the affected shuttle, and these logs are then analysed by the manufacturer to begin troubleshooting and address the issue. This process ensures timely identification and resolution of any operational challenges.

Hard brakes:

Hard braking incidents in the automated shuttle are primarily triggered by overgrown tree branches, poorly parked cars, and the overtaking of cyclists, which cause the shuttle's system to respond with sudden stops. These hard brakes can pose a safety risk, especially when passengers are not buckled up. To ensure safety, the onboard safety operator consistently reminds passengers to properly fasten their seat belts. Every seat in the shuttle is equipped with a seat belt, and Austrian law strictly prohibits passengers from standing while the shuttle is in motion. With only 8 available seats, space is limited, and to date, only one instance of a passenger falling during a hard brake has been reported by our operators.

With the transition from a Windows to a Linux-based operating system and the accompanying software update, a new corridor system was introduced, which significantly reduced the frequency of hard brakes. This new system enhances the shuttle's ability to react more smoothly in case an obstacle is detected. When the shuttle detects an obstacle, it now calculates the distance to the object and applies braking in controlled stages, rather than executing a sudden stop. By braking in intervals, the system can slow down the shuttle gradually, ensuring a smoother deceleration. This improvement not only enhances passenger comfort but also reduces the wear on vehicle components and minimizes the risk of incidents caused by abrupt stops.

Cancelled trips:

Cancelled trips were primarily due to software and hardware interruptions. Very often it took several days or in some cases even weeks to rectify the error. The biggest impact was the switch from GNSS to Lidar only mode, caused by the frequent GNSS failure. Only after switching to Linux, with the new software it was possible to start driving with GNSS again. Weather-related cancellations also occurred, trips were impacted by poor visibility in foggy conditions and heavy rainfall.

On August 10, 2022, the automated shuttle hit the kerb (approx. 20 cm high) at Pörtschach station (approx. 30 cm to the right of the lane) during the test drive in autonomous mode. There was no personal injury and no damage to property. Consequently, operation was switched from GNSS-based to Lidar only mode. This setting was also maintained during operation in 2023; only after a hardware and software upgrade by the manufacturer Gama (Navya) in spring 2024 the operation was switched back to GNSS-based.

In August 2023, a parking incident (property damage without personal injury) occurred during a daily routine procedure - parking in manual mode (with an operator at the wheel). Since then, in response to this incident and to increase safety, this daily routine procedure has also been carried out in autonomous mode.

6.10.4 The passengers´ point of view

When it comes to user acceptance, we experienced positive feedback from our passengers. People are generally accepting this new technology, however there are also points for criticism like the slow operating speed - especially for other road users – and the hard breakings (security reasons). Systematic analysis will follow in D13.5 [4].

Communication with local citizens is key as it shows the increase of public acceptance for autonomous vehicles (72% of respondents in Carinthia have a positive attitude towards autonomous vehicles).

The acceptance of automated shuttles among elderly people in Pörtschach has been very positive. The convenience and accessibility of the service have been well-received, leading to an extension of the shuttle route to better serve this demographic. In response to their needs, the route now includes stops at popular locations such as the local bakery and Café Wienerroither, making it easier for elderly residents to access key destinations in their daily routines.

We have organized many events with children of various ages (kindergarten, elementary schools, secondary school and highschool) to promote the acceptance of automated shuttles among young people and to gain insights into how they might use such services in the future. These events included interactive sessions where we asked the children various questions, such as whether they would feel scared to ride in a shuttle without a safety operator on board. The majority of children responded that they would still feel comfortable using the shuttle, even without a safety operator present. These events have provided valuable feedback and helped build confidence in the next generation regarding the use of automated shuttles.

6.10.5 The safety drivers´ point of view

When we advertised the positions for safety drivers, we received a substantial number of applications not only from younger individuals, such as students, but also intriguingly from older candidates. In Pörtschach there were 3 safety drivers and in Klagenfurt 9 safety drivers. All selected applicants underwent training from the manufacturer to become safety operators and are now rotating between roles as safety operators and field operators. The job is often quite demanding, as frequent software error messages require safety operators to intervene. Despite this, the rate of automated operations at both pilot sites remains very high, meaning that manual intervention by operators is minimal. However, operators describe the situation as particularly stressful if the shuttle stops in the middle of the road and blocks traffic, requiring quick action to resolve the blockage. On the positive side, operators appreciate the interaction with passengers, who are often very interested in the technology and eager to ask questions.

6.10.6 The other road users´ point of view

The assessment and perception of the shuttle on the road varied between the two pilot sites. In Pörtschach, the shuttle operates in an environment with narrow streets and a busy main road where drivers often travel at high speeds. To address this, a 30 km/h speed limit sign is deployed during operating hours on the main road to reduce the speed from 50 km/h. This reduction in speed is not well received by passing drivers, who criticize both the speed limit and the slow pace of the shuttle. Conversely, some local residents view the speed reduction as a welcome measure to calm traffic. However, even among locals, there is criticism regarding the shuttle’s slower speed.

In Pörtschach, the interactions with cyclists, particularly on the main road, are not always comfortable for both sides. Cyclists, especially those on racing bikes, tend to overtake the shuttle due to its relatively slow speed. After overtaking, they often merge back into the lane directly in front of the shuttle. Given the short distance maintained by the shuttle, this frequently triggers abrupt braking, which is both disturbing for passengers and the safety operator. Despite clear signage on the rear of the shuttle requesting a minimum distance of 3 meters, both drivers and cyclists frequently encroach too closely, prompting the shuttle to brake unexpectedly.

In Klagenfurt, the dynamics of shuttle interaction differ due to the road infrastructure and traffic patterns. The shuttle operates on a heavily trafficked four-lane road, with two lanes on each side, and streets around the university that feature multi-use lanes. On the four-lane road, the shuttle, limited to a speed of 20 km/h, could potentially be seen as an obstacle during heavy traffic. However, since there are two lanes in each direction, drivers can usually manoeuvre around the shuttle easily. As a result, incidents of vehicles following too closely are infrequent. Nonetheless, when such situations do occur, they can still disrupt the shuttle's operation, as its sensors detect the closely trailing vehicles as obstacles, leading to sudden braking.

Around the university, conditions were relatively calm during the summer months due to fewer cyclists on the multi-use lanes. This lower numbers in cycling activity allowed the shuttle to travel without significant disruptions. However, the seasonal nature of this quiet period suggests that as the university becomes busier, the potential for interaction with cyclists and other road users may increase.

6.10.7 The stakeholders´ point of view

In both Pörtschach and Klagenfurt, we engaged in valuable exchanges with our stakeholders. We have consistently received support from the state of Carinthia - not only regarding test applications and testing environments but also repeatedly in matters concerning operational activities.

In Pörtschach, there was also excellent cooperation with the local municipality, for example, with the green waste management, which the municipality handled for us when needed, as well as with requests related to infrastructure. Furthermore, there was good collaboration with the Pörtschach Tourism Association, as the shuttle service in Pörtschach is primarily used by tourists. In this sense, we can say that the collaboration and the expectations of the stakeholders for the test operation were met.

6.11 Key local demonstration events

It is important to reach out to people, to do presentations, to educate people on the service (not only the passengers but also other road users). In Pörtschach and Klagenfurt, articles have been published in the local newspapers about the shuttle and the service offered.

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Smart Urban Region Austria Alps Adriatic

Die Zukunft ist zurück in Pörtschach!

Der fahrerlose Shuttlebus ist wieder täglich im Ortszentrum von Pörtschach unterwegs.

JETZT TESTEN! Mit Ihren Gästen, Kunden, Freunden und Bekannten. Gerne auch für Gruppen!

Das Pilotprojekt „autonomes Fahren" geht in die nächste Phase und bringt nicht nur wertvolle Erkenntnisse für die fahrerlose Mobilität der Zukunft, sondern macht Pörtschach wieder zu einem ganz besonderen Schaufenster für Zukunftslösungen!

Mit Montag, den 06. September, tourt der elektrisch betriebene Navya-Kleinbus wieder vollkommen automatisiert (fahrerlos) durch Pörtschach und transportiert kostenlos Gäste und Einheimische. Das stellt nicht nur ein vollkommen neues und zeitgemäßes Gästeservice dar, sondern liefert obendrein dem öffentlichen Verkehr (ÖPNV) wertvolle wissenschaftliche und technologische Erkenntnisse für zukünftige Mobilitätslösungen. Bereits seit Mai 2018 wird in Pörtschach am Wörthersee - im Rahmen des Projektes SURAAA (Smart Urban Region Austria Alps Adriatic – www.suraaa.at) - an den vielschichtigen Entwicklungen rund um die fahrerlose Mobilität geforscht und entwickelt.

Interessierte aus aller Welt waren bisher zu Besuch: Zuletzt am 09. Juli Bundespräsident Alexander Van der Bellen. Und in den kommenden Wochen und Monaten kommen weitere Delegationen nach Pörtschach um sich vom Fortschritt des EU-kofinanzierten Projektes zu überzeugen (und steuern so auch einen kleinen Anteil zu den positiven Nächtigungszahlen des Ortes bei).

Damit das Projekt „autonomes Fahren" auch weiterhin erfolgreich unterwegs sein kann, wurde auch auf entsprechende Sicherheitsmaßnahmen Wert gelegt. Dazu finden Sie auf der zweiten Seite dieser Information kurz und kompakt die wesentlichen Punkte. Allen voran ist aber zu erwähnen, dass mit diesem Projekt der Gemeinde und der Bevölkerung ein vielfach geäußerter Wunsch des Gemeinderates nach einer Tempobeschränkung im Ortsgebiet auf 30 km/h zumindest schon in einigen Teilen erfüllt werden konnte. Daraus wird leicht ersichtlich, dass sich ein derartig neuartiges Projekt auch sehr sinnvoll zur erfolgreichen Ortsentwicklung genutzt werden kann.

„Mit dem autonomen Shuttlebus erlebt ganz Kärnten schon heute die Mobilität von morgen!"
Silvia Häusl-Benz, Bürgermeisterin von Pörtschach

„Das autonome Shuttle ist nicht nur praktisch für unsere Gäste, sondern stellt auch einen zusätzlichen Erlebnisfaktor in Pörtschach dar".
Christoph Neuschaller, Obmann des TVB Pörtschach

Leitprojekt automatisierte Mobilität (First-/Last Mile) im ÖPNV.
Mit SURAAA setzt das Land Kärnten mit Partnern aus Wirtschaft und Forschung eine einzigartige Initiative in den Bereichen Wirtschaft, Tourismus, Mobilität, Entrepreneurship und Innovation um. Ziel ist, sich europaweit als innovative Vorzeigeregion zu positionieren, die Attraktivität als Wirtschaftsstandort zu stärken und innovative Projekte in den Bereichen automatisierter Mobilität, Startups und Digitalisierung zu fördern.

COVID-19 SICHER!

Der Shuttlebus hatte schon hohen Besuch, auch aus Köln mit Oberbürgermeisterin Henriette Reker – begleitet von Mobilitätslandesrat Sebastian Schuschnig.

Zukunft zum Mitfahren
www.suraaa.at

INSTITUT FÜR TECHNOLOGIE UND ALTERNATIVE MOBILITÄT

Fahrplan

Montag - Freitag, außer Feier- & Fenstertag. Gültig vom 20.09.-30.11.2021
START/ENDE: Bahnhof 1
LÄNGE: 2,2 km
FAHRZEIT & INTERVALL: 20 Min.
7 HALTESTELLEN

UHR		
10	00	20	40
11	00	20	40
14	00	20	40
15	00	20	40

Alle Infos zum Shuttlebetrieb: www.suraaa.at

START ENDE · Bahnhof · see:PORT · Dermuth Parkplatz · Monte-Carlo-Platz · Schiffsanlegestelle · Wahlißwiese/Seeblick · Parkhotel

KOSTENFREIES SHUTTLE-SERVICE!

Autonomer Shuttlebus in Pörtschach wieder im Einsatz

Für den reibungslosen Shuttlebetrieb und zur allgemeinen Sicherheit bitten wir um Ihre Unterstützung:

30er-Zone
Während des Fahrbetriebes (werktags zwischen 10 und 12 Uhr bzw. 14 bis 16 Uhr), herrscht entlang der Hauptstraße, bzw. im ganzen Ort eine 30 km/h-Tempobeschränkung. Gekennzeichnet jeweils an der Ortseinfahrt und an der Ortsausfahrt.

Abstand
Bitte halten Sie hinter dem Shuttlebus genügend Abstand. Das Fahrzeug reagiert sofort auf allfällige Hindernisse davor, daneben, dahinter.

Überholen
Überholen Sie den Shuttlebus weiträumig. Die Sensoren des Busses reagieren sofort bei einer zu starken/knappen Annäherung von Verkehrsteilnehmern an den Shuttlebus und bremsen sofort ab. Damit erhöhen Sie den fließenden Verkehr.

Start- und Zielstation: Bahnhof Pörtschach

Parken
Bitte parken Sie immer innerhalb der markierten Parkplätze und sorgen Sie dafür, dass Ihr geparktes Auto genügend Abstand zur Fahrbahn hält.

Grünschnitt
Wir bitten Sie, durch regelmäßigen Grünschnitt, dafür zu Sorgen, dass keine Äste oder Hecken in die Fahrbahn stehen. Die Sensoren des Shuttlebuses erkennen auch Äste, die in die Fahrbahn hängen und definieren das als Hindernis.

Werktags von 10 bis 12 Uhr und von 14 bis 16 Uhr (20-Minuten-Takt)

Das Interesse von Bundespräsident Van der Bellen (3. v. l.) an SURAAA ist eine besondere Anerkennung! Das Staatsoberhaupt wurde von Landeshauptmann Kaiser (2. v. l.) begleitet und will für einen Praxistest wiederkommen!

Was erlaubt das Gesetz dem autonomen Shuttle?
- Max. 20 km/h (technisch möglich: bis 45 km/h)
- 8 Fahrgäste (müssen sitzen) + Operator
- Operatorloses Fahren ist noch nicht erlaubt!

Shuttle ist mit Sensoren, Kameras, Lokalisierung etc. ausgestattet, was zentimetergenaues Fahren gestattet. Bei Hindernissen, wie falsch geparkte Autos, muss per Gesetz der Operator die Steuerung übernehmen.

www.suraaa.at

„Mit dieser Testphase belegen wir abermals die Alltagstauglichkeit des autonomen Shuttles. Die 20-minütige Taktung und die kostenlose Nutzung stellen so eine völlig neue Mobilitäts-Serviceleistung für Gäste und Einheimische rund um den Wörthersee dar."
Walter Reinhard Prutej, SURAAA-Projektleiter

see:PORT
innovate and work @ the lake
(BKS-Gebäude, 2. OG)

Der Innovations- Arbeits-, Denk und Co-Creation-Raum in Pörtschach bietet ganzjährig über 100 Veranstaltungen zu vielfältigen Zukunftsthemen.

Kommen Sie gerne vorbei!

www.seeport.at

Figure 95: Press release to the local and surrounding community regarding the automated vehicle in Pörtschach. (Source: SURAAA)

During the pre-pilot phase in Pörtschach we had the official opening ceremony of the test site and our participation in the SHOW project with European Commissioner Johannes Hahn on 1. October 2021.

Figure 96: Official opening of the pilot site Pörtschach with EU-commissioner Johannes Hahn. (Source: SURAAA)

In October 2021 we were engaged in a field test with students, senior citizens and people with disabilities for automated public transport.

Figure 50: Field tests in Pörtschach with school children and people with disabilities. (Source: SURAAA)

We regularly participated at special mobility and stakeholder fairs. For example three times at the Auto&Bike Fair in Klagenfurt and twice at the MotionExpo in Graz. But also at special stakeholder events like the Austrian Community and Cities fairs, where all mayors of Austria participate.

Figure 97: Auto&Bike Klagenfurt (left) and City Day in Villach with among others Austrian President Alexander Van der Bellen (right). (Source: SURAAA)

We also organized special stakeholder events in Pörtschach, for example an event with 65 female mayors or the MAMCA workshop for the Austrian Mega Site.

Figure 98: MAMCA Workshop in Pörtschach. (Source: SURAAA)

One of the most siginficant event was the Ideathon held in Pörtschach. The Ideathon on 05.07.2023 was an Ideas competition that captured and recorded participants' ideas and visions on the topic of mobility of the future in the form of concepts. Together with experts, participants could work out new solutions for users.

Figure 99: Ideathon in Pörtschach (Source: SURAAA)

We regularly organised public days where school classes of all ages come to visit and ride our shuttle. Here are some examples of kids events:

At the kidsDAY 2023 on 02.08.2023 the SHOW public day took place under the motto “kids.DAY” in Pörtschach. The SURAAA team met with around 50 children and 5 supervisors from the Seekids group at the Wahliss meadow near the lake. The SURAAA shuttle was waiting for the excited children to take them on a short ride.

Figure 100: Workshop with kids between 6 and 10 years of age at the SURAAA headquarters. (Source: SURAAA)

At the kids.DAY2024 on 07.05.2024, 28 kids between 6 and 10 years of age have been invited to the SURAAA headquarters in Pörtschach for a short presentation of the shuttle, a quiz, drawing and craftwork and, of course, a ride in the shuttle. The children engaged in the activities with great excitement and enthusiasm.

Figure 101: Workshop with kids between 6 and 10 years of age at the SURAAA headquarters. (Source: SURAAA)

On 03.07.2024 we were very pleased to welcome 16 students between 10 and 14 from the Polytechnical School in Klagenfurt. The SURAAA Team was excited to answer their questions and engaged in a lively discussion on automated vehicles. The students embraced the opportunity to act as test passengers for the new track in Klagenfurt West.

Figure 102: Interest of kids on autonomous driving. (Source: SURAAA)

The kids.DAY on 06.08.2024 took place in Klagenfurt West where 25 kids including teachers attended. Kids between 8 and 10 years of age arrived with great excitement in a park area at the Lakeside Park. The event started with a presentation by a SURAAA employee and afterwards 3 groups rotated in between 4 different engagement points. While one group was taking a ride on the shuttle, the other groups were busy with a ball game, answering questions about the usage of the shuttle and finding a name for the autonomous shuttle. The kids were rewarded with Gummi bears and shuttle stickers after completing each task.

Figure 103: kids.DAY in Klagenfurt West (Source: SURAAA)

On 18.09.2024 another kids.DAY took place. 31 kids from the Sunshine Kindergarten in Klagenfurt came to the Foyer of the Sparkasse Bank next to the University of Klagenfurt for a presentation. After a Q&A session the kids were taken for rides in groups. In the meantime, the other groups were kept busy with games, a questionnaire and stickers.

Figure 104: kids.DAY with kindergarten children (Source: SURAAA)

On Friday 12.07.2024 the European Commissioner for Budget and Administration Johannes Hahn, Deputy Governor of Carinthia Martin Gruber, regional minister of Carinthia Sebastian Schuschnig und Albert Kreiner from the Regional Government in Carinthia together with project manager Walter Prutej, gave the signal for the start of the first autonomous fleet operation throughout Austria. Around 60 people joined the delegation and after a presentation and Q&A, the new track in Klagenfurt West has been visited including a test ride in the shuttle.

Figure 105: Official opening of the Klagenfurt demo site with EU-Commissioner Johannes Hahn (Source: SURAAA)

At the Long Night of Science on 24.05.2024 the SURAAA team participated with the Shuttle at the late-night event where 2,465 visitors participated. The Shuttle was visited by many children and families were already looking forward to the new route of the Shuttle at Klagenfurt West.

Figure 106: Participation at the Long Night of Science event (Source: SURAAA)

On 20. and 22.08.2024 a 2-day event was held for the Professional Fire Brigade of Klagenfurt to get to know the autonomous shuttle in more detail. The fire wardens were provided with a rescue plan in case of an emergency with the shuttle. A short lecture was held by the Managing Director Walter Prutej, followed by a test drive with the shuttle in its operating area. 25 people attended the training throughout the 2 days.

Figure 107: Event with first responders (Source: SURAAA)

On Tuesday, 23.07.2024, 40 experts from all over Europe gathered in person to celebrate the completion of the SHOW project in Austria. Virtual Vehicle and AVL presented autonomous robotaxis, representatives from Salzburg and Graz also presented their lessons learned and SURAAA presented the autonomous fleet. At lunchtime a meal has been enjoyed together at the beautiful Wörthersee. Afterwards, the second part of the presentations continued and rounded off with an exciting round of discussions. The day ended with a test drive of the autonomous shuttles in Klagenfurt West, between Lakeside Park, the university and the train station in Klagenfurt.

Figure 108: Austrian Megasite Final Event in Pörtschach and Klagenfurt (Source: AustriaTech/Hude)

6.12 Lessons learned & Recommendations

While driving in mixed traffic, most hard breaks and situations, where the operator had to intervene, are caused by other road users (illegal overtaking; poorly parked cars; not enough distance to the shuttle, especially pedestrians and cyclists) and by neglected vegetation in combination with overly sensitive Lidar sensors. The presence of a human inside the shuttle increases the openness for the users to discover and thus accept the AV. It was noticed that some people kept looking at the shuttle with curiosity but didn't dare to come closer; once the operator showed himself, they were more open to asking questions and even boarding.

For the shuttle to be a sustainable alternative or complement for public transport:

- The average driving speed needs to increase
- The cost of purchase, deployment and operating must decrease significantly.
- The shuttle must be able to handle all (or at least most) of the weather conditions a conventional vehicle can.
- The battery range needs to increase (on a sunny day where the AC is necessary, the battery is already empty after less than 50km)
- Ongoing communication with citizens through events and workshops to better understand the behaviour of the shuttle and to normalise autonomous shuttles in public transport.

Technical

Lessons Learned:

- **Sensor Sensitivity and False Positives:**
  Overly sensitive LiDAR sensors are causing unnecessary hard braking due to neglected vegetation and false detection of obstacles like overgrown branches.

- **Limited Weather Handling Capabilities:**
  The shuttles are unable to operate effectively in various weather conditions that conventional vehicles handle routinely.
- **Insufficient Battery Range:**
  Battery life is notably short, especially on sunny days when air conditioning is required, limiting the shuttle to less than 50 km per charge.
- **Low Average Driving Speed:**
  The current average speed of the shuttle is too low, making it less competitive compared to traditional public transportation options.

Recommendations:

- **Enhance Sensor Technology:**
  - Improve LiDAR Algorithms: Develop advanced algorithms to better distinguish between real obstacles and non-threatening objects like vegetation.
  - Integrate Multiple Sensor Types: Combine LiDAR with cameras and radar to improve object detection accuracy.
- **Increase Operational Speed:**
  - Regulatory Compliance: Work with authorities to adjust speed limits where appropriate for autonomous vehicles.
  - Continuous Improvement: Regularly update the shuttle's features based on user feedback and technological trends.

Operational

Lessons Learned:

- **Operator Interventions Predominantly Due to External Factors:**
  Most hard brakes and required interventions are caused by actions of other road users, such as illegal overtaking and pedestrians or cyclists not maintaining sufficient distance.
- **Human Presence Boosts User Acceptance:**
  Passengers and the public are more open to engaging with the shuttle when a human operator is present to provide assistance and information.

Recommendations:

- **Maintain Onboard Operators During Transition Period:**
  - Enhance User Experience: Keep operators onboard to answer questions, provide assistance, and ensure passenger comfort.
  - Safety Assurance: Operators can intervene in complex traffic situations, enhancing overall safety.
- **Improve Interaction with Other Road Users:**
  - Communication Signals: Equip shuttles with clear visual and auditory signals to indicate intentions to pedestrians and other vehicles.
  - Driver Awareness Campaigns: Educate the public about how to interact safely with autonomous shuttles.
- **Community Engagement:**
  - Host Events and Workshops: Organize regular community events to demonstrate shuttle operations and address public concerns.
  - Feedback Mechanisms: Implement channels for users to provide feedback, helping to identify and resolve issues promptly.

Business

Lessons Learned:

- **High Costs Limit Sustainability:**
  The current expenses associated with purchasing, deploying, and operating the shuttles are too high for widespread adoption.
- **Need for Increased Public Acceptance:**
  User hesitancy and lack of familiarity with autonomous technology hinder market growth and utilization rates.

Recommendations:

- **Strengthen Marketing and Public Relations:**
  Awareness Campaigns: Use targeted marketing to educate potential users about the shuttle's features and advantages etc.
- **Invest in Research and Development:**
  Innovation Grants: Seek funding opportunities to support ongoing technological advancements.

6.13 Roadmap beyond SHOW and replicability

Further research and projects will be done on the testing tracks in Pörtschach and in Klagenfurt. The team is very committed to drive the projects forward. Of course, it would be great if the test operation could become a regular operation.

We are aiming for remote control of a fleet, an operator will monitor all the shuttles on the road and give commands to the shuttle at decision points, this will require legal permission, improvement of the shuttles by installing more cameras, a reliable connection to the control centre and smoother braking to increase passenger comfort.

An increase in speed, longer and different routes and a full on-demand service (including a shuttle call system installed at the station for people without smartphones) will greatly improve the mobility service. The combination of passenger and goods transport proved to be an efficient way of using the shuttle while providing an additional service to users.

Other research and development topics we are currently focusing on include the development of AI prediction tools. These tools aim to enhance our ability to accurately forecast shuttle occupancy in both regular line services and on-demand operations. By leveraging advanced algorithms and data analysis, we hope to predict passenger demand more effectively, optimize route planning, and improve overall operational efficiency. This not only ensures a more reliable service for our passengers but also helps in resource management, reducing operational costs, and minimizing environmental impact by avoiding unnecessary trips.

In the future, we also plan to map the entire area of Pörtschach, creating a sandbox environment that will enable us to offer a true on-demand service with automated shuttles for all residents. This comprehensive mapping will allow for more precise route optimization and better integration of the shuttle system into the daily lives of the community. By leveraging this detailed geographic data, we aim to provide a flexible and efficient transportation solution that caters to the specific needs of Pörtschach's citizens, making automated shuttle services a convenient and accessible option for everyone.

7 Conclusions

With 7 automated vehicles deployed and over 11,000 passengers transported, the Austrian Triplet Mega Pilot was an overall success. Three different pilot sites, representing a variety of scenarios for automated mobility in Austria, provided insights and lessons for future deployments. While dense urban areas such as Klagenfurt saw the first deployment of a fleet of automated shuttles that not only operate on a fixed schedule but can also be booked via an on-demand app, the peri-urban areas of Graz and Salzburg were served by AVs travelling at higher speeds, allowing for better integration and acceptance in mixed traffic.

In general, a high level of passenger interest was observed in all pilot sites. This was particularly the case at the pilot sites in Carinthia, where numerous activities were carried out to involve citizens and stakeholders. These included groups of kindergarten children, groups of senior citizens or even rescue organisations and politicians, such as a group of 65 female mayors from all over Austria, Austrian Federal President Alexander Van der Bellen or European Commissioner Johannes Hahn. An additional element to deepen the learnings from the operations was the involvement of a group of "supertesters", the same group of people visiting the Austrian pilot sites and comparing different operational settings and vehicle types.

During operations, the AVs had to deal with a variety of environmental conditions, sometimes presenting technical and operational challenges. The technical maturity of the vehicles varied, with some, such as the HEAT shuttle in Salzburg, not coping well with rain, and others operating more smoothly. At the Graz pilot site in particular, the technology developers were able to make adjustments and improvements to the vehicle's operation, such as optimising LIDAR data processing for rainy or foggy conditions. Unfortunately, one accident could not be avoided. Prior to the start of the public pilot phase, the eVan deviated from its designated lane at the pilot site in Salzburg, resulting in a collision with the exterior mirror of an oncoming vehicle. This incident caused minor damage. Consequently, the test permit was revoked. In order to resume operations, the Ministry required measures to prevent the automated vehicle from leaving its lane. This included software changes that could only be made by the vehicle provider. However, as the provider did not implement the changes, the eVAN could not resume operation in the project.

All sites demonstrated robust integration with digital infrastructure based on C-ITS. In Salzburg, the implementation of this technology not only benefited the operation of the AVs and facilitated the establishment of a dedicated corridor, testing improvements for public transport access to the city but also showed the potential to reduce travel times by improving traffic flow at intersections, enhance the reliability of automated public transport services, and improve road safety by enhancing situational awareness. In Graz, digital infrastructure provided additional support for AVs to navigate through the busy public transport hub. In Klagenfurt, the shuttles communicated with traffic lights at five intersections to ensure smooth operation, and additional support from a smart camera was tested to improve operation at a pedestrian crossing.

The transfer of knowledge from SHOW was also accompanied by the establishment of an Austrian Alliance for Automated Mobility, in which the partners will continue their exchange after the end of the project in order to define transformation paths from test operation to regular deployment and to set research priorities for sustainable transport.

Further analysis of the data collected for this and all SHOW pilot sites is available in *Deliverable 12.9: Real-life demonstrations pilot data collection and results consolidation* [3], and in *Deliverable 13.5: SHOW impact assessment on user experience, awareness, and acceptance* [4]. Results on logistics are available in

D13.4: SHOW impact assessment on logistics [8]. The stakeholder analysis can be found in *D1.3: Stakeholder & travellers needs evolution through Pilots* [5].

References

[1] SHOW (2020). D1.2: SHOW Use Cases. Deliverable of the Horizon-2020 SHOW project, Grant Agreement No. 875530.

[2] SHOW (2022). D9.2: Pilot experimental plans, KPIs definition & impact assessment framework for final demonstration round". Deliverable of the Horizon-2020 SHOW project, Grant Agreement No. 875530.

[3] SHOW (2024). D12.9: Real-life demonstrations pilot data collection and results consolidation. Deliverable of the Horizon-2020 SHOW project, Grant Agreement No. 875530.

[4] SHOW (2024). D13.5: SHOW impact assessment on user experience, awareness and acceptance. Deliverable of the Horizon-2020 SHOW project, Grant Agreement No. 875530.

[5] SHOW (2024). D1.3: Stakeholder & travellers needs evolution through Pilots. Deliverable of the Horizon-2020 SHOW project, Grant Agreement No. 875530.

[6] SHOW (2023). D4.4 Open modular system architecture – third version. Deliverable of the Horizon-2020 SHOW project, Grant Agreement No. 875530.

[7] ERTRAC (2022). Connected, Cooperative, and Automated Mobility Roadmap

[8] SHOW (2024). D13.4: SHOW impact assessment on logistics. Deliverable of the Horizon-2020 SHOW project, Grant Agreement No. 875530.

[9] SHOW (2022). D9.3: Pilot Experimental Plans, KPI Definition and Impact Assessment Framework for the Final Demonstration Round. Deliverable of the Horizon-2020 SHOW project, Grant Agreement No. 875530.