AVENUE

Autonomous Vehicles to Evolve to a New Urban Experience

DELIVERABLE

D7.13 Demonstration activities for replication cities report

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Acronyms

ADS	Automated Driving Systems
AI	Artificial Intelligence
AM	Automated Mobility
API	Application Protocol Interface
AV	Automated Vehicle
BM	Bestmile
BMM	Business Modelling Manager
CAV	Connected and Automated Vehicles
CB	Consortium Body
CERN	European Organization for Nuclear Research
D7.1	Deliverable 7.1
DC	Demonstration Coordinator
DI	The department of infrastructure (Swiss Canton of Geneva)
DMP	Data Management Plan
DSES	Department of Security and Economy - Traffic Police (Swiss Canton of Geneva)
DTU	Technical University of Denmark
test track	test track
EAB	External Advisory Board
EC	European Commission
ECSEL	Electronic Components and Systems for European Leadership
EM	Exploitation Manager
EU	European Union
EUCAD	European Conference on Connected and Automated Driving
F2F	Face to face meeting
FEDRO	(Swiss) Federal Roads Office
FOT	(Swiss) Federal Office of Transport
GDPR	General Data Protection Regulation
GIMS	Geneva International Motor Show
GNSS	Global Navigation Satellite System
HARA	Hazard Analysis and Risk Assessment
IPR	Intellectual Property Rights
IT	Information Technology
ITU	International Telecommunications Union
LA	Leading Author
LIDAR	Light Detection And Ranging
MEM	Monitoring and Evaluation Manager
MT	MobileThinking
OCT	General Transport Directorate of the Canton of Geneva
ODD	Operational Domain Design
OEDR	Object And Event Detection And Response
OFCOM	(Swiss) Federal Office of Communications
PC	Project Coordinator
PEB	Project Executive Board
PGA	Project General Assembly
PRM	Persons with Reduced Mobility
PSA	Group PSA (PSA Peugeot Citroën)
PTO	Public Transportation Operator
PTS	Public Transportation Services
QRM	Quality and Risk Manager
QRMB	Quality and Risk Management Board
RN	Risk Number
SA	Scientific Advisor
SAE Level	Society of Automotive Engineers Level (Vehicle Autonomy Level)
SAN	(Swiss) Cantonal Vehicle Service
SDK	Software Development Kit
SLA	Sales Lentz Autocars
SMB	Site Management Board
SoA	State of the Art
SOTIF	Safety Of The Intended Functionality
SWOT	Strengths, Weaknesses, Opportunities, and Threats.
T7.1	Task 7.1
TM	Technical Manager
TPG	Transport Publics Genevois
UITP	Union Internationale des Transports Publics (International Transport Union)
V2I	Vehicle to Infrastructure communication
WP	Work Package
WPL	Work Package Leader

Executive Summary

This deliverable summarizes the demonstration activities for replication cities. This report contains information on the organization, the running and the evaluation of the large-scale demonstrators of the autonomous vehicle services for public transport in replication cities.

1 Introduction

AVENUE aims to design and carry out full-scale demonstrations of urban transport automation by deploying, for the first time worldwide, fleets of Automated minibuses in low to medium demand areas of 4 European demonstrator cities (Geneva, Lyon, Copenhagen and Luxembourg) and 2 replicator cities. The AVENUE vision for future public transport in urban and suburban areas, is that Automated vehicles will ensure safe, rapid, economic, sustainable and personalised transport of passengers. AVENUE introduces disruptive public transportation paradigms on the basis of on-demand, door-to-door services, aiming to set up a new model of public transportation, by revisiting the offered public transportation services, and aiming to suppress prescheduled fixed bus itineraries.

Vehicle services that substantially enhance the passenger experience as well as the overall quality and value of the service will be introduced, also targeting elderly people, people with disabilities and vulnerable users. Road behaviour, security of the Automated vehicles and passengers' safety are central points of the AVENUE project.

At the end of the AVENUE project four-year period the mission is to have demonstrated that Automated vehicles will become the future solution for public transport. The AVENUE project will demonstrate the economic, environmental and social potential of Automated vehicles for both companies and public commuters while assessing the vehicle road behaviour safety.

1.1 On-demand Mobility

Public transportation is a key element of a region's economic development and the quality of life of its citizens.
Governments around the world are defining strategies for the development of efficient public transport based on different criteria of importance to their regions, such as topography, citizens' needs, social and economic barriers, environmental concerns and historical development. However, new technologies, modes of transport and services are appearing, which seem very promising to the support of regional strategies for the development of public transport.
On-demand transport is a public transport service that only works when a reservation has been recorded and will be a relevant solution where the demand for transport is diffuse and regular transport is inefficient.
On-demand transport differs from other public transport services in that vehicles do not follow a fixed route and do not use a predefined timetable. Unlike taxis, on-demand public transport is usually also not individual. An operator or an automated system takes care of the booking, planning and organization.
It is recognized that the use and integration of on-demand Automated vehicles has the potential to significantly improve services and provide solutions to many of the problems encountered today in the development of sustainable and efficient public transport.

1.2 Fully Automated Vehicles

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

The terms *automated vehicles* and *autonomous vehicles* are often used together. The Regulation 2019/2144 of the European Parliament and of the Council of 27 November 2019 on type-approval requirements for motor vehicles defines "automated vehicle" and "fully automated vehicle" based on their autonomous capacity:

- An "automated vehicle" means a motor vehicle designed and constructed to move autonomously for certain periods of time without continuous driver supervision but in respect of which driver intervention is still expected or required
- "fully automated vehicle" means a motor vehicle that has been designed and constructed to move autonomously without any driver supervision

In AVENUE we operate ***Fully Automated minibuses for public transport***, (previously referred as Autonomous shuttles, or Autonomous buses), and we refer to them as simply *Automated minibuses* or *the AVENUE minibuses.*

In relation to the SAE levels, the AVENUE project will operate SAE Level 4 vehicles.

SAE INTERNATIONAL

SAE J3016™ LEVELS OF DRIVING AUTOMATION

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

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

1.2.1 Automated vehicle operation overview

We distinguish in AVENUE two levels of control of the AV: micro-navigation and macro-navigation. Micro navigation is fully integrated in the vehicle and implements the road behaviour of the vehicle, while macro-navigation is controlled by the transport operator running the vehicle and defines the destination and path of the vehicle and defines the higher view of the overall fleet management.
For micro-navigation Automated Vehicles combine a variety of sensors to perceive their surroundings, such as video, LIDAR, GNSS, odometry and other types of sensors. The main software, integrated in the vehicle, fuses and interpret the sensor information to identify the current position of the vehicle, detecting obstacles in the surround environment, and choosing the most appropriate reaction of the vehicle, ranging from stopping to bypassing the obstacle, reducing its speed, making a turn etc.
For the Macro-navigation, that is the destination to reach, the Automated Vehicle receives the information from either the in-vehicle operator (in the current configuration with a fixed path route), or from the remote-control service via a dedicated 4G/5G communication channel, for a fleet-managed operation centre. The fleet management system considers all available vehicles in the services area, the passenger request, the operator policies, the street conditions (closed streets) and send route and stop information to the vehicle (route to follow and destination to reach).

1.2.2 Automated vehicle capabilities in AVENUE

The Automated vehicles employed in AVENUE fully and automatically manage the above defined, micro-navigation and road behaviour, in an open street environment. The vehicles are Automatically capable to recognise obstacles (and identify the relevant ones), identify moving and stationary objects, and automatically decide to bypass them or wait behind them, based on the defined policies. For example with small changes in its route the AVENUE mini-bus is able to bypass a parked car, while it will slow down and follow behind a slowly moving car. The AVENUE mini-buses are able to handle different complex road situations, like entering and exiting roundabouts in the presence of other fast running cars, stop before zebra crossings in presence of pedestrians, communicate with infrastructure via V2I interfaces (ex. red light control).
The mini-buses used in the AVENUE project technically can achieve speeds of more than 60Km/h. However, this speed cannot be used in the project demonstrators for several reasons, ranging from regulatory to safety. Under current regulations the maximum authorised speed is 25 or 30 Km/h (depending on the site). In the current demonstrators the speed does not exceed 23 Km/h, with an operational speed of 14 to 18 Km/h. Another, more important reason for limiting the vehicle speed is safety for passengers and pedestrians. Due to the fact that the current LIDAR has a range of 100m and the obstacle identification is done for objects no further than 40 meters, and considering that the vehicle must safely stop in case of an obstacle on the road (which will be “seen” at less at 40 meters distance) we cannot guarantee a safe braking if the speed is higher than 25 Km/h. Note that technically the vehicle can make harsh breakings and stop with 40 meters in higher speeds (40 -50 Km/h) but then the break would be too harsh putting in risk the vehicle passengers, which some of them could be standing and not seated and wearing a seat belt. The project is working in finding an optimal point between passenger and pedestrian safety.
Due to legal requirements a **Safety Operator** must always be present in the vehicle, able to take control at any moment. Additionally, at the control room, a **Supervisor** is present controlling the fleet

operations. An **Intervention Team** is present in the deployment area ready to intervene in case of incident to any of the minibusses. Table 2 provides an overview of the AVENUE sites and OODs.

Table 1: Demonstration sites

	Summary of AVENUE operating sites demonstrators						
Transport Operator	**TPG**		**Holo**		**Keolis**	**Sales-Lentz**	
City	**Geneva**		**Copenhagen**	**Oslo**	**Lyon**	**Luxembourg**	
Site	Meyrin	Belle-Idée	Nordhavn	Ormøya	ParcOL	Phaffental	Contern
Funding	TPG	EU + TPG	EU + Holo	EU + Holo	EU + Keolis	EU + SLA	EU + SLA
Start date of project	August 2017	May 2018	May 2017	August 2019	May 2017	June 2018	June 2018
Start date of trial	July 2018	June 2020	September 2020	December 2019	November 2019	September 2018	September 2018
Type of route	Fixed circular line	Area	Fixed circular line	Fixed circular line	Fixed circular line	Fixed circular line	Fixed circular line
Level of on-demand service*	Fixed route / Fixed stops	Flexible route / On-demand stops	Fixed route / Fixed stops	Fixed route / Fixed stops	Fixed route/Fixed stops	Fixed route / Fixed stops	Fixed route / Fixed stops
Route length	2,1 km	38 hectares	1,3 km	1,6 km	1,3 km	1,2 km	2,3 km
Road environment	Open road	Semi-private	Open road	Open road	Open road	Public road	Public road
Type of traffic	Mixed	Mixed	Mixed	Mixed	Mixed	Mixed	Mixed
Speed limit	30 km/h	30 km/h	30 km/h	30 km/h	8 to 10 km/h	30 km/h	50 km/h
Roundabouts	Yes	Yes	No	No	Yes	No	No
Traffic lights	No	No	No	No	Yes	Yes	Yes
Type of service	Fixed line	On demand	Fixed line	Fixed line	Fixed line	Fixed line	Fixed line
Concession	Line (circular)	Area	Line (circular)	Line (circular)	Line (circular)	Line (circular)	Line (circular)
Number of stops	4	> 35	6	6	2	4	2
Type of bus stop	Fixed	Fixed	Fixed	Fixed	Fixed	Fixed	Fixed
Bus stop infrastructure	Yes	Sometimes, mostly not	Yes	Yes	Yes	Yes	Yes
Number of vehicles	1	3-4	1	2	2	2	1
Timetable	Fixed	On demand	Fixed	Fixed	Fixed	Fixed	Fixed
Operation hours	Monday-Friday (5 days)	Sunday-Saturday (7 days)	Monday-Friday (5 days)	Monday-Sunday (7 days)	Monday-Saturday (6 days)	Tuesday & Thursday Saturday, Sunday & every public holiday	Monday - Friday
Timeframe weekdays	06:30 – 08:30 / 16:00 – 18:15	07:00 – 19:00	10:00 – 18:00	7:30 – 21:30	08:30 – 19:30	12:00 – 20h00	7:00 – 9:00 16:00 – 19:00
Timeframe weekends	No service	07:00 – 19:00	No service	9:00 – 18:00	08:30 – 19:30	10:00 – 21:00	No Service
Depot	400 meters distance	On site	800 meters distance	200 meters distance	On site	On site	On site
Driverless service	No	2021	No	No	No	No	No
Drive area type/ODD	B-Roads	Minor roads/parking	B-Roads/minor roads	B-Roads	B-Roads	B-Roads	B-Roads/parking
Drive area geo/ODD	Straight lines/plane	Straight lines/ plane	Straight lines/ plane	Curves/slopes	Straight Lines/ plane	Straight lines/ plane	Straight lines/ plane
Lane specification/ODD	Traffic lane	Traffic lane	Traffic lane	Traffic lane	Traffic lane	Traffic lane	Traffic lane
Drive area signs/ODD	Regulatory	Regulatory	Regulatory, Warning	Regulatory	Regulatory	Regulatory	Regulatory
Drive area surface/ODD	Standard surface, Speedbumps	Standard surface, Speedbumps	Standard surface Speedbumps, Roadworks	Frequent Ice, Snow	Standard surface, Potholes	Standard surface	Standard surface

Table 2: Summary of AVENUE operating site (+ODD components)

1.3 Preamble

The AVENUE project's goal is to validate high quality and safe services to enhance acceptance and adoption of autonomous vehicles (AVs) for public transport. The WP7, *Autonomous vehicles for public transport demonstrators*, has the objective of realization the large-scale demonstrators of public transport AVs. In this WP were evaluated services for public transport for different user groups and transport models.

The deliverable D7.13, *Demonstration activities for replication cities report*, from WP7 describes the organisation, the running and the evaluation of large-scale demonstrators of the autonomous vehicle services for public transport in replication cities. This deliverable is related with the task T7.5, *Demonstration activities at replication cities*. On replication cities, will be realized, through the user experience, an evaluation of improvements brought by AVENUE for fully automated urban transport system. A special attention was given to data protection and privacy issues in this evaluation phase.

A replication city role is to demonstrate the AVENUE solution. The AVENUE consortium targeted a specific and detailed procedure to be followed by all replication cities in which are specified the expected results, the restrictions, the guidance, the communication information, and the deadlines. The authorities from each replication city have specific criteria and expectations from AVENUE project. In general, they want benefit for users and customers, a societal and environmental impact related to the cost, a technical maturity and excellence, something new compared to what exists and is available on the market, and that the proposed transportation solution deliver the promised results.

This deliverable will be used in WP8, *Socio-economic and environmental evaluation*, for the evaluation of the socio-economic impact.

2 Replication cities

Starting from 2021, the AVENUE use cases are replicated on two replicator sites: Sion (Suisse) and Esch-sur-Alzette (Luxembourg). The objective of the replication cities is to carry out small-scale demonstration activities by exploiting the experiences and results of the AVENUE demonstration sites (see Table 1).

2.1 Sion (Uvrier, Switzerland)

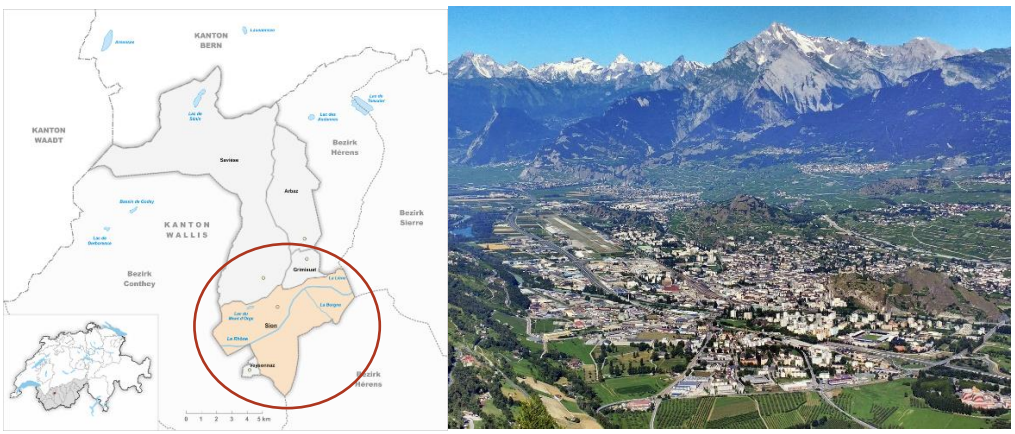

Figure 2 : Sion, replicator site for AVENUE.

Sion is the capital of the canton of Valais, with a history of 7,000 years, and being today the economic center of Valais and an important crossroads with its own international airport. Within its agglomeration, more than 50,000 people live. As the capital of the canton of Valais, Sion is home to many government offices, businesses, a specialized University, and the regional hospital. The mountainous canton of Valais has an overall population of 340,000 inhabitants and has a very strong tourist sector. Sion's bus and train stations are the heart of the Valais public transport network, offering different types of urban and regional public transport services.

2.1.1 Integration of autonomous vehicles into an existing public transport service in Sion city

The SmartShuttle project was launched in 2016 as part of the mobility lab innovation ecosystem (https://www.mobilitylab.ch/fr/), which is a public-private partnership between the City of Sion, the Canton of Valais, the academic partners EPFL, the University of Applied Sciences HES-SO Valais-Wallis and la Poste (which owns 100% of the CarPostal subsidiary). All partners support the development of autonomous services in transport. The use of the SmartShuttle for passengers is free.
The objective of the SmartShuttle for Sion is the establishment of a fleet of autonomous shuttles in the existing transport system. The project team worked in the following areas:

- passenger information (connection of trains, buses, and automated shuttles),
- integration into mobility applications,

- transportation of disabled people.

These developed topics are implemented gradually.

Since June 2016, CarPostal has been operating one of the world's first pilot projects in Sion with autonomous shuttles in a city center on public roads. For 3 years, the SmartShuttle project has continued to develop towards a last-mile transport solution in the center of Sion. Already in 2018, the complex system included mixed traffic roads with speed limits at 50 km/h or 20 km/h and pedestrian zones, where there is no other public transport service available. At the end of 2018, the track was enlarged, and the complexity increased. The SmartShuttle connects Sion station to the city center, crosses two traffic lights (communicating via a V2X protocol) and travels on a double track with a speed limit of 50 km/h and two roundabouts.

Figure 3 : Navya shuttle operated by CarPostal in SmartShuttle project in Sion (2016-2018). AVENUE started in 2018.

The SmartShuttle operated from Wednesday to Sunday between 7 a.m. and 6 p.m. The operations were financed by the City of Sion, the canton of Valais and Par Énergie Sion Region (ESR), a local energy supplier.

As a public transport provider, CarPostal relies on autonomous vehicles from the French manufacturer Navya. The service operated in SmartShuttle project was with three Navya Arma shuttles. The fleet management tool was provided by BestMile (ZF acquired BestMile technology in 2021) and formed the backbone of the entire system. The sensitive communication between the shuttles and the infrastructure complied with the highest security standards and was based on the technology provided by Siemens Mobility.

Figure 4 : ARMA® shuttle for passenger's transport from NAVYA.

2.1.2 Collaboration with AVENUE

The long-term goal of Sion city is the full integration of autonomous shuttles into the public transport system. The autonomous shuttles are seen primarily as a last-mile application, which complements the existing public transport system and additionally offers “on-demand” mobility.
The replication site is in Uvrier, a peri-urban locality of Sion. There, an “on-demand service” was implemented in a residential area (the distance from Sion is approx. 5 km).

The establishment of this on-demand zone was based on the design and implementation of the on-demand transport service in general. It was foreseen to install a dense network with bus stops (every 100 to 150 meters – the vision was to provide a door-to-door service with flexible stops whenever technically and legally was possible). The planned operation involved a fleet of three Navya’s ARMA shuttles.
There, was used the BestMile app and the BestMile control center (Fleetmanagement and Customer app). AVENUE tested its own mobile application to order a trip.

A particular attention was given to people with special needs (e.g. the elderly and people with disabilities). That enabled the design and adoption of the following two services:

- follow my child/my grandparents;
- facilitation of mutual aid.

In addition, the consideration of specific needs in the design of the service (universal design) ensured that the SmartShuttle is accessible and usable by all. In particular, the following services are part of the new system:

- automated trip planning suggestions (algorithm-based trip planning);
- trip planning via call centers (conventional trip planning for people without smartphones);
- digital or human information points;
- request for help and real-time visualization of the path/destination.

CarPostal had a legal permission from the Swiss government (Federal Roads Office, ASTRA) to operate an autonomous pilot service on the existing route until the end of 2020. As an operator, CarPostal relied on the vehicles from the French manufacturer Navya with the fleet management system from the Swiss company BestMile. We didn’t find any reason to restrict integration to the AVENUE services and platform of the already developed SmartShuttle applications.

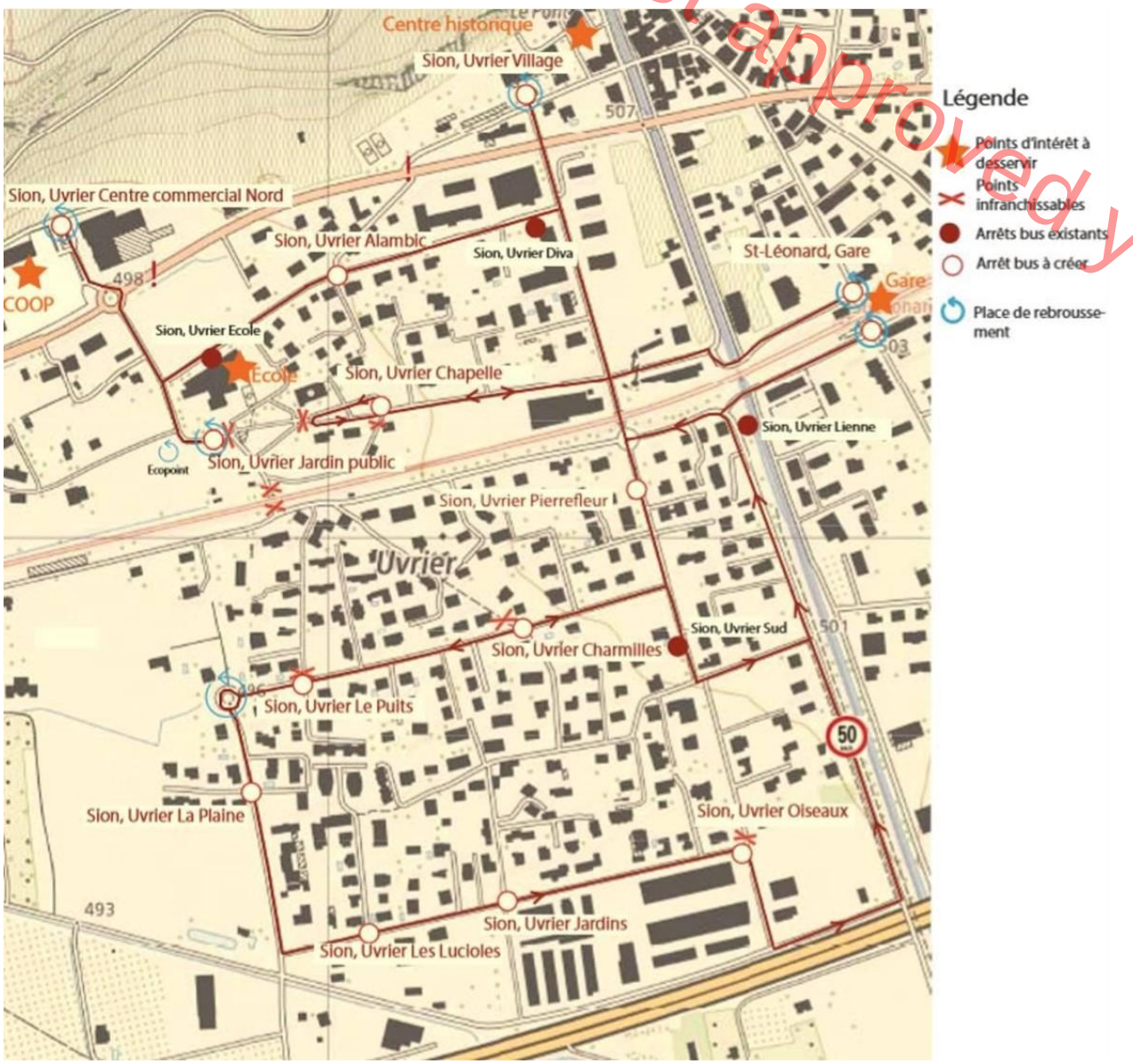

Figure 5: Uvrier, peri-urban locality of Sion.

The deployment by CarPostal of AVs in Uvrier was a replication of the AVENUE service from Belle-Idee. This replication takes into consideration:

- the AVENUE developed architecture;
- the management of the Navya mission;
- the replication of Belle-Idée site and, on top of that, integrates additional commercial products, such as the BestMile Traveler app (and potentially another booking interface);
- on the passenger's side, the AVENUE Traveler app was rolled out for testing purposes;
- the AVENUE project can learn from additional testing / deployment of commercial products and can provide recommendations for other AVs applications.

2.2 Esch-sur-Alzete (Luxembourg)

Figure 6 : Esch-sur-Alzette, replicator site

Esch-sur-Alzette has various connections to public transport. A railway line, of Société Nationale des Chemins de Fer Luxembourgeois (CFL), connects Esch-sur-Alzette and its suburbs, via three stations, to the Luxembourg capital. Different regional bus lines enter the center of Esch-sur-Alzette and thus connect different parts of the city with each other as well as with other parts of Luxembourg. Public transport in Luxembourg is made up of more than 180 regional lines operated by different transport operators, under the control of the government (RGTR-Réseau Général des Transports Routiers). The public transport in the canton of Esch-sur-Alzette (composed of 14 municipalities) is under the control and operation of the intermunicipal syndicate TICE (Transport Intercommunal de personnes dans le Canton d'Esch-sur-Alzette). TICE only operates within these fourteen municipalities in the south of Luxembourg. Buses departing from these municipalities are under the control of RGTR. The bus lines follow the wider main streets of the town, and the train line runs partly around Esch-sur-Alzette, with a station on the town border. Transport to the various residential areas is lacking due to low and medium passenger demand as well as the fact that the streets in the residential areas are not suitable to accommodate conventional size buses. The vast majority of the 35,000 inhabitants of Esch-sur-Alzette (more than 120 nationalities), as well as commuters, students, and visitors from outside, depend on their private car or taxis as transportation mode. The high use of private cars and taxis has worsened the traffic and parking situation in Esch-sur-Alzette to the point that people are avoiding the city center. The business and the residential sectors suffer from the resulting decline in the quality of life in the center of Esch-sur-Alzette. In August 2018, a large-scale survey of the inhabitants by the municipality of Esch-sur-Alzette revealed several topics that need to be addressed in the future in order to improve the life quality again. One of the major concerns of the populations is the current lack of accessibility to the center of Esch-sur-Alzette due to the overcrowded streets by private cars and the absence of public transport.

Esch-sur-Alzette is the second most populated city in Luxembourg. Esch-sur-Alzette is located on the border with France, at 17 km south from the Luxembourg-City capital. Esch-sur-Alzette has a past marked by the development of the iron and steel industry in Luxembourg. At the end of the 19th and in the first half of the 20th century, many mines and blast furnaces were located in and around Esch-sur-Alzette and contributed to the economic growth of Luxembourg. Following the steel crisis in the 1970s, steel production continuously declined in Luxembourg and infrastructure was left behind. For 10 years, Esch-sur-Alzette has given new life to the former industrial sites of Esch-Belval and Esch-sur-Alzette-Schifflange by transforming them into innovative urban living and working spaces where industrial heritage, administrative buildings and modern residential coexist in perfect harmony. In recent years, more and more technology companies, start-up incubators, medical laboratories, insurance companies, research

institutes, banks and advertising agencies are setting up on this site. In addition, four residential areas and two educational institutions are located in this area. Currently, 80 different companies have settled in the Esch-Belval region, many more are to come as the site is still in full development and is gaining a considerable reputation among companies. In the future, 7,000 residents and 20,000 employees, university and secondary students and researchers will be located on this site. The transformation of the former Esch-sur-Alzette-Schifflange steel site started in 2022.
These innovative and ambitious projects will play a major role in improving the quality of life in the regions. Innovative mobility solutions to connect the center of Esch-sur-Alzette, Esch-Belval and the former industrial site of Esch-Schifflange will be essential to ensure accessibility for all kinds of people from different socio-economic groups to different sites. In addition, Esch-sur-Alzette bears the title of "European Capital of Culture 2022". Eleven municipalities (known as the ProSud alliance) and 8 municipalities (CCPHVA, Communauté de Communes du Pays Haut Val d'Alzette) on the French border are also involved in the "European Capital of Culture 2022". The cooperation with the city of Kaunas in Lithuania, which is also a cultural city in 2022, is also planned.

2.2.1 Integration in AVENUE

The autonomous shuttles were deployed for the AVENUE project purpose in the main shopping street (rue de l'Alzette) in the center of Esch-sur-Alzette.

The *first phase* started in July 2021, with a Navya shuttle. SLA (Sales-Lentz, partner in Avenue) operated already four Navya shuttles at three different sites in Luxembourg. The legal work to obtain the necessary authorizations for other NAVYA shuttles was facilitated because the technical specifications of this particular type of vehicle had already been validated by the National Society of Automotive Vehicles (SNCA). An authorization to run on this road from the Luxembourg Ministry of Mobility and Public Works (MMTP) was necessary as well as an authorization from the municipality of Esch-sur-Alzette. As with homologation and vehicle registration, the necessary authorizations to operate on the planned road was much easier and faster because this work had already been done for the SLA four previous NAVYA shuttles. In February 2021 all the necessary legal authorizations were available. The first phase meant that one shuttle would be deployed from July 2021 on a fixed road (i.e. rue de l'Alzette) and at a fixed time during the opening hours of the shops.

Figure 7 : Navya shuttle in Esch-sur-Alzette (https://www.wort.lu/fr/luxembourg/esch-sur-alzette-prete-a-rouler-en-navette-autonome-6139da39de135b923645efbe).

In the *second phase* of this replication, the homologation of another vehicle from another car manufacturer was foreseen. SLA maintains close relationships with autonomous vehicle manufacturers like Lohr, e.GO, Apollo and HFM. These vehicles being not yet approved in Luxembourg, the time to obtain the legal authorizations was longer than the one for Navya shuttle. The homologation has been obtained in December 2021 and the deployment of the second vehicle started in January 2022. The objective was to replace the NAVYA shuttle, which circulates rue de l'Alzette, with this vehicle. The mode of operation of the vehicle had to remain the same: fixed road, fixed schedule during stores opening hours, on demand outside opening hours. This minibus called 'Gaalgebus' connected Esch-sur-Alzette station and the city center to a nearby leisure and recreation area 'Gaalgebierg'.

Figure 8: Gaalgebus (https://citylife.esch.lu/bus/gaalgebus/)

2.2.2 The long-term vision of an autonomous door-to-door service at Esch-sur-Alzette

In the first quarter of 2022, Esch-sur-Alzette became the European Capital of Culture. The objective was to start the operation of a shuttle with a dynamic route in a geographically defined area, without fixed bus lines or predefined timetables to connect the various cultural highlights (museums, event venues, concert halls, theatres, etc.).

Initially, predefined bus stops were provided for boarding and alighting passengers (*third phase*). A video on this activity was prepared for European Mobility Week, September 2022, and published on Linkedin (https://www.linkedin.com/posts/sales-lentz-autocars_sales-lentz-partner-for-more-sustainable-activity-6978011477643313152-NpRm/).

After validation of the operation of the shuttles, the objective was to switch to a real mode of "door-to-door" operation, on demand for predefined stops (*fourth phase*).

The network planned for dynamic routing was deployed within a geolocated area in the residential area of the center of Esch-sur-Alzette. Figure 9 shows the boundaries of the planned site.

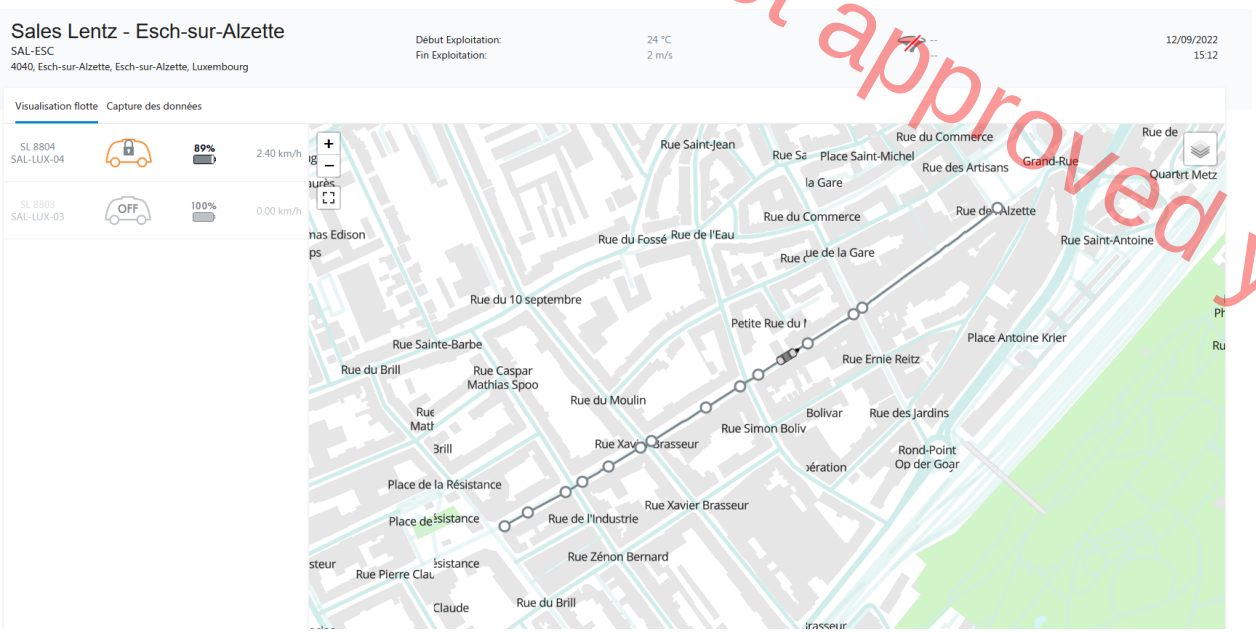

Figure 9: Demo site for AV shuttles in Esch-sur-Alzette for AVENUE project.

This arrangement of the shuttle network made possible the connection of the inhabitants of Esch-sur-Alzette to the center as well as to existing public transport stops.

The blue line in Figure 10 represents the shuttle route in the main shopping street “rue de l’Alzette” which was deployed in phase 1 of the project and which remained in service for the duration of the project.

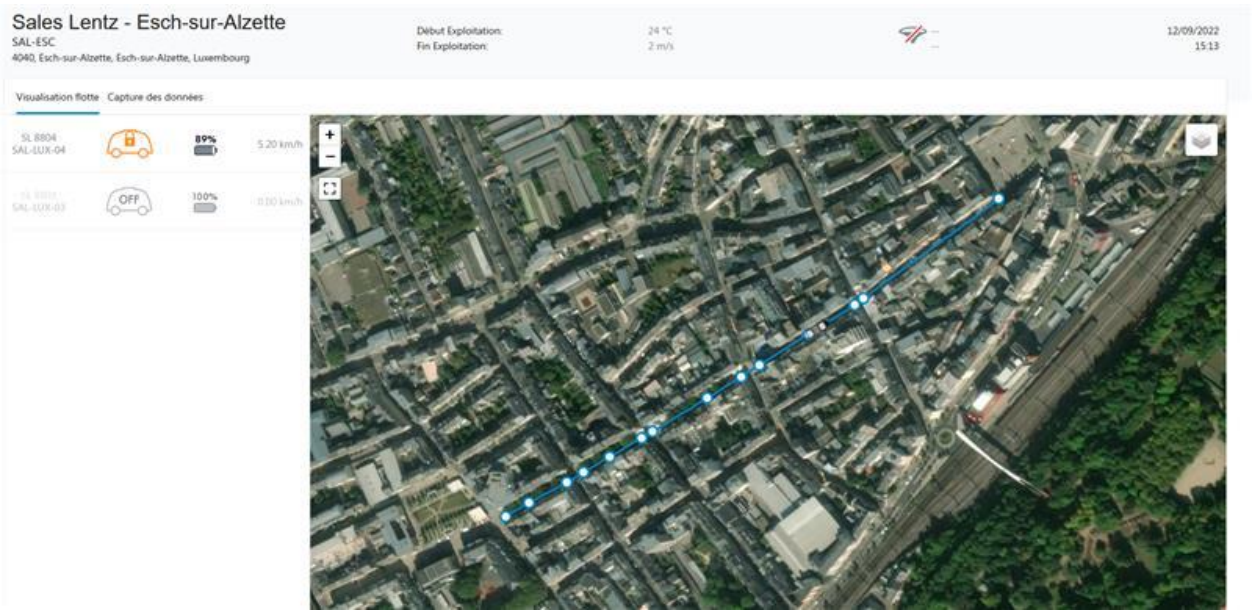

Figure 10 : AV shuttle route in Rue de l’Alzette.

The door-to-door shuttle network, as well as the two fixed lines "rue de l'Alzette" and "Gaalgebierg" filled the current void of public transport in the center of Esch-sur-Alzette. The autonomous shuttles connected the existing public transport lines, the center of Esch-sur-Alzette and residential and leisure areas.
The residential area was perfectly suited as a test bed for an on-demand, door-to-door autonomous mobility concept, as this area is excluded from public transport and, in most cases, the legal speed is limited to 30 km/h. Furthermore, the layout of the residential area with a large number of intersections

allowed efficient dynamic routing possibilities. The vision was to be the official mobility partner for the European Capital of Culture Esch 2022.

In order to improve the user-friendliness of autonomous shuttles, the objective was to integrate them into existing public transport services. In fact, today, there is a national public transport information system across the Grand Duchy of Luxembourg where the user can get automatic trip planning suggestions, including different means of transport, via a web page or a mobile app. The aim is that in future the autonomous shuttles will also be integrated into this service and that the user will receive a travel suggestion for using the autonomous shuttles in combination with the various bus and train connections, including new mobility solutions such as bike and scooter sharing services available in Esch-sur-Alzette.

For the planned "door-to-door" autonomous mobility service, it is essential that the user knows, when he is in an area, where he can call an autonomous shuttle and that there is a system for him to call it. A system explaining how the mobility service works is essential to make shuttles accessible to everyone, even people who are not familiar with technology. For the use case in Esch-sur-Alzette, this is very important due to the fact that more than 120 different nationalities of all age groups live here. Different nationalities and age groups have different knowledge and understanding of technology. Users should be notified when they enter an “on-demand” zone and need an easy solution to call a shuttle and get an explanation of how to use it or get help with any urgent questions (one-button vehicle calls and request for help).

The real-time view of the path/destination, in-vehicle entertainment, automatic emergency call system, improve the sense of security and confidence, the prevention of nighttime aggression, the interaction of virtual personality, the facilitation of mutual aid, follow my child / grandmother / grandfather are services inside and outside the vehicle that could be implemented and tested on the proposed site. The very diverse population of Esch-sur-Alzette, which represented the main users of the shuttle service, brought important results on the acceptance and use by the different groups of users of the services offered inside and outside the vehicle.

3 Conclusions

This document presented the demonstration activities realized at replication cities Sion (Uvrier) and Esch-sur-Alzette.

The Sion city objective is to integrate autonomous shuttles in order to complement and improve the actual public transport system. The demo was realized in Uvrier, a peri-urban locality of Sion. It made possible the experimentation of the “on-demand” service in a residential area focusing on vulnerable or with specific needs people.

In Esch-sur-Alzette the accent was made on the connection of the inhabitants to the city center and to other public transport systems using autonomous shuttles. Thus, the integration of this new mobility solution into the existing public transport system was proved. The provided AV service used the same functions as the one used in Sion city. The acceptance was proven on different users separated by nationalities or age groups.

These replication activities were realized with success and proved that the AVENUE project objectives were accomplished.