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Autonomous Vehicles to Evolve to a New Urban Experience

DELIVERABLE 4.2

**Transport services
Second iteration**



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Acronyms

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

Executive Summary

This deliverable presents an overview of the deployed demonstrator transport services at the different project sites.

To be noted that this deliverable is a Demonstrator deliverable and NOT a report. In the document we provide an overview of the deployed services at the project sites.

This deliverable is a collection of factual information. For more detailed information regarding every demonstrator site, please consult the WP7 site deliverables.

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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 to 3 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 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 <u>are</u> driving whenever these driver support features are engaged – even if your feet are off the pedals and you are not steering			You <u>are not</u> 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	
What do these features do?	These are driver support features			These are automated driving features		
	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	<ul style="list-style-type: none"> • automatic emergency braking • blind spot warning • lane departure warning 	<ul style="list-style-type: none"> • lane centering OR • adaptive cruise control 	<ul style="list-style-type: none"> • lane centering AND • adaptive cruise control at the same time 	<ul style="list-style-type: none"> • traffic jam chauffeur 	<ul style="list-style-type: none"> • local driverless taxi • pedals/steering wheel may or may not be installed 	<ul style="list-style-type: none"> • same as level 4, but feature can drive everywhere in all conditions

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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 operator running the vehicle and defines the destination and path of the vehicle, as defined the higher view of the overall fleet management.

For micro-navigation Automated Vehicles combine a variety of sensors to perceive their surroundings, such as 3D video, LIDAR, sonar, GNSS, odometry and other types sensors. Control software and systems, integrated in the vehicle, fusion and interpret the sensor information to identify the current position of the vehicle, detecting obstacles in the surround environment, and choosing the most appropriate reaction of the vehicle, ranging from stopping to bypassing the obstacle, reducing its speed, making a turn etc.

For the Macro-navigation, that is the destination to reach, the 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 4/5G communication channel, for a fleet-managed operation. The fleet management system takes into account all available vehicles in the services area, the passenger request, the operator policies, the street conditions (closed streets) and send route and stop information to the vehicle (route to follow and destination to reach).

1.2.2 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 some of them), 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 round-about in the presence of other fast running cars, stop in zebra crossings, communicate with infrastructure via V2I interfaces (ex. red light control).

The 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 than 40 meters distance) we cannot guarantee a safe braking if the speed is more than 25 Km/h. Note that technically the vehicle can make harsh break and stop with 40 meters in high speeds (40 -50 Km/h) but then the break would too harsh putting in risk the vehicle passengers. The project is working in finding an optimal point between passenger and pedestrian safety.

Due to legal requirements a **Safety Operator** must always be present in the vehicle, able to take control 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 mini-busses.

1.3 Preamble

WP4: Development, Adaptation and integration of Passenger Transport and in-, out-of-, vehicle services, aims to design, develop, adapt and integrate services to support users of autonomous vehicles before the trip, during the trip, and at the end of the trip. The main objective of WP4 is to provide services in order to demonstrate that the user experience can be seamless and secure, and that people embrace this new technology. Hence, we have to include the following services:

- Adapt and integrate existing transport services
- Develop autonomous vehicle specific services
- Provide services that foster the acceptance of driverless vehicles by both passengers and people interacting with the shuttles
- Introduce safety related services

The target of task T4.1 is to define and validate the transport services of the operators. Deliverable 4.2 is a demonstrator, of the developed and operated transport services. We present in the following the deployed services and details for each site.

2 Overview of the deployments

In the last 36 months of the project, we deployed automated vehicle-based services in 4 cities and 7 sites, in an incremental complexity deployment. Although the overall target is the same, each of the 7 deployment sites has its own special issues and challenges. To be noted that in none of the sites any special indications were installed regarding the presence of Automated Vehicles on the street.

The Meyrin (section 3.1), Nordhavn, (4.1) and Pfaffenthal (5.1) sites are first deployments, implementing simple, fixed route, fixed bus-stop services. They were the first to be deployed at the start of the project and where the operators gained knowledge in the issues related to autonomous vehicles. The contributed also in raising awareness to the public on the future automated vehicle public transportation.

The Belle-Idee site (3.2) is the most advanced deployment in the project, providing fully automated on-demand, door-to-door services, with no intervention from the on-board operator.

The Slagelse (4.2) is the first deployment where a full integration to the existing PTO information system is made. The automated vehicles itineraries are integrated in the overall PTO service, from where they also receive the trip orders.

The Contern site (6.2) is implemented in heavily mixed road environment, with complex road condition : narrow roads, many parked cars on the side of the roads, sharing the road with heavy vehicles.

In the Lyon Parc OL site, V2X infrastructure has been integrated, allowing the vehicles to control barriers and traffic lights. The site also includes a very complex round-about, shared with high speed vehicles.

2.1 Linked deliverables

This document provides a factual snapshot of the deployments, which constitute the actual deliverable. It is not meant to provide details and explanations on issues faced and solutions provided. These are given to the related report deliverables. In the table below we provide the list of related report deliverables where the related information can be found.

Content and information	Related Deliverables
Detailed description of the deployments and statics	D7.2, D7.5, D7.8, D7.11
Detailed description of use cases , including ODD components (Table 30)	D2.8
In and out of vehicle services	D4.5, D4.8

3 Transport Publics Genève - TPG

3.1 XA-Line Meyrin

The XA-Line at Meyrin/Geneva was the first deployment of fixed bus-stop, fixed itinerary transport service. It provided a traditional public transport service using fully automated vehicles, connecting the train station to the tram line in the center of Merin.

The objective of this public transport solution is to start to offer a simple transport service for habitants of a residential area where there was no public transport before.

Project details	
Start date project	01.08.2017
Start date trial	02.07.2018
End date trial	31.01.2021
Demonstrator Layout	
Type of route	Fixed circular line
Route length	2.1 [km]
Bidirectional route sections	0
Roads	Open road
Type of roads	Mixed: double lane, speed bumps
Type of traffic	Mixed: cars, busses, trucks, bicycles
Speed limit	30 [km/h]
Round about	Yes: between track and depot
Traffic lights	No
Number of bus stops	4
Type of bus stops	Predefined points
Bus stops with infrastructure	4
Virtual bus stops	0

Vehicle depot	At 400 [m] distance
Vehicle depot : entrance/exit vehicles	Manually
Transport Services	
Number of vehicles	1 (+ 1 reserve)
On demand	No
Door 2 door	No
Dynamic routing	No
Ride pooling	Yes
Connected to existing network	Yes: 1 bus/tram hub and 1 bus/train hub
Supervision @ distance	No
Safety operator actions	Yes : vehicle control and selection of destination
Fully driverless (no safety operator onboard)	No
Passenger services	
Timetable	Fixed
Operation hours	Monday-Friday (5 days)
Timeframe weekdays	06:30 - 08:30 / 16:00 - 18 :15
Timeframe weekend / holidays	No service (from June 2019)
Ticketing	TPG standard ticketing policy

3.2 Belle-Idée Thonex

The Belle-Idée/Geneva site was the 2nd deployment site in Geneva, offering on-demand, door-to-door services. The deployment provides transport services for the employees, patients and visitors of the hospital site. The transport services provided cover parking to building transport, (used by personnel and visitors), building to building (for personnel mainly) and bus-stop to building (for visitors).

The objective of this public transport solution is to start to offer a state of the art on-demand transport service for different type of users of a hospital area connected to the existing public transport network.

Project details	
Start date project	01.05.2018
Start date trial	01.07.2020 (9 months project deployment)
End date trial	Continues after Avenue
Demonstrator Layout	
Type of route	Area (Geographical Zone)
Route length	38 [hectare] 9.6 [km] of routes
Bidirectional route sections	6
Roads	Semi open road
Type of roads	Mixed: one lane, double lane
Type of traffic	Mixed: cars, busses, trucks, bicycles, pedestrians
Speed limit	30 [km/h]
Round about	Yes

Traffic lights	No
Number of bus stops	75
Type of bus stops	Predefined points
Bus stops with infrastructure	5
Virtual bus stops	70
Depot	On site
Depot vehicle entrance/exit	100% Automated
Transport Services	
Number of vehicles	3 (+ 1 reserve)
On demand	Yes
Door 2 door	Yes
Dynamic routing	Yes
Ride pooling	Yes
Connected to existing network	Yes, 5 bus hubs
Supervision @ distance	Yes on site
Safety operator actions	No : vehicle and on-demand 100% automated
Fully driverless (no safety operator onboard)	2022
Passenger services	
Timetable	On demand only
Operation hours	Sunday-Saturday (7 days)
Timeframe weekdays	06:00 – 19:00
Timeframe weekend / holidays	06:00 – 19:00 (from 09.2021)
Ticketing	Free of charge

4 Copenhagen - Nordhavn & Slagelse

4.1 Nordhavn

Nordhavn was the first deployment site at Copenhagen. The objective of this public transport solution is to start to offer a simple transport service in a residential area where there was no public transport before. The transport services offered, due to Danish legislation restrictions were fixed itinerary and fixed bus stop services with fully automated buses for the region residents. The service was interrupted due to heavy works and the too complex procedure for changing itineraries.

Project details	
Start date project	01.04.2018
Start date trial	04.08.2020

End date trial	28.02.2021
Demonstrator Layout	
Type of route	Fixed circular line
Route length	1.2 [km]
Bidirectional route sections	0
Roads	Open road
Type of roads	Mixed: double lanes, bicycle and pedestrian lanes
Type of traffic	Mixed: cars, busses, trucks, bicycles, pedestrians
Speed limit	30 [km/h]
Round about	No
Traffic lights	No
Number of bus stops	6
Type of bus stops	Predefined points
Bus stops with infrastructure	6
Virtual bus stops	0
Vehicle depot	At 800 [m] distance
Vehicle depot : entrance/exit vehicles	Manually
Transport Services	
Number of vehicles	1 (+ 1 reserve)
On demand	No
Door 2 door	No
Dynamic routing	No
Ride pooling	Yes
Connected to existing network	Yes: 1 metro (200 meters distance)
Supervision @ distance	Yes
Safety operator actions	Yes : Vehicle control (manual) + safety mitigations
Fully driverless (no safety operator onboard)	No
Passenger services	
Timetable	Fixed
Operation hours	Monday-Friday (5 days)
Timeframe weekdays	10:00-13:00, 14:00-17:00
Timeframe weekend / holidays	No service
Ticketing	Standard ticketing policy

4.2 Slagelse

Slagelse is the 2nd deployment site at Copenhagen, within a hospital area. The objective of this public transport solution is to start to offer a state of the art on-demand transport service for different type of users of the hospital area. The transport services are provided to patients, employees and visitors, linked to the backbone transportation services, and fully connected to the regional transport services (ticketing, reservations, routes).

Project details	
Start date project	01.06.2019

Start date trial	01.09.2021
End date trial	Continues after Avenue
Demonstrator Layout	
Type of route	Hospital area
Route length	4-5 kms of road
Bidirectional route sections	1
Roads	Open roads
Type of roads	Mixed: double lanes, bicycle and pedestrian lanes
Type of traffic	Mixed: cars, busses, trucks, bicycles, pedestrians
Speed limit	30 [km/h]
Round about	No
Traffic lights	No
Number of bus stops	6
Type of bus stops	Predefined points
Bus stops with infrastructure	6
Virtual bus stops	0
Depot	On site
Depot vehicle entrance/exit	Manually
Transport Services	
Number of vehicles	2 (1 AVENUE + 1 SHOW) (+ 2 reserve AVENUE)
On demand	Yes
Door 2 door	Yes (department to department)
Dynamic routing	Yes (to some extend)
Ride pooling	Yes
Connected to existing network	Yes, 2 bus hubs and 2 taxi hubs
Supervision @ distance	Yes
Safety operator actions	Yes : Vehicle control (manual) + safety mitigations
Fully driverless (no safety operator onboard)	No
Passenger services	
Timetable	On demand (some timetable slots)
Operation hours	Monday-Friday (5 days)
Timeframe weekdays	07:00 - 18:00
Timeframe weekend / holidays	No service
Ticketing	Free operation

5 Luxembourg

5.1 Pfaffenthal

The Pfaffenthal transport services are connecting two major transport hubs in Luxembourg, offering a connection that did not exist before, and allowing citizens an easier access to the back-bone transport services. The service is on fixed itinerary, fixed bus stops.

Project details	
Start date project	01.07.2018
Start date trial	19.09.2018
End date trial	Continues after Avenue
Demonstrator Layout	
Type of route	Fixed Circular line
Route length	2.1 klm
Bidirectional route sections	All the route
Roads	Open roads
Type of roads	Mixed: double lanes, bicycle and pedestrian lanes
Type of traffic	Mixed: cars, busses, trucks, bicycles, pedestrians
Speed limit	350 [km/h]
Round about	No
Traffic lights	No
Number of bus stops	4
Type of bus stops	Fixed predefined
Bus stops with infrastructure	Yes
Virtual bus stops	0
Depot	On site
Depot vehicle entrance/exit	Manually
Transport Services	
Number of vehicles	2
On demand	Yes
Door 2 door	No)
Dynamic routing	No)
Ride pooling	Yes
Connected to existing network	Yes,
Supervision @ distance	Yes
Safety operator actions	Yes : Vehicle control (manual) + safety mitigations
Fully driverless (no safety operator onboard)	No
Passenger services	
Timetable	Fixed)
Operation hours	7/7)

Timeframe weekdays	10:00 - 21:00
Timeframe weekend / holidays	Yes
Ticketing	Free operation

5.2 Contern

Contern is the 2nd deployment site in Luxembourg, aiming in fully automated, door-to-door, on-demand transport services, for the employees of the under development industrial and office area. The transport services offered include parking to office, office to office and office to restaurant.

Project details	
Start date project	01.07.2018
Start date trial	19.09.2018
End date trial	Continues after Avenue
Demonstrator Layout	
Type of route	Industrial area
Route length	3 kms of road
Bidirectional route sections	1
Roads	Open roads
Type of roads	Mixed: double lanes, bicycle and pedestrian lanes
Type of traffic	Mixed: cars, busses, trucks, bicycles, pedestrians
Speed limit	50 [km/h]
Round about	No
Traffic lights	No
Number of bus stops	2
Type of bus stops	Predefined points
Bus stops with infrastructure	Yes
Virtual bus stops	0
Depot	On site
Depot vehicle entrance/exit	Manually
Transport Services	
Number of vehicles	1
On demand	Yes
Door 2 door	Yes (department to department)
Dynamic routing	Yes (to some extend)
Ride pooling	Yes
Connected to existing network	No
Supervision @ distance	yes
Safety operator actions	Yes : Vehicle control (manual) + safety mitigations
Fully driverless (no safety operator onboard)	No
Passenger services	
Timetable	On demand (some timetable slots)

Operation hours	Monday-Friday (5 days)
Timeframe weekdays	07:00 - 18:00
Timeframe weekend / holidays	No service
Ticketing	Free operation

6 Lyon – Parc OL

The Lyon Par OL site is an office and activities site. The site is under development with target to become an important activities are in Lyon. The offered transport services targeted are on-demand, door-to-door services in mixed traffic and pedestrian area. T

Project details	
Start date project	01.06.2018
Start date trial	01.11.2019
End date trial	Continues after Avenue
Demonstrator Layout	
Type of route	Circular route
Route length	2.6 kms of road
Bidirectional route sections	1
Roads	Open roads
Type of roads	Mixed: double lanes, bicycle and pedestrian lanes
Type of traffic	Mixed: cars, busses, trucks, bicycles, pedestrians
Speed limit	30 [km/h]
Round about	Yes (2)
Traffic lights	Yes (4)
Number of bus stops	2
Type of bus stops	Predefined points
Bus stops with infrastructure	2
Virtual bus stops	0
Depot	On site
Depot vehicle entrance/exit	Manually
Transport Services	
Number of vehicles	2
On demand	Yes
Door 2 door	No (under design)
Dynamic routing	No (under design)
Ride pooling	Yes
Connected to existing network	Yes, bus hubs and metro hubs
Supervision @ distance	Yes
Safety operator actions	Yes : Vehicle control (manual) + safety mitigations
Fully driverless (no safety operator onboard)	No

D4.2 Transport services

Passenger services	
Timetable	On demand (some timetable slots)
Operation hours	Monday-Saturday (6 days)
Timeframe weekdays	08 :30 - 20:00
Timeframe weekend / holidays	No Sunday service
Ticketing	Free operation

Not approved yet

Not approved yet