Autonomous Vehicles to Evolve to a New Urban Experience

DELIVERABLE

D7.1

First Iteration Geneva Large Scale Pilot Use Case Demonstration Report

Co-funded by the Horizon 2020 programme of the European Union

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Figure 1: Transport via an Autonomous Vehicle

Document History

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0.1	01.08.2019	Jeroen Beukers	D7.1 draft for TPG
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3.0	20.04.2020	Jeroen Beukers	Corrections following EU project officer recommendations

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Acronyms

ADS	Automated Driving Systems
AI	Artificial Intelligence
AM	Autonomous Mobility
API	Application Protocol Interface
AV	Autonomous Vehicle
BM	Bestmile
BMM	Business Modelling Manager
CAV	Connected and Autonomous 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 test track	Technical University of Denmark test track
EAB	External Advisory Board
EC	European Commission
ECSEL	Electronic Components and Systems for European Leadership
EM	Exploitation Manager
EU	European Union
EUCAD	European Conference on Connected and Automated Driving
F2F	Face to face meeting
FEDRO	(Swiss) Federal Roads Office
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

WPL Work Package Leader

Executive Summary

This is the first Deliverable of Task T7.1 - First Iteration Geneva Large Scale Pilot Use Case Demonstration report - which is due in month 16. The main focus of this Task is to describe the setup, authorization processes and foreseen operations including barriers of the demonstrator sites in detail.

This deliverable is structured in three main sections:

- A detailed description of the demonstrator site homologation process in order for the Public Transport Operator to receive the necessary authorizations (section 2)
- A summary on the autonomous vehicles, including technical data, options, covering, vehicle inspections, maintenance and supervision (section 3)
- An overview of the current and future demonstrator sites including an exhaustive description on the Xa Line in Meyrin as well as the future Belle-Idée site project (section 5)

A conclusion and wrap-up section together with a set of next steps concludes the deliverable.

The Copenhagen, Geneva, Luxembourg and Lyon - First Iteration Large Scale Pilot Use Case Demonstration reports - use the same template in order to be able to compare the demonstrator sites.

Figure 2: Autonomous vehicle on the Belle-Idée demonstrator site

1 Introduction

The target of the AVENUE project is to demonstrate and pilot the adaptability and efficiency of the deployment of small and medium autonomous vehicles (AV's) in Lyon, Luxembourg, Geneva, Copenhagen and 2 to 3 replicator cities as of the 3rd year of the project. The AVENUE vision for future public transport in urban and suburban areas is that autonomous vehicles will ensure safe, rapid, economic, sustainable and personalised transport of passengers, while minimising vehicle changes. The goal is to provide door to door, on-demand autonomous transport allowing commuters to benefit from autonomous vehicles.

At the end of the AVENUE project four year period the mission is to have demonstrated that autonomous vehicles will become the future solution for public transport. The AVENUE project will demonstrate the economic, environmental and social potential of autonomous 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 support 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 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 autonomous 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 Autonomous Vehicles

A self-driving car, referred in the AVENUE project as **an Autonomous Vehicle** (**AV**) is a vehicle that is capable of sensing its environment and moving safely with no human input. The choice of Autonomous vs Automated was made in AVENUE since, in the current literature, most of the vehicle concepts have a person in the driver's seat, utilize a communication connection to the Cloud or other vehicles, and do not independently select either destinations or routes for reaching them, thus being "automated". In

AVENUE the target is to reach a system comprising of vehicles and services that independently select their destination and routes (via a fleet management system).

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

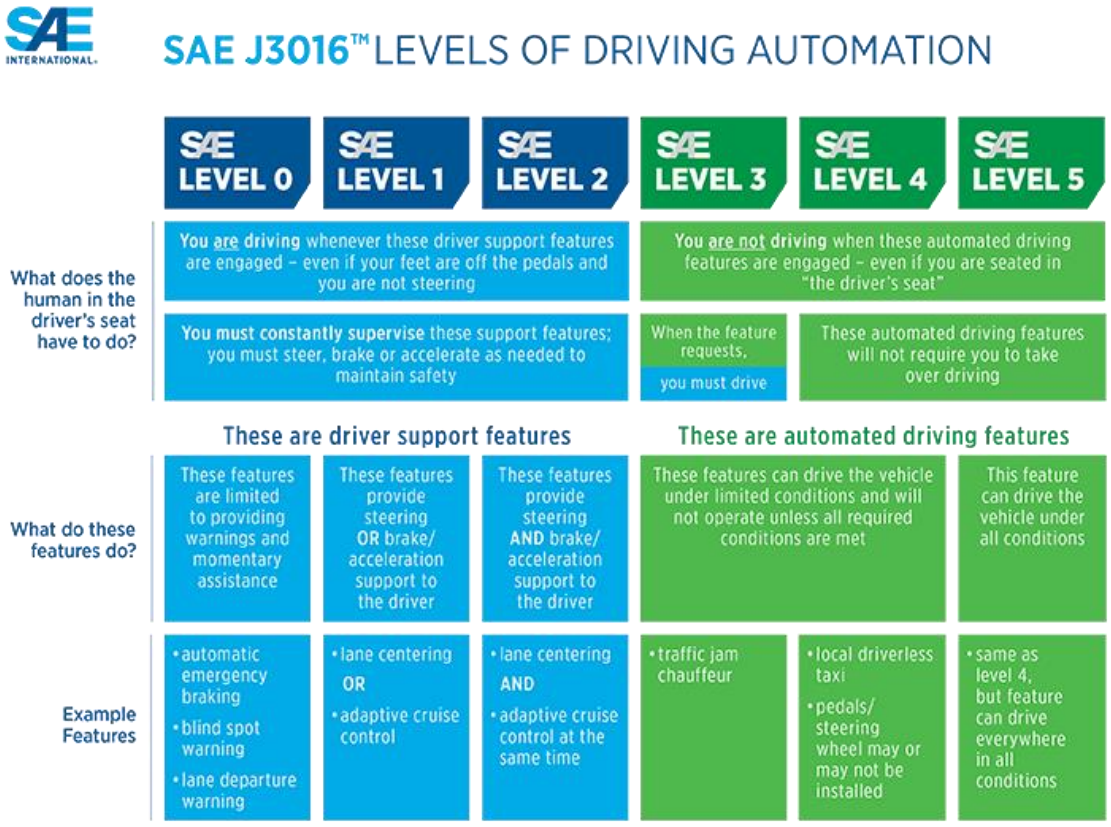


Figure 3: SAE J3016 Levels of driving automation

1.2.1 Autonomous 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 controls 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.

For micro-navigation Autonomous Vehicles combine a variety of sensors to perceive their surroundings, such as 3D video, lidar, sonar, GNSS, odometry and other advanced sensors. Advanced control systems integrated in the vehicle interpret sensory information to identify appropriate navigation paths, as well as obstacles, and choose the most appropriate reaction of the vehicle, from stopping to bypassing the obstacle, reducing its speed, making a turn etc.

For the Macro-navigation, that is the destination to reach, the Autonomous Vehicle receives the information from either the in-vehicle operator, or from the remote control service with 4/5G communication.

1.3 Preamble

The AVENUE project is set up to offer on demand door-to-door solutions integrated within existing public transportation services, and evaluates the feasibility of operating autonomous shuttles with routes and schedules based on real-time passenger demand, instead of following fixed itineraries and pre-determined timetables.

AVENUE's objective is to showcase these customized transport solutions at demonstrator sites in Copenhagen, Geneva, Luxembourg and Lyon, and later duplicate them in several other European cities.

Work package **WP7** aims to organize, run and evaluate these large scale demonstrators of the autonomous vehicle services for public transport, targeting different user groups, and transport models. The goal is to validate a high quality, safe service, which will enhance acceptance and adoption of autonomous vehicles for public transport.

The purpose of task **T7.1** is to integrate autonomous vehicles into the existing public transport services. From day one of the project TPG will promote the new services, the security of the vehicles and the efficiency of the system, which targets to increase the acceptance by citizens, public authorities and other actors through important information campaigns.

In deliverable **D7.1**, the main focus is on the organization, the running and the evaluation of the large scale demonstrators of the autonomous vehicle services for public transport in Geneva, Switzerland.

Figure 4: Vehicles P53 and P103 in Meyrin Village

2 Project homologation

Swiss authorities are having a positive attitude towards the development of future transport modes and fully support initiatives such as autonomous driving and connected vehicles.

In order to run a Pilot project, which falls out of the scope of current existing Swiss legislations, a predefined process has to be followed in order to be able to acquire the necessary permissions.

2.1 Authorities

Switzerland, officially the Swiss Confederation, is a federation of 26 cantons. Swiss cantons can be considered to having an independent government and are an administrative subdivision of the Swiss Confederation.

Municipalities are the lowest level of administrative division in Switzerland. Each municipality is part of one of the Swiss cantons, which form the Swiss Confederation.

In order to receive an accreditation, the following Authorities have to approve the pilot project:

Authority	Acronyms	Level
General Secretariat of Federal Department of the Environment, Transport, Energy and Communications	GS DETEC	Federal
Federal Roads Office	FEDRO	Federal
Federal Office of Transport	FOT	Federal
Federal Office of Communications	OFCOM	Federal
The Department of Infrastructure	DI	Cantonal
General Transport Directorate of the Canton of Geneva	OCT	Cantonal
Department of Security and Economy - Traffic Police	DSES	Cantonal
Cantonal Vehicle Service	SAN	Cantonal
Village/Town/City		Municipal

Table 1: Homologation - Authorities

2.2 Vehicle homologation

The vehicles in itself only need to be homologated on a Federal level by the Swiss Federal Office of Transport. It concerns a technical approval of the construction and functioning of every single vehicle as supplied by the constructor and includes some security tests as well as a brake test and an in-depth check of the safety measures around the electric components.

In Switzerland the brake and electrical components tests are carried-out by a specialized firm.

Since an autonomous vehicle only has the right to drive on a predefined route, this specific route has to be defined and homologated before a formal authorization to use the vehicle can be given.

2.3 Test site homologation

In order to homologate the test site, an applicant has to extensively describe the test site and also comply with standard concessions. The homologation process will take up to 3-9 months depending on the level of difficulty of the test site and your former experience with autonomous vehicle projects.

2.3.1 Concessions

The application process of a concession regarding an autonomous vehicle is in line with the process as followed for a non-autonomous vehicle.

2.3.1.1 Telecommunications

A telecommunications concession, necessary for transmission of radio and 3/4/5 G signals, is delivered through the Federal Office of Communications (OFCOM) in Bern. Delivery of a concession takes up to around two months'.

2.3.1.2 Passenger transport concession

The passenger transport concession, necessary for the transport of people, is delivered through the Federal Transport Office (FOT) in Bern. Delivery of a concession takes up to around three months'.

2.3.2 Application

The following chapters and information needs to be included in the application.

Chapter	Information
Project	• Description • Official waiver request • Objectives
Authorities	• Operator service agreement
Concessions	• Radio communication • Transport of passengers
Routes	• In-depth description
Bus stops	• Description • Identification
Vehicle	• Description of the vehicle

	• Transport capacity • Detailed documentation
Safety	• Operational safety measures • Legal bases • Derogation of traffic rules • Compensation measures for the derogations of traffic rules
Operations	• Concept • Principals • Timetable • Remote supervision • Documentation and procedures
Positions	• Expert • Trainer • Super operator • Operator
Operators	• Operator commitment • Operator instructions • Accident procedures
Training	• Theoretical training • Practical training • Trainers training • Assessement, Certfication
IT	• Data security • Software • Embedded systems
Reporting	• Authorities
Communication	• Internal • External • Clients

Table 2: Homologation – Application Data

3 Vehicles

Before being partner within the EU funded AVENUE project, the TPG already started to test an autonomous vehicle. In 2017, only four known manufacturers world-wide were able to supply a production vehicle which could be used for public transport.

Brand	Type	Country
Navya	Arma-DL4	France
EasyMile	EZ-10	France
Local Motors	Olli	USA
Baidu	Apolong	China

Table 3: Vehicles - Manufacturers

After discussions with both French manufacturers, the TPG opted for a Navya Arma-DL4 for their first autonomous test project. Since Navya is also partner within the AVENUE project, and the only manufacturer, it was logic choice to also acquire the same type of vehicles for the AVENUE test site.

3.1 TPG

The TPG currently disposes of four vehicles homologated to transport a safety driver with either ten clients at a time or seven clients including one using a wheelchair.

Type	ID	Type	Funded by	Project	Covering
Navya Arma DL4	P53	Monodirectional	TPG	XA-Line	SIG
Navya Arma DL4	P102	Bidirectional	AVENUE	Belle-Idée	TPG
Navya Arma DL4	P103	Bidirectional	AVENUE	Belle-Idée	TPG
Navya Arma DL4	P105	Bidirectional	AVENUE	Belle-Idée	None

Table 4: Vehicles – TPG Fleet

3.2 Technical data

See appendix A

3.3 Options

3.3.1 General

- Air conditioning

3.3.2 Seat-belts

Even if it is not legally imposed in Switzerland, the TPG has opted for the installation of seat-belts.

3.3.3 Wheelchair ramp

Public transport companies have the duty to offer transport for everyone, including the disabled. The Navya Amra-DL4 is equipped with a manual folding ramp which can be deployed by the safety driver to give access to a wheelchair. The Navya Arma-DL4 may be retrofitted with an automatic ramp.

Swiss legislation regarding the maximum slope for hand-propelled wheelchair ramps:

- 18% grade when help is assured
- 6% grade when autonomous

This means that we still have to find a solution before we are able to drive fully driverless since a 6% slope means a ramp with a length of more than three meters.

3.4 Covering

TPG's sister organisation TP Pub sells publicity on TPG vehicles, hence we drive with two types of covering. P53 in Services Industriels de Genève (SIG) colours and P103 in Transport Publics Genevois (TPG) colours.

3.4.1 Transport Publics Genevois (TPG)

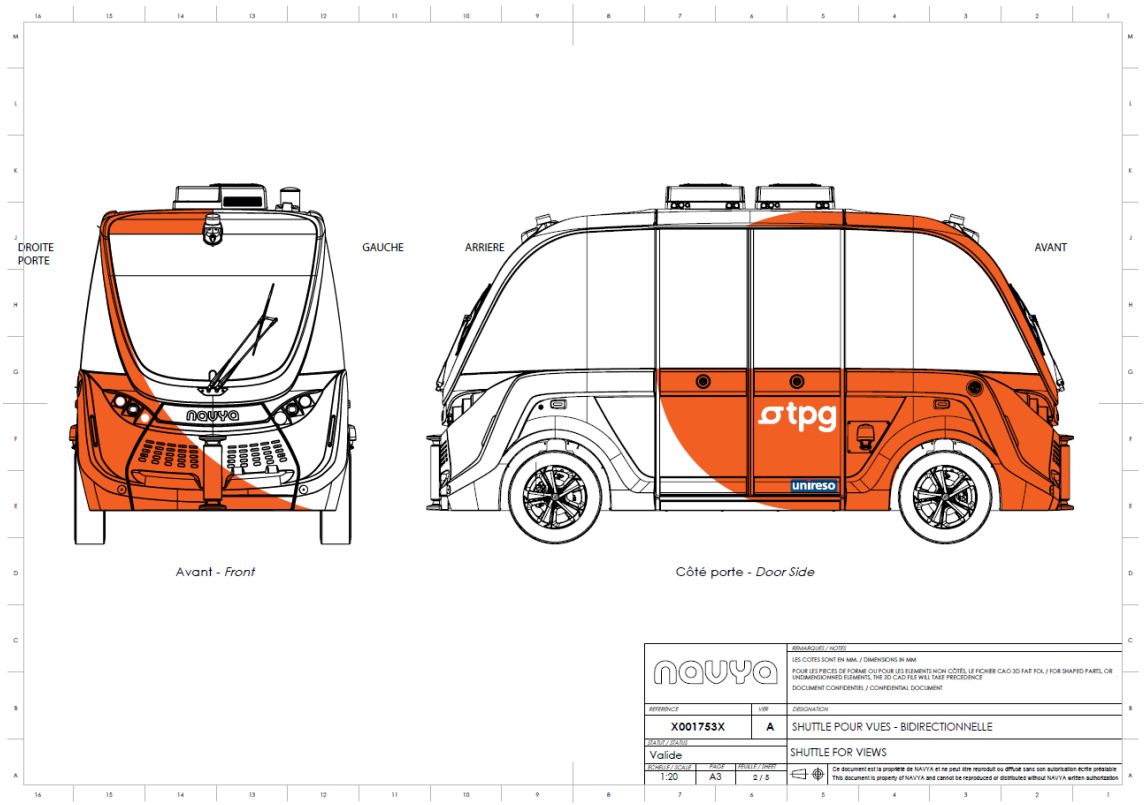


Figure 5: Vehicle covering TPG colors

3.4.2 Services Industriels de Genève (SIG)

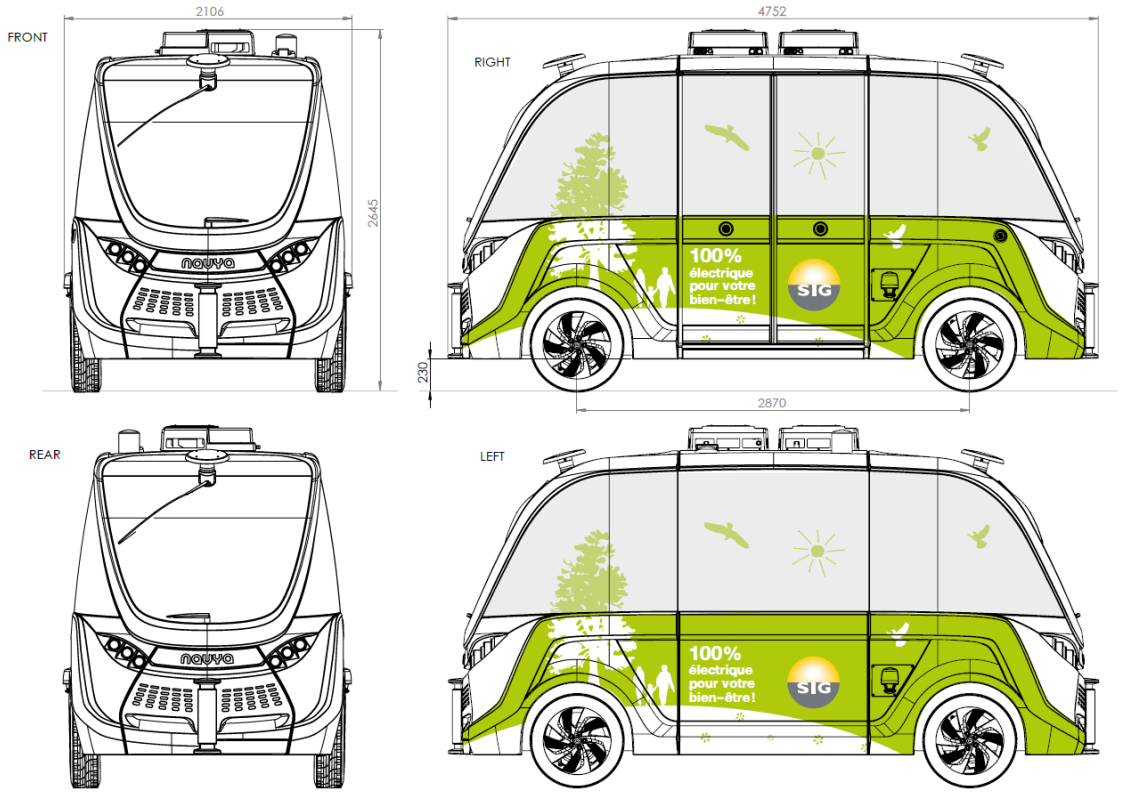


Figure 6: Vehicle covering SIG colors

3.4.3 AVENUE EU Logo

Vehicles within the AVENUE framework and funded by the EU are equipped with an AVENUE project disclaimer in French and English in front and at the back of the vehicle.

3.4.3.1 French

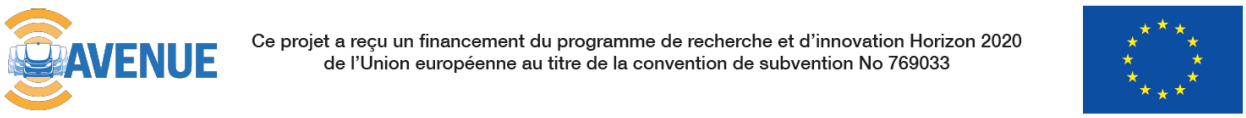


Figure 7: Vehicle covering EU Logo French

3.4.3.2 English

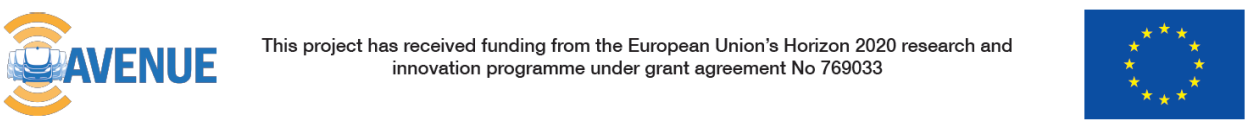


Figure 8: Vehicle covering EU Logo English

3.4.3.3 On vehicle example

Figure 9: Vehicle covering EU Logo on Vehicle example

3.5 Vehicle inspection

As with all vehicles used for public transport, the autonomous shuttle has to undergo a yearly inspection at the Bureau de l'Auto (Cantonal Vehicle Service) in order to be able to continue to be used on the road.

We are in the process of trying to pass the annual check with vehicle P53 and we experience some difficulties with the roller test brake bench.

3.6 Maintenance

The maintenance of vehicles and GNSS base station is entirely done by Navya. Public transport operators have the possibility to carry out in-house maintenance work on their vehicles until a certain maintenance level.

3.7 Supervision

In case of an issue the safety drivers are able to connect with Navya's supervision department via a whatsapp group or the SOS intercom. They always reply within a few minutes.

4 Operations

Current pole of people who are involved in the day-to-day operations of the autonomous vehicles.

Name	Expert	Operator	Super Operator	Tech Operator	Trainer
Bentaïba Ilyes		X			
Beukers Jeroen	X				
Brandao Carlos		X	X		
Corazza Marcello		X			
Di Stefano Michael		X			
Fahrni David		X	X		X
Fazlic Melisa		X			
Felix Eric	X				
Gonzalez De Sousa Daniel		X			
Hertrich Jérôme		X			
Kallaba Festim		X			
Kilic Sabahudin		X			
Launay François		X			
Marcelino Pinto Licinio		X			
Martins Carlos		X			
McGill William		X			
Perez Laurent		X			
Porchet Judit		X			
Ruckebusch Stanislas		X			X
Sauge Jean	X			X	
Zoulalian Jean		X			

Table 5: TPG – Safety Drivers

5 TPG test sites

Within the AVENUE framework, the TPG runs two test sites:

- Xa-Line in the community of Meyrin
- Belle-Idée site in the community of Thônex

The Xa-Line has been initiated by the TPG in 2017 and is integrated within the AVENUE project in order to be able to exchange experiences. Both test sites are located in the Canton of Geneva, Switzerland

	Xa-Line	Belle-Idée
Community	Meyrin	Thônex
Funding	TPG	EU + TPG
Start date project	01.08.2017	01.05.2018
Start date trial	02.07.2018	15.12.2019 (intended)
Type of route	Fixed circular line	Area
Distance	2.1 [km]	38 [hectare]
Road	Open road	Semi private
Type of trafic	Mixed	Mixed
Speed limit	30 [km/h]	30 [km/h]
Roundabout	Yes (between track and depot)	Yes
Trafic lights	No	No
Type of service	Traditional busline	On demand
Concession	Line	Area
Number of bus stops	4	> 35
Type of bus stop	Fixed	Fixed
Bus stop infrastructure	Yes	Sometimes, mostly not
Number of vehicles	1	3-4
Timetable	Fixed	On demand
Operation hours	Monday-Friday (5 days)	Sunday-Saterday (7 days)
Timeframe weekdays	06:30 - 08:30 / 16:00 - 18 :15	07:00 – 19:00
Timeframe weekend / holidays	No service (from June 2019)	07:00 – 19:00
Depot	At 400 [m] distance	On site
Driverless service	No	2021

Table 6: TPG demonstrator site comparison

5.1 Xa Line

The core objective is to be able to connect the Meyrin train station with the main TPG tram lines. Commuters, who live in suburban areas or in neighbouring France and who arrive by train, have to change their mode of transport in order to be dispatched around the centre of Geneva city. Up until the beginning of the project a public transport solution to connect both hubs did not exist. The distance between Meyrin train station and the tramlines at Meyrin Village is around one km, which is a 10-15 minutes' walk.

The TPG transport solution serves the sparsely populated area of Meyrin and connects both hubs during morning and evening rush hour while taking into account the connecting timetables related to in- and outgoing trains and trams. The vehicle circles around in the direction of the clock.

During the first operations of the Xa line, we rapidly noticed the importance of further developing the vehicle and fine-tuning its behaviour on the road.

5.1.1 Xa Line Route

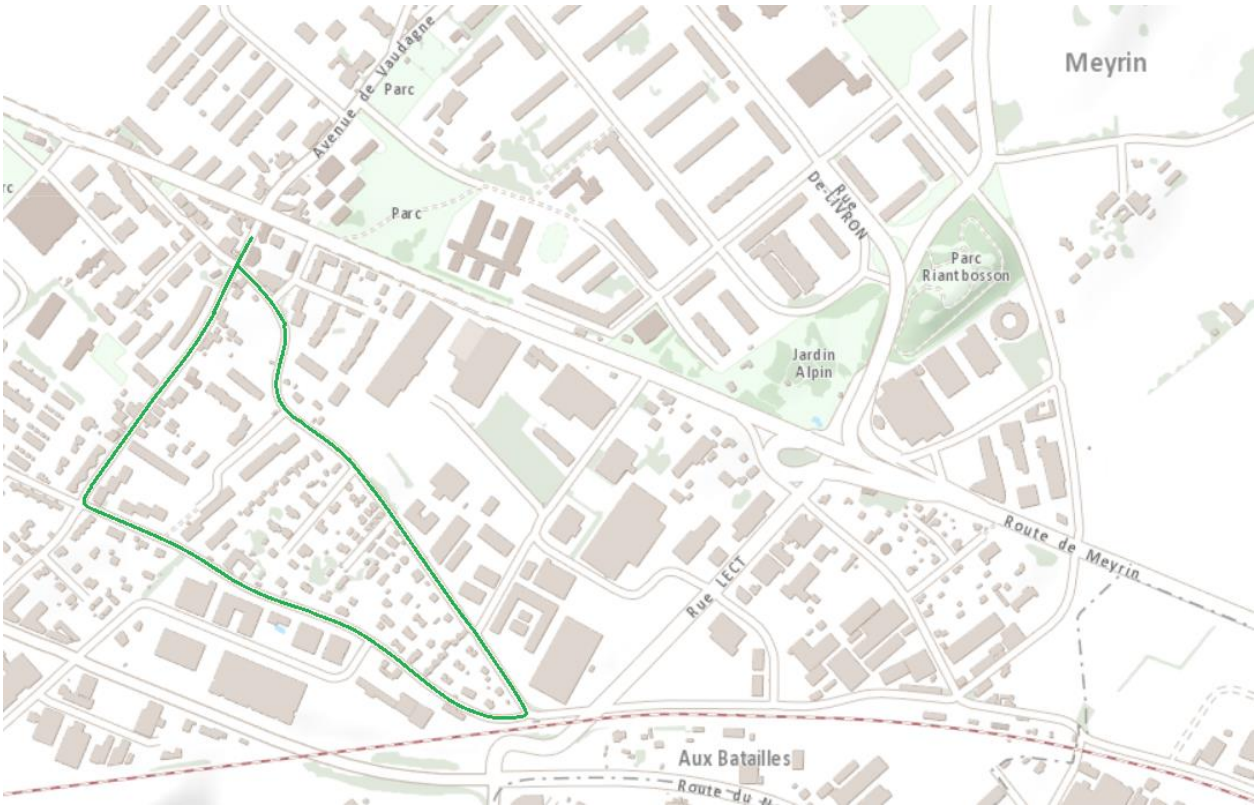


Figure 10: Xa Line Meyrin Map

Driving direction	Clock-wise
Route length	2.1 [km]
Speed limit all traffic	30 [km/h] area
Road	Urban open road

Table 7: Xa Line Meyrin - Information

5.1.2 Xa Line Bus stops

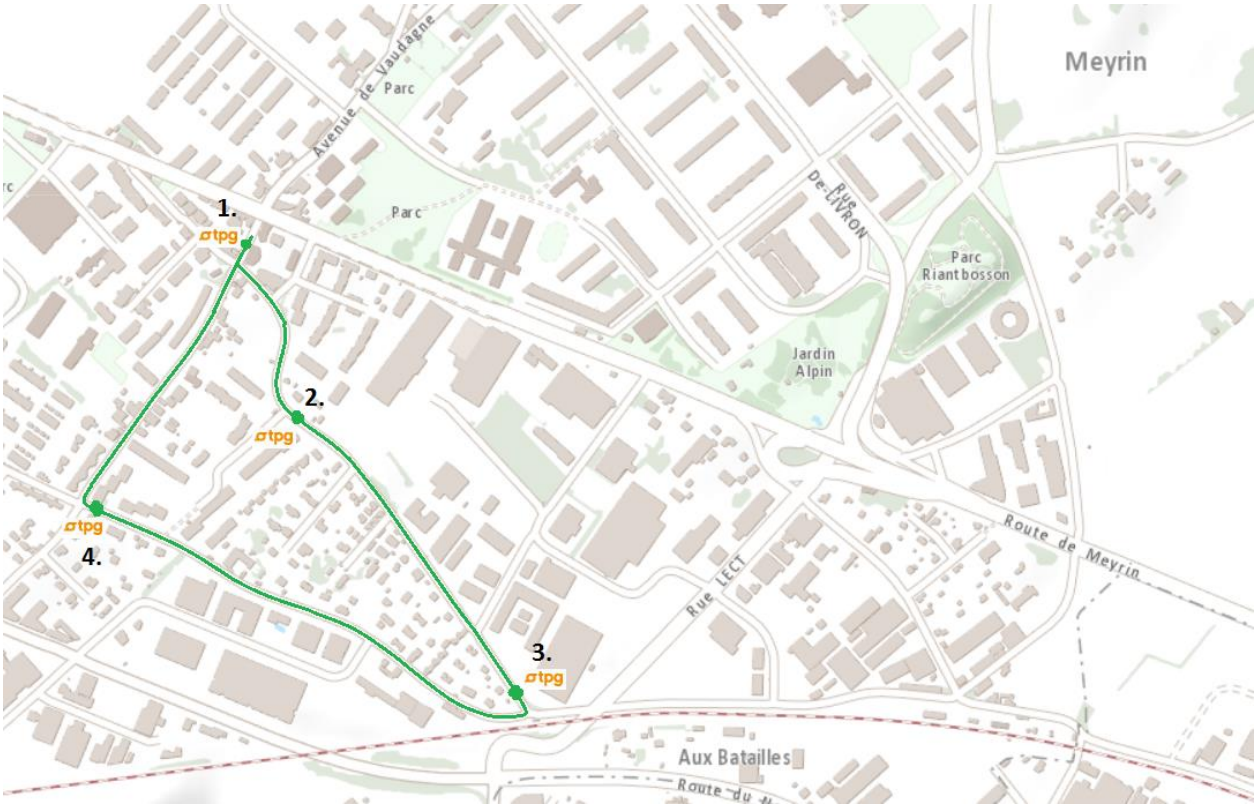


Figure 11: Xa Line Meyrin Map with Bus stops

Bus stop 1.	Meyrin-Village
Bus stop 2.	Grand-Puits
Bus stop 3.	Meyrin-Gare (train station)
Bus stop 4.	Vieux-Bureau

Table 8: Xa Line Meyrin – Bus stop naming

5.1.3 Timetable

Lundi-Vendredi

Correspondances						
Genève		*6:46*	*7:18*	*7:48*	*8:19*	*8:49*
Meyrin		*6:51*	*7:23*	*7:53*	*8:24*	*8:54*
Meyrin-Gare		6:59	7:28	7:59	8:29	8:59
Vieux-Bureau		7:04	7:33	8:03	8:34	9:04
Meyrin-Village		7:09	7:38	8:08	8:39	9:09

Correspondances						
Genève		*15:49*	*16:18*	*16:49*	*17:19*	*17:47*
Meyrin		*15:54*	*16:23*	*16:54*	*17:24*	*17:52*
Meyrin-Gare		15:59	16:29	16:59	17:29	17:57
Vieux-Bureau		16:04	16:34	17:04	17:34	18:02
Meyrin-Village		16:09	16:39	17:09	17:39	18:07

Lundi-Vendredi

Meyrin-Village	6:53	7:20	7:48	8:17	8:46
Grand-Puits	6:55	7:22	7:51	8:19	8:48
Meyrin-Gare	6:59	7:26	7:56	8:23	8:52

Correspondances					
Meyrin	*7:03*	*7:32*	*8:04*	*8:28*	*9:04*
Genève	*7:12*	*7:41*	*8:13*	*8:37*	*9:13*
Meyrin-Village	15:53	16:23	16:53	17:21	17:51
Grand-Puits	15:55	16:25	16:55	17:23	17:53
Meyrin-Gare	15:59	16:29	16:59	17:27	17:57

Correspondances					
Meyrin	*16:03*	*16:32*	*17:04*	*17:32*	*18:04*
Genève	*16:12*	*16:41*	*17:13*	*17:41*	*18:13*

Figure 12: Xa Line Meyrin Timetable

5.1.4 Route between the Xa Line and the vehicle depot

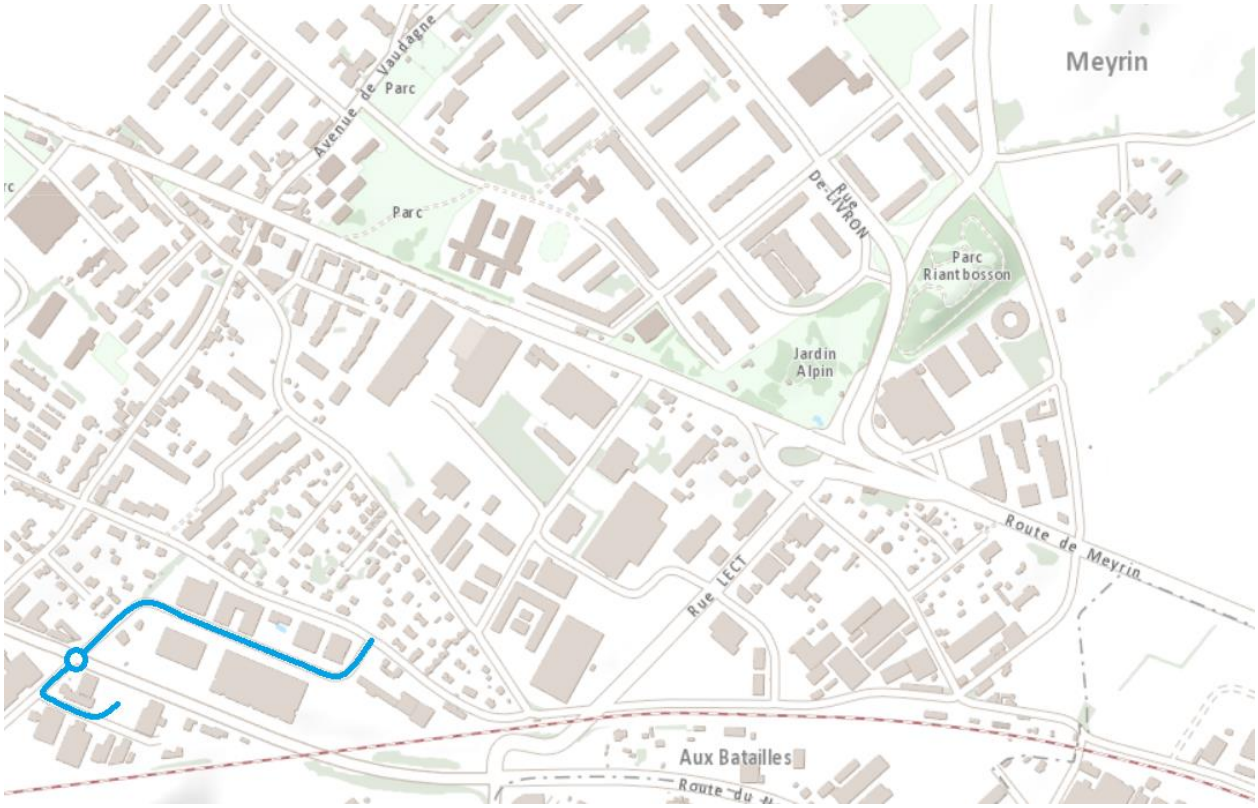


Figure 13: Xa Line Meyrin route to depot Map

5.1.5 Depot

Figure 14: P103 & P53 side by side in the Meyrin Depot

5.1.6 Operating issues

During one year of service we encountered the following issues:

5.1.6.1 Transfer of GPS corrections

We are almost on a daily bases confronted with issues related to the transfer of GPS corrections which are necessary for the positioning of the vehicle on its predefined path.

Every time a GPS receiver calculates its position, there is some amount of error inherent in the calculated position. Errors can be introduced from a number of sources (e.g. GPS clock errors, atmospheric conditions, the distribution of GPS satellites) over which the GPS user has little control.

In order for the vehicle to identify its exact position, differential correction is a commonly used technique to reduce the systematic errors that decrease the accuracy of GPS positions. All differential correction techniques use correction data from a GPS base station to improve GPS locations calculated by a GPS receiver in the vehicle. The GPS base station is permanently fixed to the same location, and, as a result, its location is known with a high degree of certainty.

These differential corrections have to be transferred from the base station to the Shuttle in real time. This is done via radio signals as well as 3/4G connectivity.

Out of path errors have resulted in situations where the vehicle drove upon the side-walk.

Around the Meyrin-Gare bus stop, the vehicle drives in the shadow of a large building and encounters a signal loss, hence, loss of necessary GPS corrections. It concerns a zone of almost 30% of the total route.

In order to reduce the transfer of GPS corrections issues in this area, it is decided to use Odometrics and 3D mapping (instead of 2D mapping) to accurately position de vehicle.

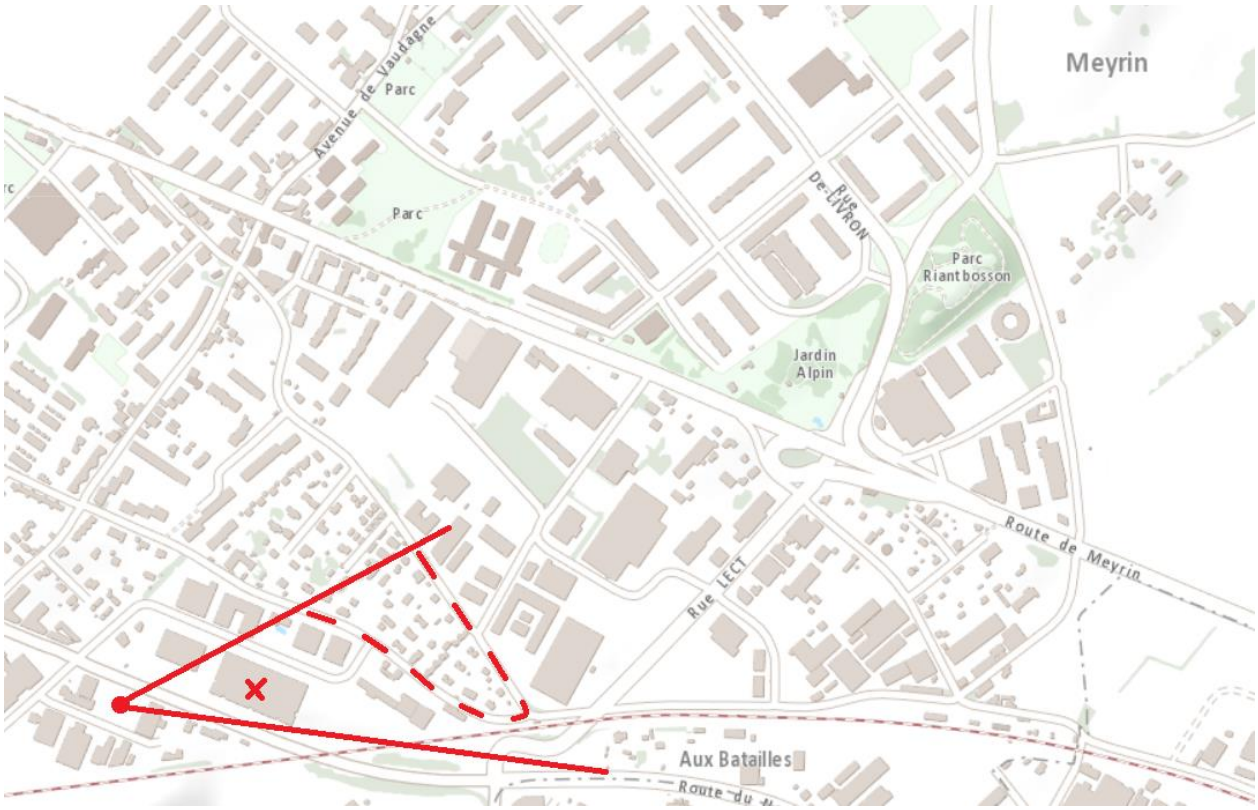


Figure 15: Xa Line Meyrin radio signal interference

30% of the route does not receive the necessary GPS corrections due to the interference of radio signals

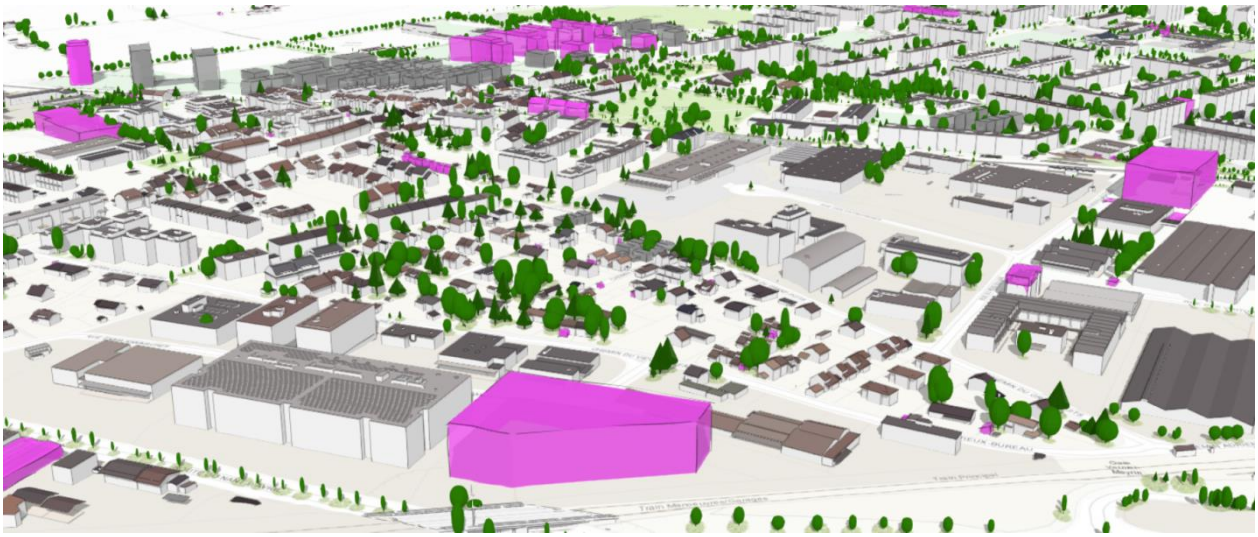


Figure 16: Xa Line Meyrin Map extra foreseen radio signal interference

Not only that, they are planning to build another building (foreground in purple) next to the one which is already interfering with our GNSS base to vehicle radio signals.

5.1.6.2 Main issues

Apart from the GPS corrections issues, the vehicle has been out of order for longer periods of time due to the following issues:

Start date	End date	Issue
18.06.2019	In progress	Accident: caused by TPG driver inside the depot driving in manual mode. Vehicle currently at Navya factory in Vénisseux (FR) for repair, the retro-fit of mechanical components and update of software. Vehicle substituted by AVENUE vehicle P103 with TPG livery
29.04.2019	03.05.2019	Mechanical: Air suspension problem
16.04.2019	24.04.2019	Electrical: Doors do not close issue
12.03.2019	05.04.2019	IT: GPS corrections issue
30.01.2019	25.02.2019	Mechanical: Traction engine support broken (welds). Vehicle send back to Navya factory in Vénisseux (FR) for repair.
18.12.2018		IT: GNSS base Router change
02.11.2018	03.12.2018	Incident: shuttle drove upon the sidewalk. Problem related to GPS corrections
02.10.2018	09.10.2018	IT: Router shuttle
17.09.2018		Mechanical: Doors issue
12.09.2018		Incident: Skateboarder driving behind the vehicle couldn't stop and hit the vehicle from behind

Table 9: Vehicles – Technical issues

5.1.6.3 Second vehicle

Due to the frequent standstill of vehicle P53 and since we already ordered and homologated the three vehicles for our main AVENUE project on the Belle-Idée site, we have asked the Federal Roads Office (Fedro) to use one of them (P103) for the use of:

- Replacement of P53 in case of issue
- Operator training
- Testing of on-demand software and applications

The Federal Roads Office (Fedro) approved our demand in July 2019.

5.1.6.4 Infrastructure issues

The advancement of the vehicle is regularly obstructed by:

- Trees
- Wrongly parked cars

5.1.6.5 Road behaviour

Current roads are not yet designed for autonomous vehicles and undesirable situations may occur, for example:

Parking places or other obstacles placed on the side of the road which are not prominent enough encourage two passenger vehicles to pass or overtake the hurdle side by side at the same time. It would be better to redesign this traffic situation in a way for just one vehicle to be able to pass at a time.

With the experience gained from the first vehicle in terms of road holding, we tried a different set-up and gave the second vehicle a more prominent place on the road to ensure safer traffic behaviour and improved handling. The second vehicle is able to better cope with traffic situations, the vehicle completes less emergency stops, and the driving experience is much more fluid.

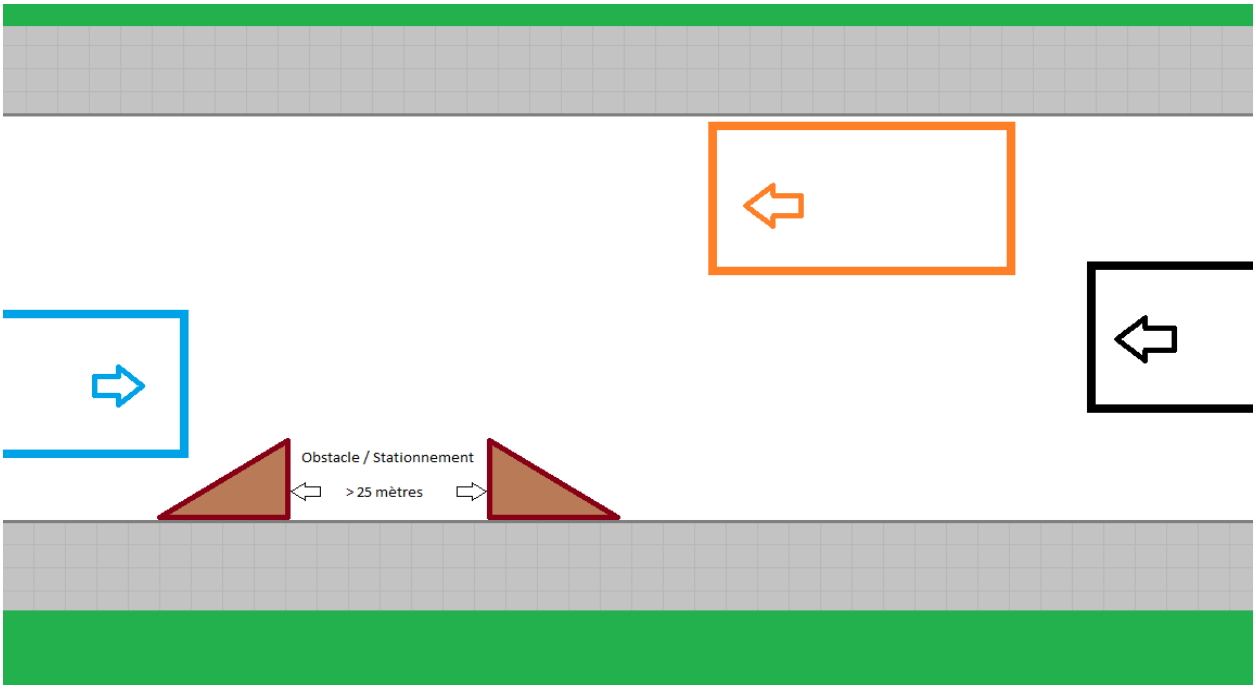


Figure 17: Enhance road behaviour as well as safety by rethinking road situations

5.1.1.1 Safety drivers

Experienced PTO drivers have a daily routine to control their bus or tram and to interfere in case of a dangerous traffic situation. With the arrival of the autonomous vehicle, these drivers are confronted with a vehicle which decides for itself without control or interference from the driver. This is against the habit of the driver and requires a change in mind-set.

5.1.7 Vehicle Development

In order for the vehicle to be better accepted by other road users and clients we have to develop:

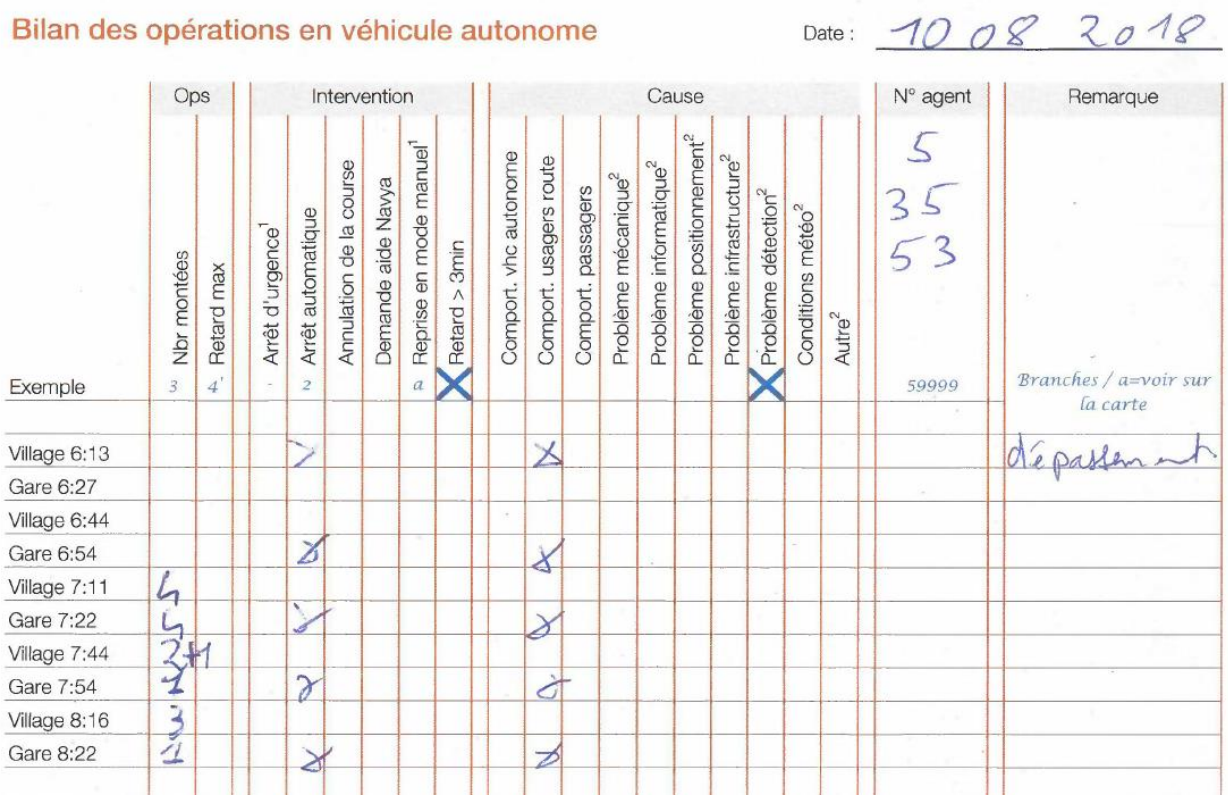
Develop:	• Driveability • Object Identification (not only detection)
In order to enhance:	• Security • Acceptance
Which enables us to:	• Increase Vehicle Speed
Which leads to:	• Experience / comfort / fluidity

Table 10: Vehicles - Development

5.1.8 Reporting

5.1.8.1 Safety driver

Safety drivers have to fill-in a report with their findings and interventions during every service.



Bilan des opérations en véhicule autonome

Date : 10 08 2018

	Ops		Intervention						Cause										N° agent	Remarque
	Nbr montées	Retard max	Arrêt d'urgence[1]	Arrêt automatique	Annulation de la course	Demande aide Navya	Reprise en mode manuel[1]	Retard > 3min	Comport. vhc autonome	Comport. usagers route	Comport. passagers	Problème mécanique[2]	Problème informatique[2]	Problème positionnement[2]	Problème infrastructure[2]	Problème détection[2]	Conditions météo[2]	Autre[2]		
Exemple	3	4'	-	2			a	X								X			59999	Branches / a=voir sur la carte
Village 6:13				X						X									5	dépassement
Gare 6:27																			35	
Village 6:44																			53	
Gare 6:54				X						X										
Village 7:11	4																			
Gare 7:22	4			X						X										
Village 7:44	2+1																			
Gare 7:54	2			X						X										
Village 8:16	3																			
Gare 8:22	2			X						X										

Figure 18: Safety driver reporting

5.1.8.2 Clients

We ask clients who travelled with our autonomous vehicle to fill-in a survey online:

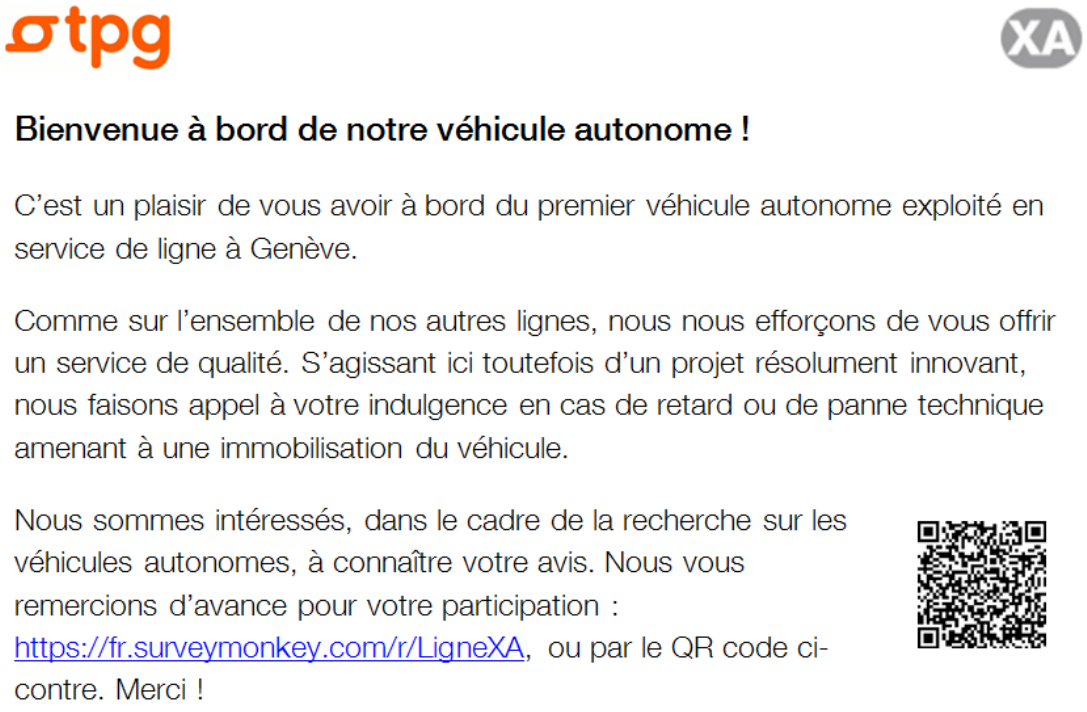


Figure 19: Online client's satisfactory survey

5.1.8.3 Authorities

A bi-annual report is send to all concerning authorities and includes topics such as the number of clients transported, issues to overcome etc.

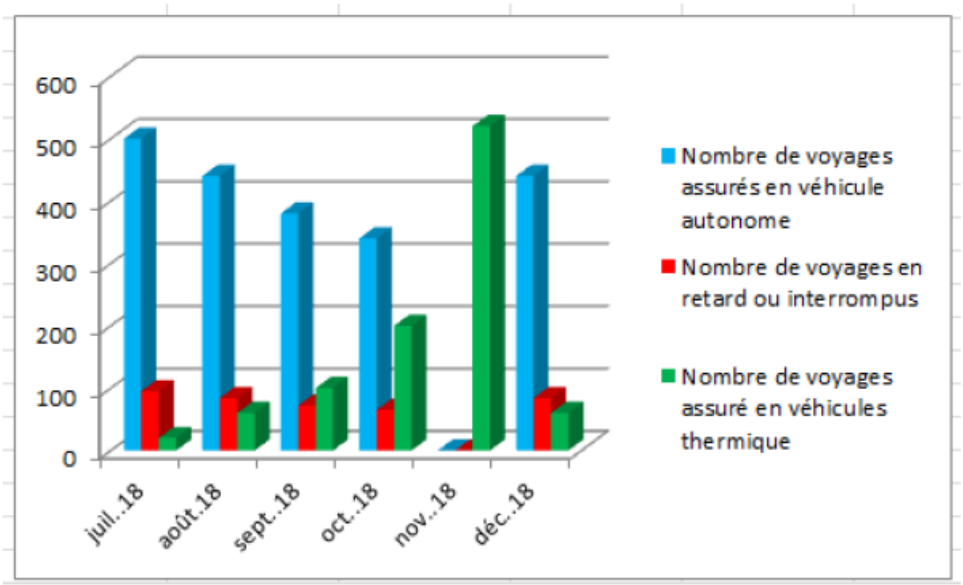


Figure 20: Xa Line Meyrin operations reporting

Number of travels in autonomous mode (blue bar)

5.1.9 Future developments

The following changes and extensions during or after the AVENUE project may be foreseen. When the Belle-Idée site trial is up and running, we may discuss an evolution of the Xa-Line, such as:

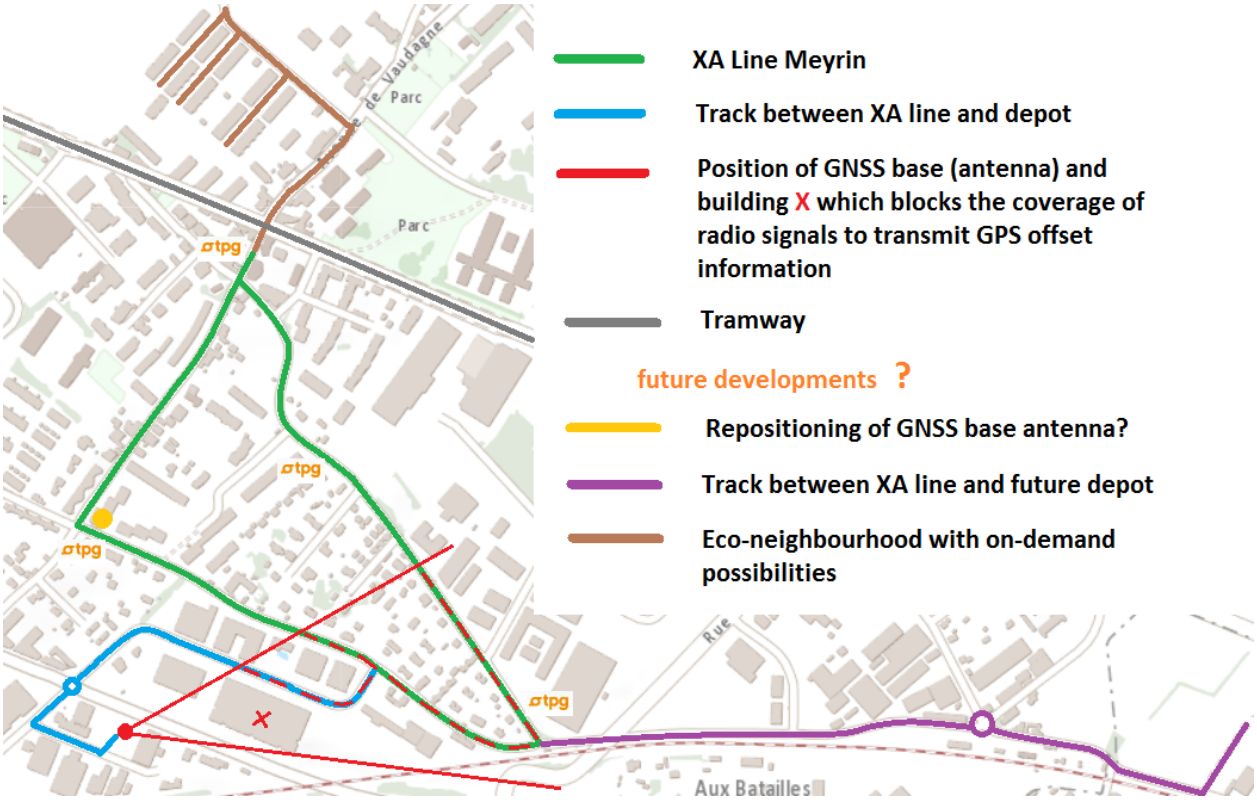


Figure 21: Xa Line Meyrin future developments

5.2 Belle-Idée

In AVENUE's vision for the future of urban and suburban public transportation, autonomous vehicles will ensure safe, fast, and personalized passenger transportation, minimizing vehicle changes, taking care of passengers from their doorstep and bringing them as close as possible to their destination. The projects main objective is to demonstrate that autonomous vehicles will be a key element of the solution for public transport in the future.

The project will not only assess the safety of autonomous vehicles in public transport, but it will also demonstrate the economic, environmental and social benefits of autonomous vehicles for both public transport companies and users, paving the way for widespread adoption of autonomous vehicles in public transport after the end of the project.

AVENUE will integrate, adapt, develop and validate innovative in- and out- of vehicle services, maximizing personalization and route optimization, and making travel a real experience for its passengers. AVENUE will revisit the public transportation services offered, from the initial problem of allowing passengers to travel from one place to another.

Initially three vehicles, type Navya Arma DL4 identical to the one that circulates today in Meyrin, will be deployed on the semi-private site of the Belle-Idée clinic, with the subsequent possibility of assigning a fourth. TPG plans to integrate them into the existing transport network without imposing fixed trips or stops. The goal is to develop an on-demand service, which can be managed via a Smartphone and will transport the customer from door to door. Like taxis but in the form of shared autonomous public transport.

5.2.1 University Hospitals of Geneva (HUG)

The HUG was created in 1995, and is part of a tradition of excellence in medicine and science dating back hundreds of years. The group brings together 10 Geneva public hospitals and 40 outpatient units throughout the canton of Geneva, and together they form the leading Swiss University Hospital.

The Belle-Idée site brings together most of the general and specialized hospital psychiatric units. It also includes a day hospital, consultation facilities for autistic patients, a community geriatric unit and a sleep laboratory.

Located at 2 chemin du Petit-Bel-Air in Thônex in the Canton of Geneva, the Belle-Idée estate covers an area of approximately 38 hectares and includes several buildings and care units.

The Belle-Idée area is moderated at 30 km/h, open to the public, limited by automatic barriers and contains a network of small lanes with a relatively low traffic load.

5.2.2 Objectives

The "AVENUE" project on the Belle-Idée estate foresees three main objectives:

1. Test three to four autonomous vehicles in an on-demand environment within a geographically defined area, without fixed bus lines or predefined timetables.
2. Test the possibility to board and alight passengers at system-defined bus stops without any infrastructure such as a yellow zigzag on the ground to mark the stop or a pole to display passenger information.
3. At the end of the project, test at least one vehicle in 100% autonomous mode, without operator on board, with the authorization to supervise several vehicles simultaneously at a distance.

5.2.3 Belle-Idée estate

Figure 22: Belle-Idée Demonstrator General Map

HUG - Belle-Idée estate - Chemin du Petit-Bel-Air n°2 - 1226 Thônex

5.2.4 Boundaries

Figure 23: Belle-Idée Demonstrator Bounderies Map

The belle-Idée site comprises six land plots

5.2.4.1 Land plots

Land plot	Egrid	Community	Owner
4514	CH69.6584.8263.30	Chêne-Bourg	State of Geneva
4524	CH35.7965.8663.43	Chêne-Bourg	City of Geneva
4525	CH36.8665.6379.20	Chêne-Bourg	State of Geneva
4701	CH35.5065.8863.44	Thônex	State of Geneva
6349	CH35.8665.8063.66	Thônex	Dependency
6374	CH62.8490.6563.81	Thônex	State of Geneva

Table 11: Belle-Idée – Land Plots

5.2.5 Current public transport status

Figure 24: Belle-Idée Demonstrator Current Bus Lines Map

TPG bus line n° 1 and n° 31 through the main axe of the estate

Bus stop 1.	Seymaz
Bus stop 2.	Petit-Bel-Air
Bus stop 3.	Belle-Idée-Salève to be renamed Belle-Idée-Reception
Bus stop 4.	Belle-Idée to be renamed Belle-Idée-Centre
Bus stop 5.	Hôpital Trois-Chêne

Table 12: Belle-Idée – Current TPG Bus stops

5.2.6 Future situation

Main Bus line n° 1 will probably be displaced from the Belle-Idée estate to a new housing area.

Figure 25: Belle-Idée Demonstrator Future Developments Map

Foreseen housing area with 2.400 new apartments (marked in blue)

5.2.7 AVENUE solution

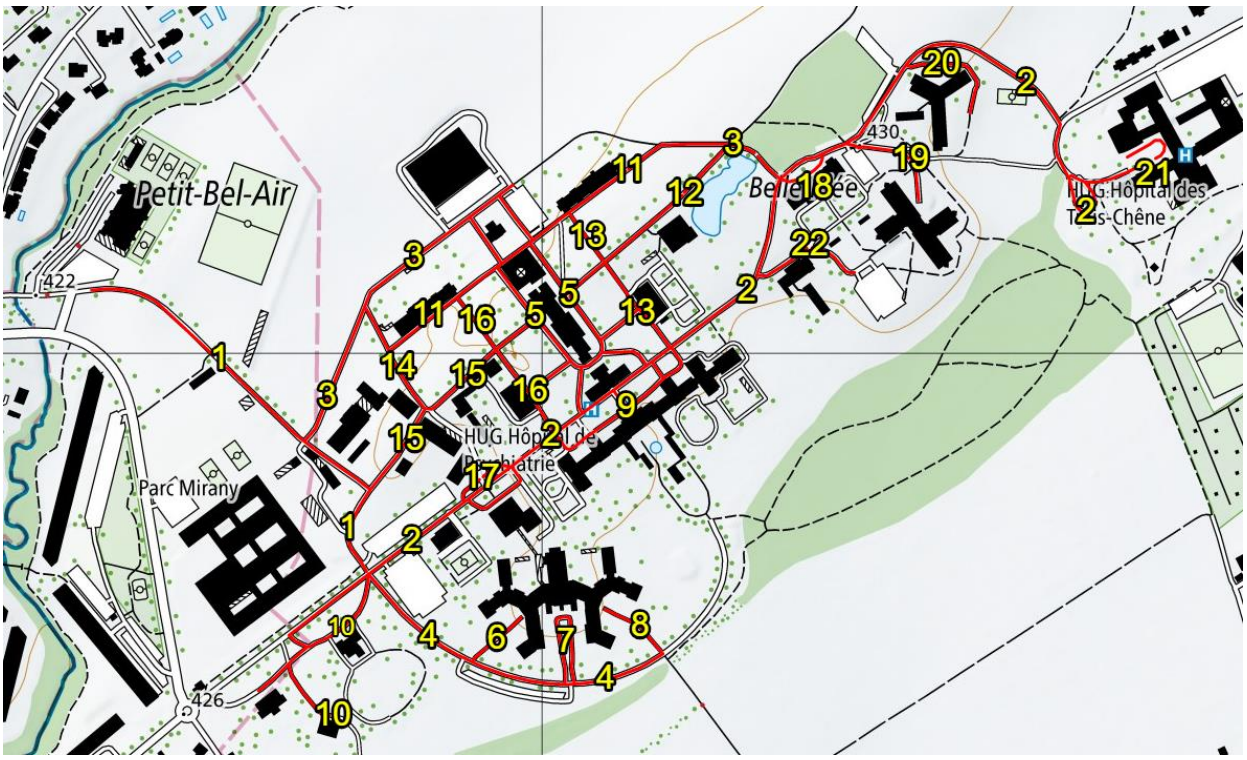


Figure 26: Belle-Idée Demonstrator On Demand Routes Map

AVENUE - on demand dispatching

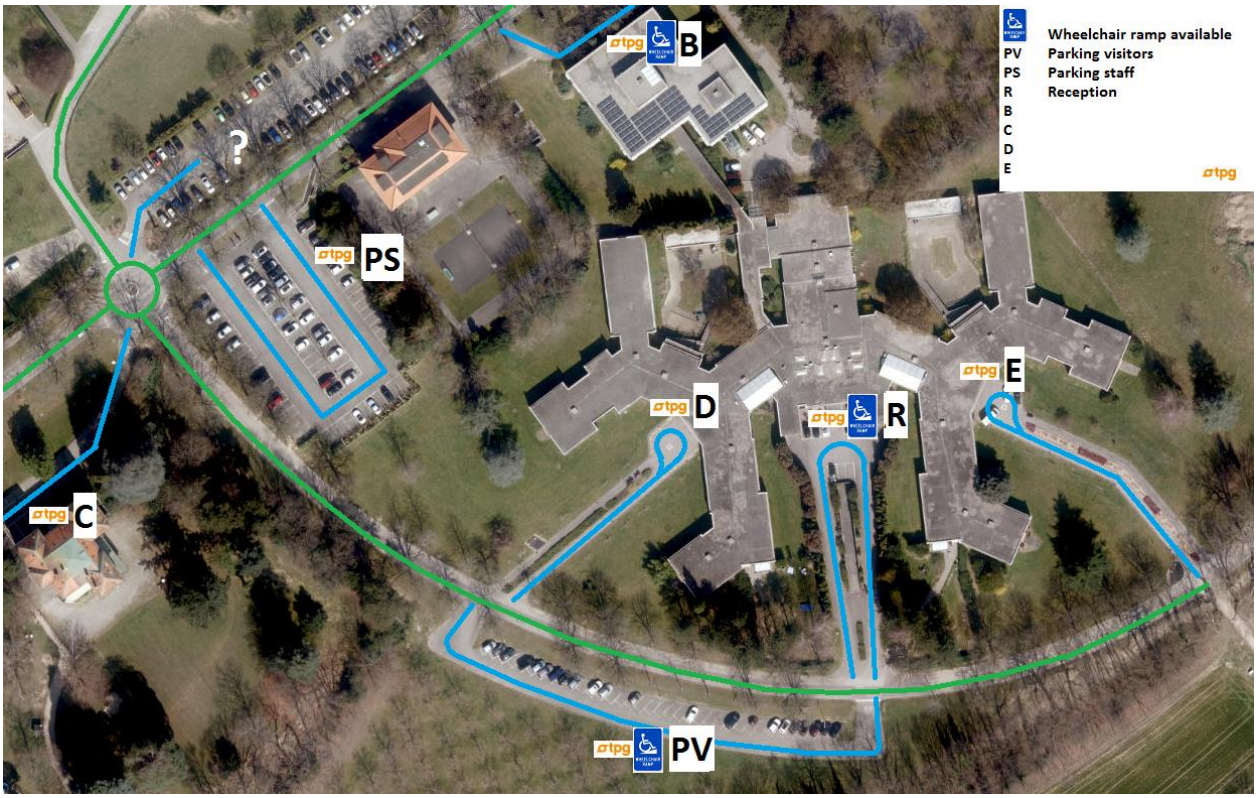


Figure 27: Belle-Idée Demonstrator On Demand How To

From parking PV to building B without going to building E, R and D as well as parking PS first

5.2.8 Bus stops

Most bus stops are only technically defined in the system and without any infrastructure such as a ZigZag on the ground or a pole with travel information.

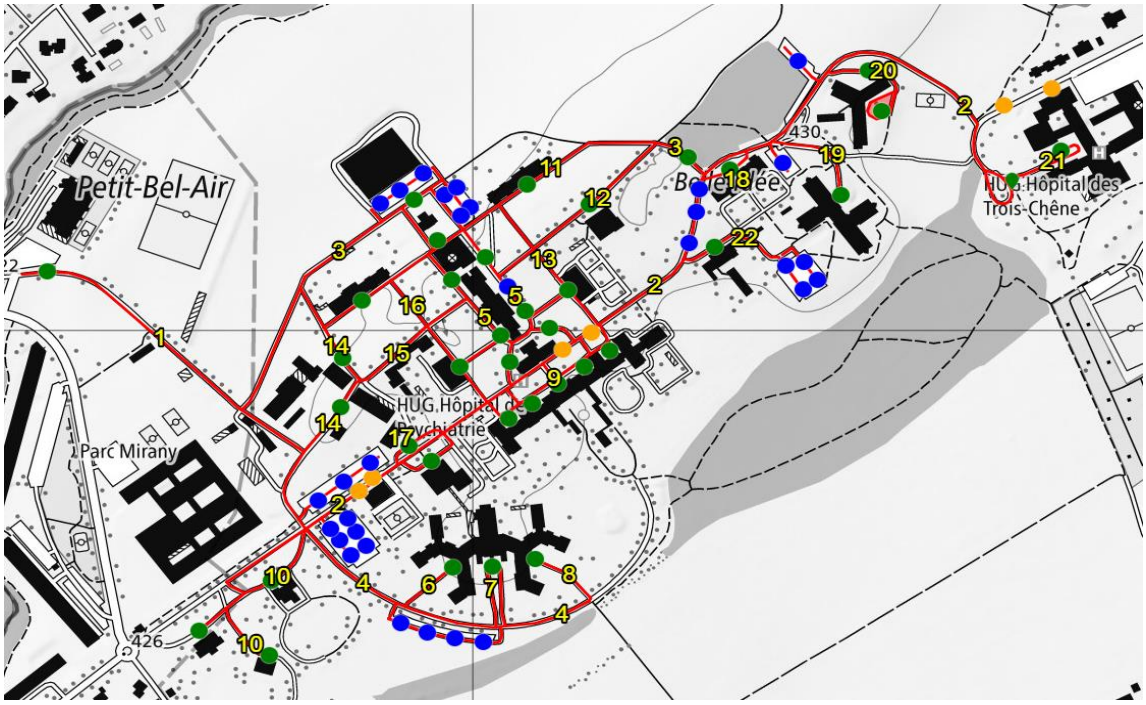


Figure 28: Belle-Idée Demonstrator Bus Stops

5.2.8.1 Bus stop identification

See appendix B

5.2.9 Vehicle depot

The vehicle depot is situated on site and can hold 3-4 vehicles as well as a fully equipped mobile office which can also serve as office space to supervise the driverless vehicles. The depot is equipped with three phase 32 Amp connectors to charge the vehicles and a household 12 V system.

Figure 29: Belle-Idée Demonstrator Vehicles Depot

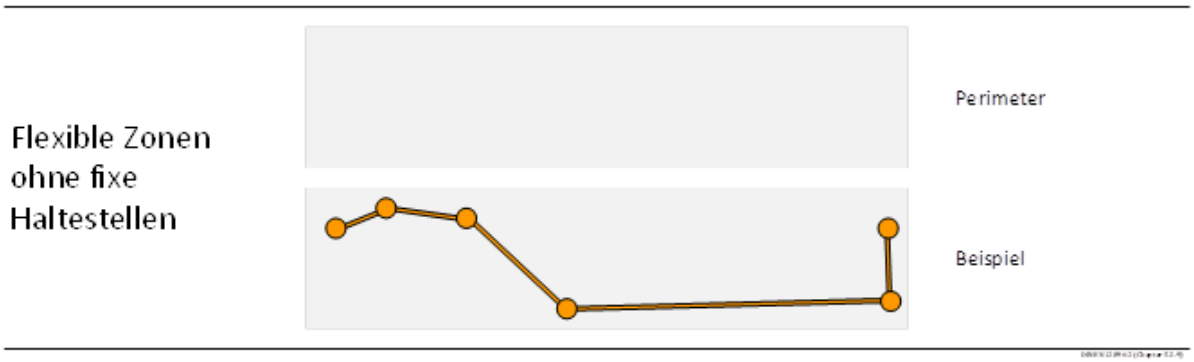
Figure 30: Belle-Idée Demonstrator Vehicles Depot Inside

5.2.10 GNSS base antenna

The antenna will be placed on the highest building on site. It is important to test the interference with other radio waves beforehand.

Figure 31: Belle-Idée Demonstrator GNSS base Antenna Placement

5.2.11 Operations



Instead of opting for a geographical coordinate's service were a vehicle may stop everywhere, we technically defined every bus stop in order to guarantee that our clients can board and alight a vehicle in security. Hence, a flexible zone with fixed (defined) stops.

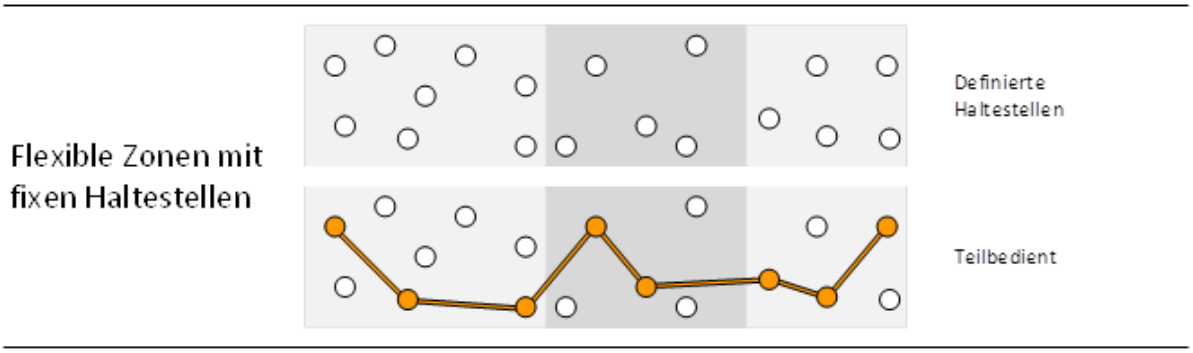


Figure 32: Belle-Idée Demonstrator On Demand Operations

5.2.12 Map concession

Representation of the Belle-Idée concession: a grey area with on-demand door-to-door service and an orange line signifying the existing bus lines and stops.

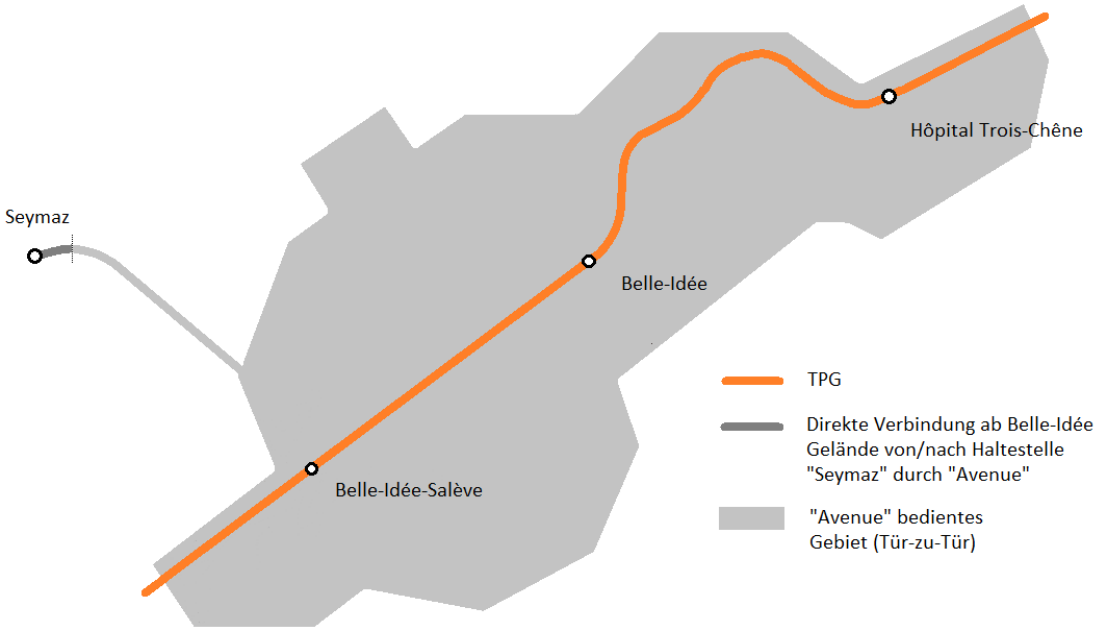


Figure 33: Belle-Idée Demonstrator Transport Concession

5.2.13 Timetable

We will assure a seven days a week service from 07:00 to 19:00 with at least one vehicle all day long and will test a second and third vehicle in parallel when demand is high during weekdays. We equip the main vehicle with a TPG operator, who serves as the reference person on site, and the other vehicles with students.

5.2.13.1 Monday-Friday

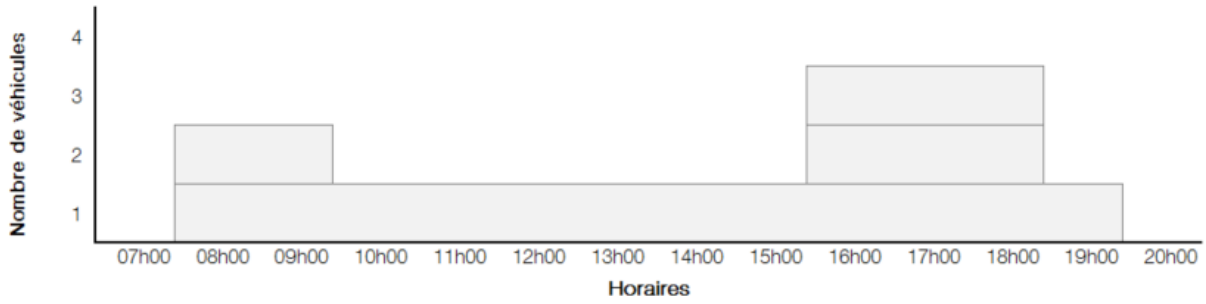


Figure 34: Belle-Idée Demonstrator Timetable weekdays

5.2.13.2 Weekend and holidays

Figure 35: Belle-Idée Demonstrator Timetable weekends

5.2.14 Way to book a shuttle

An on-demand service requires that a client is able to book a ride. The objective is to do this directly by means of an application on your smart-phone or indirectly via a telephone-number and the help of an operator.

5.2.14.1 Client Application

Examples of the application as developed by MobileThinking.

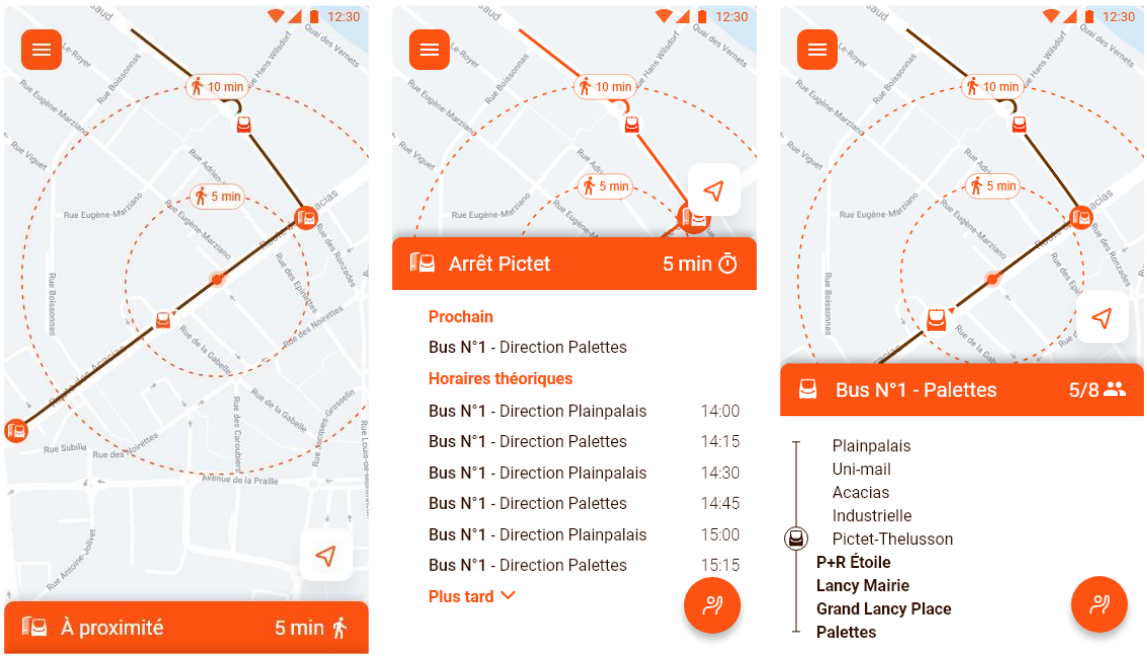


Figure 36: Belle-Idée Demonstrator On Demand Application

5.2.14.2 Vehicle dispatching

Vehicle dispatching through Bestmiles' autonomous fleet orchestration platform.

Q4 – 2019 Manual mode

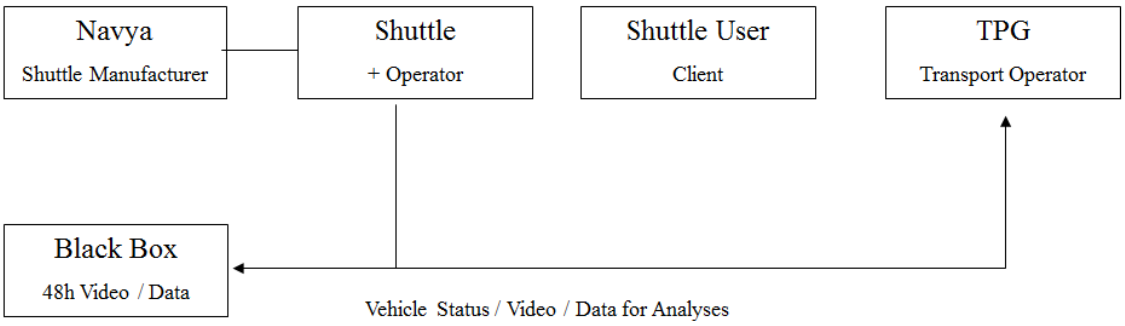


Figure 37: Belle-Idée Demonstrator On Demand Dispatching Phase 1

2019-2021 – Introducing automation

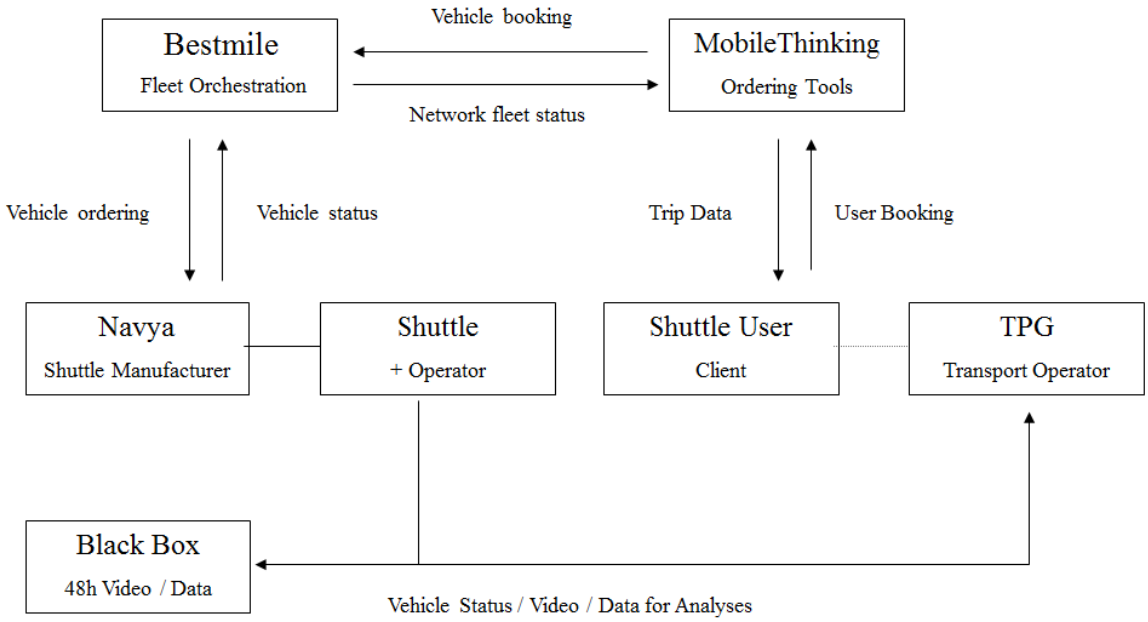


Figure 38: Belle-Idée Demonstrator On Demand Dispatching Phase 2

2021-2022 - Full Automation

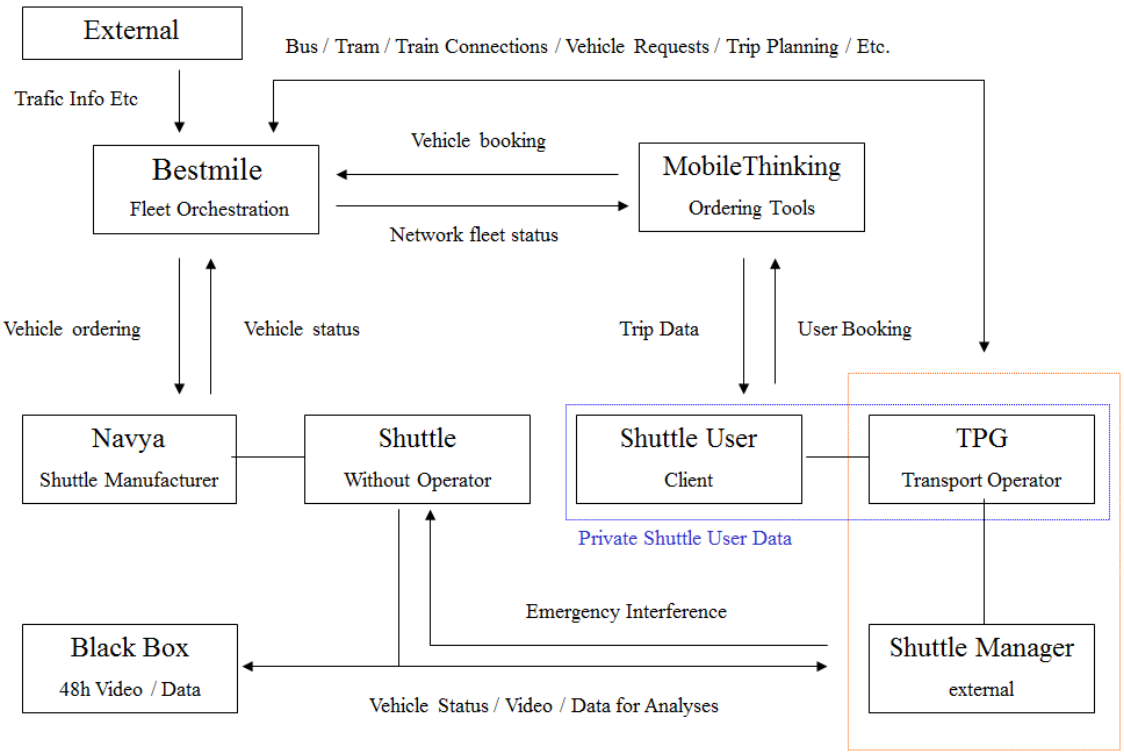


Figure 39: Belle-Idée Demonstrator On Demand Dispatching Phase 3

5.2.15 Traveller information

In order to inform clients about the availability of a driverless vehicle at their service, we could consider installing information points on strategic places, advertise on social media or send out flyers:

Figure 40: Belle-Idée Demonstrator Traveller Information

6 Planning

Belle-Idée site

Objectifs	Description	Schedule
Application :	Application in view of the Homologation of the Belle-Idée site	July 2019
Mapping :	Image mapping of all 3D objects for the path of the vehicle	August 2019
Depot:	Preparation of the vehicle storage space including electrical connexions for the charging of the vehicles and the installation of a mobile office unit.	October 2019
Antenna :	Installation of the GNSS base station	October 2019
Presse release :	Presentation of the AVENUE project	November 2019
Testing :	First tests with a safety driver but without clients on board	November 2019
Start trial :	Start operations with one to three vehicles including safety drivers and clients	15 December 2019

Table 13: Belle-Idée - Planning

7 Conclusion

We are moving in the right direction. It is however important to notice that we are in a premature stage with the development of self-driving vehicles for public transport and it may not yet be considered a plug and play solution.

Currently, we do not advice public transport operators to substitute a normal minibus on a traditional line with a driverless vehicle in order to try to compensate the fact that it is too expensive to operate a bus line with a driver inside. That said, in Switzerland it is even not yet allowed to drive with a self-driving vehicle without a safety driver on board.

The Xa line must be considered a test site and less regarding the profitable transport of passengers.

The Belle-Idée project is aligned with the objectives of the AVENUE project: offer an on demand service without fixed bus lines or predefined timetables and offering numerous bus stops without infrastructure.

8 Footnote

Transport Publics Genevois (TPG) is the public transport operator of reference in the Geneva region. Their mission is to contribute to the management of mobility in the Canton of Geneva, Switzerland by proposing to the public a quality offer in accordance with the principles of sustainable development. Involved in innovation, they are active in the fields of electric and autonomous vehicles.

Appendix A

Technical data Navya Arma-DL4

Description	value
Capacity	
Passengers	15
Sitting	11
Standing	Not homologated in Switzerland
Dimensions	
Length	4.75 [m]
Width	2.11 [m]
Height	2.65 [m]
Clearance	0.20 [m]
Tyres	215/60 R17
Wheels	Steel wheel rims
Empty weight	2400 [kg]
Gross weight	3450 [kg]
Engine	
Drive wheels	2
Engine	Electric
Power	15 [kW] nominal
Maximum speed	45 [km/h]
Operating speed	25 [km/h]
Maximum slope	12 %
Energy	
Battery	Battery pack LiFe P04
Capacity	33 [kWh]
Average theoretical autonomy	9 hour
Charge duration for 90 %	8 hour at 3.6 kW, 4 hour at 7.2 kW
Charging technology	Induction / Plug
Charging temperature	0 to +40 °C

Operating temperature	-10 to +40 °C
Direction	
Steering wheels	2x2
Turning radius	< 4.5 [m]
Equipment	
Airconditioning	Automatic
Heating	Central
Doors	Double wings
Body	Polyester
Windows	Glass
Visual information	15” touchscreen
Sound information	Speakers
Lighting	Unidirectional
Sound warning	Buzzer/claxon
Safety	• Handholds (4) • Supporting bar (2) • Emergency hammer • Triangle • Safety vest • First aid kit • Fire extinguisher • Interior camera
Wheel chair access	Manuel ramp
Localization & object detection	
Lidar 1	Two 360° multi-layer lidars
Lidar 2	Six mono-layer lidars
Cameras	Front stereo vision cameras
Odometry	Wheel encoder + inertial unit
Safety	
Emergency stop button	2 buttons
SOS intercom	1 button / via supervision
Emergency break	Automatic
Parking brake	Automatic

Appendix B

Belle-Idée bus stops

Bus stop	Short ID	Long ID
Erables	BI02	BI0200
Magnolias	BI03	BI0300
Comptines	Bi04	BI0400
Salève	BI06	BI0600
Parking Salève	BI06	BI0601
Parking Salève	BI06	BI0602
Parking Salève	Bi06	BI0603
Parking Salève	BI06	BI0604
Parking Salève	BI06	BI0605
Parking Salève	BI06	BI0606
Accueil	BI08	BI0800
Sillons	BI91	BI9100
Admission	BI09	BI0900
Parking admission	BI09	BI0901
Parking admission	BI09	BI0902
Parking admission	BI09	BI0903
Parking admission	BI09	BI0904
Glycines	BI92	BI9200
Abraham Joly	BI37	BI3700
Parking Abraham Joly	BI37	BI3701
Parking Abraham Joly	BI37	BI3702
Parking Abraham Joly	BI37	BI3703
Seymaz	BI31	BI3100
Jura	BI26	BI2600
Buanderie	BI22	BI2200
Parking Buanderie	BI22	BI2201
Parking Buanderie	BI22	BI2202
Parking Buanderie	BI22	BI2203

Chapelle	BI25	BI2500
Parking Chapelle	BI25	BI2501
Parking Chapelle	BI25	BI2502
Parking Chapelle	BI25	BI2503
Parking Chapelle	BI25	BI2504
Centrale thermique	BI27	BI2700
Centrale thermique	BI27	BI2701
Service généraux	BI28	BI2800
Service généraux	BI28	BI2801
Parking service généraux	BI28	BI2802
Ajuriaguerra	BI29	BI2900
Ajuriaguerra	BI29	BI2901
Alpes	BI10	BI1000
Voirons	BI11	BI1100
Laboratoires	BI12	BI1200
Cèdres	BI13	SEYM10
Marronniers	BI14	BI1400
Tilleuls	BI19	BI1900
Platanes	BI21	BI2100
Restaurant l'étang	BI20	BI2000
L'Etang	BI20	BI2001
Grands-Bois	BI16	BI1600
Parking Grands-Bois	BI16	BI1601
Parking Grands-Bois	BI16	BI1602
Parking Grands-Bois	BI16	BI1603
Parking Grands-Bois	BI16	BI1604
Parking Grands-Bois	BI16	BI1605
Parking Grands-Bois	BI16	BI1606
Parking Grands-Bois	BI16	BI1607
Chênes	BI17	BI1700
Parking Chênes	BI17	BI1701
Champs	BI50	BI5000

Lilas	BI18	BI1800
Lilas 2	BI18	BI1801
Parking Lilas	BI18	BI1802
Hopital des Trois-Chênes	BI80	BI8000
Hopital des Trois-Chênes	BI80	BI8001
Belle-Idée Salève	BISA	BISA00
Belle-Idée Salève	BISA	BISA01
Belle-Idée	BLID	BLID00
Belle-Idée	BLID	BLID01
Hôpital 3-Chêne	HTCH	HTCH00
Hôpital 3-Chêne	HTCH	HTCH01
Hôpital 3-Chêne	HTCH	HTCH02
Garage	BIGA	BIGA00
Garage	BIGA	BIGA01
Seymaz	SEYM	SEYM10