Autonomous Vehicles to Evolve to a New Urban Experience

DELIVERABLE

D7.2

Second Iteration Geneva Large Scale Pilot Use Case Demonstration Report

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Disclaimer

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Figure 1: Navya - Fully Automated Vehicle

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Acronyms

ADS	Automated Driving Systems
AI	Artificial Intelligence
AM	Automated Mobility
API	Application Protocol Interface
AV	Fully 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)
EAB	External Advisory Board
EC	European Commission
EM	Exploitation Manager
EU	European Union
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
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 Transport 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)	WPL	Work Package Leader
WP	Work Package		

Executive Summary

This is the second Deliverable of Task T7.1 - Second Iteration Geneva Large Scale Pilot Use Case Demonstration report - which is due in month 36 (was 34). 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:

- An overview of the two demonstrator sites including an exhaustive description on the XA Line in Meyrin as well as the Belle-Idée site in Thônex (section 2)
- A detailed description of the demonstrator site homologation process in order for the Public Transport Operator to receive the necessary authorizations (section 3)
- A summary on the fully automated vehicles, including technical data, options, covering, vehicle inspections, maintenance and supervision (section 4)

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

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

Findings and observations – Belle-Idee site

Locating a suitable area, zone or fixed bus line for the deployment of fully automated vehicles can be laborious due to infrastructural and legal requirements.

Also the preparation of a complete file regarding the legal authorization to deploy the project and the validation phase within the authorities can be very time consuming.

We bought the same Navya Arma vehicles we already used within another project in order to make sure that the vehicle homologation process did not obstruct the advancement of the project.

Hence, in order to have a fully operational service transporting passengers for at least one year in order to gain valuable insights, it is extremely important to already know what to expect and to be prepared before setting up a project within the framework of a EU funded program.

The pre-preparation process, set-up and deployment of the project may take no longer than 2.5 years.

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

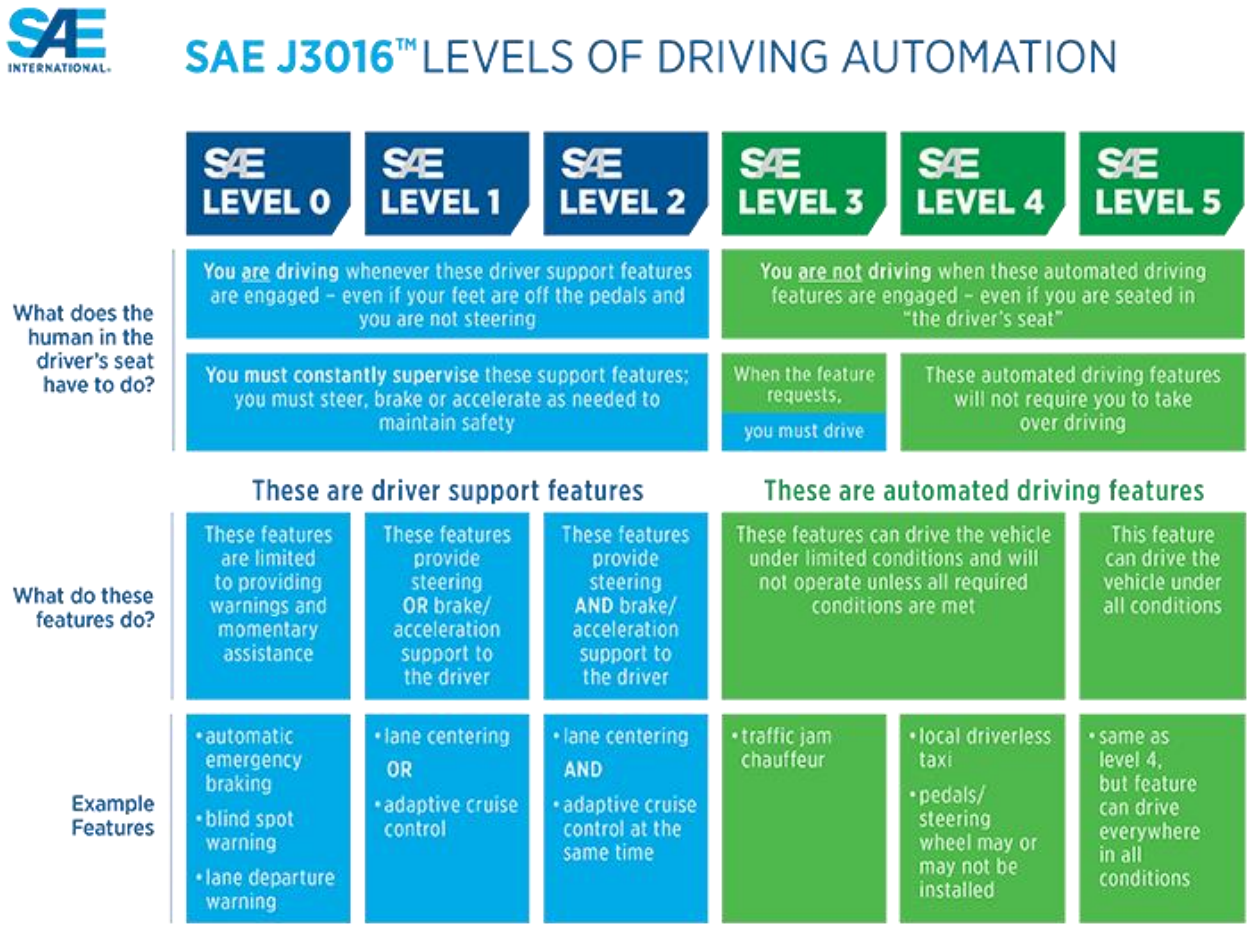
A self-driving car, referred in the AVENUE project as **a Fully Automated Vehicle** (**AV**), also referred as Autonomous Vehicle, is a vehicle that is capable of sensing its environment and moving safely with no human input.

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 operator supervision but in respect of which operator intervention is still expected or required
- "fully automated vehicle" means a motor vehicle that has been designed and constructed to move autonomously without any operator 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.



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 shuttle is able to bypass a parked car, while it will slow down and follow behind a slowly moving car. The AVENUE vehicles 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 shuttles used in the AVENUE project can technically achieve speeds of more than 25 Km/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 Km/h. 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 an emergency stop until standstill within 40 meters at high speeds (40 -50 Km/h) but then braking would be 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

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 fully automated 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 fully automated 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 fully automated vehicles for public transport.

The purpose of task **T7.1** is to integrate fully automated 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 **D7.2**, the main focus is on the organization, the running and the evaluation of the large scale demonstrators of the fully automated vehicle services for public transport in Geneva, Switzerland.

2 TPG test sites

Within the AVENUE framework, the TPG operates 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 Meyrin	Belle-Idée Thônex
Funding	TPG	EU + TPG
Start date project	01.08.2017	01.05.2018
Start date trial	02.07.2018	01.07.2020 (deployment)
End date trial	31.01.2021	
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	75
Type of bus stop	Fixed	Fixed
Bus stop infrastructure	Yes	5 regular bus stops, 70 virtual
Number of vehicles	1	3-4
Timetable	Fixed	On demand
Operation hours	Monday-Friday (5 days)	Sunday-Saturday (7 days)
Timeframe weekdays	06:30 - 08:30 / 16:00 - 18 :15	06:00 – 19:00
Timeframe weekend / holidays	No service (from June 2019)	06:00 – 19:00
Depot	At 400 [m] distance	On site
Driverless service	No	End 2021

Table 1: TPG demonstrator site comparison

2.1 XA-Line Meyrin

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.

Figure 2: XA-Line Meyrin Village

2.1.1 Partners

2.1.1.1 XA-Line deployment

- TPG | Public Transport of Geneva
- Navya
- Bestmile

2.1.1.2 Authorities

- Community of Meyrin
- General Transport Directorate of the Canton of Geneva
- Department of Security and Economy of the Canton of Geneva - Traffic Police
- Swiss Federal Roads Office

- Swiss Federal Office of Transport
- Swiss Federal Office of Communications
- Swiss Cantonal Vehicle Service

2.1.2 Objectives

The XA Line in Meyin foresees two main objectives:

1. Public transport company's first experience with fully automated driving.
2. Able to connect the Meyrin train station with the main TPG tram lines at Meyrin Village.

2.1.3 Site description

Meyrin was originally a small agricultural village until the 1950s, when construction of the European particle physics research organisation - CERN at the North of the village began. Meyrin is now a commuter town dominated with apartment high-rises, and many of its residents work at CERN or in central Geneva. Geneva International Airport is partially situated within the community. The XA-Line is located in an old residential area between a main tram line as well as the train station and surrounded by industrial activity. The XA-Line is an extension of TPG's public transport service within this area.

Figure 3: XA-Line General Map

2.1.3.1 Route

Figure 4: XA-Line Map of Route

Driving direction	Clock-wise
Route length	2.1 [km]
Speed limit all traffic	30 [km/h] area
Road	Urban open road (with high density traffic in red)

Table 2: XA-Line Site Information

2.1.3.2 Current public transport status

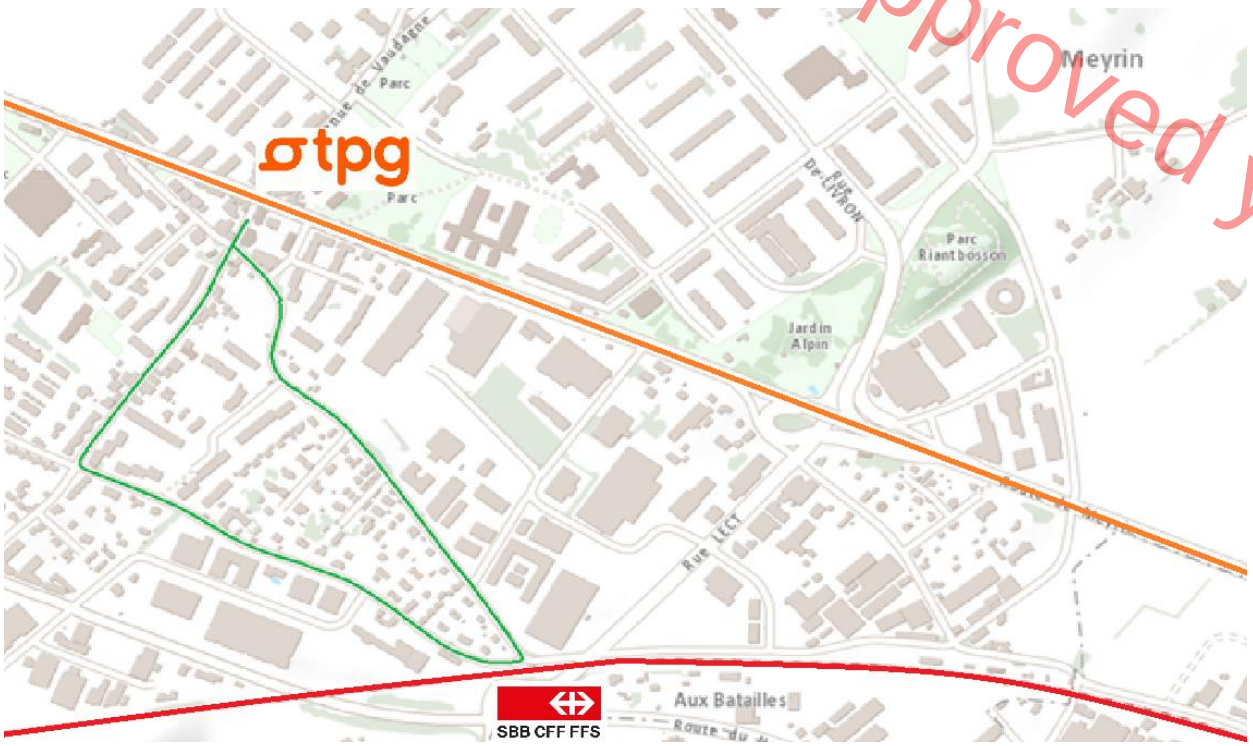


Figure 5: XA-Line current available public transport

TPG Tram 18 (orange line)	Meyrin Village Bus stop
SBB CFF FFS (red line)	Meyrin Train Station

Table 3: XA-Line current available public transport stations

2.1.3.3 Bus stops

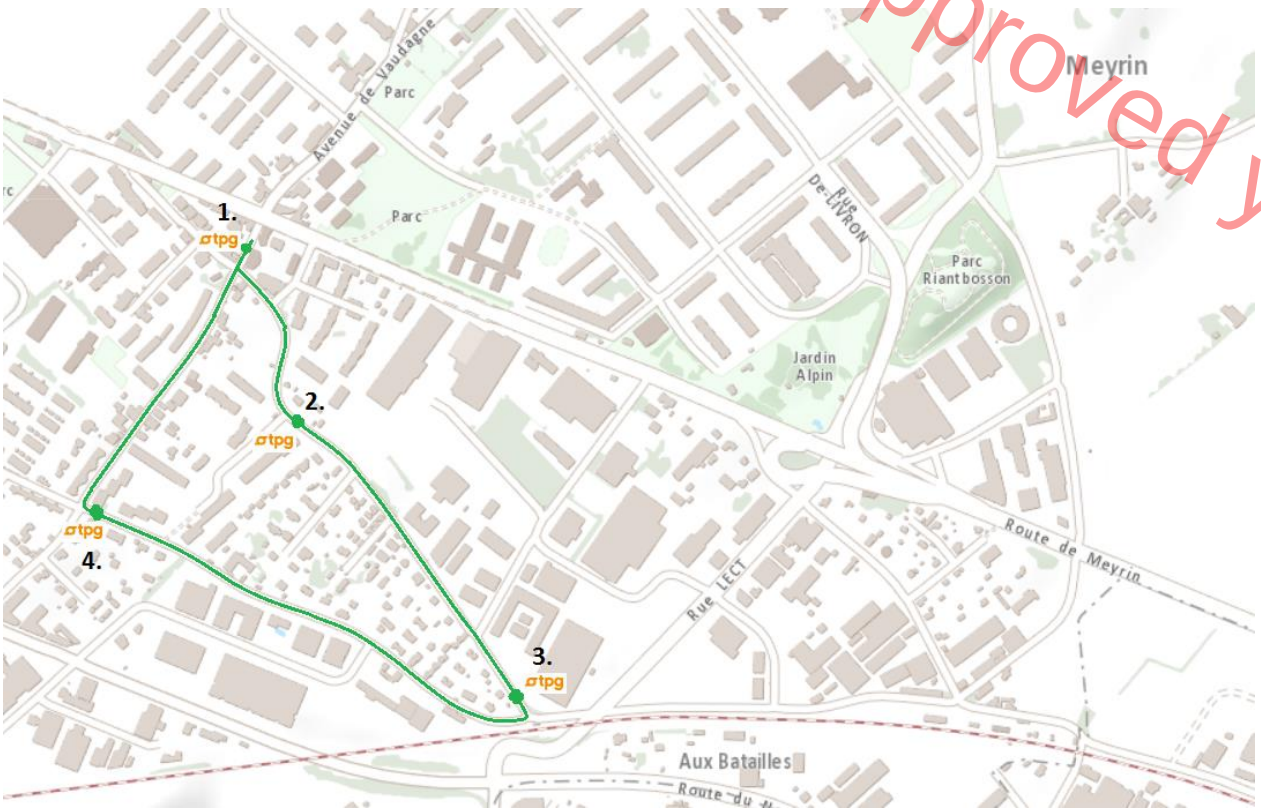


Figure 6: XA-Line Map with Bus stops

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

Table 4: XA-Line Bus stop naming

2.1.3.4 Vehicle depot

The fully equipped vehicle depot is situated nearby and can hold 1-2 vehicles. The depot is equipped with three phase 32 Amp connectors to charge the vehicles and a household 12 V system.

Figure 7: XA-Line Vehicle depot

2.1.3.4.1 Route to vehicle depot

Figure 8: XA-Line Route to depot Map

2.1.3.5 GNSS base antenna

The GNSS base antenna is situated on one side of the vehicle depot.

Figure 9: XA-Line GNSS base Antenna

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 GNSS base station to improve GPS locations calculated by a GPS receiver in the vehicle. The GNSS 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 GNSS base station to the Shuttle in real time. This is done via radio signals as well as 3/4G connectivity.

2.1.4 Operations

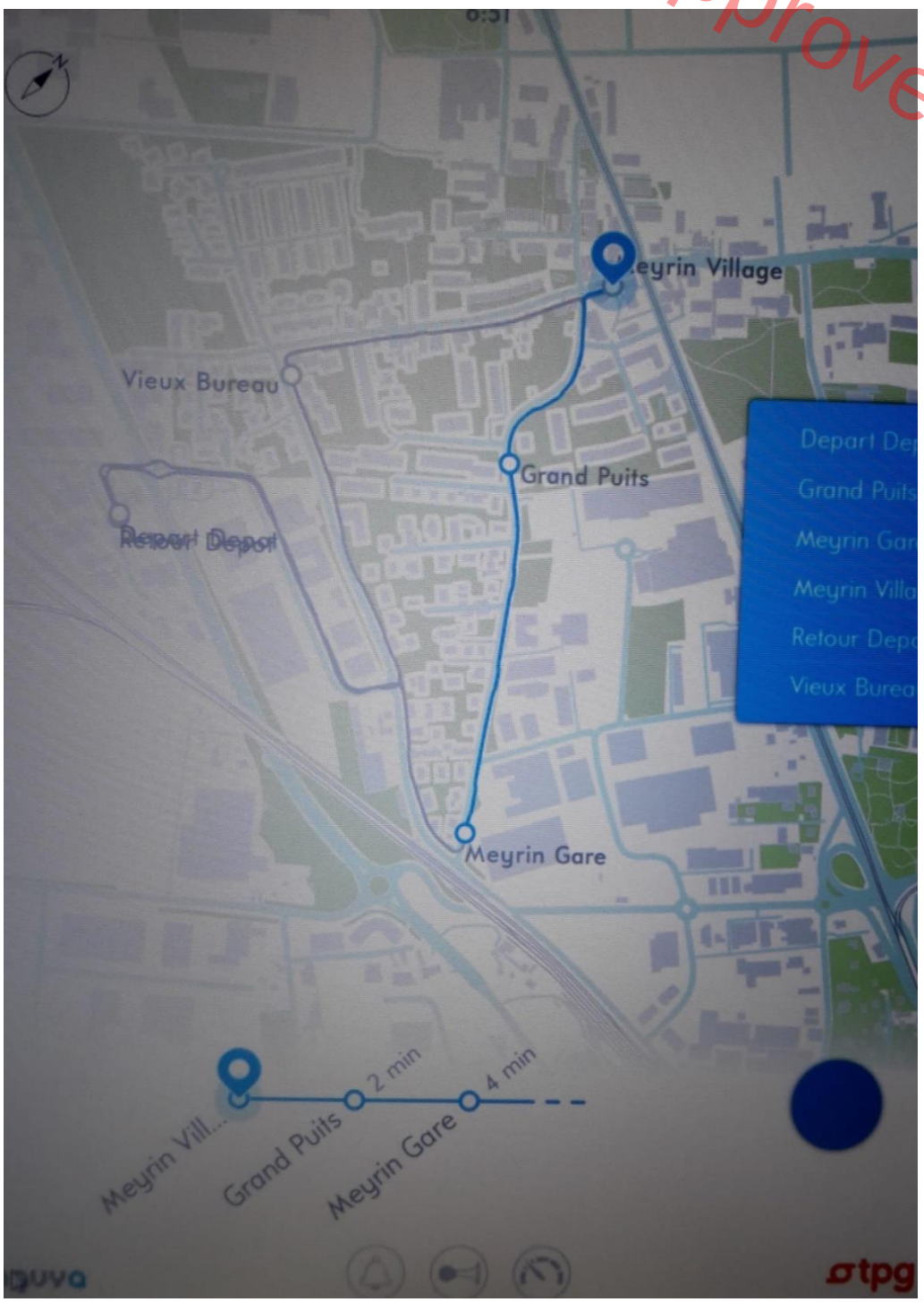


Figure 10: XA-Line Operations

The above image shows an example of the in-vehicle-operator-screen with the vehicle being located at the Meyrin-Village busstop and the next two busstops (Grand-Puits and Meyrin-Gare) being selected by the safety operator. Hence, the safety operator always needs to manually select the next busstop(s)

2.1.4.1 Map concession

Representation of the XA-Line concession

Figure 11: XA-Line Transport Concession

2.1.4.2 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 Timetable

2.1.5 Way to book a shuttle

The XA-Line is a traditional fixed bus line with a fixed timetable. It is not possible to order or book a vehicle. It is possible to live see where the vehicle drives via the Bestmile application.

2.1.6 Traveller information

In order to inform clients about the availability of the XA-Line service, regular passenger information is available at every four bus stops as well as on the website and official application of the TPG.

Figure 13: XA-Line Traveller Information with Covid-19 message

2.1.7 Reporting

2.1.7.1 Safety operator

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

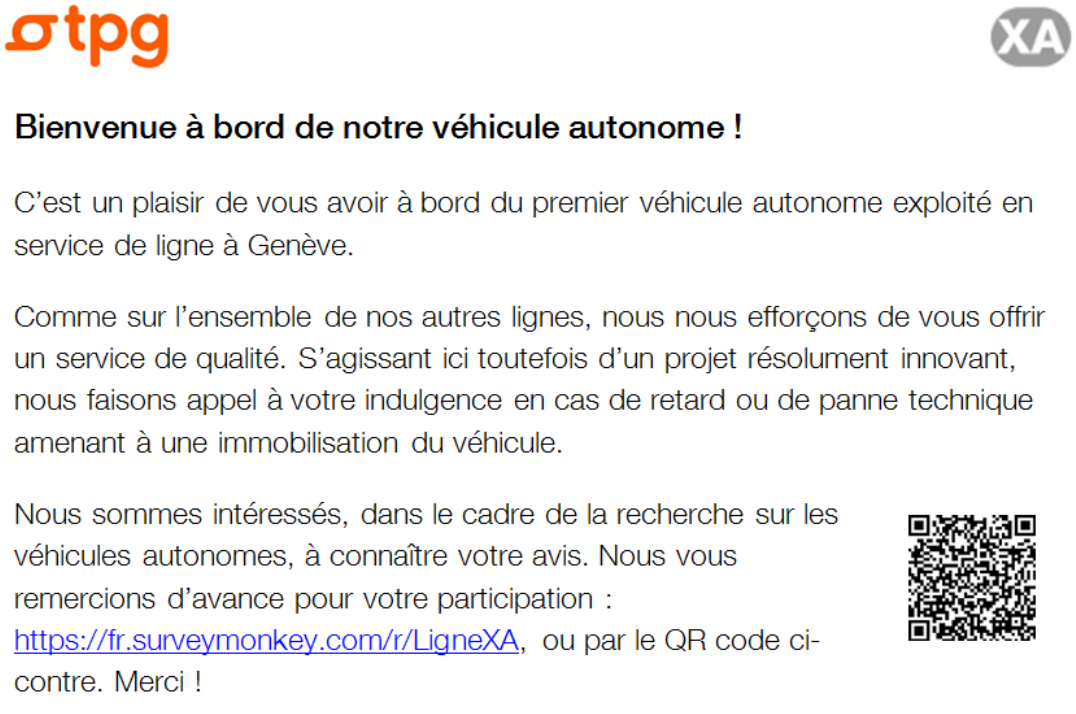
Bilan des opérations en véhicule autonome Date : 10 08 2018

	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	départ
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	3+1																			

Figure 14: XA-Line Safety operator reporting

2.1.7.2 Clients

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



tpg XA

Bienvenue à bord de notre véhicule autonome !

C'est un plaisir de vous avoir à bord du premier véhicule autonome exploité en service de ligne à Genève.

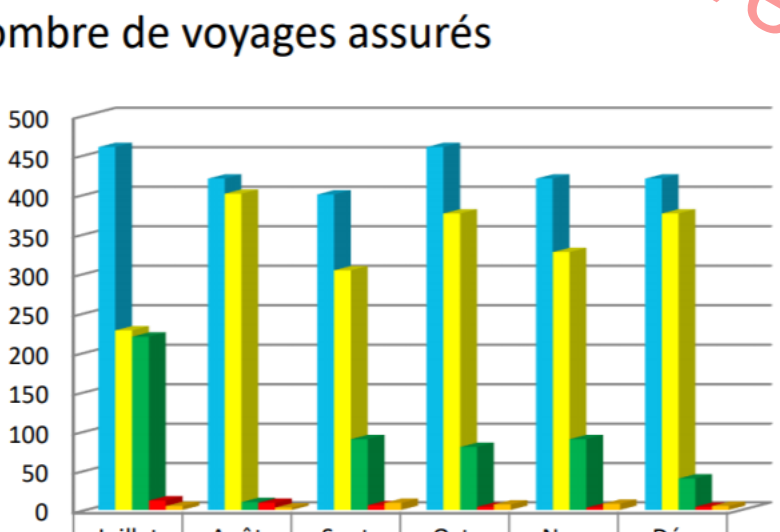
Comme sur l'ensemble de nos autres lignes, nous nous efforçons de vous offrir un service de qualité. S'agissant ici toutefois d'un projet résolument innovant, nous faisons appel à votre indulgence en cas de retard ou de panne technique amenant à une immobilisation du véhicule.

Nous sommes intéressés, dans le cadre de la recherche sur les véhicules autonomes, à connaître votre avis. Nous vous remercions d'avance pour votre participation : https://fr.surveymonkey.com/r/LigneXA, ou par le QR code ci-contre. Merci !

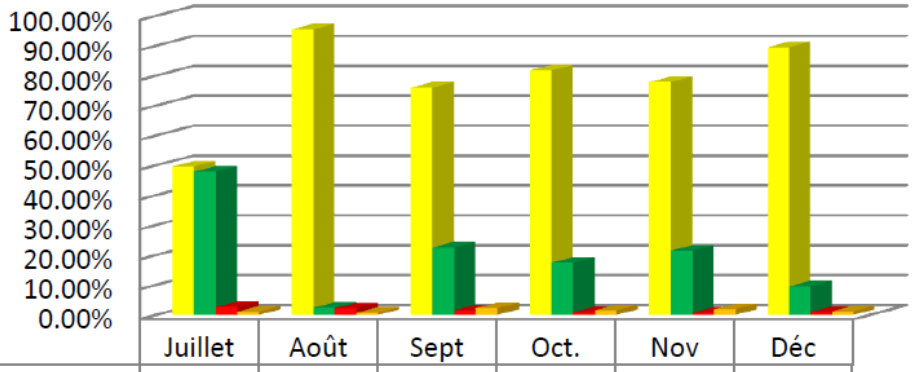
Figure 15: XA-Line Online client's satisfactory survey

2.1.7.3 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.



	Juillet	Août	Sept	Oct.	Nov	Déc
Nombre de voyages théorique	460	420	400	460	420	420
Nombre de voyages en autonome	228	401	304	376	327	376
Nombre de voyages en thermique	220	10	90	80	90	40
Nombre de voyages interrompus	12	9	6	4	3	4
Nombre de voyages en retard	5	3	9	7	8	5



	Juillet	Août	Sept	Oct.	Nov	Déc
Pourcentage des voyages assurés en autonome	49.57%	95.48%	76.00%	81.74%	77.86%	89.52%
Pourcentage des voyages assurés en thermique	47.83%	2.38%	22.50%	17.39%	21.43%	9.52%
Pourcentage des voyages des interrompus	2.61%	2.14%	1.50%	0.87%	0.71%	0.95%
Pourcentage des voyages en retards	1.09%	0.71%	2.25%	1.52%	1.90%	1.19%

Figure 16: XA-Line Operations reporting

These reports are available in French on the website of the Swiss Federal Transport Office – FEDRO:

XA-Line Meyrin Intermediate report June-December 2019 (*pdf in French)

2.1.8 Evaluation

During one year of service we encountered the following issues:

2.1.8.1 Operations related

GNSS Base and GPS Corrections

We are almost on a daily bases confronted with issues related to the transfer of GNSS 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 GNSS base station to improve GPS locations calculated by a GPS receiver in the vehicle. The GNSS base station is permanently fixed to the same location, and, as a result, its location is known with a high degree of certainty.

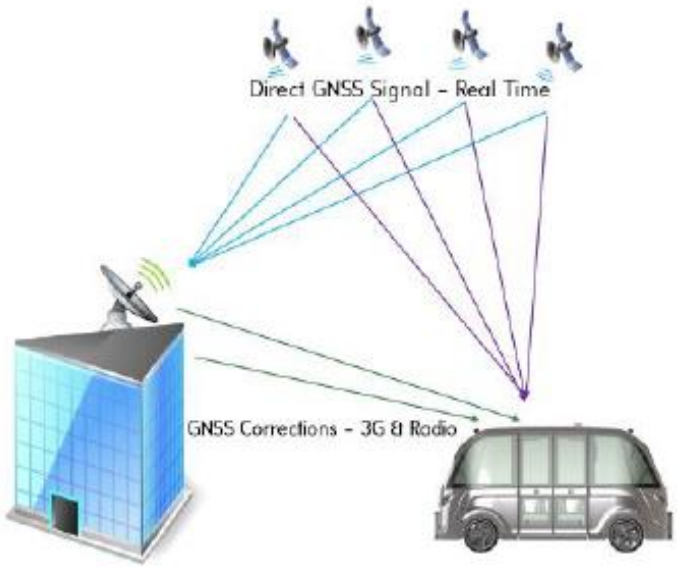


Figure 17: XA-Line transfer of GNSS corrections

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.

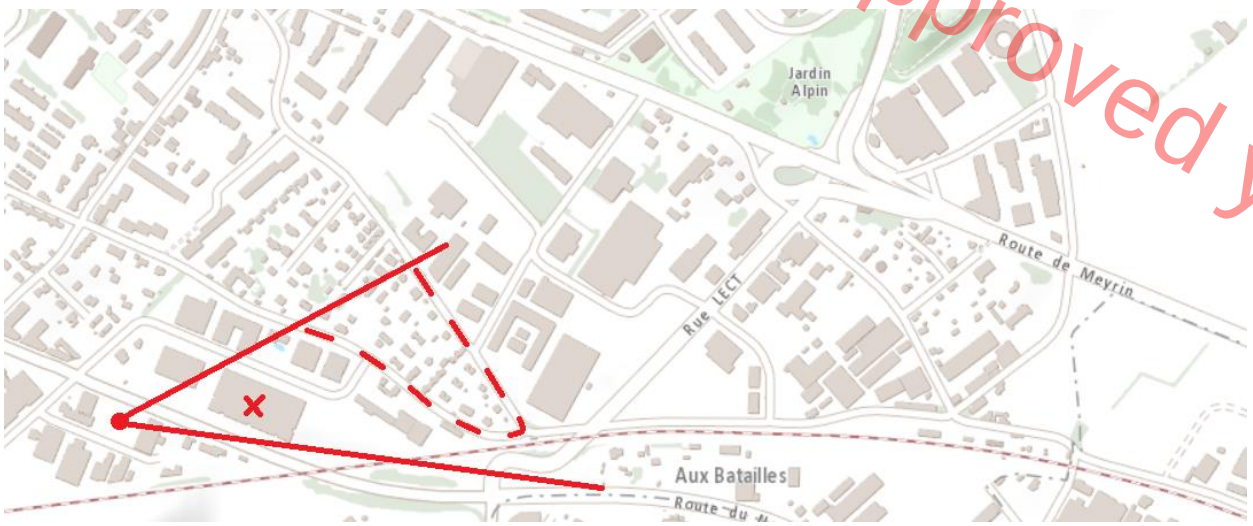


Figure 18: XA-Line Radio signal interference

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

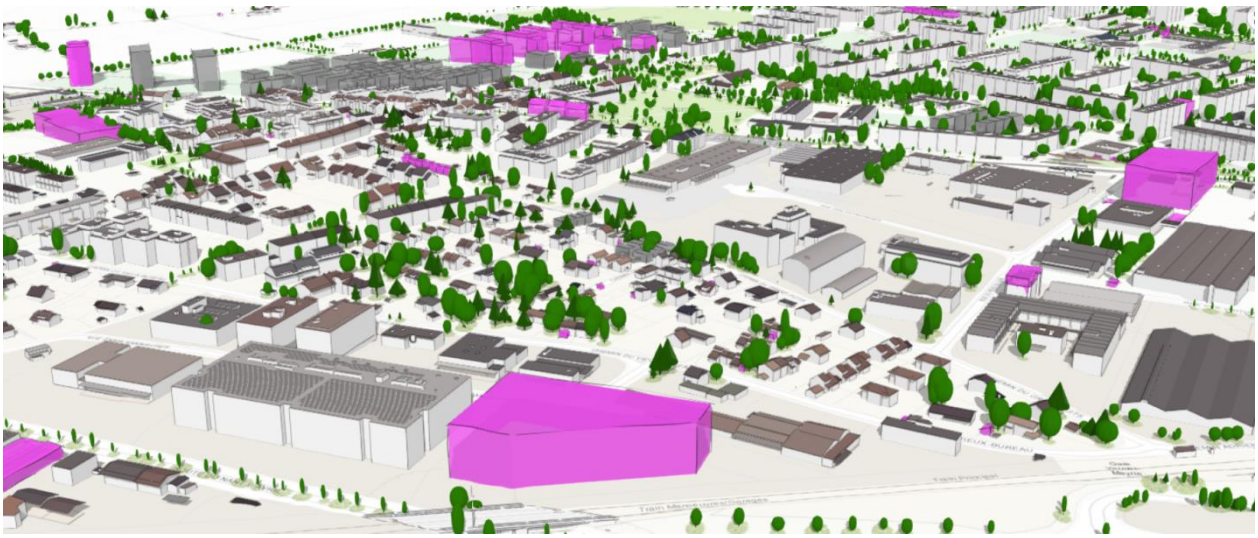


Figure 19: XA-Line Map extra foreseen radio signal interference

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.

2.1.8.2 Vehicle related

Apart from the GPS corrections issues, the vehicle has been out of order for longer periods of time due to several mechanical and IT related issues. Within time the number of occurrences started to be less frequent.

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.

Current average speed of the vehicles is less than 10 km/h with a maximum speed of 18,7 km/h. These speeds are perfectly adapted to the traffic situation and in line with the infrastructure and environment.

2.1.8.3 Infrastructure related

The advancement of the vehicle is regularly obstructed by:

- Trees and other greenery (branches hanging over the track due to wet rainy branches being more heavy and wild grow)
- Wrongly parked cars

In October 2020, the community of Meyrin announced to install 14 speedbumps on the XA-Line route in order to reduce speed of the private cars inside the 30 km/h zone. Speed bumps are detected as obstacles and difficult to overtake and due to the high number of bumps installed reduce a comfortable ride for the passengers.

2.1.8.4 Safety operator related

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 fully automated vehicle, these operators are confronted with a vehicle which decides for itself without control or interference from the operator. This is against the habit of the operator and requires a change in mind-set. This resulted in a number of safety operators leaving the project.

2.1.8.5 Covid-19 related

Due to the sanitary situation around Covid-19, a transparent separator was developed and installed inside the vehicle in order for the safety operator to be separated from clients.

It was decided to design a separation which could be attached to already available points inside the vehicle. This way no modifications to the vehicle had been made.

The separator has been inspected and approved by the Dynamic Test Center. Unfortunately, we are not able to perform the transparency test required by the Federal Transport Office. This test foresees a minimum legal transparency of 70% measured through both the separator as well as the rear window at the same time.

Figure 20: XA-Line Covid-19 separator

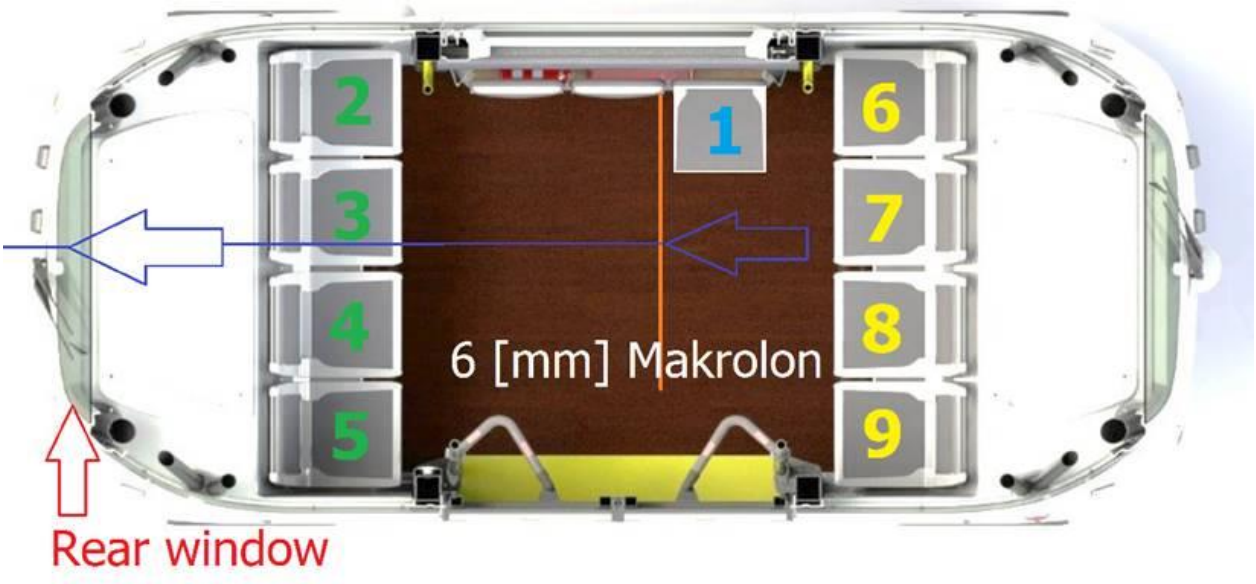


Figure 21: XA-Line Covid-19 separator window transparency testing

2.1.8.6 Other issues

Road behaviour

Current roads are not yet designed for fully automated 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.

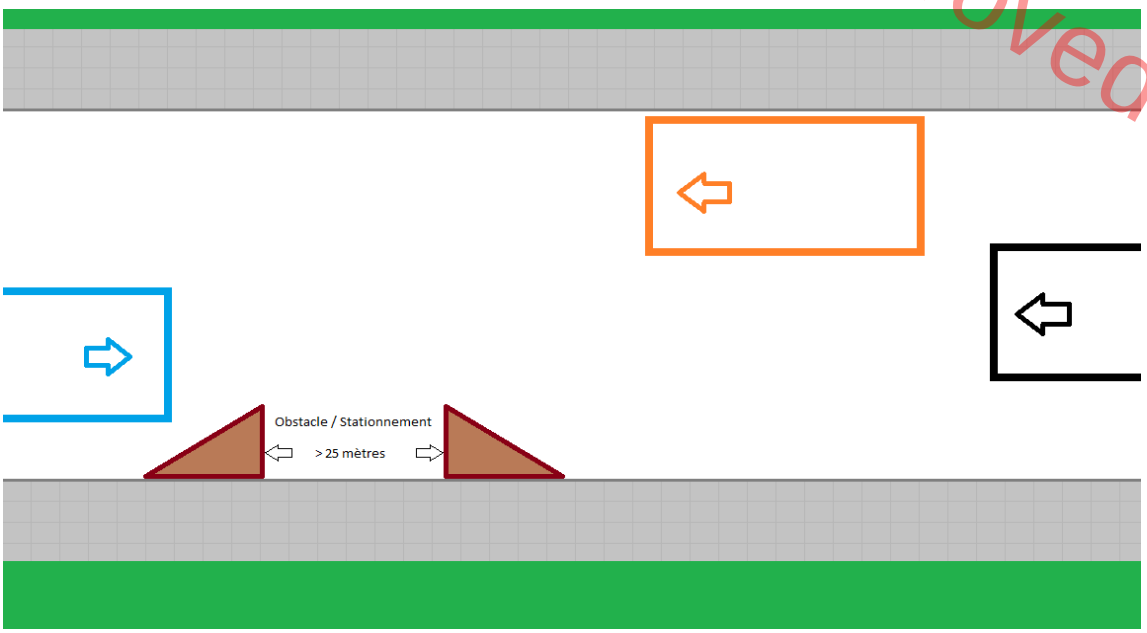


Figure 22: XA-Line Enhance road behaviour as well as safety by rethinking road situations

2.1.9 Recommendations

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

Develop:	• Driveability (roadholding capacity of the vehicle) • Object Identification (not only detection) .f.e: it is a bicycle, it is in standstill or in movement in the direction of x/y/z with a speed of s
In order to enhance:	• Security • Acceptance by passengers and other road users
Which enables us to:	• Increase Vehicle Speed (> 18 km/h)
Which leads to:	• Experience / comfort / fluidity

Table 5: XA-Line Vehicle development

2.1.10 Future developments

In October 2020, the community of Meyrin announced to install 14 speedbumps on the XA-Line route in order to reduce speed of traffic of the private cars inside the 30 km/h zone which unfortunately did put a halt on the project. Speed bumps are detected as obstacles and difficult to overtake and due to the high number of bumps installed reduce a comfortable ride for the passengers

2.2 Belle-Idée Thônex

In AVENUE's vision for the future of urban and suburban public transportation, fully automated 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 fully automated vehicles will be a key element of the solution for public transport in the future.

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

2.2.1 Partners & authorities

2.2.1.1 Belle-Idée deployment

- HUG | University Hospitals of Geneva
- TPG | Public Transport of Geneva
- Navya
- Bestmile
- Mobilethinking

2.2.1.2 Avenue research

- AVL
- Ceesar
- CentraleSupélec
- Certh
- The department of infrastructure of the Canton of Geneva
- Hochschule Pforzheim
- Siemens
- University of Geneva
- Virtual vehicle

2.2.1.3 Authorities

- Community of Chêne-Bourg
- Community of Thônex
- General Transport Directorate of the Canton of Geneva
- Department of Security and Economy of the Canton of Geneva - Traffic Police
- Swiss Federal Roads Office
- Swiss Federal Office of Transport
- Swiss Federal Office of Communications
- Swiss Cantonal Vehicle Service

2.2.2 Objectives

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

1. Test three to four fully automated 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 stop points 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% fully automated mode, without operator on board, with the authorization to supervise several vehicles simultaneously at distance.

The future objectives of the Hospital are to:

1. Reduce or eliminate completely the motorized traffic on the estate.
2. Offer a made to measure mobility service to be able to transport everyone on site.

2.2.3 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.

Figure 23: Belle-Idée Chemin du Petit-Bel-Air n°2 - 1226 Thônex

2.2.3.1 Use cases

The Belle-Idée site shows daily movement of patients, personnel, visitors, migrants, students, …

- Psychiatric hospital
- Elderly hospital
- Nurses training center
- Laundry factory
- Kindergarten
- Conference center
- Restaurants
- Migrant center
- Agricultural farm
- High school College
- Residential area

2.2.3.2 Site Data

The Belle-Idée site comprises :

- 38 acres
- 30 km/h zone
- Open to the public
- Access via automated barriers
- Labyrinth of small and narrow roads
- Six parking areas
- One roundabout
- 24 buildings
- Great number of trees and vegetation
- Fixed bus lines through main axe
- Mixed traffic from bicycles to large trucks
- No specific pedestrian zones or sidewalks

2.2.3.3 Boundaries

Figure 24: Belle-Idée Bounderies Map

2.2.3.4 Land plots

The Belle-Idée site comprises six 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 6: Belle-Idée Land Plots

2.2.3.5 Current public transport status

Figure 25: 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-Reception
Bus stop 4.	Belle-Idée-Centre
Bus stop 5.	Hôpital Trois-Chêne

Table 7: Belle-Idée Current TPG Bus stops

2.2.3.6 Future situation

Belle-Terre, a new residential area next to Belle-Idée is under construction.

- Foreseen residential area with 2.400 new apartments (670 available from 2021)
- Main Bus line n° 1 could be displaced from the Belle-Idée estate to this new area.

Figure 26: Belle-Idée Belle-Terre Residential Area

Figure 27: Belle-Idée Belle-Terre Residential Area Map

2.2.3.7 AVENUE solution

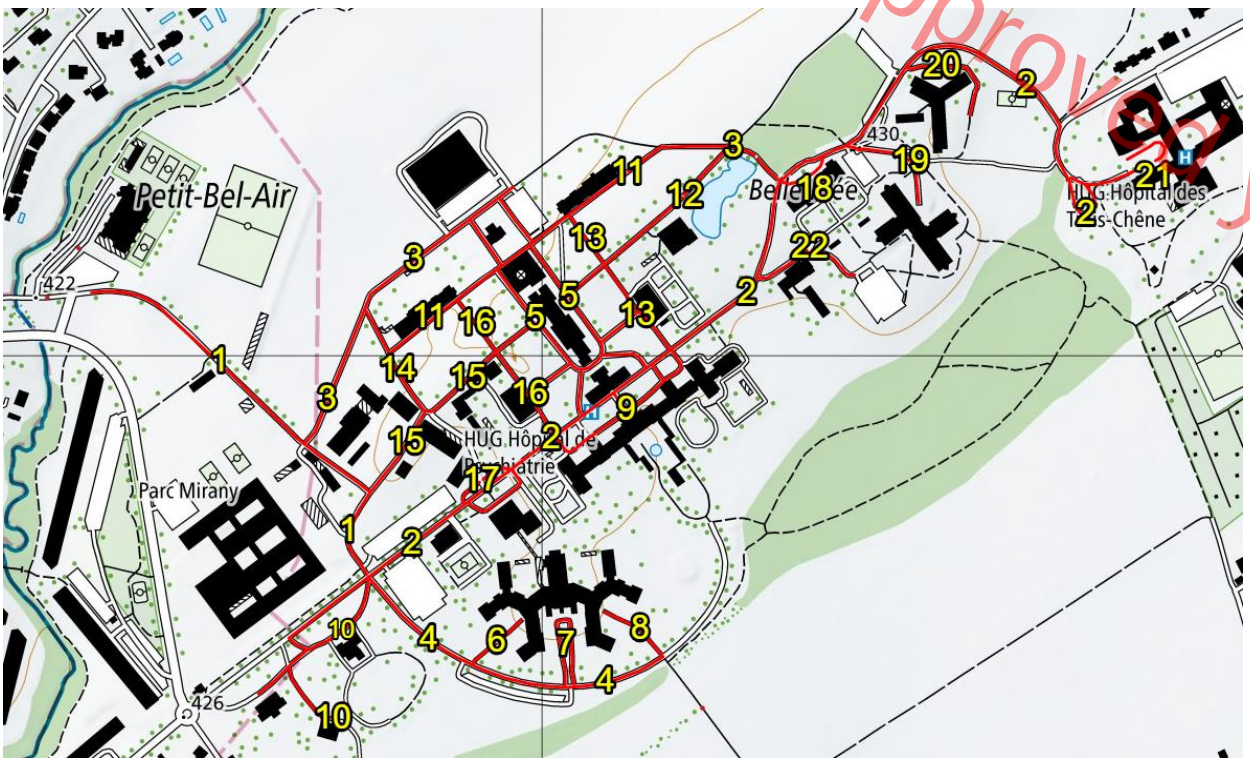


Figure 28: Belle-Idée On Demand Routes Map

AVENUE - on demand dispatching

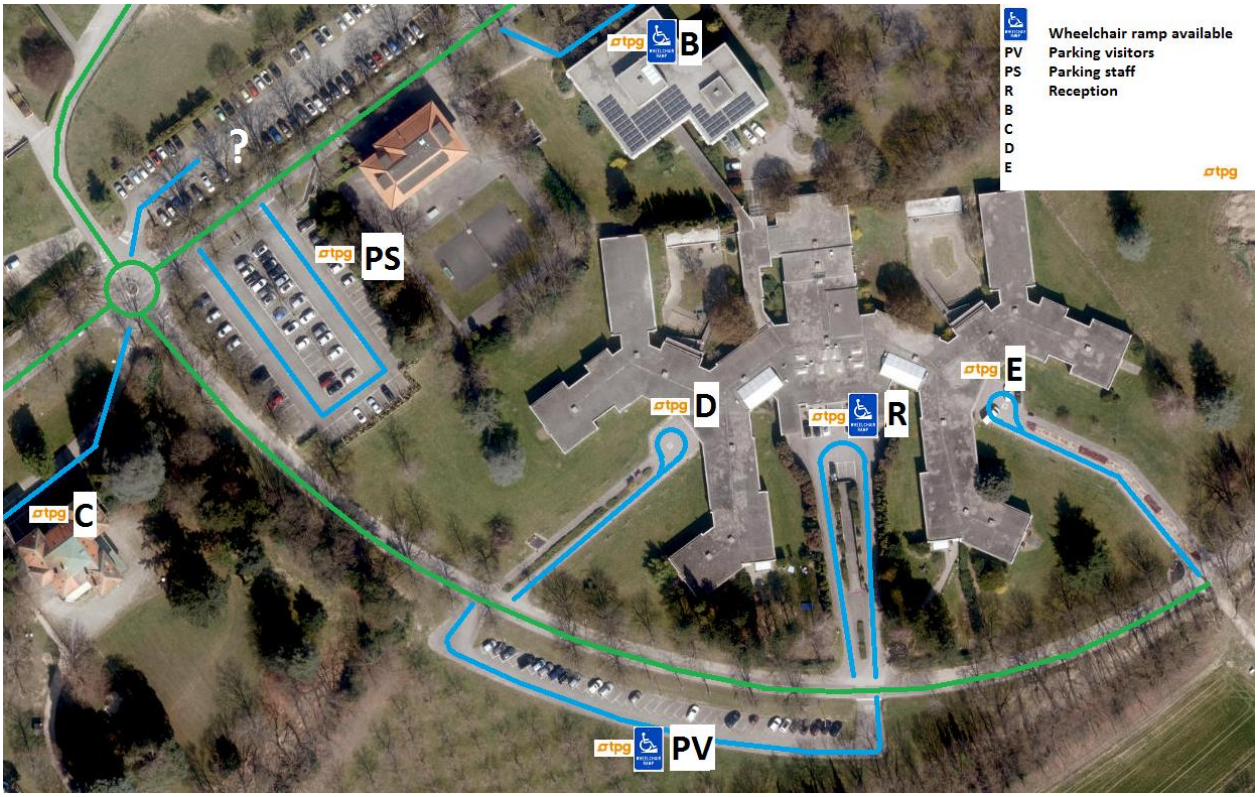


Figure 29: Belle-Idée On Demand How To

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

2.2.3.8 Bus stops

70 out of 75 stop points are only technically defined in the system, without any infrastructure such as a ZigZag on the ground or a pole with travel information. The other five are regular bus stops.

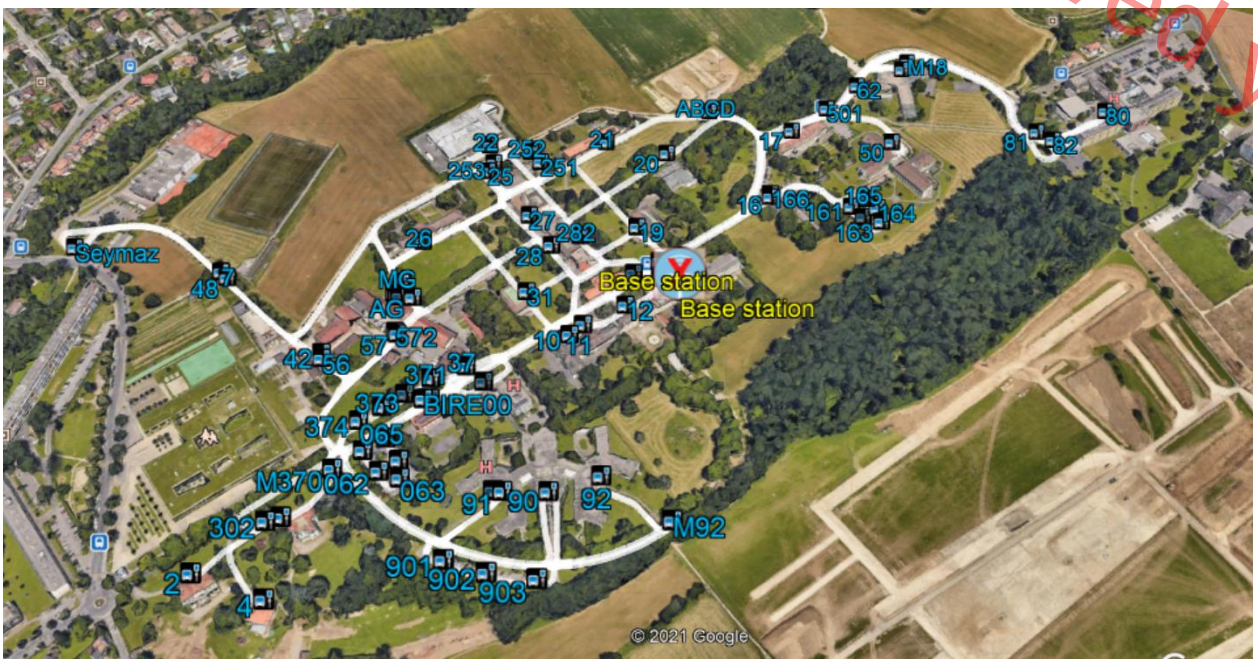


Figure 30: Belle-Idée 75 Stop points

2.2.3.9 Bus stop identification

See appendix B

2.2.3.10 Vehicle depot

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

Figure 31: Belle-Idée Vehicle Depot Location

Figure 32: Belle-Idée Vehicle depot with portable office space

Figure 33: Belle-Idée Vehicle depot three Phases 32 Amp Connector

2.2.3.11 GNSS base antenna

The antenna is be placed on the highest centrally located building on site.

Figure 34: Belle-Idée GNSS base Antenna

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 GNSS base station to improve GPS locations calculated by a GPS receiver in the vehicle. The GNSS 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 GNSS base station to the Shuttle in real time. This is done via radio signals as well as 3/4G connectivity.

The GNSS base antenna is located on a 3 story building in the centre of the Belle-Idée estate.

2.2.3.12 Supervision

Supervision section from our portable office space inside the vehicle depot.

Figure 35: Belle-Idée on site Supervision Office

Figure 36: Belle-Idée Bestmile Supervision Dashboard

2.2.3.13 Safety operator room

A safety operator section has also been created inside the portable office space. Safety operators start their service on site and vehicle preparation at the begin and the end of service is measured at six minutes. Since the depot is centrally located in the operating zone, there is no deadheading.

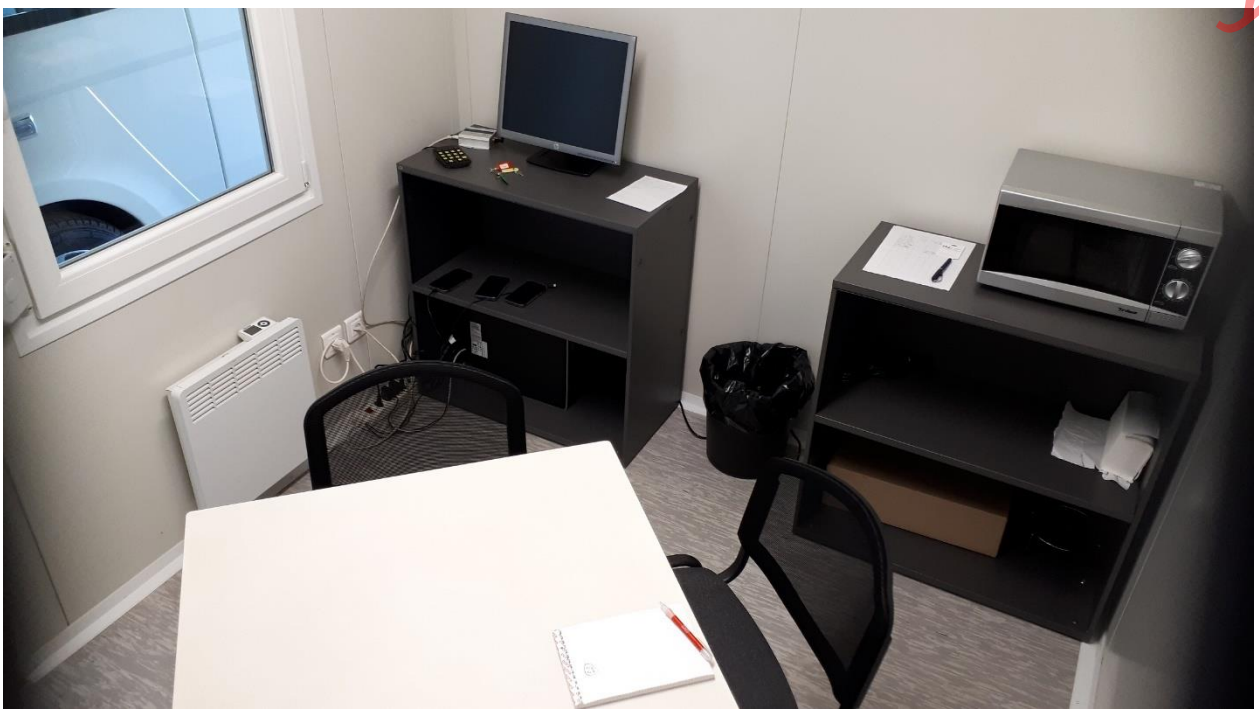
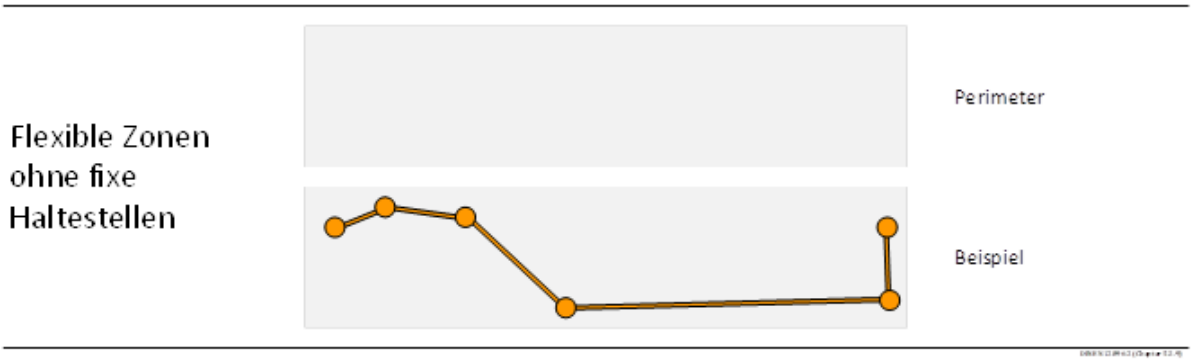


Figure 37: Belle-Idée Safety Operators Room

2.2.4 Operations



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

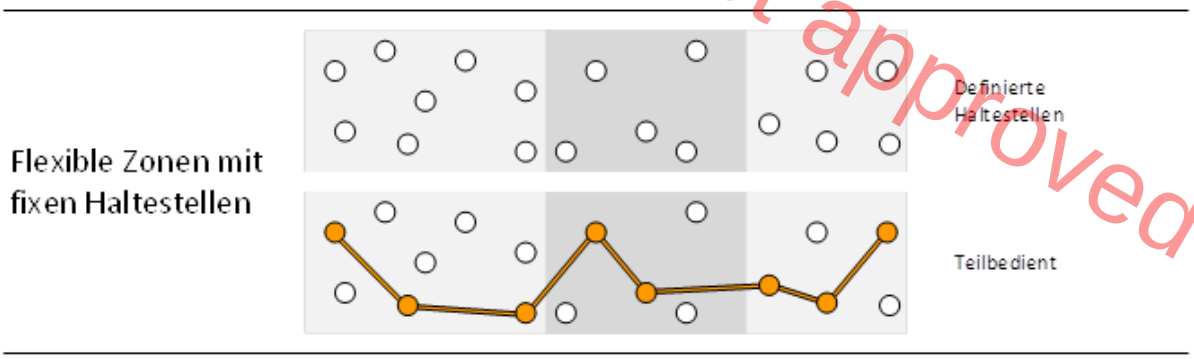


Figure 38: Belle-Idée On Demand Operations

2.2.4.1 Timetable

We will assure a seven days a week service from 06:00 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. Future operating hours may be adjusted according to passenger demand.

2.2.4.1.1 Monday-Friday

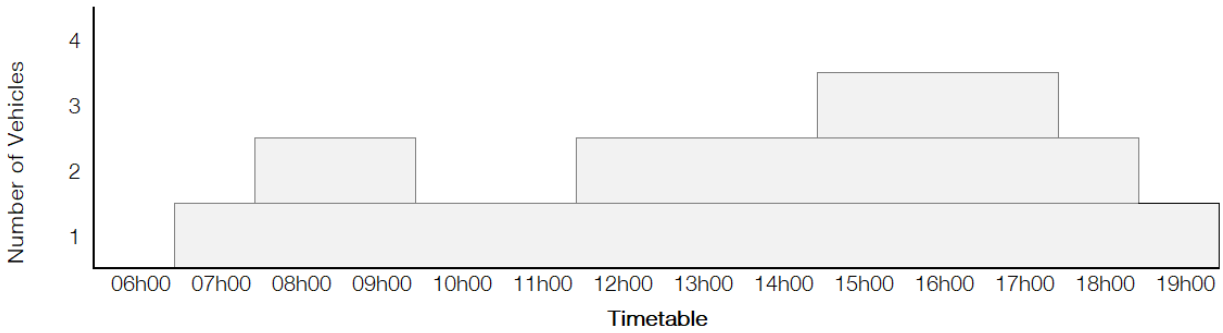


Figure 39: Belle-Idée Timetable weekdays

2.2.4.1.2 Weekend and holidays

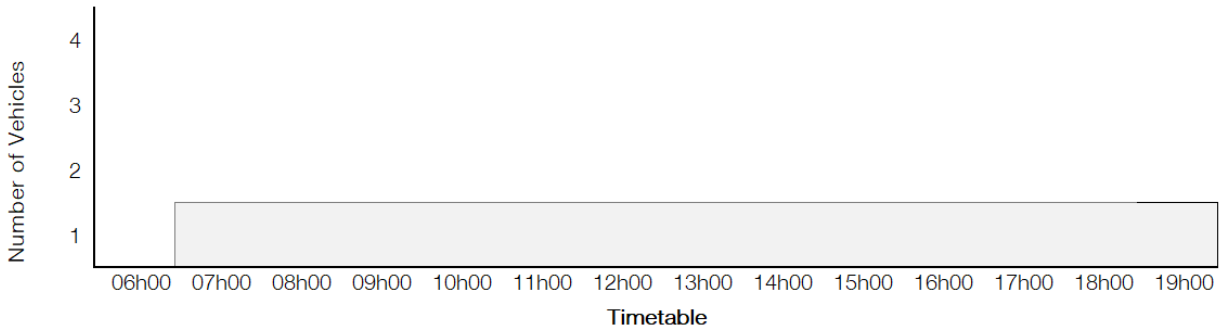


Figure 40: Belle-Idée Timetable weekends

2.2.5 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.

2.2.5.1 Client Application

Examples of the application as developed by MobileThinking.

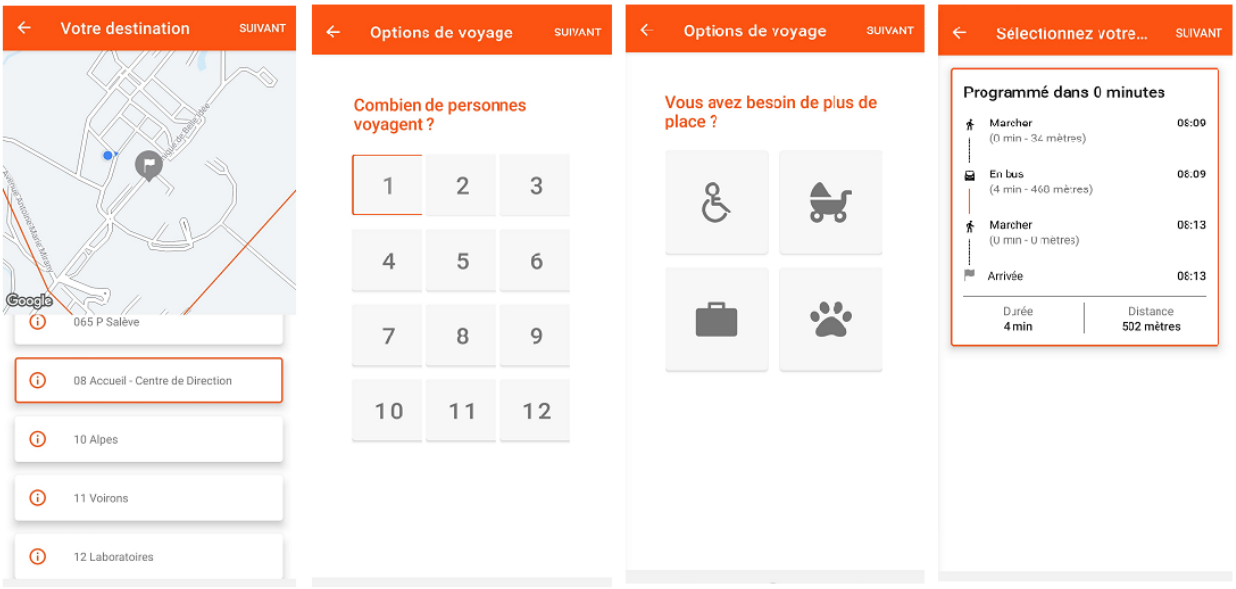


Figure 41: Belle-Idée Mobilethinking On-Demand Application

2.2.5.2 Vehicle dispatching

An in-depth description of Bestmile's automated fleet orchestration platforms IT architecture can be found in WP5 – D5.3

The vehicle booking and orchestration system dataflow diagram from manual to full automation can be found below.

Q4 – 2020 Manual mode

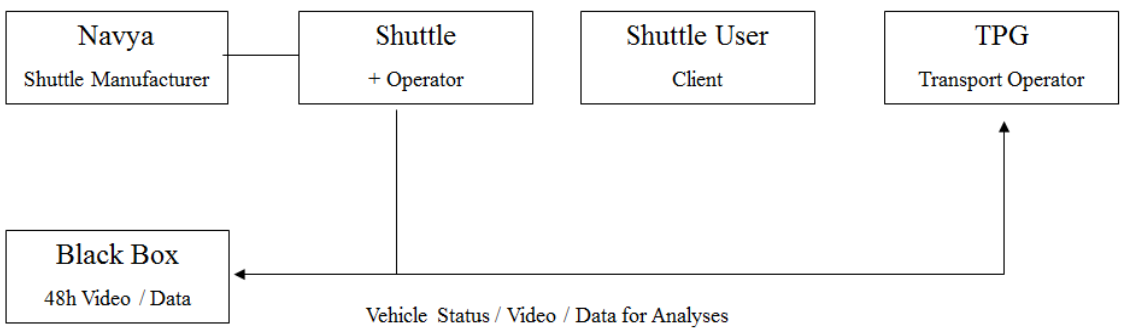


Figure 42: Belle-Idée On Demand Dispatching with safety operator interference

2021 – Introducing automation

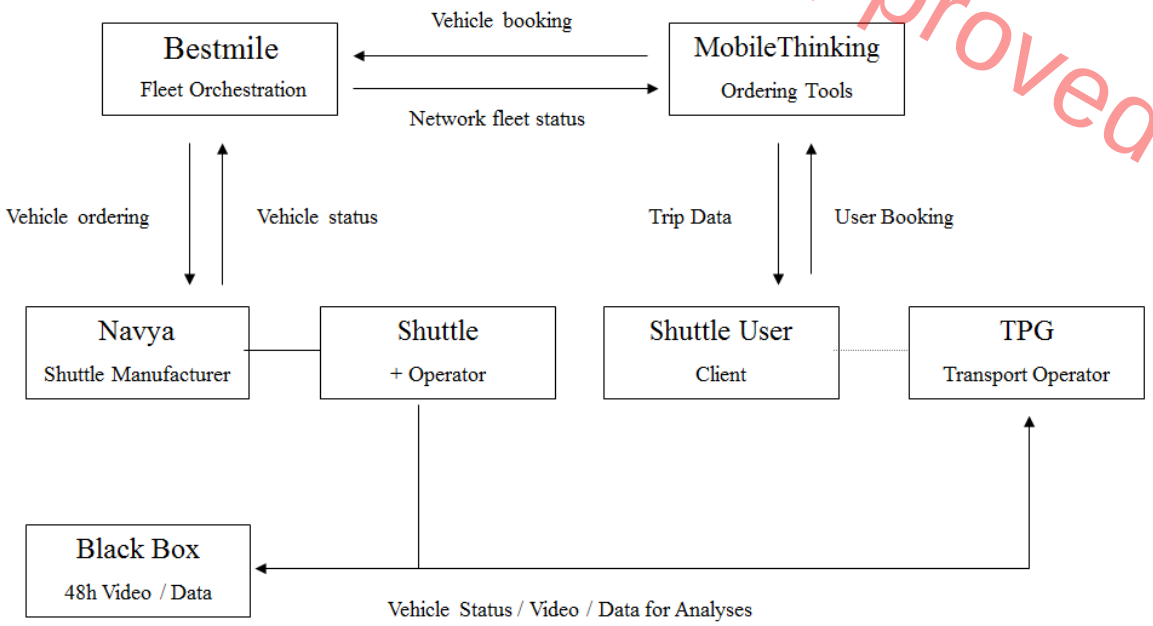


Figure 43: Belle-Idée On Demand Dispatching towards 100% automation

2021-2022 – 100% Automation without safety operator and with connections to external data sources

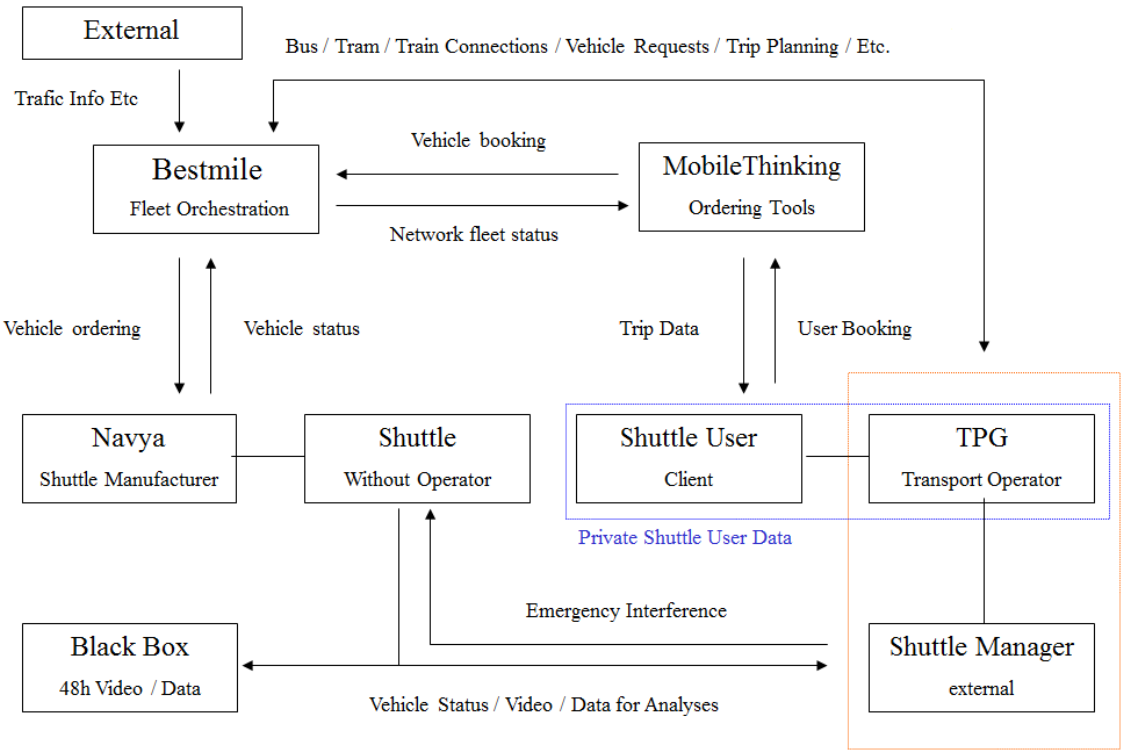


Figure 44: Belle-Idée On Demand Dispatching full automation

2.2.5.1 Vehicle Identification

On-demand vehicles don't operate on a predefined route and destination is always different. In order for passengers to be able to identify the vehicle they booked, we attributed them the letters H, U and G in the stretch in front of the vehicle.

Figure 45: Belle-Idée Vehicle identification stretch

Figure 46: Belle-Idée Vehicle identification

2.2.6 Traveller information

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

Figure 47: Belle-Idée Traveller Information

2.2.7 Reporting

2.2.7.1 Safety operator

Safety operators have to report back their findings and interventions during testing. Below, safety operator feedback on vehicle obstruction due to trees and other greenery.

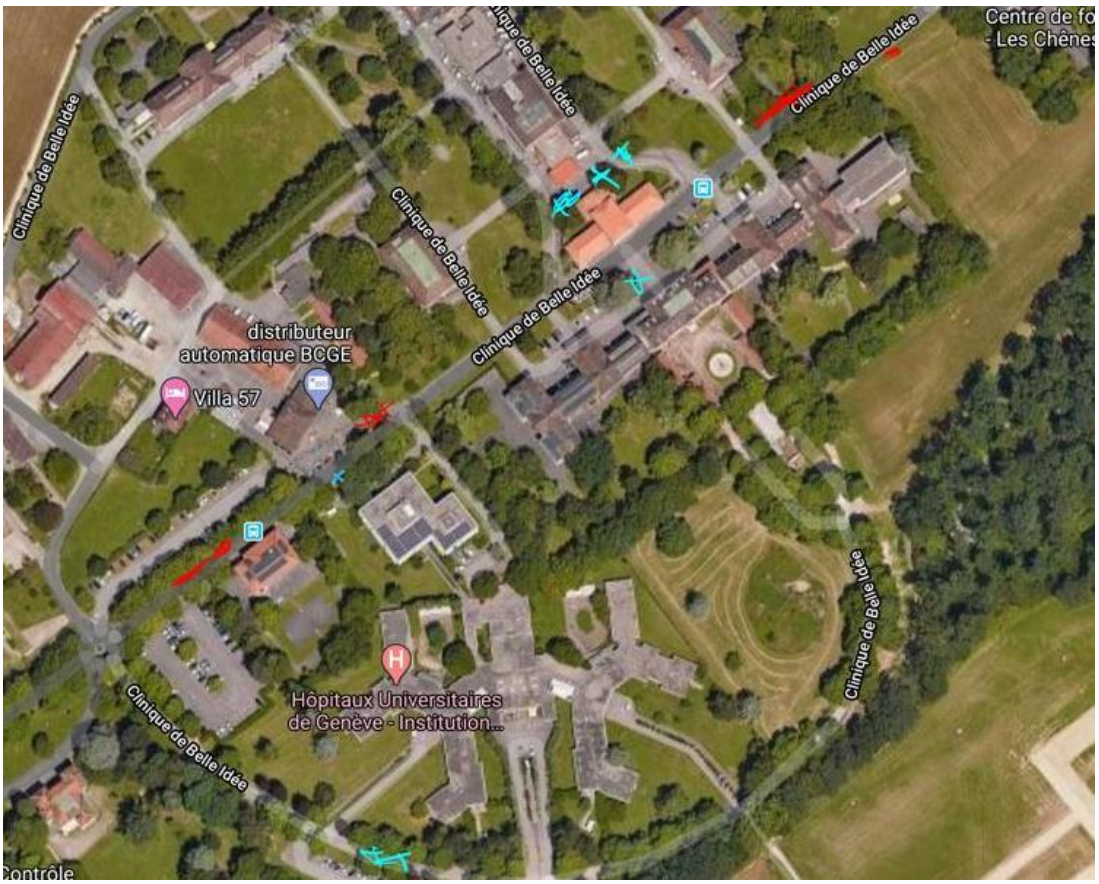


Figure 48: Belle-Idée Safety operator reporting

2.2.7.2 Clients

Within the framework of the Avenue project it is scheduled in WP8 to carry out a survey among passengers who use the fully automated mobility service.

2.2.7.3 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.

These reports are available in French on the website of the Swiss Federal Transport Office – FEDRO:

[Belle-Idée Fedro Intermediate report June-December 2020 (*pdf in French)]

2.2.8 Deployment

Due to the complexity and large amount of work, a deployment period of between six and nine months has been scheduled from receiving the authorisation until the start of operations. The following work has been accomplished. The initial planning was delayed mostly due to the sanitary situation around Covid-19.

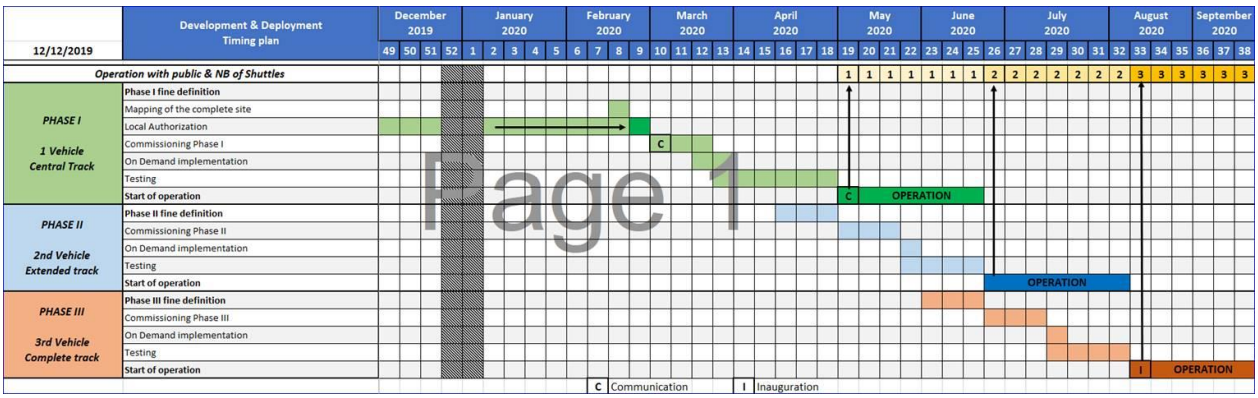


Figure 49: Belle-Idee Deployment Phase I

2.2.8.1 Pre-preparations

Between May 2018 and November 2020

- Convention EU-TPG projet Avenue
- Convention HUG-TPG
- Pre site study Navya
- Authorities approval
- Establish contacts with HUG units
- Preparations vehicle depot
- Installation of a portable office space
- Installation of the GNSS base station
- Mapping of the site
- Site pruning

2.2.8.2 Phase I

Between July and September 2020

- Mapping of the entire Belle-Idée site (summer map)
- Deployment of one vehicle on 45% of all available roads
- Creation of 27 stop points, four existing TPG bus stops and 23 virtual stop points
- First tests with a safety operator and without passengers
- Training of safety operators

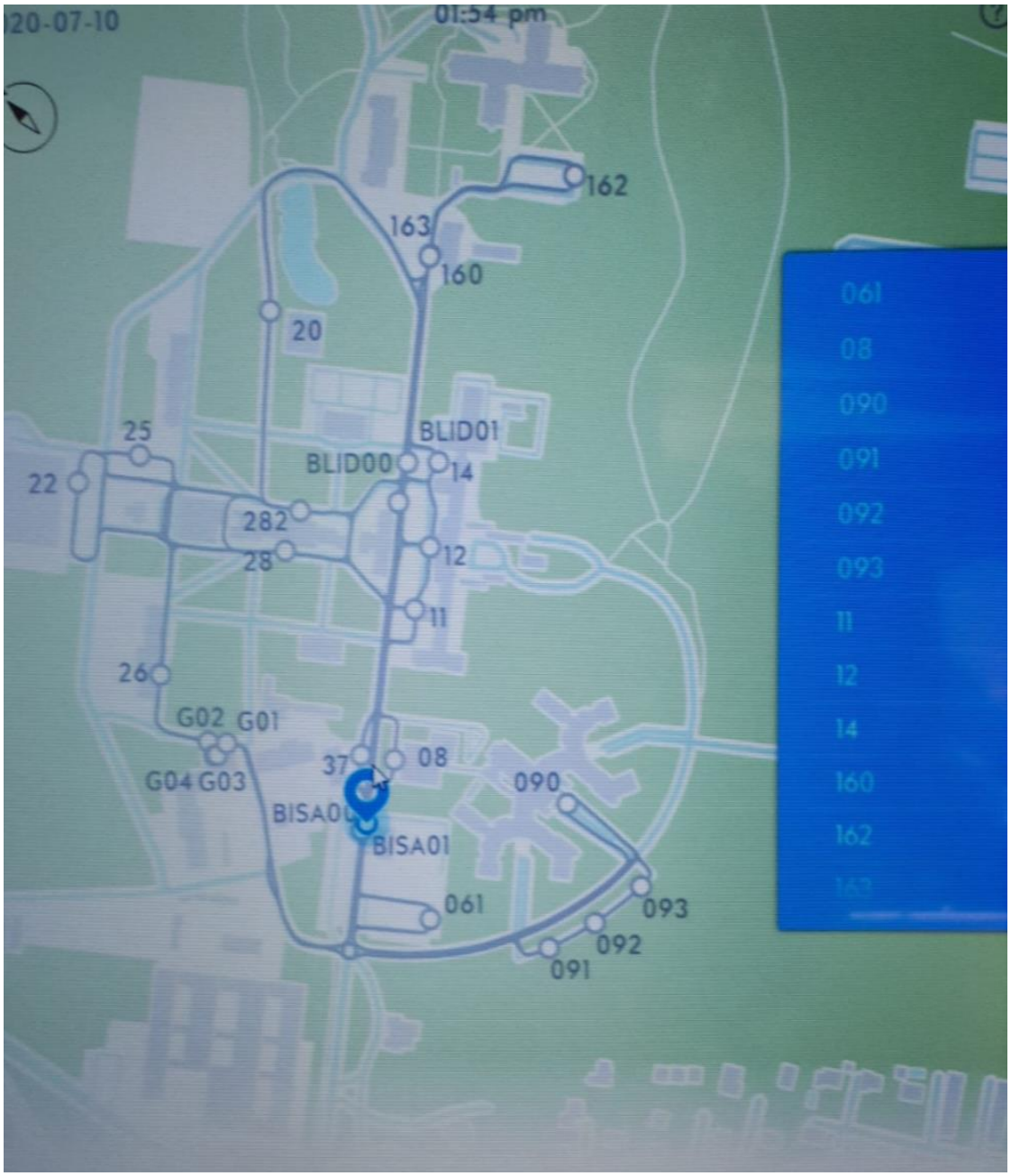


Figure 50: Belle-Idee Deployment Phase I

2.2.8.3 Phase II

Between October and December 2020

- Deployment/update of two vehicles on 70% of all available roads
- Creation/update of 53 stop points, four existing TPG bus stops and 49 virtual stop points
- Vehicle testing with a safety operator and without passengers
- First "fully automated on-demand system" testing
- First software release 6.0 test
- Training of safety operators

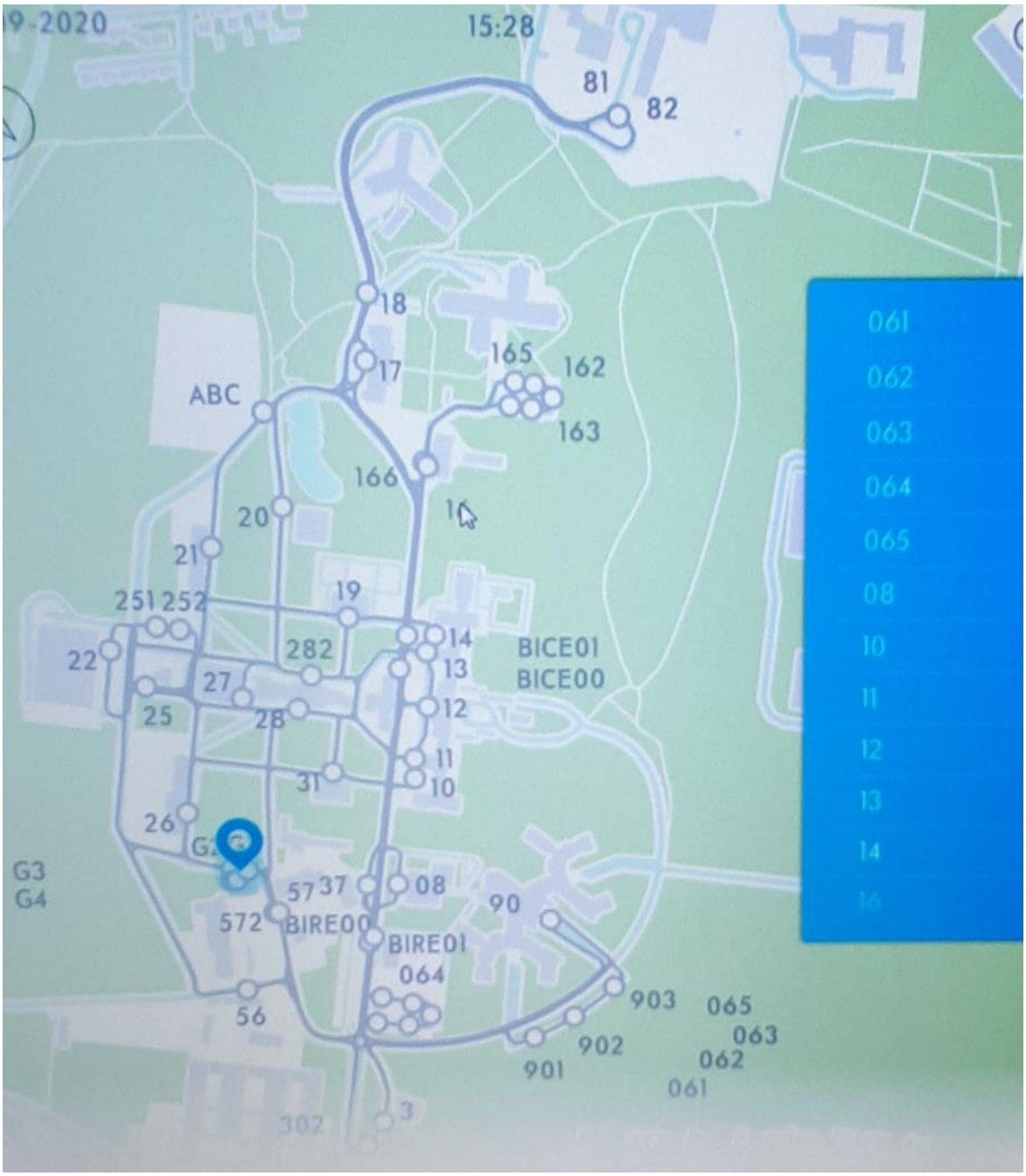


Figure 51: Belle-Idee Deployment Phase II

2.2.8.4 Phase III

Between January and March 2021

- Mapping of the entire Belle-Idée site (winter map)
- Deployment/update of three vehicles on 99% of all possible roads
- Tracing of a route to the TPG Seymaz bus stop outside the domain
- Creation/update of 75 stop points, five existing TPG bus stops and 70 virtual stop points
- Installation of software update 6.01 which enables better road holding and easier on-demand
- Fully automatic depot entrance and exit of vehicles
- Vehicle testing with a safety operator and without passengers
- On-demand system testing with application booking, 100% automated
- Training of safety operators

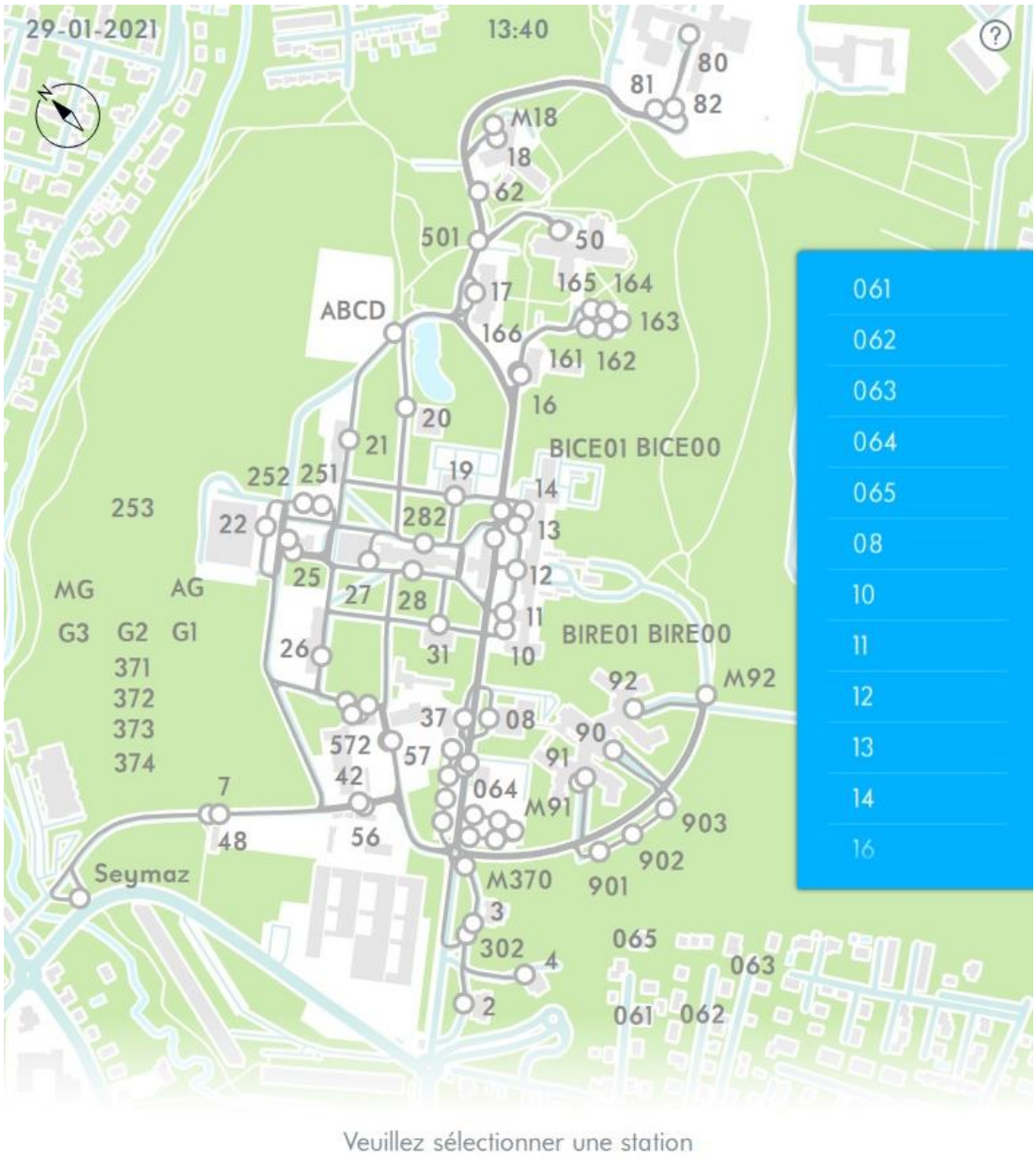


Figure 52: Belle-Idee Deployment Phase III

2.2.8.5 First passenger

We are awaiting the installation of software release 6.1 at the end of April 2021. It is expected to be able to welcome the first passenger when test results of this software release are good and validated.

2.2.9 Evaluation

During the deployment phases, every safety operator drove numerous kilometres on site in order to test and identify issues as well to get acquainted with the overall traffic situations. First trained and accompanied by the automated vehicle assistant/trainer. We encountered the following issues during these tests:

2.2.9.1 Operations related

Operations have not been started yet.

2.2.9.2 Vehicle related

We experienced some minor technical and IT related issues which could be resolved at distance or via a swift on site venue of a Navya intervention team.

2.2.9.3 Infrastructure related

Greenery and trees are well existing on site, which makes it necessary for the gardeners to frequently intervene. Also, heavy rain drops falling on the Tim (sensor) sometimes make the vehicle believe there's an obstacle.

2.2.9.4 Safety operator related

Instead of starting their duty in one of the three main TPG depots in Geneva, the safety operators have to travel to the Belle-Idée site. This seems inconvenient for some of them.

2.2.9.5 Covid-19 related

A maximum number of four people including the safety operator are allowed to enter the vehicle all wearing a face mask.

The Covid-19 glass separation inside the vehicle is still not approved by the authorities.

2.2.9.6 Other issues

Obstacles

The only issue which keeps us from driving 100% fully automated are obstacles, such as wrongly parked cars, which the vehicle cannot (yet) bypass. When the vehicle detects a standing object it will stop driving until the object has been removed. When it concerns an object moving in the same direction as the vehicle , the vehicle will adapt its speed and follow the object from a distance. When an object is moving in another direction as the vehicle, the vehicle comes to a halt, waits for the object to go out of the way, and when the road is free, starts driving again.

nIoVe

TPG is also partner in the EU funded nIoVe project regarding fully automated vehicles and cybersecurity. Unfortunately, the permanent installation of hardware inside the vehicles to make tests requires a new approval from the Swiss authorities.

2.2.10 Recommendations

SAE Level 4+ for public transport

The development of fully automated vehicles is going slower than expected and previously announced by the bigger car manufacturers. The highest amount of achievements available on the market today in terms of automated driving can be divided in two use cases:

- SAE Level 3/4 automated high way lane and traffic jam driving, the advanced driver assistance
- SAE Level 4 fully automated driving on a pre-programmed virtual route at very low speeds

Hence, it all comes down to driving speeds and difficulty of driving conditions. SAE Level 5 fully automated driving as well as SAE Level 4 pre-programmed automated driving at speeds exceeding 30 km/h is impossible today and will probably not be commercially available before 2030.

This, however, doesn't mean that we need to stop the development and testing of fully automated vehicles. With regards to public transport operators there is an important use case being created on a political level.

Thermic powered vehicles are banned from city hyper centres, parking places removed and speed limits reduced to 30 and even 20 km/h. Fully automated on-demand public transport minibuses, in combination with the existing main axes of bus, metro and tram lines, could be the solution for the gap this creates in terms of mobility.

As public transport operators, we know exactly on which roads we want to drive and where to stop. Hence, if we trace the routes and configure stop points we do not need advanced automated vehicles capable of driving in SAE Level 5 modus.

Also, public transport is not a taxi service. Public transport needs to be the cheapest way of non-human powered travel. Maybe, we first have to define fully automated mobility service levels, f.e.

Public transport fixed line or predefined geofenced zone local transport with predetermined stop points either with or without infrastructure. On-demand transport possible, ride pooling options mandatory.

Shared autonomy long and short distance shared or private transport by non-privately owned vehicles, able to drive and stop everywhere.

Owned autonomy private transport by a privately owned vehicle. 100% control on mobility requirements.

However, it isn't economically feasible for public transport companies to equip every fully automated vehicle with a legally required safety operator. Removing the safety operator is defined as SAE Level 5. The interim solution is to create an extra SAE Level, between Level 4 and 5, for public transport only which aligns with the following requirements:

- 30 km/h speed limit
- Pre-programmed virtual line driving
- Without a safety operator
- Supervision at near distance

The creation of such a "**SAE Level 4+ for public transport"** or SAE Level 4.5, hence between SAE Level 4 and 5, has already been proposed by the Association of German Transport Companies – VDV – in 2020

Automatisierungs-Level	Stufe 0	Stufe 1	Stufe 2	Stufe 3	Stufe 4	Stufe 4 ÖV	Stufe 5
Stufenbeschreibung	**alleine der Fahrer**	**assistiert**	**teilautomatisiert**	**hochautomatisiert**	**vollautomatisiert**	**fahrerlos im spezifischen ÖV-Anwendungsfall**	**fahrerlos**
technische Fahreraufgaben	Fahrer führt dauerhaft längs- **und** Querführung aus	Fahrer führt dauerhaft längs- **oder** Querführung aus	Fahrer muss das System dauerhaft überwachen	Fahrer muss das System dauerhaft nicht mehr dauerhaft überwachen aber potentiell übernehmen.	Kein Fahrer erforderlich im spezifischen Anwendungsfall (bsp. Autobahn-Pilot, Staupilot, einparken)	Kein Fahrer im Fahrzeug im **ÖV-Betrieb auf spezifischer Linie oder im spezifischen Bedienungsgebiet** anwesend	Von **„Start" bis „Ziel"** ist kein Fahrer erforderlich
technische Systemaufgaben	Kein eingreifendes Fahrzeugsystem aktiv	System übernimmt die jeweils andere Funktion	System übernimmt Längs- und Querführung in einem spezifischen Anwendungsfall	System übernimmt Längs- und Querführung im spezifischen Anwendungsfall. System erkennt Grenzen und fordert mit Zeitreserve zur Übernahme auf.	System **kann im spezifischen Anwendungsfall** alle Situationen automatisch bewältigen	System **kann** im ÖV-Betrieb auf spezifischer Linie oder im spezifischen Bedienungsgebiet dynamische Fahraufgabe automatisch bewältigen und wird durch Leitstelle **fakultativ** unterstützt	Das System übernimmt die Fahraufgabe vollumfänglich bei allen Straßentypen, Geschwindigkeitsbereichen und Umfeldbedingungen.

Abbildung 1: Die Stufen der Automatisierung mit der zusätzlichen Stufe 4 ÖV, anlehnend an SAE eigene Darstellung, VDV (2020)

Figure 53: Belle-Idee SAE Level 4+ for public transport recommendation

This enables public transport operators to offer a mobility solution in a predefined service area by using fully automated vehicles capable of offering passengers a made to measure transport service.

The key elements of future public transport are electric, on-demand and fully automated.

2.2.11 Future developments

The following Belle-Idée post Avenue extensions can be considered:

Add routes and different transport hubs

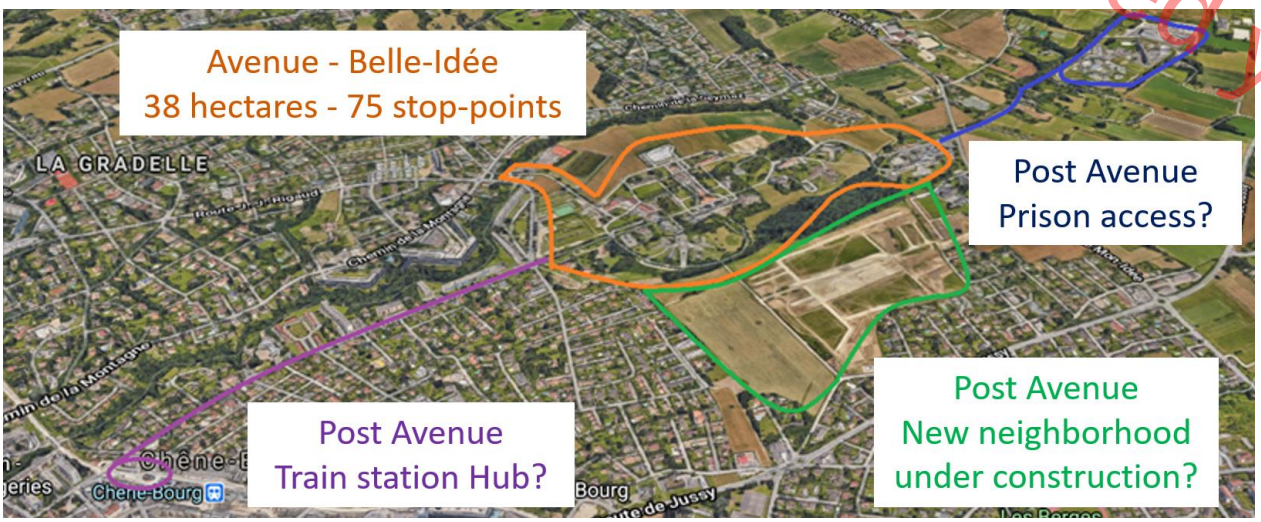


Figure 54: Belle-Idee Adding routes post Avenue

Add more and different vehicles to the existing fleet

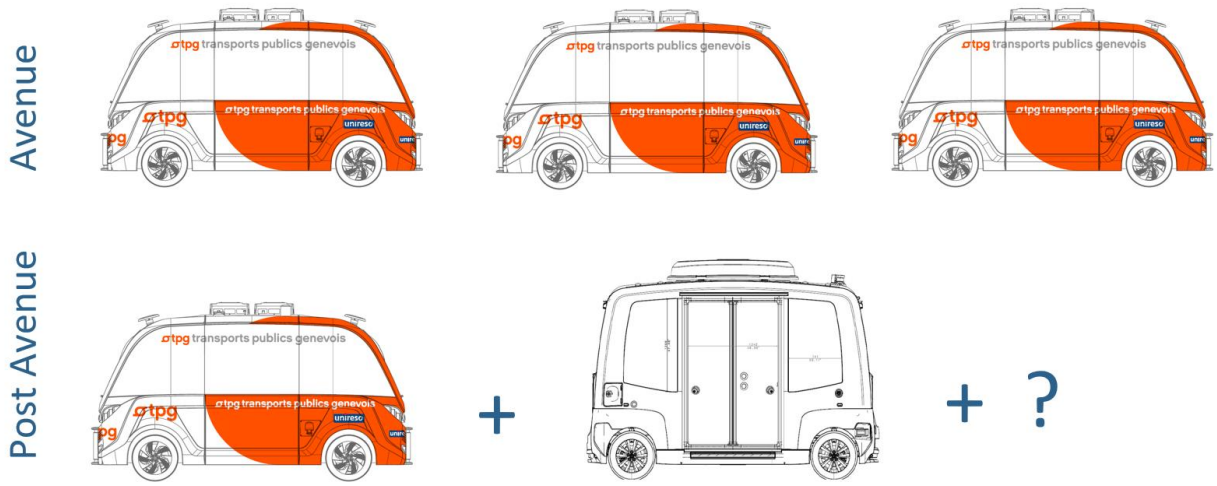


Figure 55: Belle-Idee Adding vehicles post Avenue

3 Project homologation

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

3.1 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 8: Homologation - Authorities

3.2 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 a fully automated 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.

If any changes are to be made in or on the vehicle, new tests may apply. The installation of a Covid-19 separator inside the vehicle or an induction charging system under the vehicle requires new testing.

3.3 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 fully automated vehicle projects.

3.3.1 Concessions

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

3.3.1.1 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'.

3.3.1.2 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'.

The Belle-Idée site required an application for a geofenced area concession with virtual bus stops.

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.

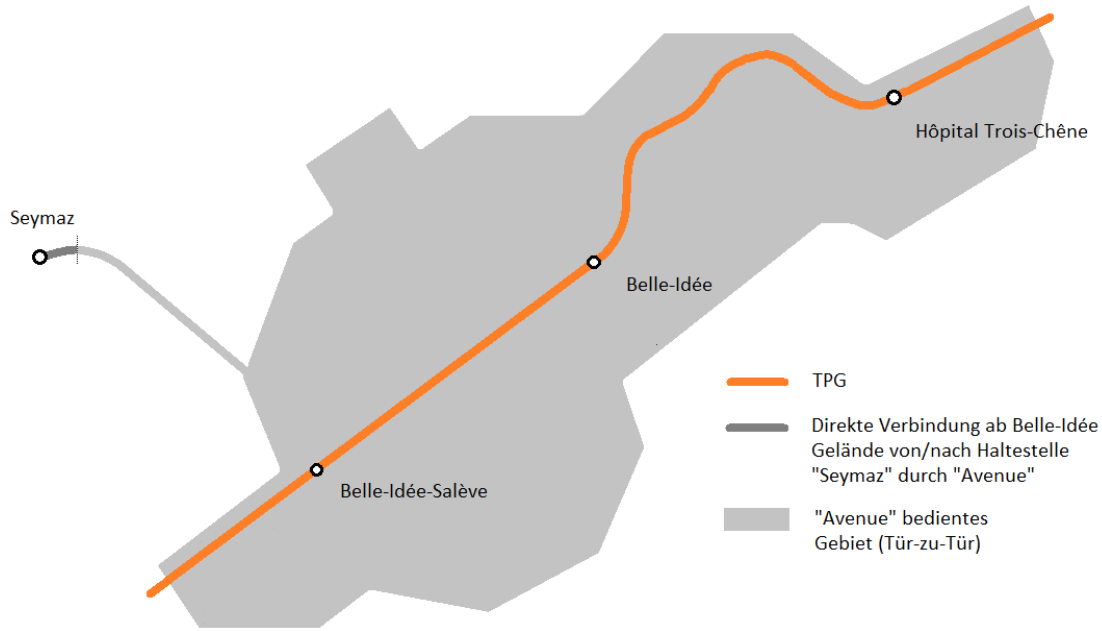


Figure 56: Homologation Belle-Idée Transport Concession

3.3.2 Application

3.3.2.1 Timetable

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 9: Homologation Application Data

3.3.2.2 Costs

Vehicle

The brake and electrical components tests are carried-out by specialized firms which is rather expensive.

A small administrative fee applies regarding the homologation of the vehicles by the Swiss Federal Office of Transport.

Test site

The cost of the Federal approval and all concessions together is less than 8’000 Swiss Francs. The duration of the approval is limited to two years or in case of Belle-Idée, three years.

4 Vehicles

Before being partner within the EU funded AVENUE project, the TPG already started to test a fully automated 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 10: Vehicle Manufacturers

After discussions with both French manufacturers, the TPG opted for a Navya Arma-DL4 for their first fully automated 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.

4.1 TPG

The TPG currently disposes of four vehicles homologated to transport a safety operator 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	Out of Use	TPG
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	TPG

Table 11: Vehicles TPG Fleet

4.2 Technical data

See appendix A

4.3 Options

4.3.1 General

- Air conditioning

4.3.2 Seat-belts

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

4.3.3 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 operator 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 fully automated

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.

4.4 Covering

4.4.1 Transport Publics Genevois (TPG)

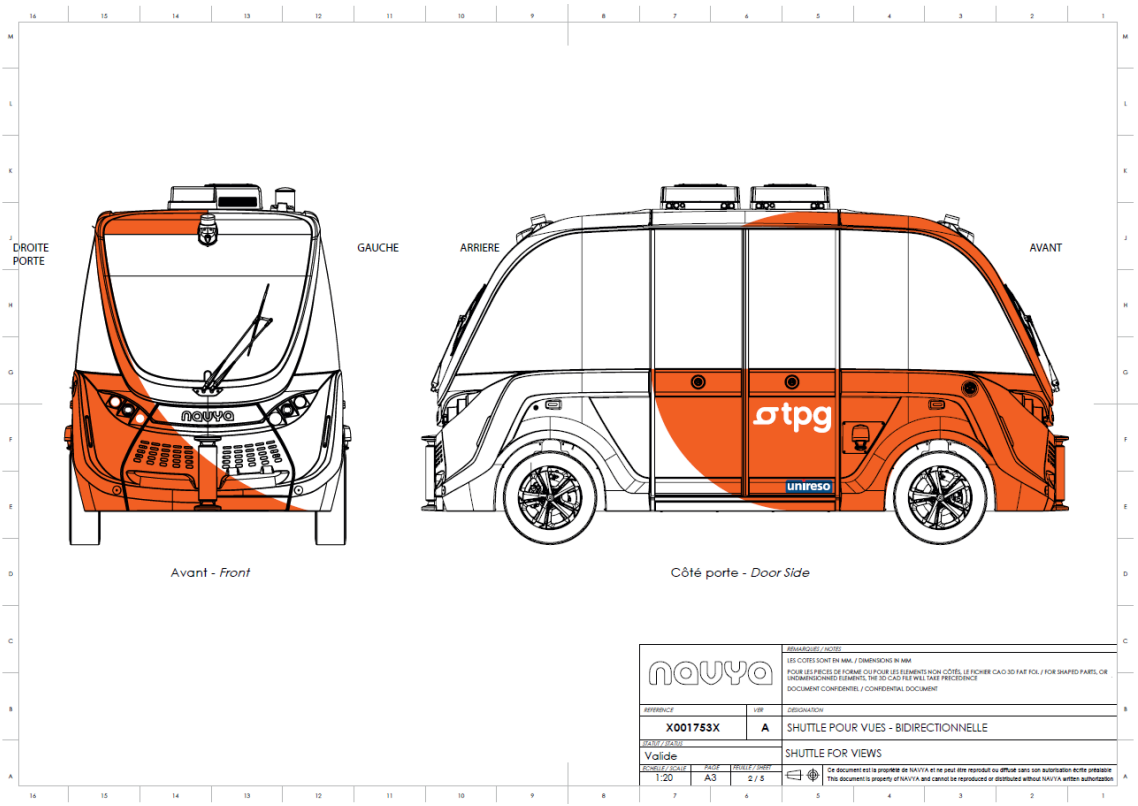


Figure 57: Vehicle covering TPG colors

4.4.2 AVENUE EU Logo

Vehicles within the AVENUE framework and funded by the EU are equipped with an AVENUE project disclaimer in French and/or English in front, at the back, on the doors and inside the vehicle.

4.4.2.1 French

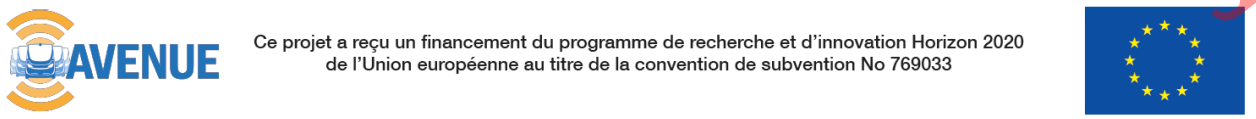


Figure 58: Vehicle covering EU Logo French

4.4.2.2 English

Figure 59: Vehicle covering EU Logo English

4.4.2.3 On vehicle example

Figure 60: Vehicle covering EU Logo in Front/Back

Figure 61: Vehicle covering EU Logo Doors

Figure 62: Vehicle covering EU Logo Inside

4.5 Vehicle inspection

As with all vehicles used for public transport, the fully automated 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.

RAG Data logger

The RAG is tested at the same time as well. The RAG data loggers are an unquestionable means of proof in the event of a traffic accident. They record the data of a trip based on the vehicle's movement impulses and different states.

4.6 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.

4.7 Supervision

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

5 Personnel

5.1 Supervisor

The automated vehicle assistant/trainer supervises the operations, either from within the mobile office or directly on site.

5.2 Safety operator

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

Name	Expert	Operator	Super Operator	Tech Operator	Trainer
Beaud Grégory		X			
Bentaïba Ilyes		X			
Beukers Jeroen	X	X	X		
De Freitas Bruno		X			
Deville Jacques		X			
Di Stefano Michael		X			
Fazlic Melisa	X	X	X		X
Felicio Marco		X			
Ferreras Felipe		X			
Hertrich Jérôme		X			
Kilic Sabahudin		X			
Launay François		X			
Lenz Cyril		X			
Martins Carlos					
Pereira Correia Germano		X			
Planell Georges		X			
Raleche Mikaël		X			
Rizzo Tony		X			
Ruckebusch Stanislas	X	X	X		X
Soulé Bruno		X			
Sauge Jean	X			X	
Zoulalian Jean		X			

Table 12: Personnel Safety Operators

6 Planning

Belle-Idée

Who	Description	Schedule
Navya	Installation of software release 6.1	April 2021
Navya	Testing road holding vehicle	April 2021
Bestmile Mobilethinking Navya	Testing on-demand system	April 2021
Passenger	Welcome first passenger	April 2021

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 fully automated vehicles for public transport and it may not yet be considered a plug and play solution.

Public transport operators also need to well express their requirements in terms of mobility in order for companies such as Bestmile, Mobilethinking and Navya to be able to develop their product or service.

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

The following developments need to have the highest priority:

- **Technical**: be able to circumvent an object which blocks the way
- **Legal**: be able to operate a fully automated vehicle without a safety operator inside

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 and future mobility solutions, they are active in the fields of electric, on-demand and fully automated 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