Autonomous Vehicles to Evolve to a New Urban Experience

DELIVERABLE

D7.6

Lyon Large Scale Pilot Use Case Demonstration Report

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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)
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 Transportation Operator
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)
WP	Work Package
WPL	Work Package Leader

Executive Summary

Period 2 of the H2020 Avenue project enabled Keolis Lyon to finalize its preparatory work for the Groupama Stadium experiment, and thus launch the commercial service open to the public.

This phase demonstrated the capacity of autonomous vehicles to integrate into mixed and dense traffic in a peri-urban area, thus meeting a particularly interesting use case for the future of this new technology. To do this, Keolis Lyon and all the partners in the project confirmed the hypothesis that vehicles alone cannot solve all the problems we may encounter in a road with mixed and dense traffic. Thus, the development of communications between the autonomous shuttles and the traffic lights has been one of the major axes to allow the crossing of the most complex intersections.

This commercial launch also enabled the autonomous shuttles to be compared with the rest of the fleet of vehicles that make up Lyon's public transport network. Indeed, the theoretical timetables that were created for the autonomous shuttles had to allow for perfect integration into the Décines Grand Large multimodal exchange hub, where there is also a tramway line (T3) and several bus lines. The shuttles were designed to be interchanged with the other modes of transport, and thus offer a relevant service for passengers. However, we found it difficult to respect these timetables because of the many malfunctions that the Safety Drivers encounter throughout the day. The majority of these problems are known but recurrent, which delays the service and often prevents the theoretical timetables from being respected, thus penalizing the quality and relevance of the mobility offer.

In addition, Keolis' experience in the operation of public transport networks allows for an efficient relationship between the operating teams and the vehicle fleet maintenance teams. Thus, Keolis is autonomous when it comes to mechanical problems with buses, trams or metro systems, and we can therefore react quickly in the event of a malfunction in the equipment. However, in the case of autonomous vehicles, we do not have a large enough fleet of vehicles, nor the technical expertise necessary to maintain this responsiveness and autonomy.

The subject of operator autonomy is broader than maintenance. Indeed, at the moment, the level of involvement of NAVYA in the operation is too high to be accepted. In the future, both operators and transport authorities will not be able to accept a new transport system that they do not control, nor have access to the black boxes, nor the possibility of modifying the operating parameters (e.g. speed, braking, curves, etc.). This level of dependence cannot be achieved outside of an experiment

We knew that NAVYA and Keolis Lyon would need time to make the shuttles reliable. Unfortunately, the COVID-19 crisis has forced Keolis Lyon to suspend the operation of the shuttles, preventing NAVYA from continuing to address the identified problems and postponing technical interventions on the vehicles until after the service resumes in September 2020.

1 Introduction

AVENUE aims to design and carry out full-scale demonstrations of urban transport automation by deploying, for the first time worldwide, fleets of Automated minibuses in low to medium demand areas of 4 European demonstrator cities (Geneva, Lyon, Copenhagen and Luxembourg) and 2 to 3 replicator cities. The AVENUE vision for future public transport in urban and suburban areas, is that Automated vehicles will ensure safe, rapid, economic, sustainable and personalised transport of passengers. AVENUE introduces disruptive public transportation paradigms on the basis of on-demand, door-to-door services, aiming to set up a new model of public transportation, by revisiting the offered public transportation services, and aiming to suppress prescheduled fixed bus itineraries.

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

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

1.1 On-demand Mobility

Public transportation is a key element of a region's economic development and the quality of life of its citizens.

Governments around the world are defining strategies for the development of efficient public transport based on different criteria of importance to their regions, such as topography, citizens' needs, social and economic barriers, environmental concerns and historical development. However, new technologies, modes of transport and services are appearing, which seem very promising to the support of regional strategies for the development of public transport.

On-demand transport is a public transport service that only works when a reservation has been recorded and will be a relevant solution where the demand for transport is diffuse and regular transport is inefficient.

On-demand transport differs from other public transport services in that vehicles do not follow a fixed route and do not use a predefined timetable. Unlike taxis, on-demand public transport is usually also not individual. An operator or an automated system takes care of the booking, planning and organization.

It is recognized that the use and integration of on-demand Automated vehicles has the potential to significantly improve services and provide solutions to many of the problems encountered today in the development of sustainable and efficient public transport.

1.2 Fully Automated Vehicles

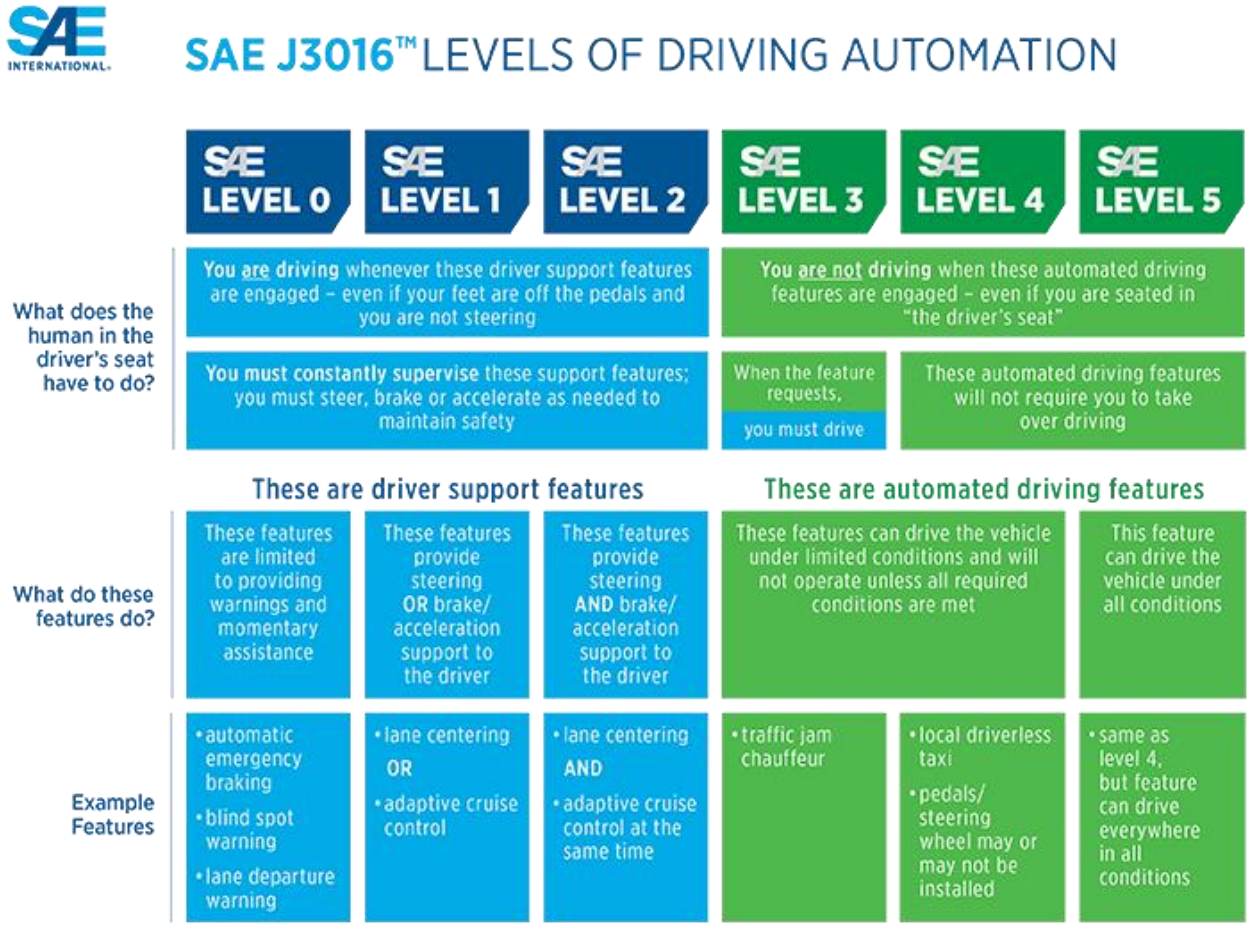
A self-driving car, referred in the AVENUE project as **a Fully Automated Vehicle** (**AV**), also referred as Autonomous Vehicle, is a vehicle that is capable of sensing its environment and moving safely with no human input.

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

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

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

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



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 must be able to evolve to a speed between 30 and 40 km/h. However this speed cannot be used in the project demonstrators at the time for several reasons, ranging from regulatory to safety. Under current regulations the maximum authorised speed is 25 or 30 Km/h (depending on the site). In the current demonstrators the speed does not exceed 23 Km/h, with an operational speed of 14 to 18 Km/h. Another, more important reason for limiting the vehicle speed is safety for passengers and pedestrians. Due to the fact that the current LIDAR has a range of 100m and the obstacle identification is done for objects no further than 40 meters, and considering that the vehicle must safely stop in case of an obstacle on the road (which will be “seen” at less than 40 meters distance) we cannot guarantee a safe braking if the speed is more than 25 Km/h. Note that technically the vehicle can make harsh break and stop with 40 meters in high speeds (40 -50 Km/h) but then the break would too harsh putting in risk the vehicle passengers. The project is working in finding an optimal point between passenger and pedestrian safety.

Due to legal requirements a **Safety Operator** must always be present in the vehicle, able to take control any moment. Additionally, at the control room, a **Supervisor** is present controlling the fleet operations. An **Intervention Team** is present in the deployment area ready to intervene in case of incident to any of the mini-busses.

1.3 Preamble

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 **T7.4** is to integrate autonomous vehicles into the existing public transport services. From day one of the project Keolis Lyon 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 **D7.6**, 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 Décines, France.

2 Keolis Lyon test sites

Within the AVENUE framework, Keolis Lyon runs one test site:

- Line N1 : Groupama stadium site, city of Décines, Grand Lyon Métropole

	N1
Community	Décines
Funding	Keolis Lyon + SYTRAL + H2020
Start date project	01.06.2018
Start date trial	15.11.2019
Type of route	Fixed route (A←→B)
Distance	2.6 [km] way-back
Road	Open road
Type of trafic	Mixed
Speed limit	30 [km/h]
Roundabout	Yes (2)

Trafic lights	Yes (4)
Type of service	Traditional busline
Concession	Line
Number of bus stops	2
Type of bus stop	Fixed
Bus stop infrastructure	Yes
Number of vehicles	2
Timetable	Fixed
Operation hours	Monday - Saturday (6 days)
Timeframe weekdays	08:30 – 20:00
Timeframe weekend / holidays	Idem
Depot	Groupama Stadium Parking
Driverless service	No

Table1 Keolis Lyon demonstrator site

2.1 Partners

SYTRAL

SYTRAL (Syndicat Mixte des Transports pour le Rhône et l'Agglomération Lyonnaise) is the sole organising authority for public transport in Lyon and the Rhône. It coordinates the deployment of the project, and co-finances the project and the operation of the experiment.

KEOLIS LYON

KEOLIS LYON holds the public service delegation contract for the Lyon transport network TCL and will be the operator of these shuttles. As part of the AMO mission, KEOLIS will also assist SYTRAL in its orientations, validate the measures taken by SYTRAL, and ensure the coherence of the project in relation to the AVENUE project (European programme co-financing the project).

OLYMPIQUE LYONNAIS

- The OLYMPIQUE LYONNAIS (OL) is the owner of the Groupama Stadium, a major site in the conurbation, and is one of SYTRAL's partners in this project to :
- specify the conditions for the development of the Parc OL site;
- to accommodate the storage and reloading of shuttles.

KEOLIS

KEOLIS contributes the experience acquired during the various experiments carried out in the group and offers its subsidiary KEOLIS LYON the tools to structure the approach.

H2020 AVENUE	The Parc OL service project is funded by the H2020 AVENUE project, a European research project on the mobility of tomorrow. Details of this European project are available on their website https://h2020-avenue.eu/
METROPOLE DE LYON	The METROPOLE DE LYON is carrying out and co-financing the project, managing the road network and traffic permits.
VILLE DE DECINES	The CITY OF DECINES hosts the experimentation, and accompanies its exploitation to coordinate the interventions of the Municipal Police, the town planning authorizations,...
NAVYA	NAVYA is the manufacturer of the shuttles, and Keolis' historical partner in the experimentation of autonomous vehicles. The close collaboration between NAVYA and Keolis has led to numerous experiments around the world

2.2 Objectives

The "AVENUE" project on the Groupama Stadium area foresees three main objectives:

1. Testing the integration of autonomous vehicles in dense traffic, with numerous interactions (pedestrians, bicycles, scooters, etc.)
2. Testing the communication capabilities between the autonomous vehicles and the connected infrastructure (V2X) with complex use cases (e.g. a roundabout with 45,000 vehicles/day)
3. Accompany the economic development of an area under construction by making the transportation service evolve according to the changing mobility needs in the OL Valley area
4. To test an on-demand transport service over a large area that includes residences, shops and professional offices.

2.3 Site description

SYTRAL and Keolis Lyon wish to offer an innovative public transport service to the Groupama Stadium, to support the economic development of the area near the Groupama Stadium. This service will be provided outside of stadium events (matches, concerts, etc.), during which the T3 tramway line will take over to meet the significant transport needs associated with the crowds.

Inaugurated in 2016, Groupama Stadium is the football stadium owned by Olympique Lyonnais, the leading professional football club in France. The construction of the Groupama Stadium is the central element of the OL City economic project, which aims to develop a district made up of various centres of attraction, such as rental offices, hotels and restaurants, a leisure centre, a medical centre and an analysis laboratory. The ambition of OL City is to attract 1,500,000 visitors per year by 2021.

The shuttle bus route will link the T3 Décines Grand Large tramway station to Groupama Stadium, reinforcing the existing 85 bus line. The entire route will be on roads open to general traffic. The route passes through a deprived neighbourhood where many incivilities are recorded by the police. The route also crosses several schools (high schools, colleges, technical high schools, religious schools). Thanks to this social, cultural and economic mix, it will be interesting to evaluate the integration of the shuttle in an unprotected environment.

The introduction of several autonomous shuttles will provide a solution for the last kilometre that will encourage the use of public transport.

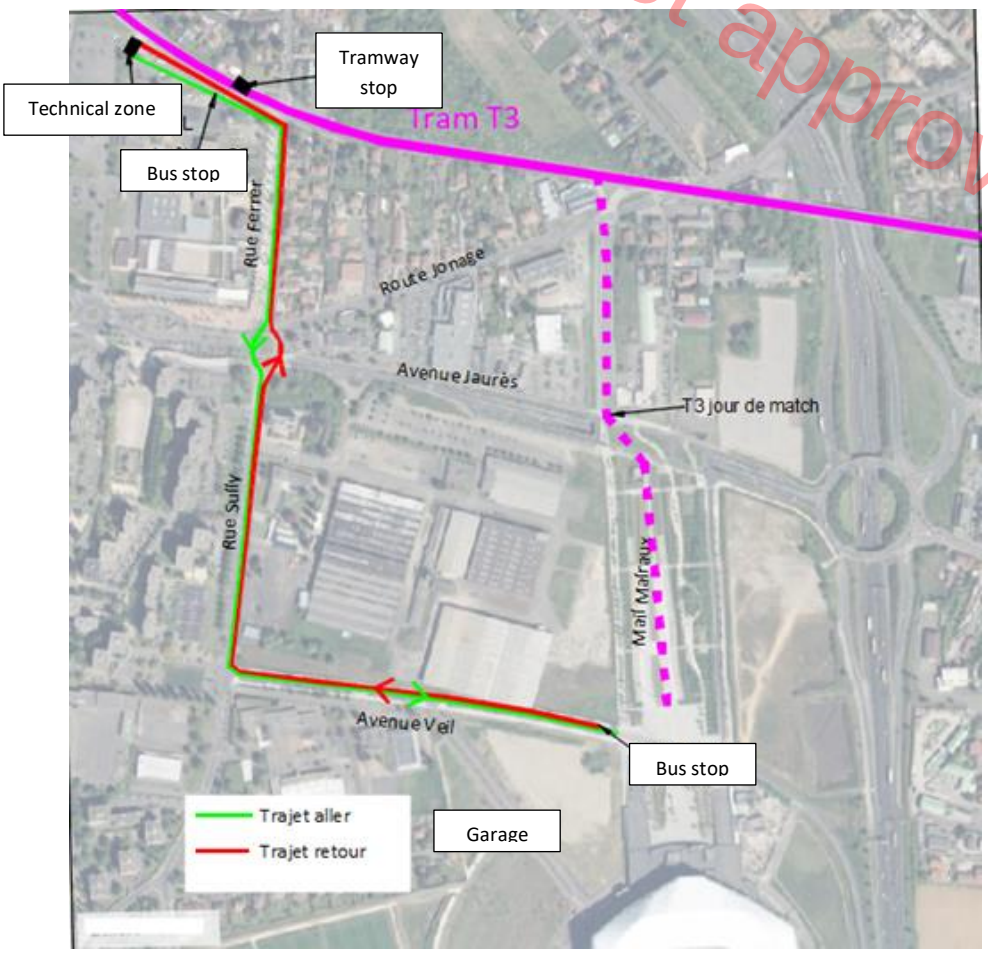


Figure 1 Groupama Stadium Demonstrator General Map (fixed Line)

Figure 2 Groupama Stadium Demonstrator General Map (On demand Service)

2.3.1 Use cases

2.3.1.1 First Phase

At the time of the inauguration on 15 November 2019, only the offices of Olympique Lyonnais were occupied and had daily activities.

In the months following the inauguration, the district saw the opening of a medical centre, a laboratory and a hotel.

These new centres of attraction generate movements in the district that did not exist before. Indeed, we expected a small flow of people throughout the day.

To meet this need, rather than increasing the service on bus line 85 (frequency = 30 minutes), the introduction of an autonomous shuttle service seemed appropriate.

The experimentation in this format took place from November 2019 to February 2021, with an interruption from March 2020 to September 2020 due to constraints related to the COVID 19 crisis.

In February 2021, the inauguration of a new Tramway line (T7), offering the same service as the N1 Autonomous Shuttles line (Décines Grand Large <-> Groupama Stadium), and the development of the neighborhood with new flow generators, determined the interruption of the fixed line experimentation to work on the deployment of a new experimentation in transport on demand.

2.3.1.2 Second Phase

During the first 15 months of the project, the OL vallée district developed to accommodate new traffic generators. At the beginning of the project, only the Groupama Stadium and its offices were generating daily trips in the area. When the first phase of the experiment ended in February 2021, the area had welcomed the following new buildings

- Leisure
    - All in Padl
    - Bowling of lights
    - City Surf Park
    - Exalto Park
    - L'appart Fitness
    - Five OL (indoor soccer)
    - Prison island (escape game)
    - Theatre
    - Vortex (shooting simulation)

Restaurant

- Amercian City
- Au fut et a Mesure
- Brut Butcher
- Garrison Tavern
- Baker's Bistro
- MANAO
- Nikasi
- O planet

This distribution was proposed following work carried out by Keolis Lyon's marketing department, studying the potential of this new service

A first service for OL Vallée employees that has found its clientele:

- 500 OL Vallée employees in 2019/2020,
- In a non-COVID logic, 1000 theoretical trips, reduced to 800 considering 80% of presence on site (sick, travel, holidays, etc.)
- N1 market share = 6.25%

For this second phase, the new generators could develop a discovery use of autonomous vehicles. On NAVLY, an equivalent use would generate an average of 100 trips/day in 2019, and 180 trips on Saturdays.

The T3 Décines-Grand Large connection still has potential:

- The boarding of passengers from Part Dieu descent from Décines Grand Large (1983 passengers/day on weekdays, including 1762 without connection)

- The boarding of passengers from Meyzieu ZI down to Décines Grand Large (438 passengers/day on weekdays, including 373 without connection)
- Of these 2045 journeys/day, we consider here that 30% of this population could travel to OL Vallée,
- Considering a 5% market share for autonomous shuttles, this represents a potential of 63 trips/day,

Market share projection:

- 1.5M visitors per year (museum/resto/leisure centre/medical centre)
- That is to say approximately 4000 per day (strong day ratio of 360), i.e. a potential of 8000 trips per day,
- Considering a market share of N1 = 5%, potential 400 trips/day,

		2021			TOTAL 2021	2022			TOTAL 2022	TOTAL N1 PHASE 2
		Emplois	Pôle loisirs	Clinique/hôtel/labo		Emplois	Pôle loisirs	Clinique/hôtel/labo		
	Effectifs / Visiteurs annuels	800	600 000	400 000	1 000 800	1000	1 000 000	400 000	2 401 000	3 401 800
	Déplacements	320 000	1 200 000	800 000	2 320 000	400 000	2 000 000	800 000	3 200 000	5 520 000
Hypothèse 1*	Part de marché N1	5%				5%				
	Voyages / 4 mois	5 333	20 000	13 333	38 667	6 667	33 333	13 333	53 333	**92 000**
Hypothèse 2*	Part de marché N1	3%				3%				
	Voyages / 4 mois	3 200	12 000	8 000	23 200	4 000	20 000	8 000	32 000	**55 200**
Hypothèse 3*	Part de marché N1	1%				1%				
	Voyages / 4 mois	1 067	4 000	2 667	7 733	1 333	6 667	2 667	10 667	**18 400**

The project is due to open to the public in the last quarter of 2021. Nevertheless, the modification of the decree governing the authorisation to conduct experiments with autonomous vehicles is causing our application to be processed more slowly than before. Potential delays are envisaged in this case.

2.3.2 Route

- Phase 1 : Fixed route

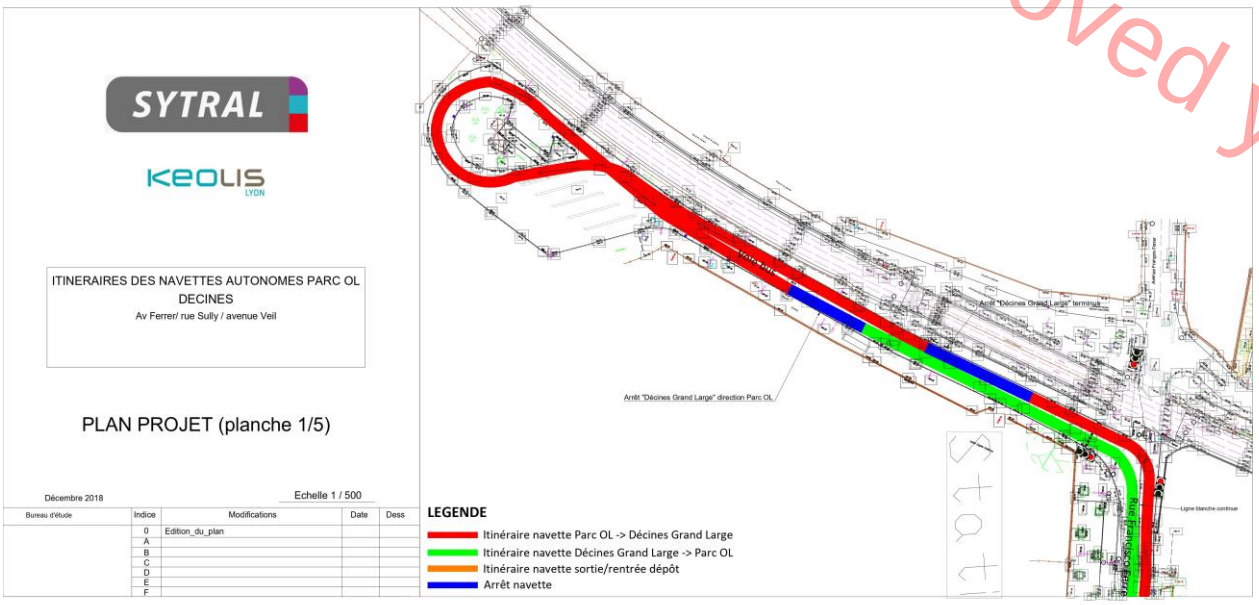
Driving direction	Clock-wise
Route length	2.6 [km]
Speed limit all traffic	30 [km/h] area
Road	Peri-Urban open road

Table 2 Site Information

2.3.3 Land plots

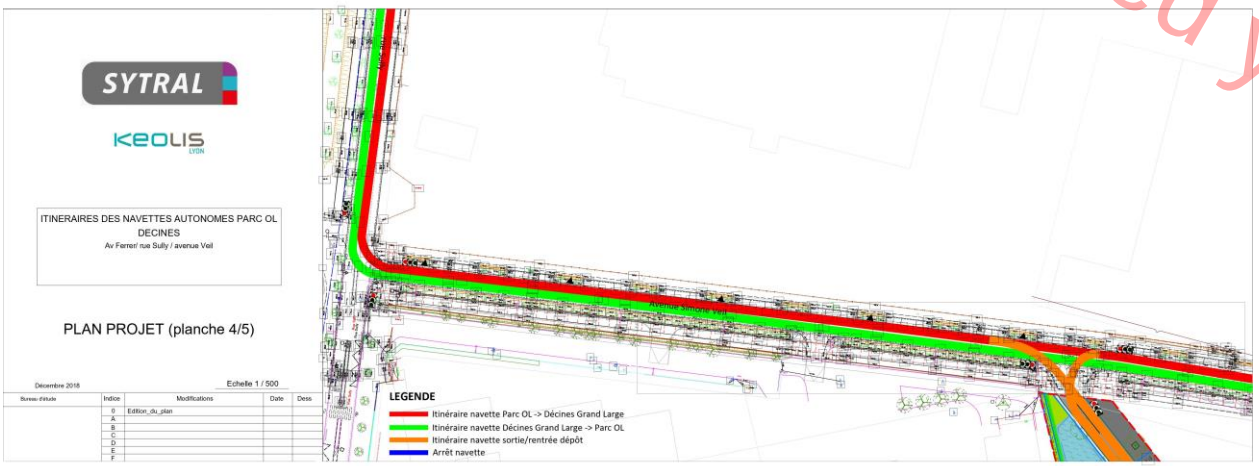
Type	Name	From	To	Manager	Accuracy
Track	Service road for the Décines Grand Large bus station	Bus control area	Francisco Ferrer street	SYTRAL	Voie publique
Street	Francisco Ferrer	T3 junction	East gyratory of the Esplanade du Grand Large (RD317	Métropole de Lyon	Voie publique
Street	Sully	East gyratory of the Esplanade du Grand Large (RD317)	Avenue Simone Veil	Métropole de Lyon	Voie publique
Avenue	Simone Veil	Sully street	Parc OL forecourt	Métropole de Lyon	Voie publique
Track	Access road Parking P7	Avenue Simone Veil	Storage car park Shuttles	Olympique Lyonnais	Voie privée
Track	Pedestrian podium	Groupama Stadium	Avenue Simone Veil	Olympique Lyonnais	Voie privée
Track	Parvis T7	Avenue Simone Veil	T7 Tramway Station	Métropole de Lyon	Voie publique with limited access

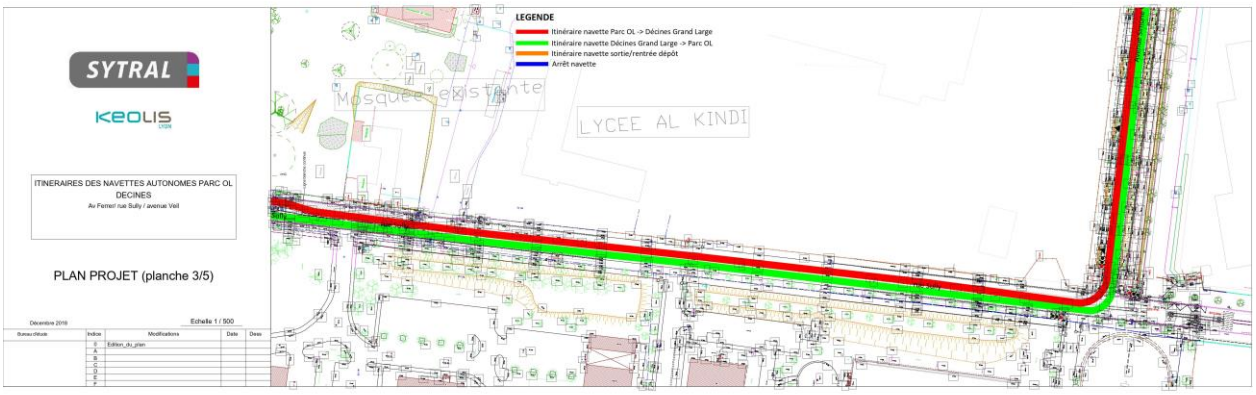
Table 3 Lands plots



Map of the Décines Grand Large bus lane. The axis does not present any difficulty in terms of road traffic as it is reserved for TCL network vehicles. The intersection between the bus lane and Rue Francisco Ferrer has been equipped with a traffic light junction which is interfaced with the tramway line signals.

Map of Francisco Ferrer Street and the roundabout to get to Sully Street. The roundabout has two lanes and five junctions. It is one of the main entry points to the east of the Lyon metropolitan area, with 45,000 vehicles per day recorded. This roundabout has been equipped with light signals that are set to give priority to autonomous shuttles. When the shuttles approach the roundabout, they are detected by the traffic light controller, and all the traffic lights turn red, except the one where the shuttle is to be inserted. The timing of the lights has been calculated according to the speed of the autonomous shuttles to ensure that the roundabout is cleared of traffic by the time the shuttles enter.





Plan of the intersection between Rue Sully and Avenue SImone Veil. The intersection has been equipped with light signals, and allows for increased safety of the autonomous shuttles when they turn left (green route on the diagram). When the shuttle passes the foot of the light, it is then

considered to be engaged in the intersection. The traffic light controller turns the opposite light red to allow the autonomous shuttles to cross the lane without the risk of encountering a vehicle.

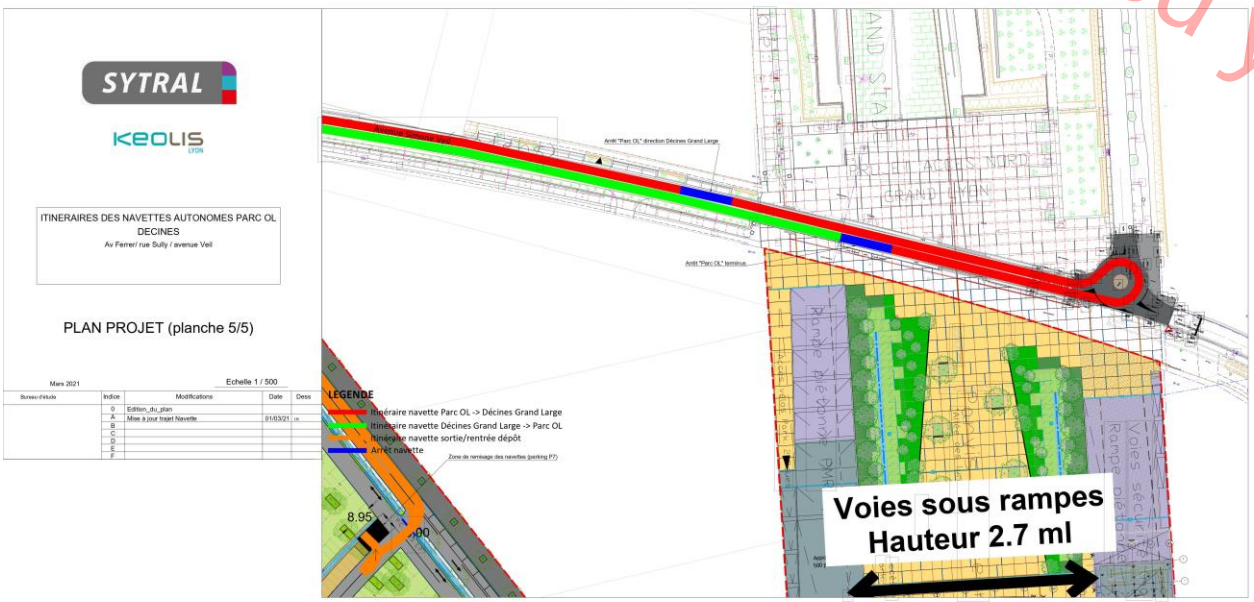


Figure 2 Groupama Stadium area – Land Plots

2.3.4 Current public transport status

2.3.4.1 Phase 1: Fixed route

The service offered by the autonomous shuttles is a complement to the service already provided by bus line 85.

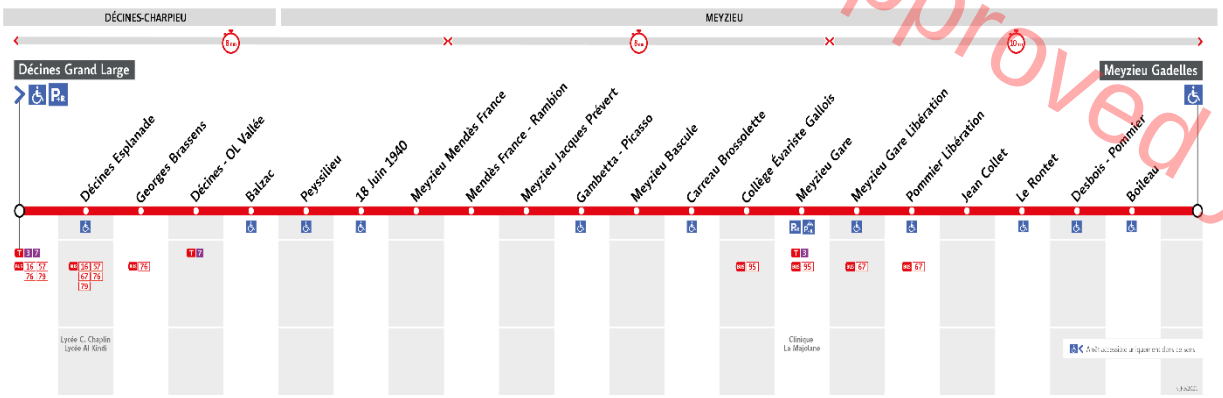


Figure 3 Bus line 85

Line 85 also starts at the Décines Grand Large multimodal interchange, and also serves Groupama Stadium (stop Décines – OL Vallée) before continuing its service at 18 additional stops. This line has a frequency of approximately 30 minutes from 5.30am to 9pm.

Thanks to the autonomous shuttles, we have been able to reinforce the transport offer at the Groupama Stadium, as this was the only point on line 85 that required a reinforcement of the transport offer. The timetables of the autonomous shuttles were therefore worked out to be interleaved with the timetables of line 85 and the T3 Décines Grand Large tramway line, to ensure that passengers have the shortest possible waiting time.

The Groupama stadium has been able to benefit from a public transport service with a frequency of 10 minutes at peak times, and 15 minutes at off-peak times, whereas previously the frequency was 30 minutes all day. In addition, thanks to the priorities given to the shuttles by the traffic lights at the crossroads, the theoretical journey times allow the autonomous shuttles to complete their journey in less than 10 minutes, which means that the buses on line 85 are not blocked. In practice, the operators on board also benefit from the TCL live public application, which gives the real time position of all the vehicles in the TCL network, thus allowing local regulation of departures.

2.3.4.2 Phase 2: On demand service

Since February 2021, a new tramway line (T7) is available for passengers of the TCL network. This tramway service will meet the needs of mass transit in the area, especially during morning and evening rush hours. With the evolution of the district, mobility needs have evolved, and it was no longer possible to benefit from a sufficient offer with the autonomous shuttles.

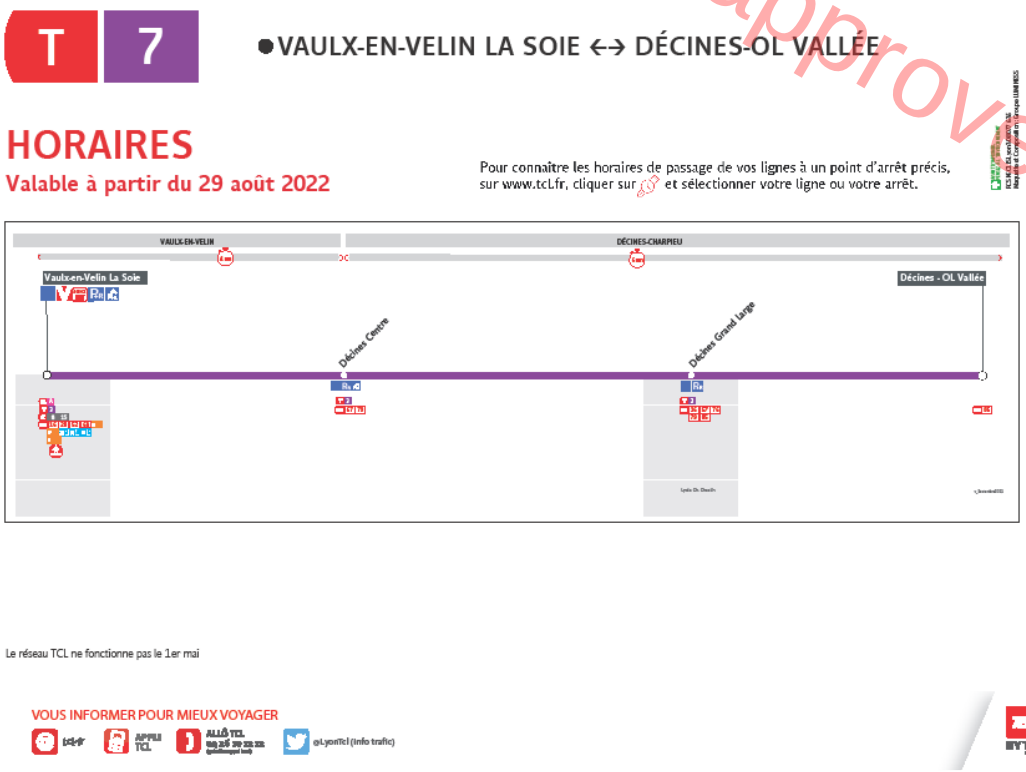


Figure 4 Tramway line T7

The transformation of the autonomous shuttle service from a fixed-route service to a transportation-on-demand service makes it possible to offer a service that is increasingly complementary to the conventional offer of the public transit network

2.3.5 Vehicle depot

The vehicles are stored in the P7 car park at Groupama Stadium. A room has been specifically set up to receive and recharge the autonomous shuttles.

This room is equipped with a 220V 32A power supply to allow for rapid recharging of the shuttle batteries (4h max recharge time vs. 8h for 220V 16A recharging).

Figure 5 Groupama Stadium Demonstrator Vehicles Depot

2.3.5.1.1 Route to vehicle depot

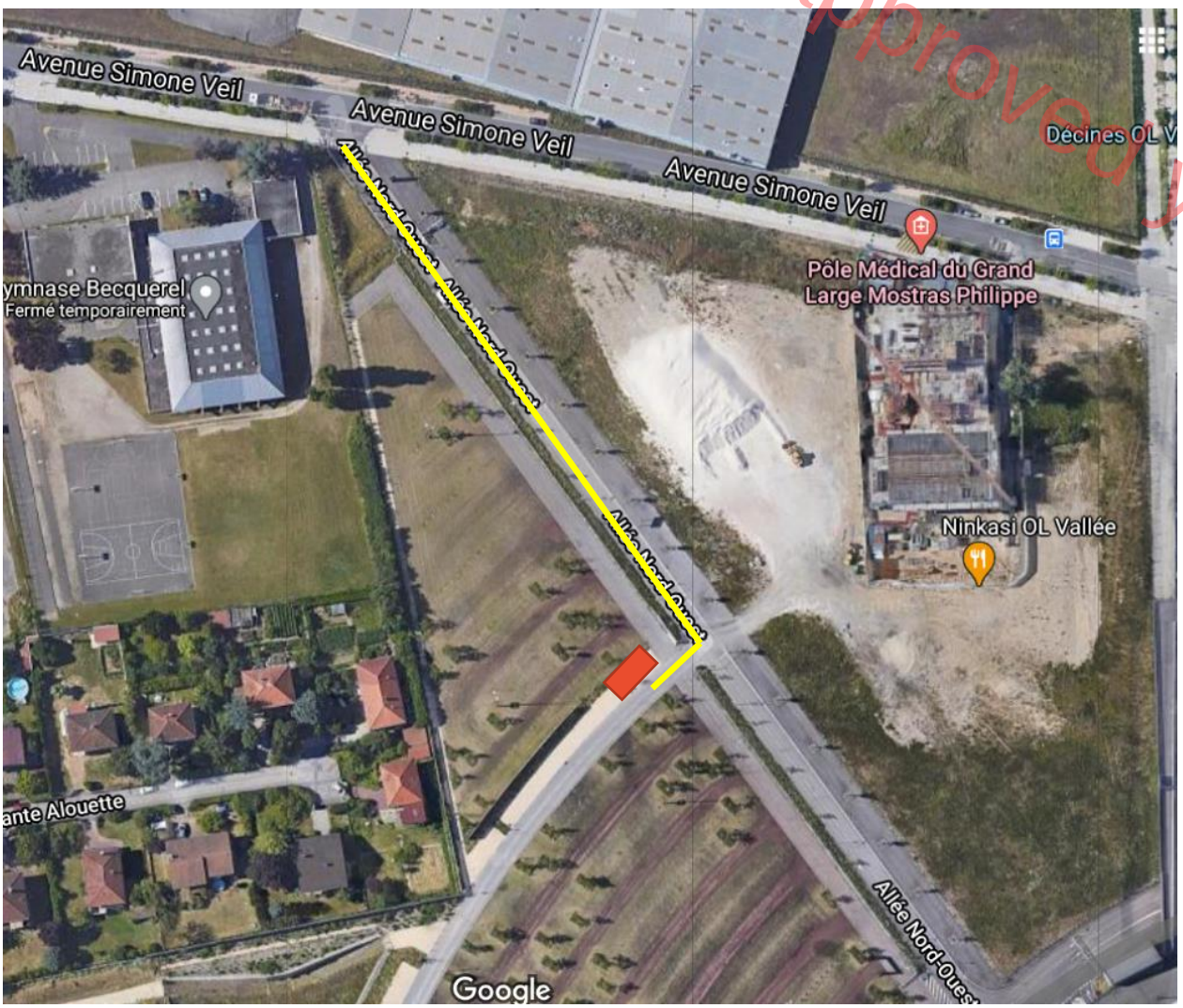


Figure 6 Route to depot Map

2.3.6 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.

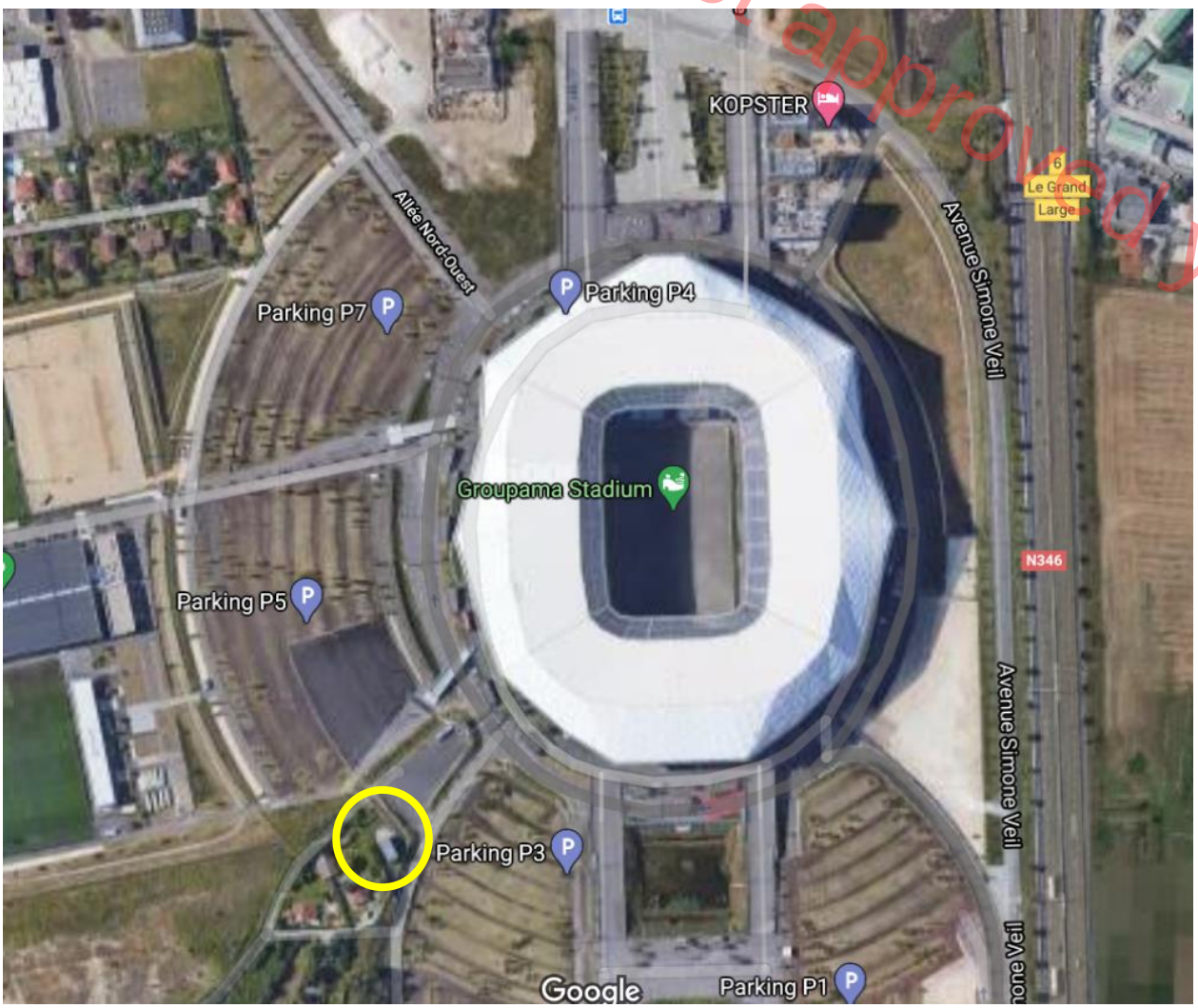


Figure 7 Belle-Idée Demonstrator GNSS base Antenna Placement

Due to many difficulties in using the GNSS base, the GPS correction is now done via an NTRIP subscription.

The operation of the GNSS base and the NTRIP technology is an area of expertise not shared by NAVYA, as it is considered an industrial secret. In the context of this experiment, NAVYA is the holder of the NTRIP subscription.

The transition of GNSS corrections from the GNSS base to NTRIP technology must allow for several sources to benefit from these corrections.

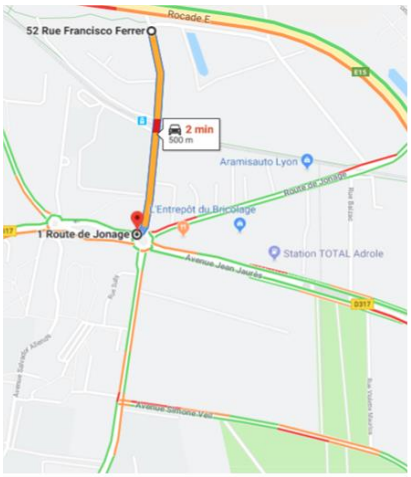
The switch to NTRIP technology has reduced the number of GNSS losses during operation by about 80%, substantially improving the availability rate of autonomous shuttles.

Prior to using NTRIP, we averaged 1 GNSS loss per day per shuttle, with an average recovery time of approximately 22 minutes. It is important to note that full days of GNSS correction unavailability have been excluded from this statistic.

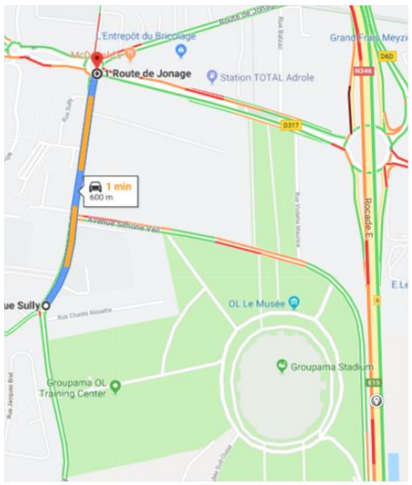
2.3.7 Study of car flows in the neighbourhood and impact of the experiment

Evaluation made after 3 months of operation by Cerema.

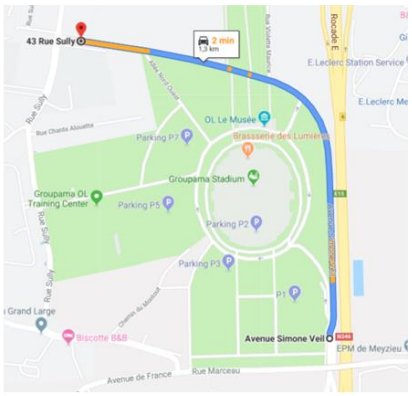
- Routes potentially impacted by the introduction of autonomous shuttles
    - Routes along the autonomous shuttle route (towards the roundabout)



Rue Francisco Ferrer

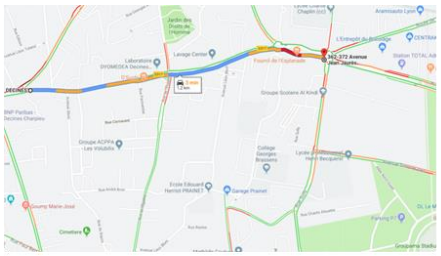


Rue Sully



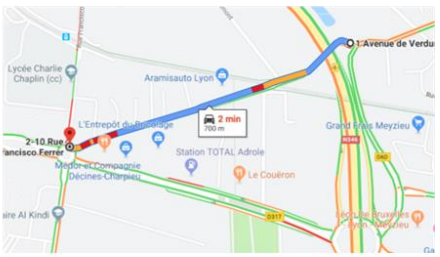
Avenue Simone Veil

    - Routes along the route of the autonomous shuttles
    - Potential vehicle transfer routes

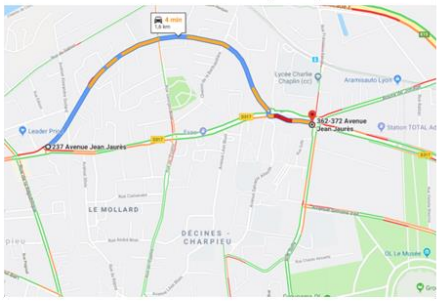


Avenue Jean Jaurès (Ouest)

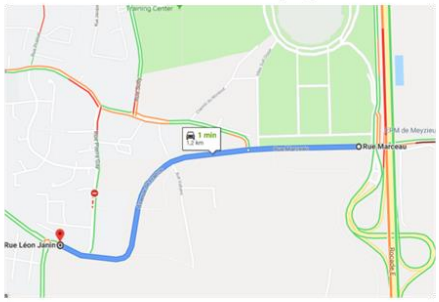
Avenue Jean Jaurès (Est)



Route de Jonage

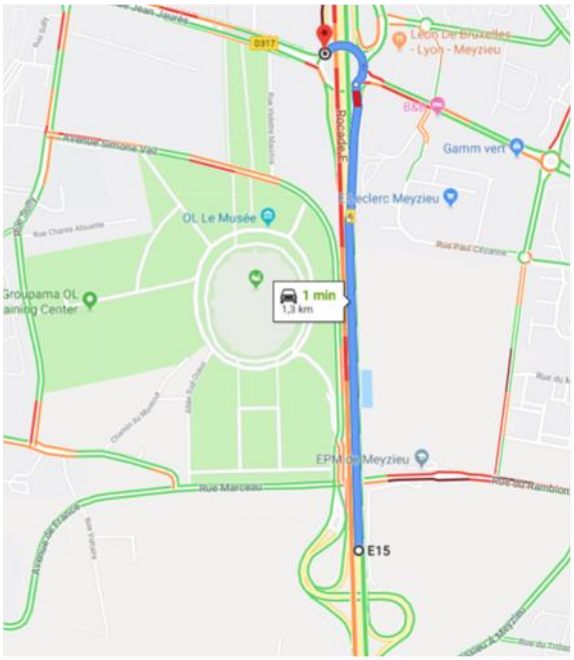


Edouard Herriot

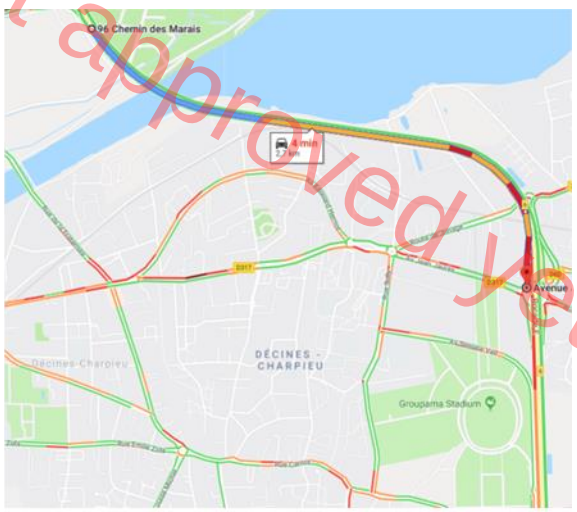


Rue Marceau – Avenue de France

    - Routes along the route of the autonomous shuttles
    - Potential vehicle transfer routes
    - The eastern ring road (impact of possible queue jumping)



RN346 (sud de l'échangeur n°6 – Le Grand Large)



RN346 (nord de l'échangeur n°6 – Le Grand Large)

Flow rates

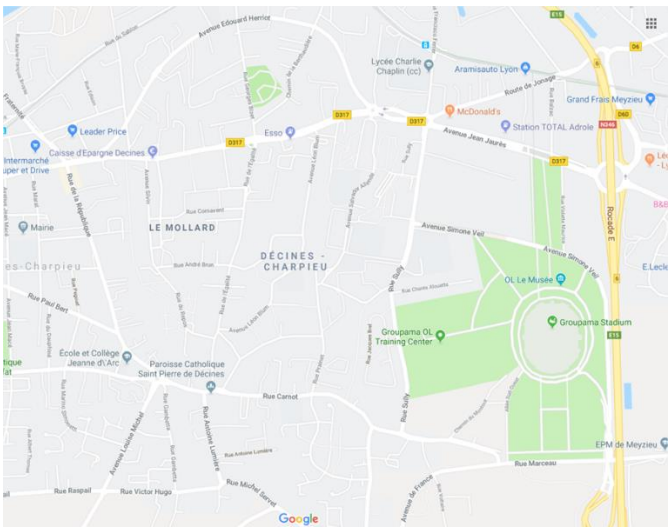
- From pneumatic loop data GRANDLYON la métropole
- Consolidated with existing counts GRANDLYON la métropole

The rise of queues

- From automatic snapshots taken with Google Maps - Speed Cerema

Speeds

- From Google Traffic queries - Consolidated with existing counts Cerema
- Consolidated with FCD data GRANDLYON la métropole



Observations on representative days in terms of traffic

- One consecutive Tuesday and one Thursday, excluding public holidays and events at Groupama Stadium
- Baseline condition: Monday 20 to Friday 24 May 2019
- 3-month traffic condition: Tuesday 18 to Monday 24 February 2020

A probable impact of the shuttle on traffic on certain routes

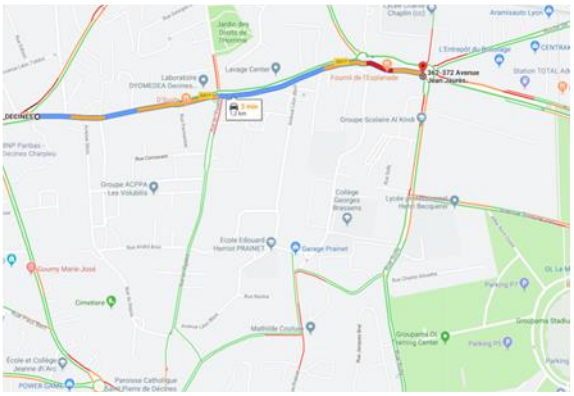
- A drop in traffic flows on Avenue Jean Jaurès, particularly during the evening rush hour (4pm-8pm)
- Likely shifts to the route using rue Marceau and avenue de France
- A drop in speed during off-peak hours (9am-4pm) on the routes leading to the roundabout: traffic calming by the traffic lights placed at the entrances to the roundabout?
- Difficulties in isolating the effects of the shuttle: changes in traffic flow cannot be attributed solely to the introduction of the shuttle (general increase in demand, changes on certain routes, etc.)

Other routes that are not affected

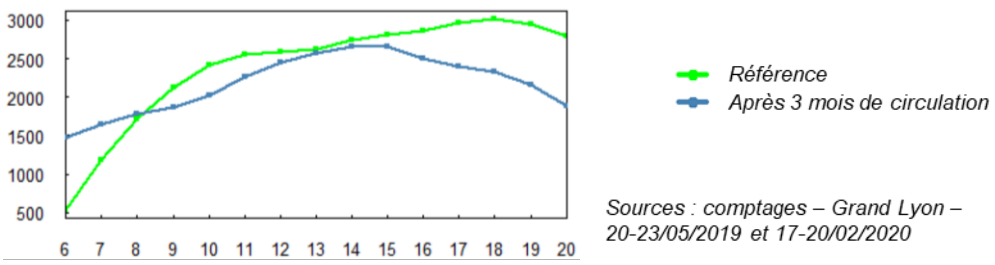
- No or little impact of the shuttle on traffic on Rue Francisco Ferrer, Avenue Simone Veil and Route de Jonage

A drop in traffic flows and speeds following the introduction of the shuttle

Avenue Jean Jaurès – Ouest (650 mètres)

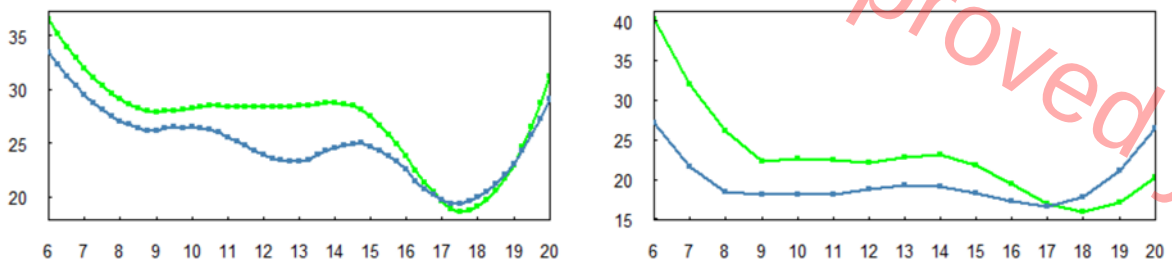


- The most used route: 11600 vehicles/day in reference
- Significant drop in traffic flows between 4pm and 8pm (550 fewer vehicles/day): transfer to other routes?



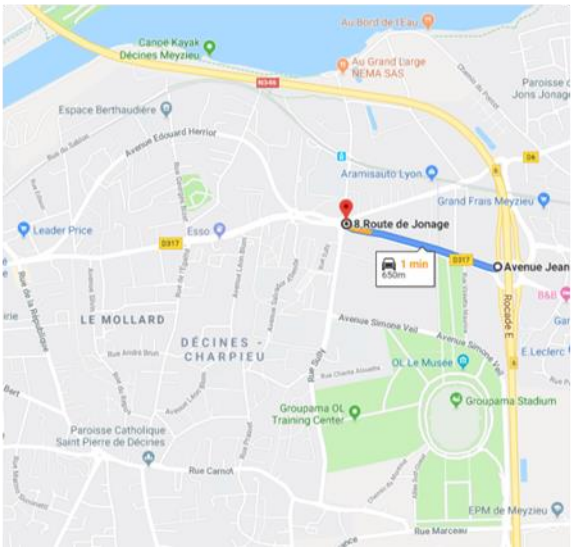
Sources : comptages – Grand Lyon – 20-23/05/2019 et 17-20/02/2020

- Maintaining speeds during evening peak hours
- Lower speeds at off-peak times: traffic calming by traffic lights at the entrance to the roundabout?



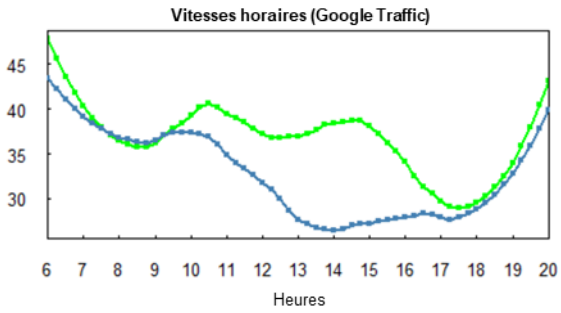
Less marked effects to the east of the roundabout

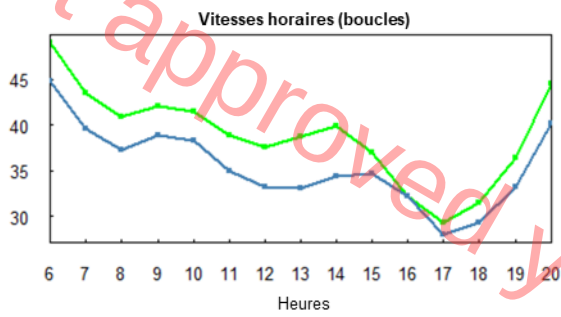
Avenue Jean Jaurès – Est (1200 mètres)



- A very busy route: 10,500 vehicles/day in reference
- A drop in traffic flows during the evening peak hours (350 vehicles/day less): transfers to other routes?

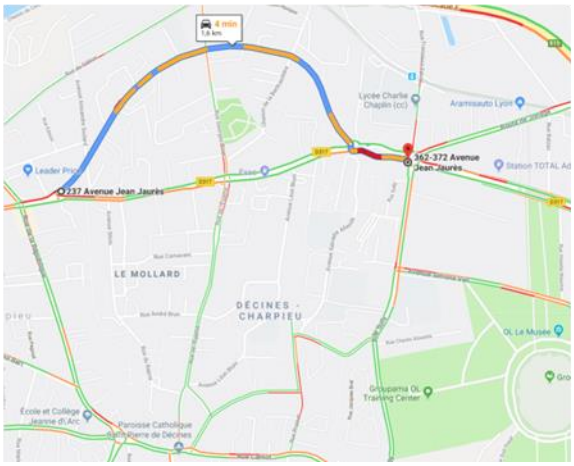
- A significant drop in speeds between 10am and 4pm: traffic calming by the traffic lights at the entrance to the roundabout?
- Speeds are maintained at morning and evening peaks



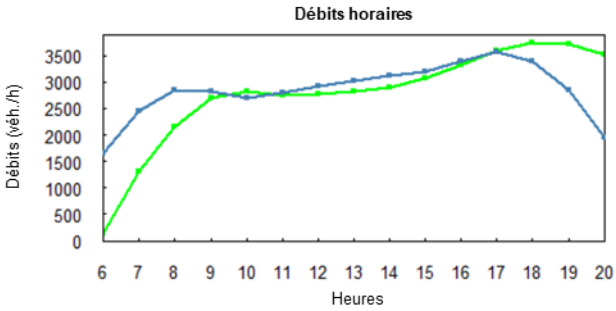


A drop in speed on Avenue Edouard Herriot following the introduction of the shuttle

Avenue Edouard Herriot (1600 mètres)



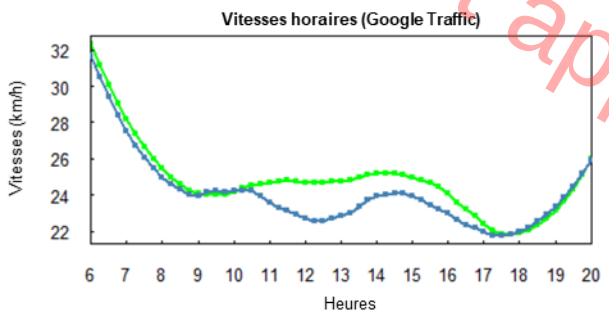
- Comparable flows between 9am and 5pm
- A drop in the evening rush hour: transfers to other routes?



Référence
Après 3 mois de circulation

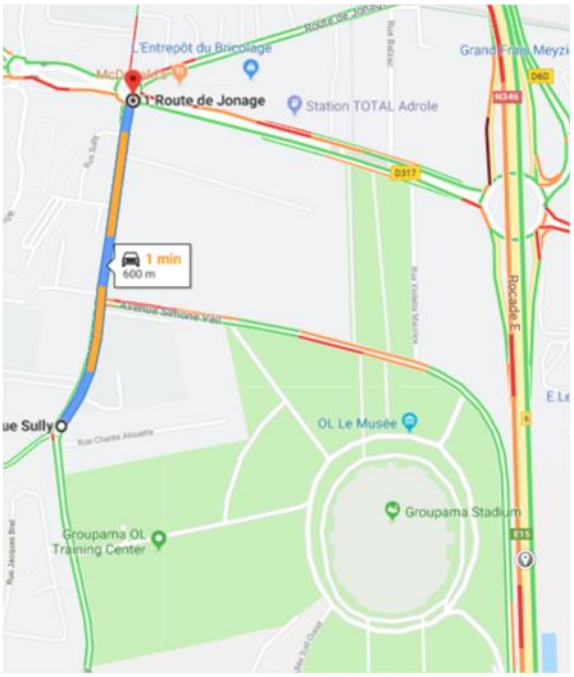
Sources : comptages – Grand Lyon – 20-23/05/2019 et 17-20/02/2020

- A slight drop in speeds during off-peak hours: is this linked to the slower traffic during this period on Avenue Jean Jaurès, on which this route leads?

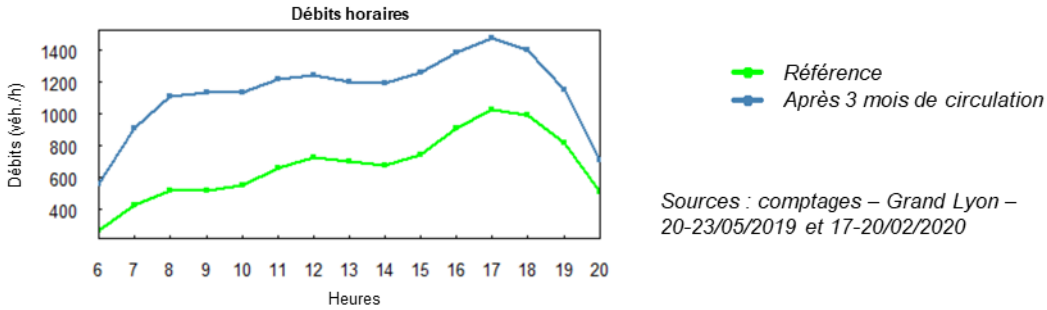


A significant increase in traffic flows on Sully Street following the introduction of the shuttle

Rue Sully (600 mètres)

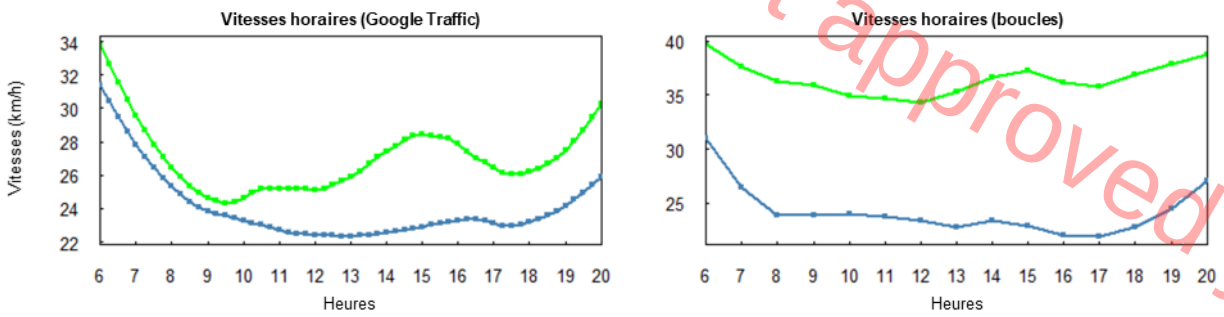


- Up to 300 additional vehicles between 8am and 9am: transfers using exit 7 of the Eastern bypass and rue Marceau, or an increase in traffic on this route?



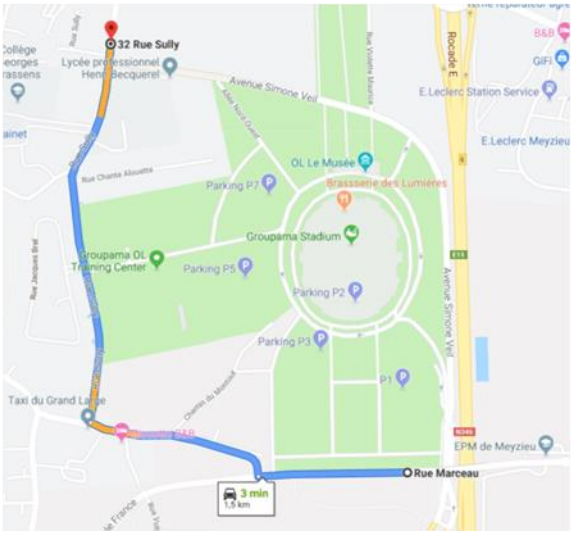
Sources : comptages – Grand Lyon – 20-23/05/2019 et 17-20/02/2020

- Speeds that are maintained during the morning rush hour
- And worsen between 9am and 7pm, but remain stable: regulation by traffic lights at the entrance to the roundabout?

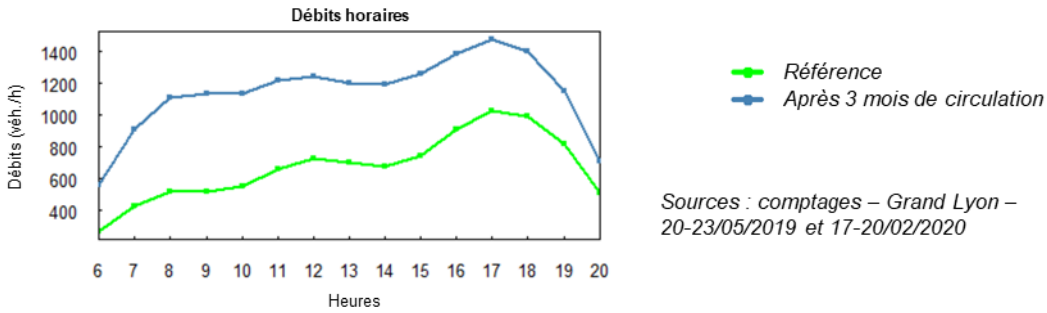


Increasing traffic flows throughout the day in Rue Marceau

Rue Marceau – Rue Sully (1500 mètres)

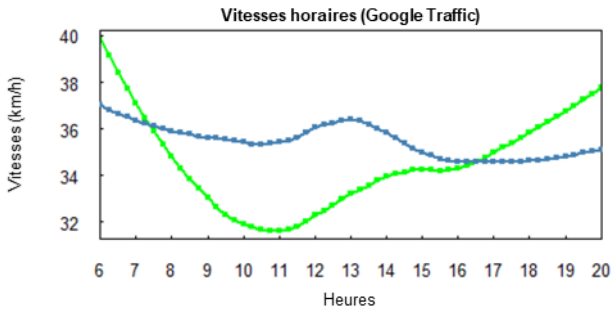


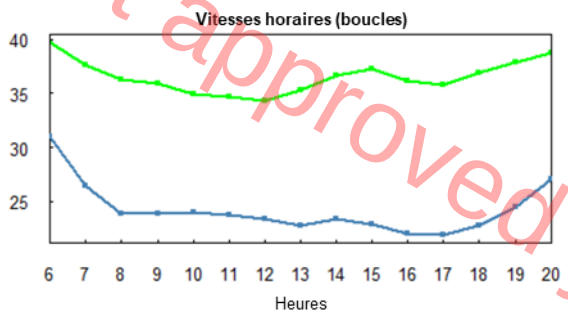
- From 4,700 to 6,800 vehicles/day at rue Marceau
- A slightly more pronounced increase in traffic flows during the morning rush hour



Sources : comptages – Grand Lyon – 20-23/05/2019 et 17-20/02/2020

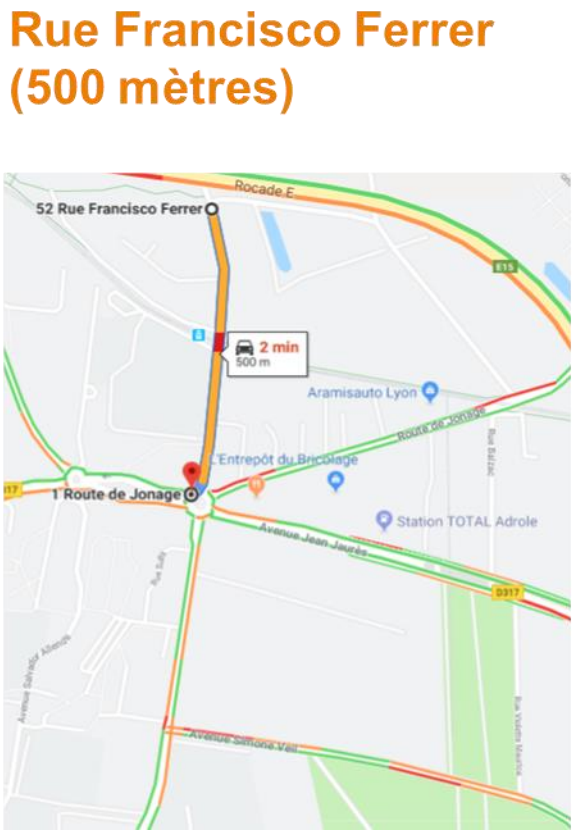
- Speeds maintained, which remain relatively stable



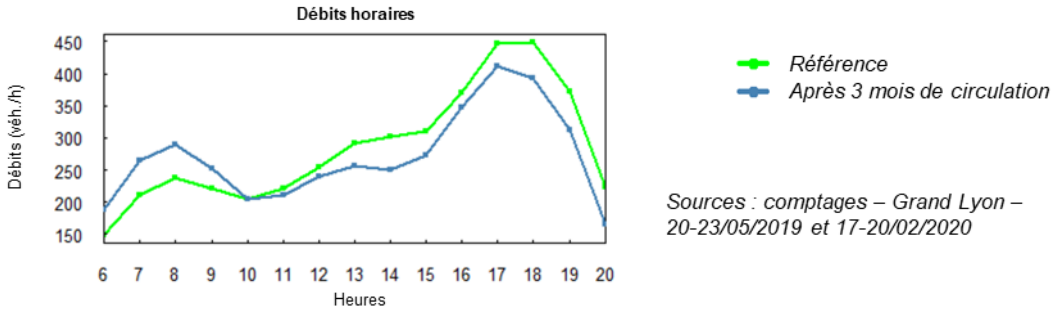


Little impact on other routes along the shuttle route

Modest traffic flows on Francisco Ferrer Street

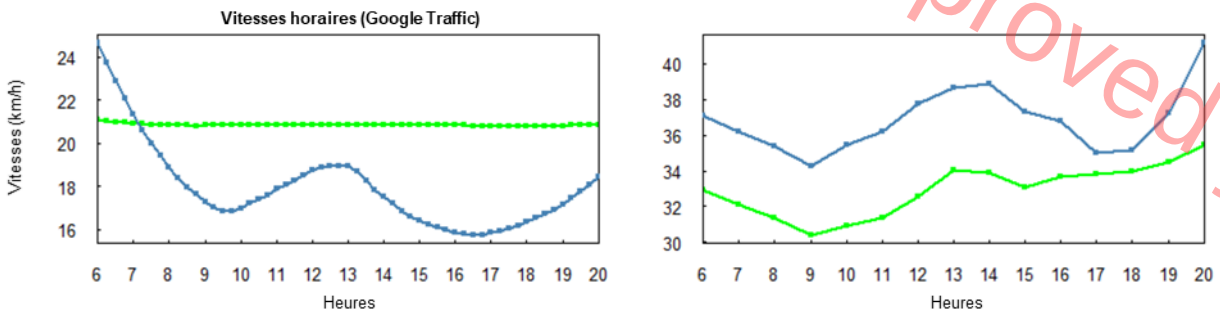


- A lightly trafficked route: 1100 vehicles/day
- Increasing traffic volumes during the morning peak hours and decreasing during the rest of the day

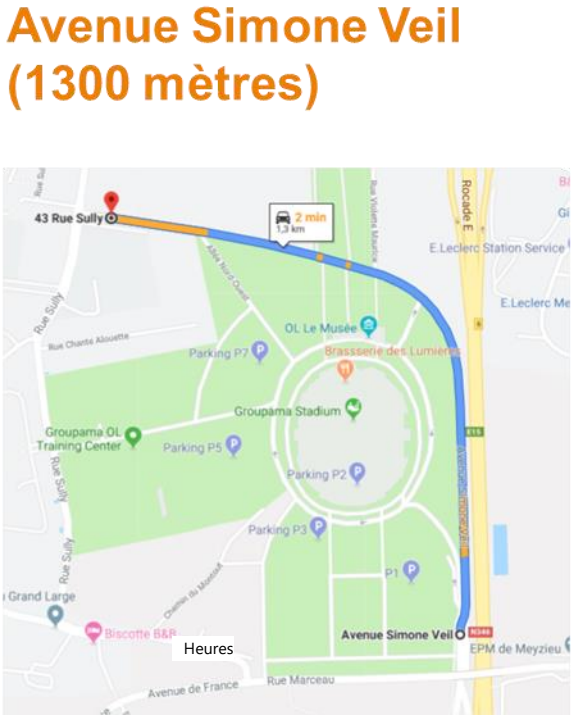


Sources : comptages – Grand Lyon – 20-23/05/2019 et 17-20/02/2020

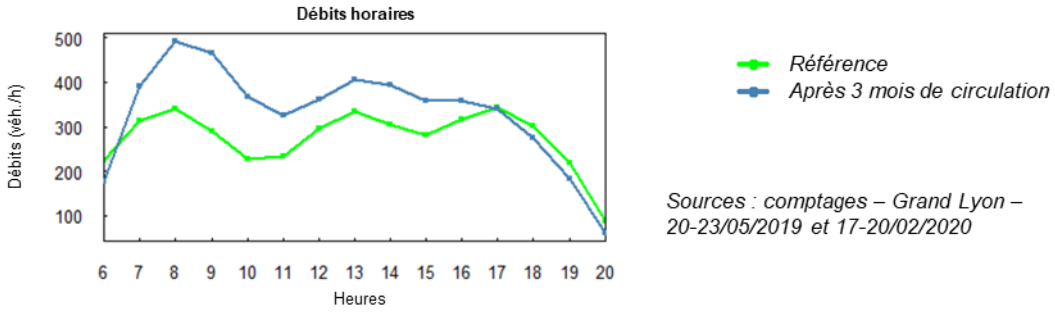
- Decreasing speeds, with the appearance of variations at peak times that did not exist before: an effect of the shuttle on the flow of vehicles?



Flow rates increasing on Avenue Simone Veil, but remaining modest

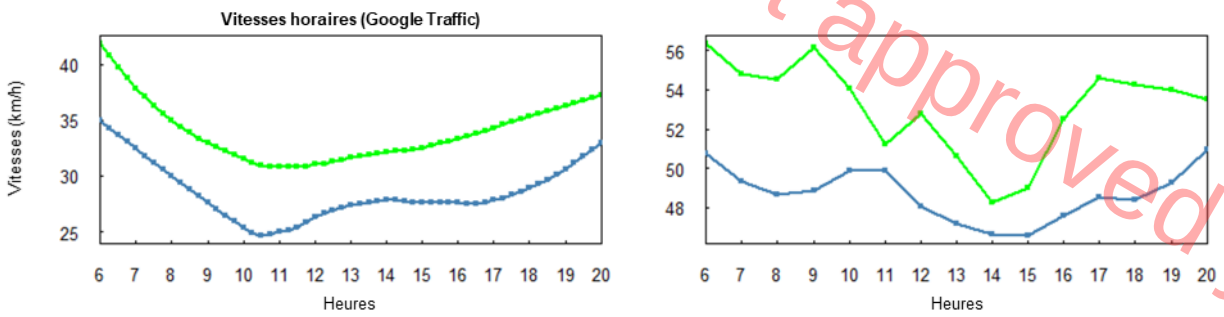


- Flow rates increasing between 7am and 4pm, and remaining stable during the evening peak hours

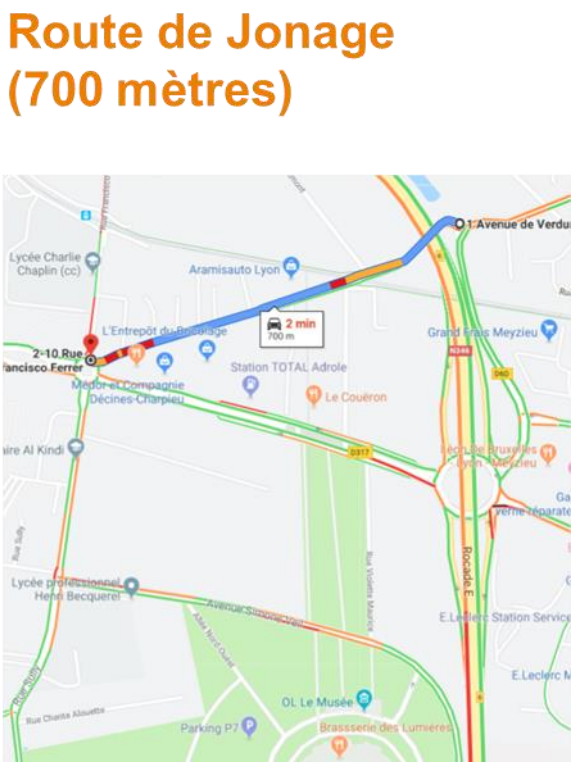


Sources : comptages – Grand Lyon – 20-23/05/2019 et 17-20/02/2020

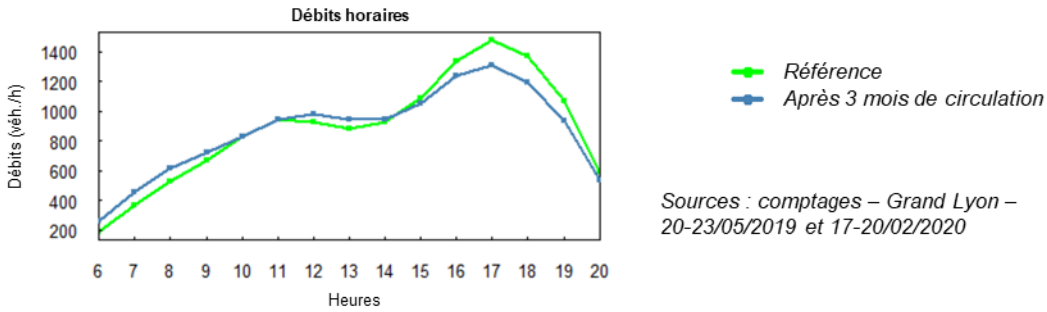
- Decreasing speeds on the route (but not on the approach to rue Sully): an effect of the increase in traffic flows rather than of the shuttle bus traffic?



Little change in traffic conditions on the Jonage road

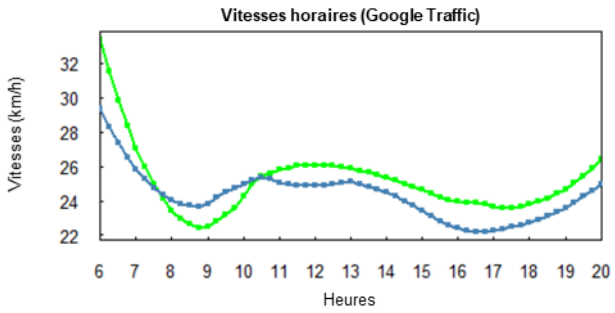


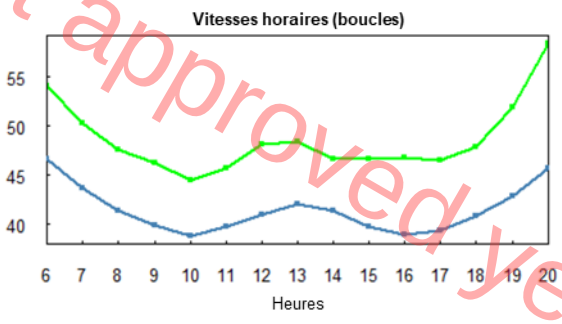
- Almost identical traffic flows after 3 months of traffic, with the exception of a slight decrease in the evening peak hours



Sources : comptages – Grand Lyon – 20-23/05/2019 et 17-20/02/2020

- Speeds have decreased overall on the route, but are close to those recorded in the reference





2.4 Operations

2.4.1 Phase 1

For the first phase of the experiment, here is the timetable for the line operated with two autonomous shuttles:

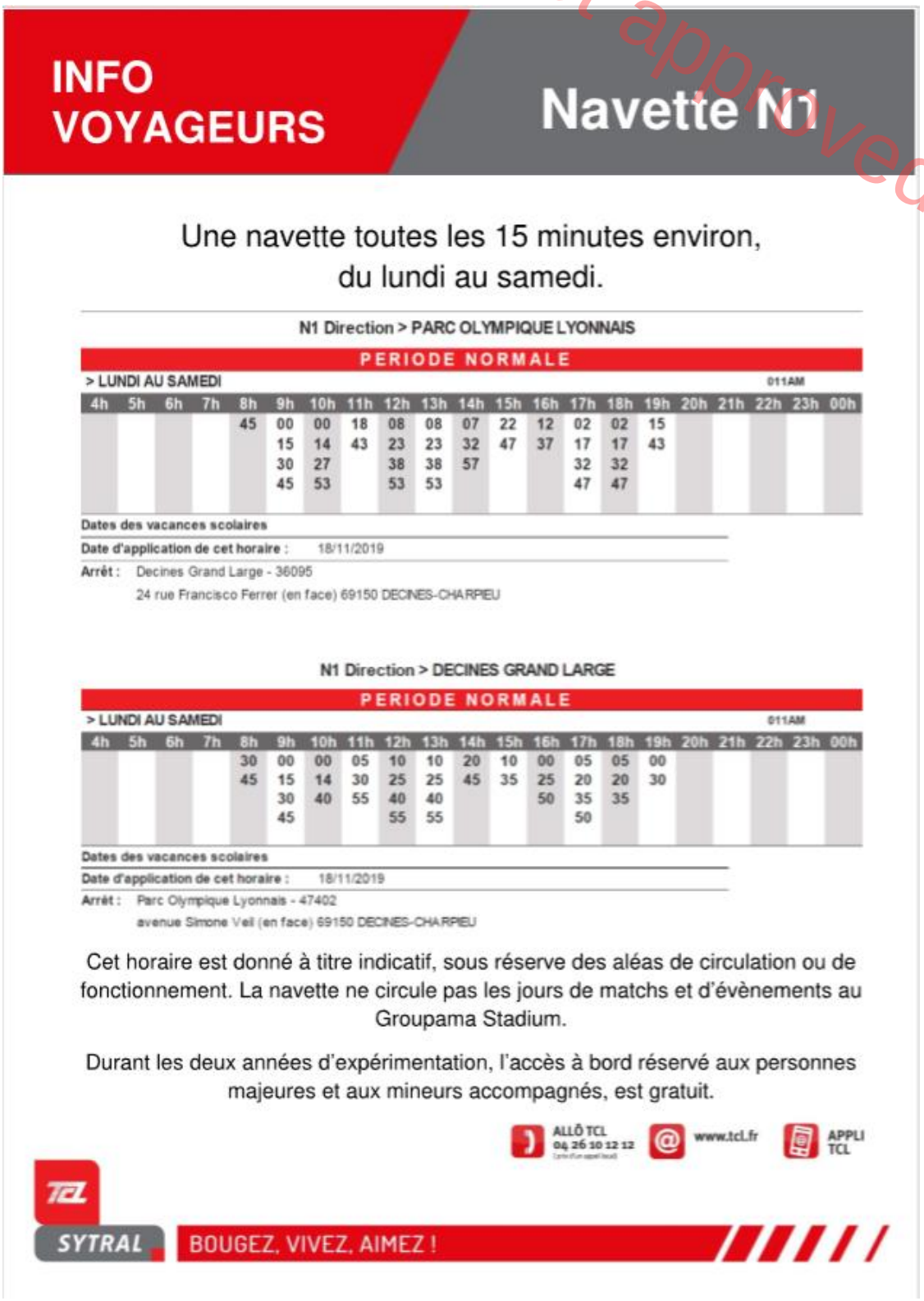


Figure 8 Groupama Stadium Demonstrator On Demand Operations

The service is free for travellers.

The operation of the autonomous shuttles is carried out continuously, also during the winter periods and at night. The lidar technology that is used by the autonomous shuttles is not degraded with the decrease of the luminosity.

On the other hand, we found that during heavy rainfall, the hardware of the autonomous shuttles failed, with leaks inside the vehicle. In order to protect the on-board computers and all the electronic components, the operation of the shuttles was suspended as soon as this water infiltration appeared.

More generally, we also noted a deterioration in the operating conditions of the shuttles:

- rain, so water drops on the lidars cause unexplained braking due to phantom detections
- fog, which the lidars can mistake for obstacles, causing unexplained braking

2.4.2 Phase 2 : On demand service

The on-demand service was available by reservation via a smartphone application. The operation was carried out from Tuesday to Saturday, from 12:00 to 20:00

Comment ça marche ?

1. Téléchargez l'appli OL Vallée à la Demande.
2. Réservez un trajet et suivez votre navette en temps réel.
3. La navette vous rejoint à l'arrêt de votre choix.
   Un opérateur est à bord pour vous accueillir.
4. La navette vous dépose à l'arrêt de votre choix.

Ce service est entièrement gratuit

Arrêts désservis :

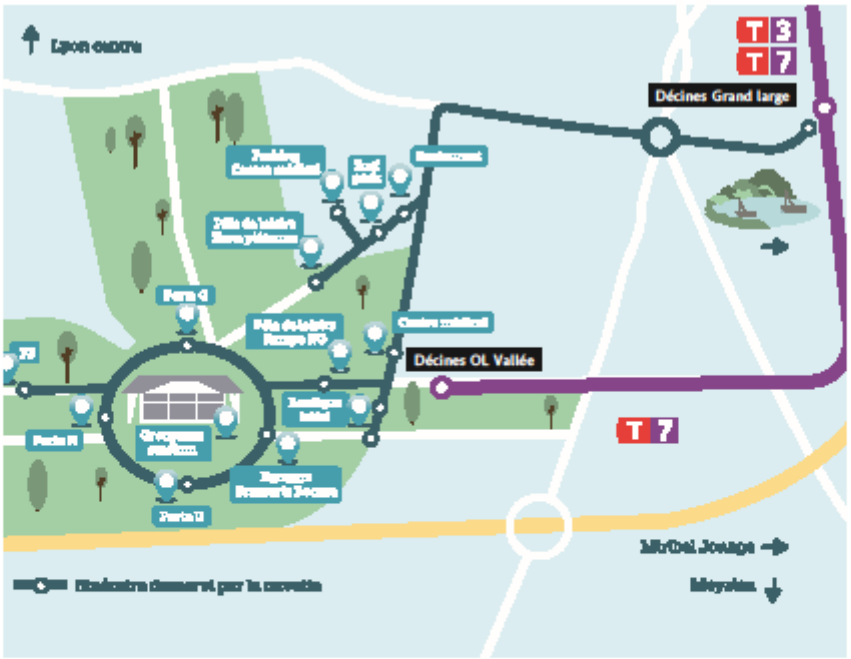


Figure 9 "OL Vallée à la demande" Flyer

2.4.3 Reporting

2.4.3.1 Phase 1

This part concerns the period from 18 November 2019 to 14 March 2020, when the experiment was stopped due to the COVID-19 crisis. It seems appropriate to present the pre- and post-COVID period separately as they represent different realities. Indeed, since the end of the first confinement, the whole of the Lyon public transport network has only recovered about 70% of its use:

Monitoring of the experiment:

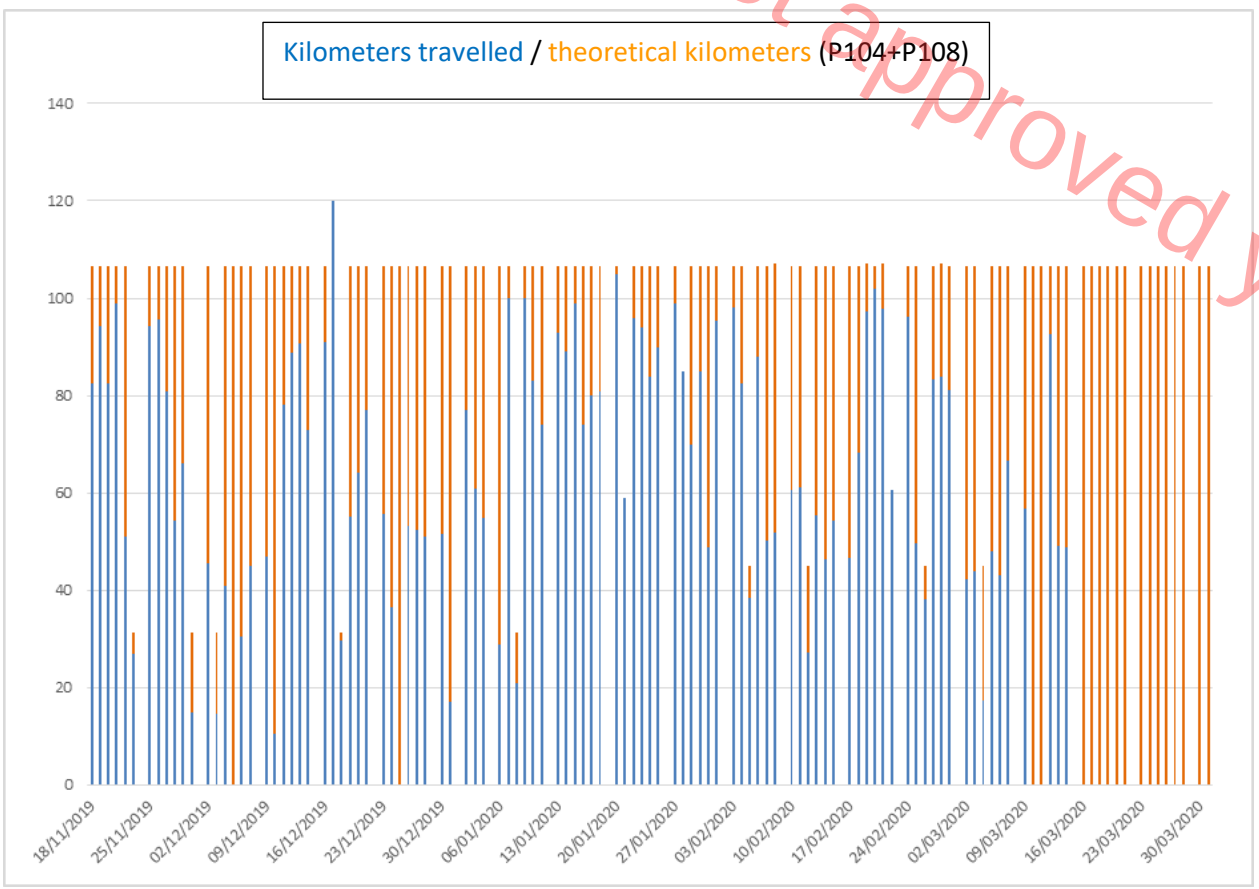
- 4,000 passengers
- 6,400 km
- 1.13 passengers/journey made

Awareness among CT users (650 people from the panel –link with T6.2 on social impact):

- 46% are aware of the experiments in Lyon
- 55% have a favorable opinion of autonomous vehicles
- 1/3 would be ready to give up their car if a TAD service with autonomous vehicles was proposed

Rate of completion of the service:

- 85% (theoretical km - km to be achieved by a shuttle when it is out of service and km to be achieved during operational stops caused by external reasons).
- 65% if all theoretical km are kept
- Equipment reliability problem and known cause :
    - Prototype" vehicle
    - (1800km of untested operation + Transpolis tests where the limits of the shuttles were tested).



kilometers travelled / theoretical kilometers

	P108		P104	
Month	**% AUTO**	**Average Speed (km/h)**	**% AUTO**	**Average Speed (km/h)**
nov-2019 (à partir du 15/11)	93%	9,6	95%	9,7
déc-19	91%	9,7	92%	9,8
janv-20	88%	9.9	89%	10
févr-20	85%	10,1	87%	10,1
mars-20	75%	8,9	93%	10,1

The average speed is a data provided by NAVYA. It represents the average of all operating speeds. The average speed is normally low because it includes slowdowns when approaching stops where passengers are exchanged, as well as all the slowdowns caused by events on the route (red lights, crossing times at junctions, awkward parking, etc.)

The initial setting provides for the following speeds depending on the section:

Street name	Direction of travel	Set speed	Comments
Bus lane T3 Décines Grand large	Groupama Stadium → T3 Décines Grand large	10 km/h	Path used by many pedestrians exiting the T3 tramway and going to a bus stop or to the autonomous shuttle bus stop. The speed is low in order to harmonise its behaviour with the speed of pedestrians, and to offer a reassuring behaviour for the people outside the vehicle
	T3 Décines Grand large→ Groupama Stadium		
Rue Francisco Ferrer	Groupama Stadium → T3 Décines Grand large	12 km/h	Francisco Ferre Street is narrow with parking on both sides of the road. The speed of 12 km/h has been chosen to avoid strong braking when cars are poorly parked, and when they enter the path of the autonomous shuttles. In addition, the presence of a high school and schools in the vicinity causes a large pedestrian flow during rush hours.
	T3 Décines Grand large→ Groupama Stadium		
Rue Sully	Groupama Stadium → T3 Décines Grand large	12 km/h	In this direction, there are parked cars, and the shuttle passes a primary school. As young children can be hidden by parked cars, the speed of 12 km/h avoids braking too hard when they enter the

			path of the autonomous shuttle.
	T3 Décines Grand large→ Groupama Stadium	19 km/h	No parking, wide pavement protected by a guardrail preventing pedestrians from crossing.
Avenue Simone Veil	Groupama Stadium → T3 Décines Grand large	13 km/h	Presence of parking hidden by vegetation. This speed avoids braking too hard in case of detection of an object on the path of the autonomous shuttles
	T3 Décines Grand large→ Groupama Stadium	19 km/h	No parking, wide pavement protected by a guardrail preventing pedestrians from crossing.

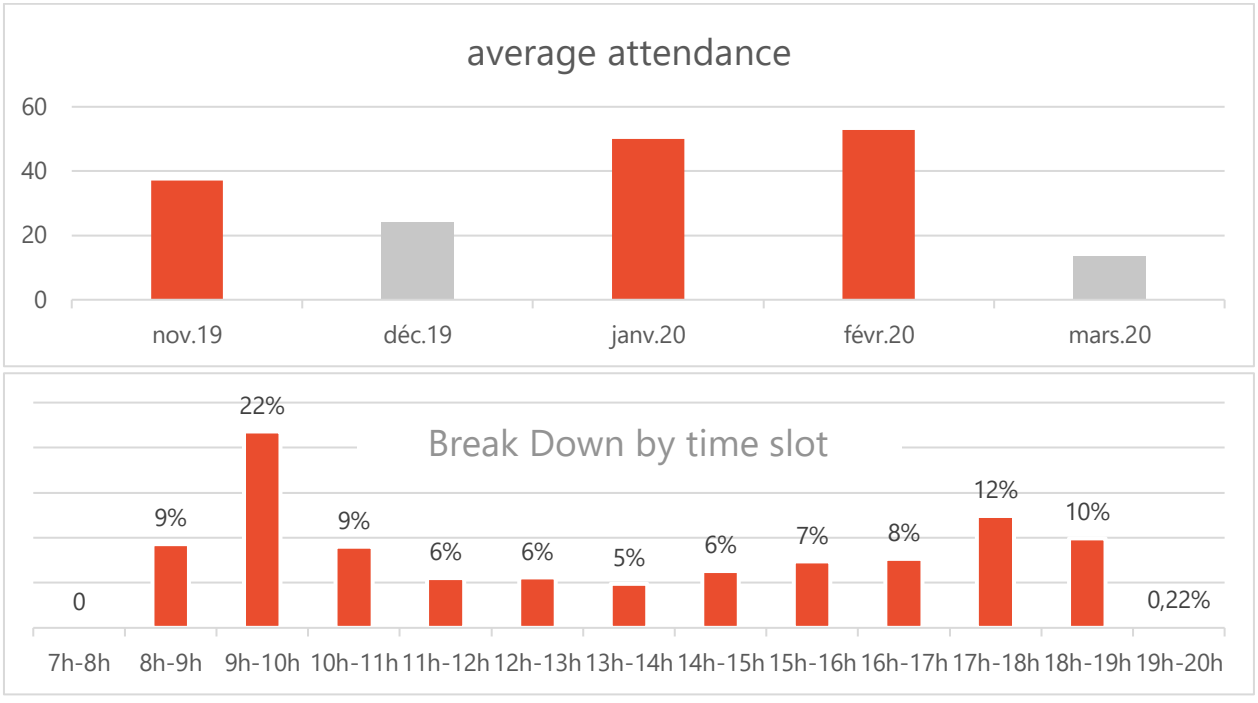


Table 4 Operation reports

The distribution by time slot shows that the use of the services is consistent with the morning and evening peak hours. At the time of the experiment, only the offices of the Olympique Lyonnais and the regional medical analysis laboratory were open, in both cases only receiving employees.

On graph N°1, the mont Out of order in grey colour indicate that only one of the two shuttles was available due to technical malfunctions, penalizing the number of potential passengers.

2.4.3.2 COVID Crisis impact

As of 14 March 2020, the operation of the experiment was forced to stop due to the containment imposed by the French government. Although public transport was considered to be one of the vital activities for the country, and should continue to operate despite the lockdown, certain safety rules had to be respected. Among these rules, a distance of one meter between each person had to be respected in public transport. However, in view of the size of the autonomous vehicles, Keolis Lyon considered that it was preferable not to continue this activity while this rule was in force. The health of the Safety Driver inside the vehicle could not be ensured in the same way as in the rest of the TCL network vehicles.

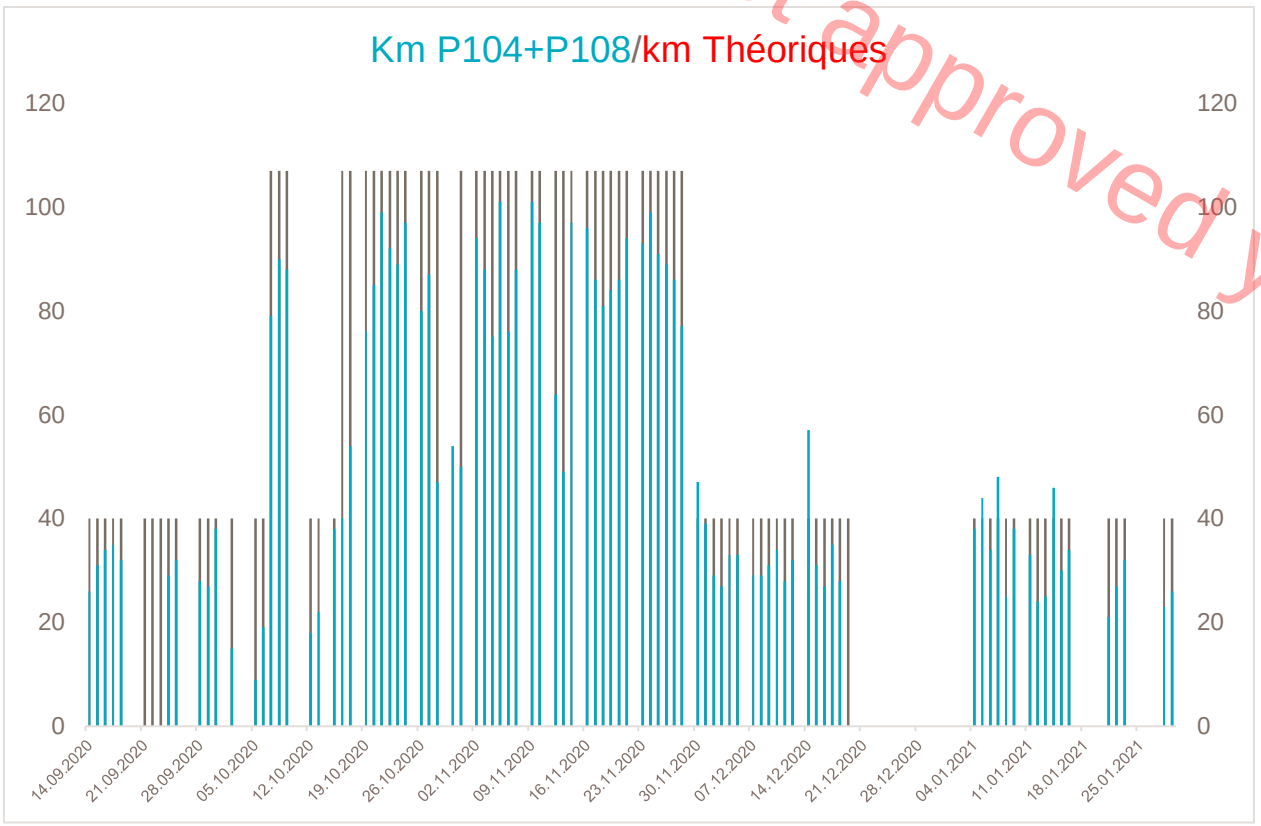
From June onwards, the restrictions linked to the COVID-19 crisis were reduced, and the public transport network gradually returned to an almost normal level (80% of the theoretical offer). Nevertheless, Lyon was one of the cities most affected by the first phase of COVID-19, and Keolis Lyon had to face new difficulties related to the management of the staff. Indeed, between the contact cases, the employees considered as fragile persons, and the positive cases, a lack of employees was noted. In addition, French law requires companies to give employees leave during the summer period, further reducing the number of available employees. For all these reasons, the resumption of the operation of the autonomous shuttles could not be carried out before September 2020 (preceded by a two-week tests period, necessary to repair certain malfunctions observed before the health crisis).

The following grapOut of order cover the period between 14/09/2020 and 31/01/2021.

Monitoring of the experiment:

- 1,639 passengers
- 4,750 km
- 0.3 passengers/journey made

The graph below shows the total km travelled by the two shuttles compared to the theoretical km. Two different values of theoretical km are present. They represent the theoretical km to be achieved depending on the presence of one or two shuttles (107km for two shuttles, 40km with one shuttle).



MOIS	P104		P108	
	% AUTO	Average speed (km/h)	% AUTO	Average speed (km/h)
September 2020	autonomous shuttle not available		autonomous shuttle not available	
October 2020	90%	10.7	77%	14.4
November 2020	75%	14.4	85%	14.4
December 2020	78%	14.5	54%	-

Table 5 Post COVID operation report

2.4.3.3 Reporting on the operation of the on-demand service

The on-demand service was started on April 17, 2022 and was operational until October 28, 2022. It is important to note that due to driver shortages during the summer period, the experiment was interrupted in July and August.

Monitoring of the experiment (from 17/05/2022 to 28/10/2022):

- 1,148 passengers
- 1,556 km

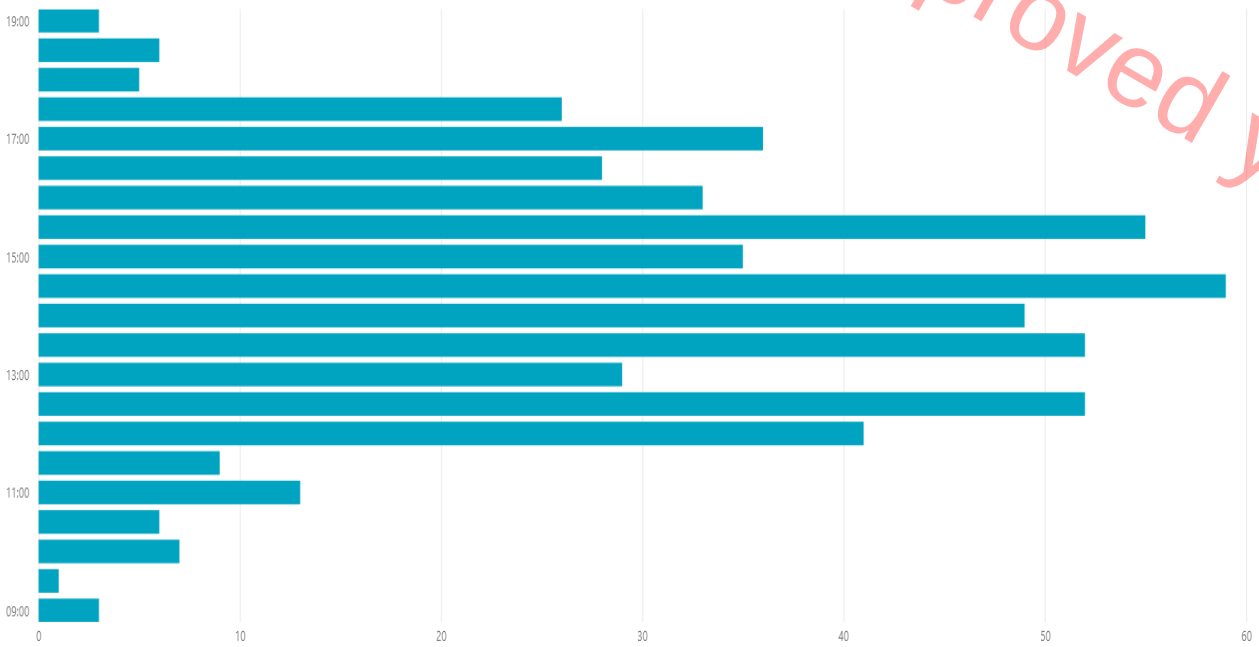


Figure 10 Breakdown of trips by time slot

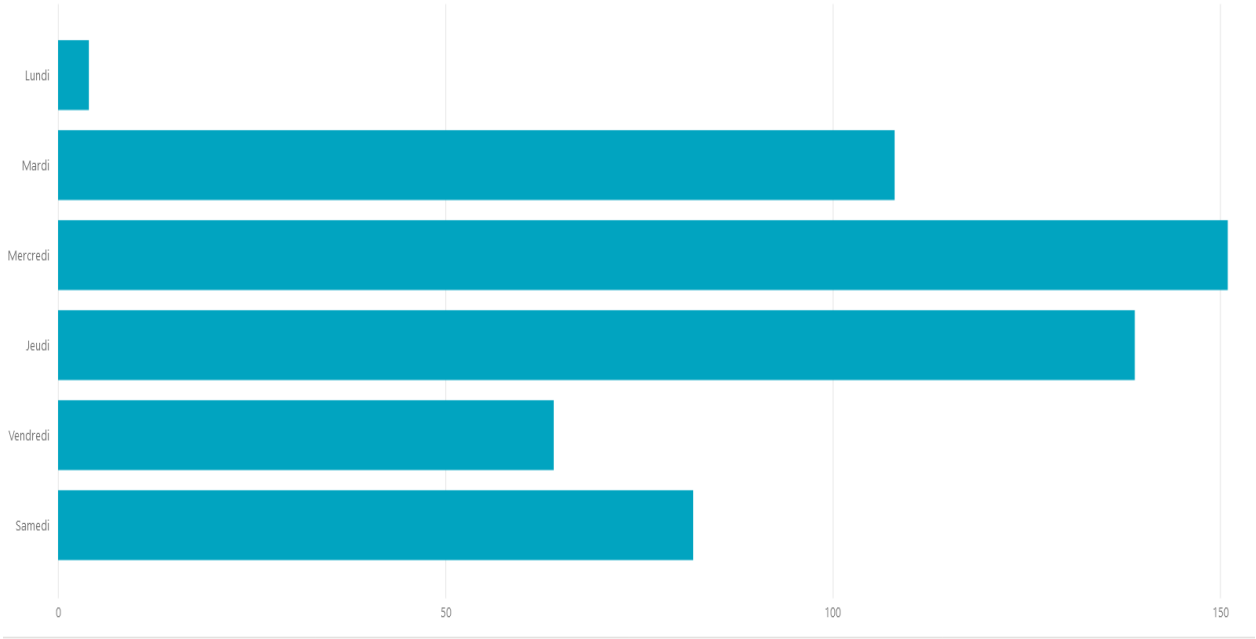


Figure 11 Distribution of reservations by day of the week

Arrêt de prise en charge	Trajets de passagers
MONTEE - DECINES GRAND LARGE	111
PARC OL PORTE N	89
BUREAUX OL / BRASSERIE BOCUSE	83
T7 OL VALLEE	49
SURF PARK (accessible fauteuil roulant)	40
PARC OL PORTE U	34
PARC OL PORTE G	29
POLE DE LOISIRS N+1 (MONTEE)	22
DESCENTE - DECINES GRAND LARGE	21
POLE DE LOISIRS ZONE PIETONNE	20
BRUT BUTCHER	18
HOTEL / BOUTIQUE (accessible fauteuil roulant)	15
CENTRE MEDICAL (accessible fauteuil roulant)	8
POLE DE LOISIRS N+1 (DESCENTE)	5
PARKING CENTRE MEDICAL	4
Total	**548**

Arrêt de dépose	Trajets de passagers
BUREAUX OL / BRASSERIE BOCUSE	105
DESCENTE - DECINES GRAND LARGE	90
PARC OL PORTE N	90
POLE DE LOISIRS ZONE PIETONNE	87
T7 OL VALLEE	51
MONTEE - DECINES GRAND LARGE	35
PARC OL PORTE U	22
PARC OL PORTE G	17
PARKING P3	17
POLE DE LOISIRS N+1 (MONTEE)	12
BRUT BUTCHER	7
HOTEL / BOUTIQUE (accessible fauteuil roulant)	7
SURF PARK (accessible fauteuil roulant)	5
CENTRE MEDICAL (accessible fauteuil roulant)	2
PARKING CENTRE MEDICAL	1
Total	**548**

Figure 12 Distribution of pick-up and drop-off stops

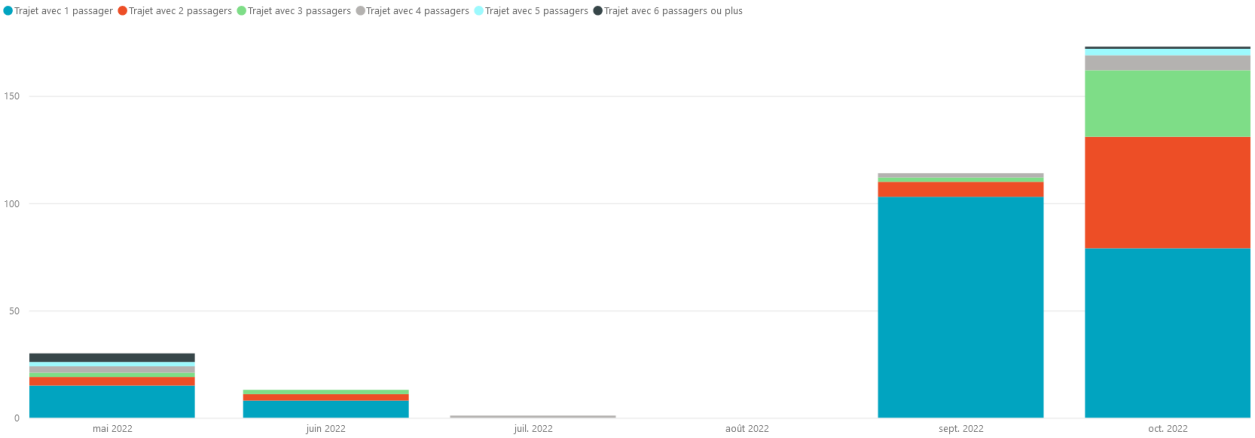


Figure 13 On-demand passenger pooling performance

These tables are extracts from the management interface proposed by the PADAM Mobility tool, which carries out the management of the autonomous shuttle fleet according to the customers' reservations.

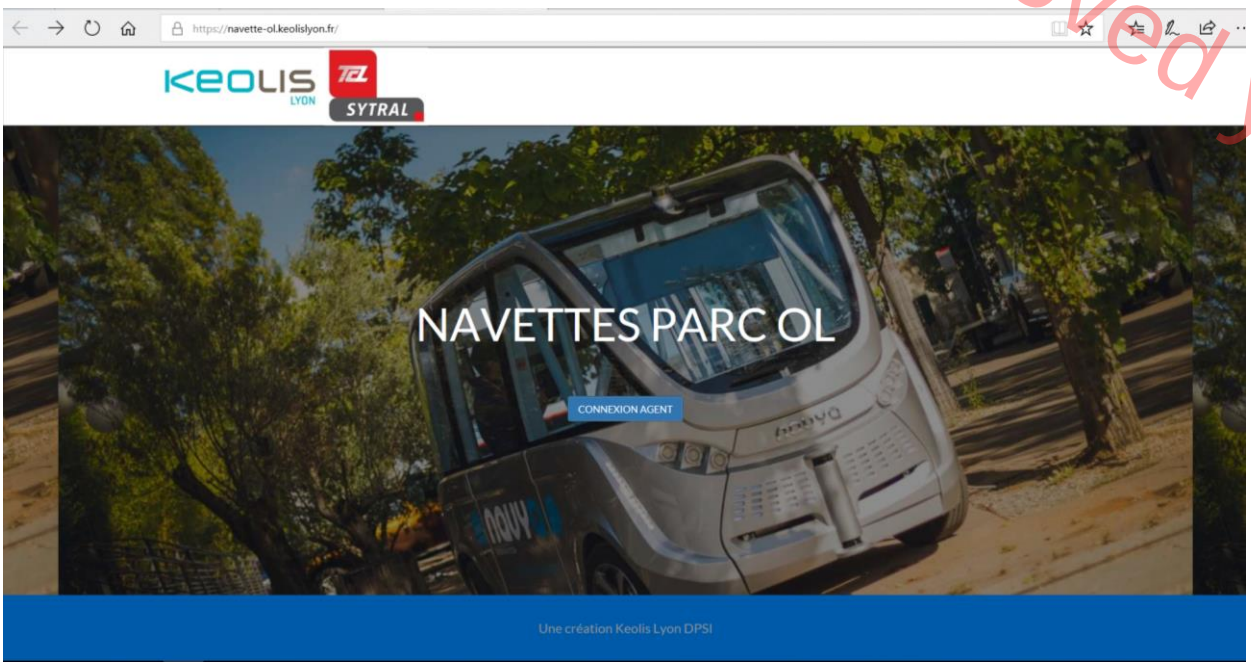
All the details are available on request from the H2020 Avenue project through an access to be created in the Power BI interface.

2.4.3.4 Safety Operator

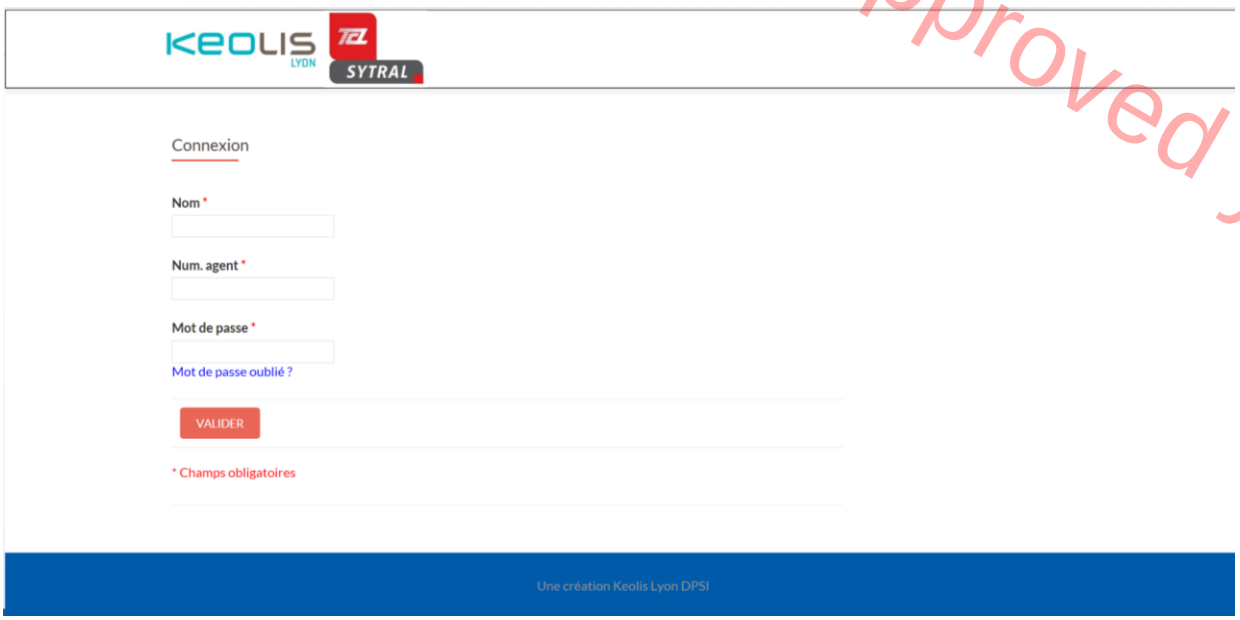
A daily report is automatically sent to Keolis Lyon mailing list. This daily report is based on information's that operators inside AVs put on a dedicate application. Each AVs include 2 digital tablets:

Operator's application screenshots:

Homepage:



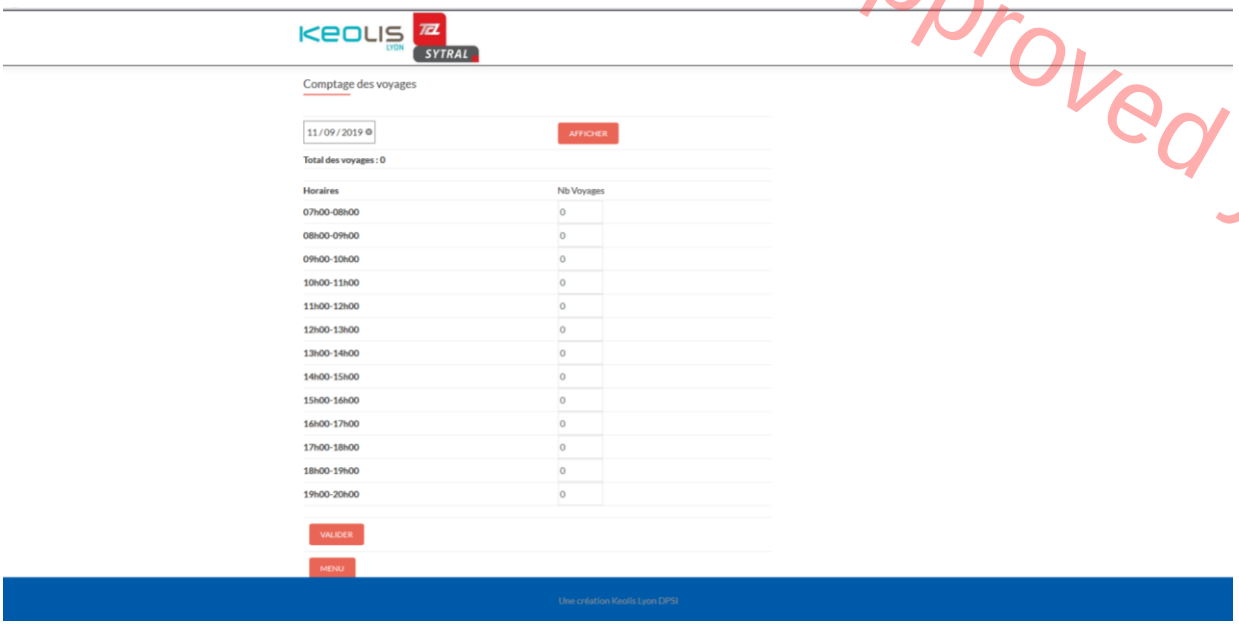
Every operator has a personal login and password:



Browsing:

- Frequentation counting
- Capture incident
- See incident

Frequentation counting:



Capture incident:

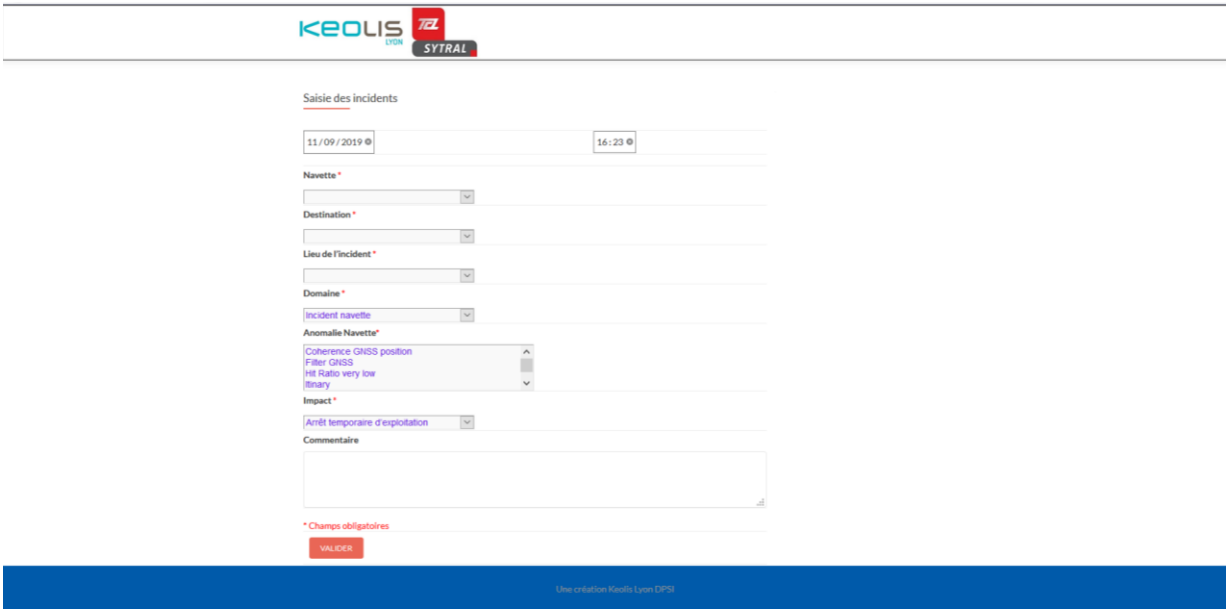


Figure 14 Safety driver app screenshot

Requested information's:

- AVs number :
  - P104
  - P108

  Pull-down menu
- Destination :

- Décines – Grand Large
- Parc OL

Pull-down menu

- Place of the incident :
  - Reversal area Décines – Grand Large
  - Bus lane Décines – Grand Large
  - Crossroad bus lane – Ferrer street
  - Ferrer street
  - Roundabout Décines Esplanade
  - Sully street
  - Crossroad Sully street – Simone Veil Avenue
  - Simone Veil Avenue
  - Crossroad Simone Veil Avenue – Groupama Stadium Parking
  - Reversal area Groupama Stadium
  - Groupama stadium parking

Pull-down menu

Comments:

- Free

- See incident :

Allow to search incidents day per day

With the implementation of the PADAM Mobility platform, the security operators on board the shuttles were able to stop filling in this tool. All trips, km, and other KPI's are directly proposed by the PADAM Mobility platform.

2.4.3.5 Operating Cost (period 2) :

The costs presented below are not declared by Keolis Lyon under a grant from the H2020 Avenue project. This information is only provided for the purpose of knowledge sharing and to feed the WP6 work on the business model of autonomous shuttles in public transport.

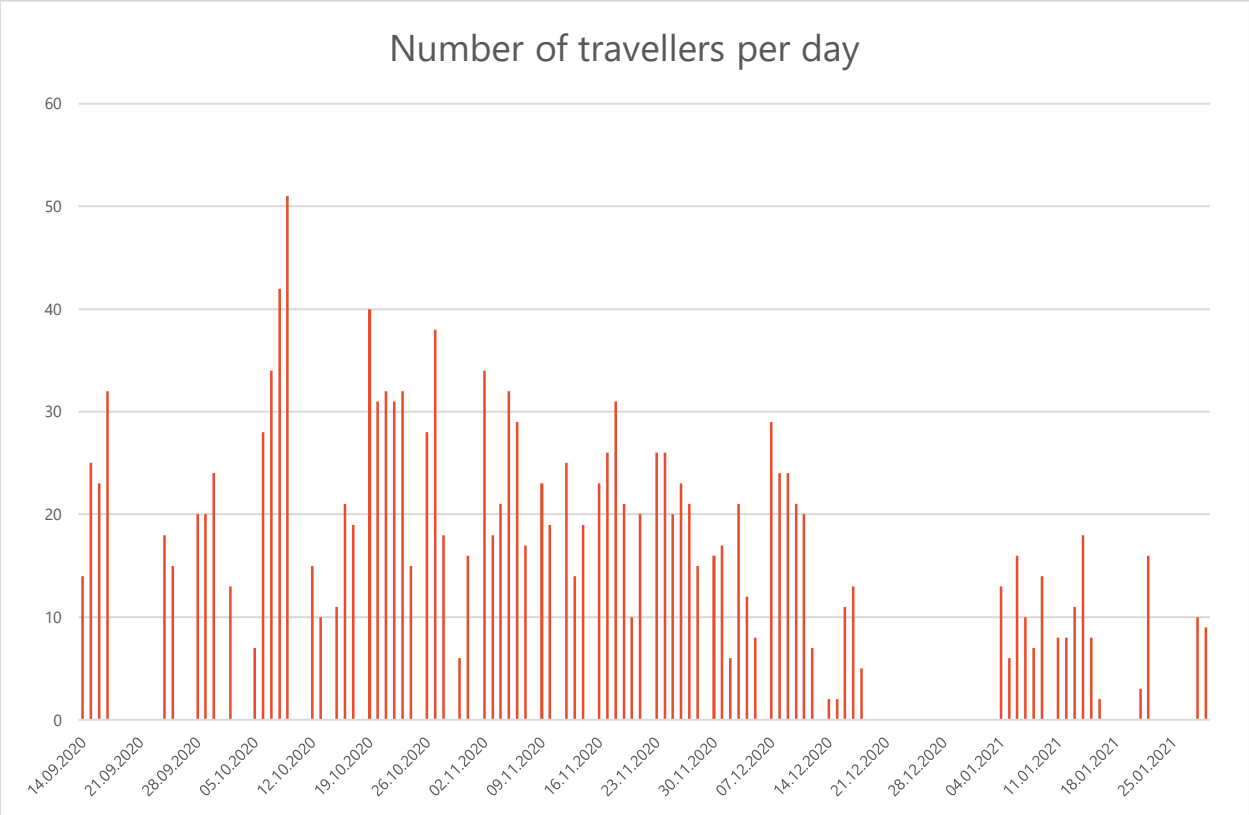
Nature of the expenditure	Amount 2020	Amount 2021	TOTAL
Supplies building storage autonomous shuttles	44 €		44€
BUILDING MAINTENANCE	3 841 €	7 583 €	11 424 €
Shuttle cleaning costs	1 752 €	660 €	2 412 €

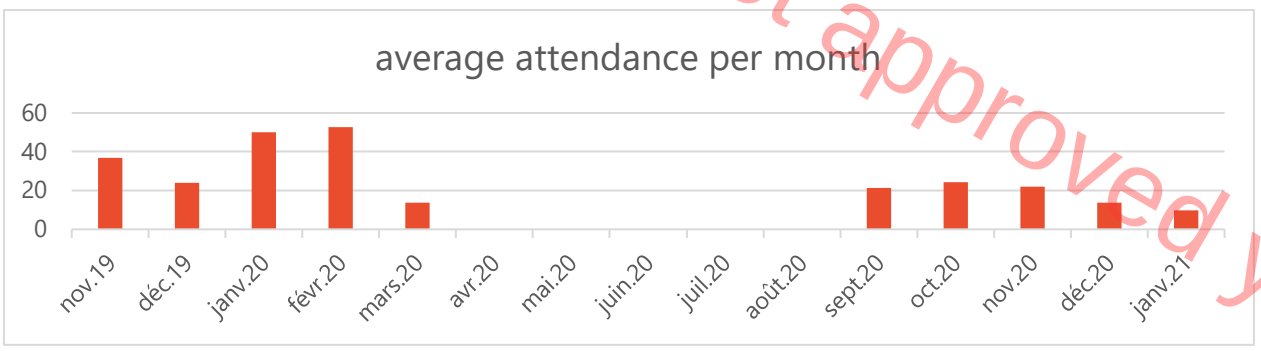
Site and travel security (external agency)	12 530 €		12 530 €
Costs imposed by NAVYA for the remapping of the area	9 000 €		9 000 €
Application development for safety drivers	9 900 €		9 900 €
Safety drivers costs	72 552 €	7 733 €	83 285 €
TOTAL	112 619 €	15 976 €	128 595 €

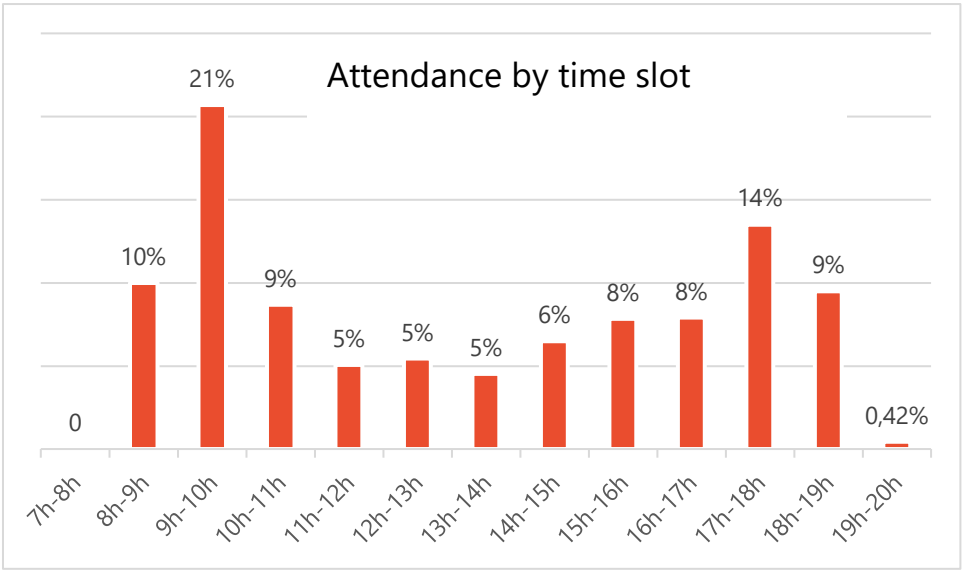
2.4.3.6 Authorities

The public service delegation contract between SYTRAL and Keolis Lyon precise that Keolis has to send monthly, quarterly and annually, a reporting of the project. In the first step of the project, we will only use available information's, but in a second time, NAVYA will have to increase his reporting system.

Here are some examples of the graphics provided in these reports.







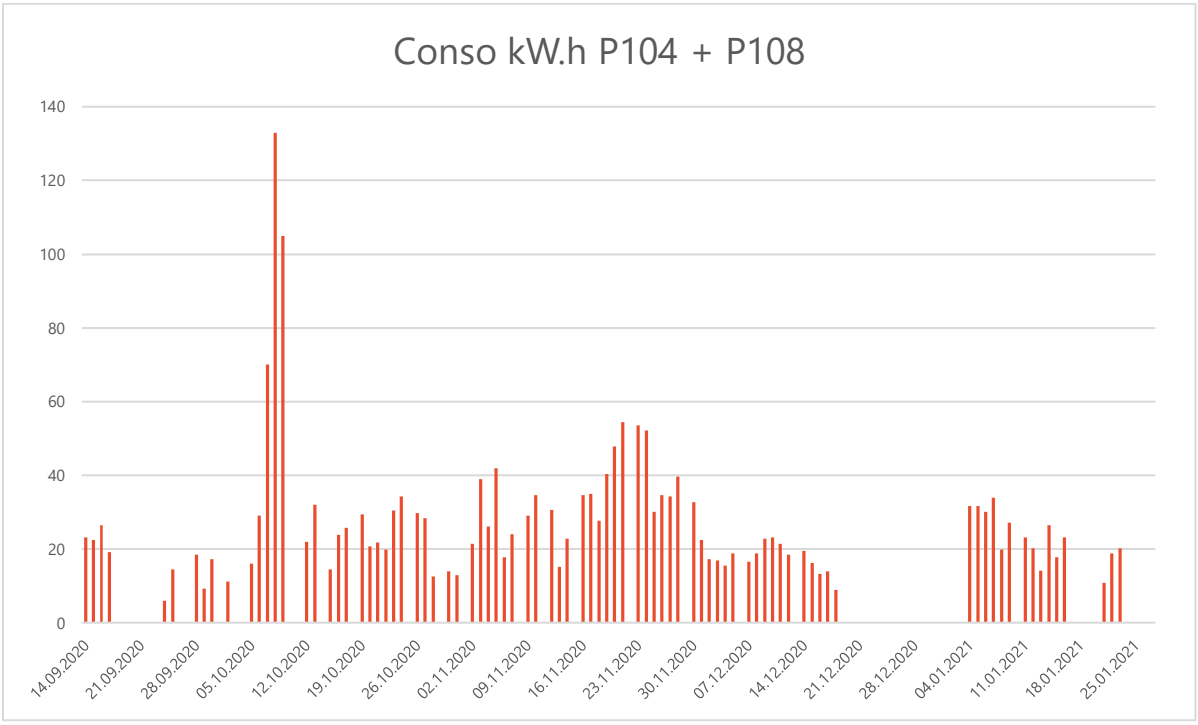


Figure 10: Groupama Stadium operations reporting

These data are expressed in raw form because that is how the organising authority's request was formulated. See section 2.4.1 for more details on the data collected during operation.

It is important to note that SYTRAL has withdrawn from the project following the change of elected officials of the Lyon metropolis in September 2020.

2.4.4 Deployment

The work of setting up the shuttles by NAVYA was officially validated on 16/09/2019. As of this date, Keolis Lyon considered that all the settings were satisfactory, and allowed the two autonomous shuttles to be operated in complete safety.

In order to ensure the overall smooth running, and also to meet the regulatory obligations imposed on the experimentation of autonomous vehicles in France, a test run was conducted from 17/09/2019 to 14/11/2019.

During this period, no events were observed that could call into question the safety of the major experiment. On the other hand, the first technical malfunctions were observed and were not remedied by NAVYA:

- Blockage of the steering system causing the temporary shutdown of the P104 shuttle

- Daily loss of the GNSS signal causing the temporary shutdown of both autonomous shuttles

Date	total distance (km) P104 + P108	rate of service delivery	number of trips (target 72/day)	energy consumption kW/h	Disruption
17/09/2019	**12**	**11%**	**8**	**0**	**0**
18/09/2019	**40**	**38%**	**27**	**15**	**0**
19/09/2019	**42**	**40%**	**29**	**13**	**0**
20/09/2019	**52**	**49%**	**35**	**15**	**0**
21/09/2019	**63**	**59%**	**43**	**18**	**7**
22/09/2019					
23/09/2019	**77**	**72%**	**52**	**15**	**11**
24/09/2019	**0**	**0%**	**0**	**0**	**0**
25/09/2019	**39**	**37%**	**26**	**8**	**0**
26/09/2019	**66**	**62%**	**44**	**16**	**0**
27/09/2019	**113**	**106%**	**76**	**22**	**0**
28/09/2019	**0**	**0%**	**0**	**0**	**0**
29/09/2019					

30/09/2019	0	0%	0	0	0
01/10/2019	77	72%	52	27	8
02/10/2019	74	69%	50	10	7
03/10/2019	39	37%	27	9	0
04/10/2019	36	33%	24	10	0
05/10/2019	50	47%	34	5	1
06/10/2019					
07/10/2019	95	89%	64	10	1
08/10/2019	67	63%	45	17	0
09/10/2019	32	30%	22	7	0
10/10/2019	25	24%	17	0	0
11/10/2019	53	50%	36	7	1
12/10/2019	0	0%	0	0	0
13/10/2019					
14/10/2019	0	0%	0	0	0
15/10/2019	24	22%	16	0	0
16/10/2019	26	24%	18	7	1
17/10/2019	29	27%	20	0	1
18/10/2019	36	34%	24	3	0
19/10/2019	0	0%	0	0	0
20/10/2019					
21/10/2019	30	28%	20	0	0
22/10/2019	34	32%	23	3	1
23/10/2019	22	21%	15	0	0
24/10/2019	28	27%	19	0	0
25/10/2019	27	25%	18	0	0
26/10/2019	0	0%	0	0	0
27/10/2019					
28/10/2019	25	23%	17	0	0
29/10/2019	37	35%	25	16	6
30/10/2019	23	22%	16	0	0

31/10/2019	**35**	**33%**	**24**	**0**	**2**
01/11/2019	**0**	**0%**	**0**	**0**	**0**
02/11/2019	**31**	**29%**	**21**	**0**	**0**
03/11/2019				**0**	
04/11/2019	**37**	**35%**	**25**	**12**	**4**
05/11/2019	**39**	**36%**	**26**	**6**	**1**
06/11/2019	**13**	**12%**	**9**	**1**	**2**
07/11/2019	**63**	**59%**	**42**	**22**	**2**
08/11/2019	**30**	**28%**	**20**	**6**	**1**
09/11/2019	**68**	**63%**	**46**	**6**	**1**
10/11/2019				**0**	
11/11/2019	**0**	**0%**	**0**	**0**	**0**
12/11/2019	**57**	**54%**	**39**	**8**	**0**
13/11/2019	**14**	**13%**	**10**	**4**	**0**
14/11/2019	**0**	**0%**	**0**	**0**	**0**
15/11/2019	**49**	**46%**	**33**	**0**	**0**
16/11/2019	**43**	**41%**	**29**	**15**	**1**

Table 6 Trial tests report

At the same time as this test run, Keolis Lyon officially applied to SYTRAL, the organising authority for mobility in the Lyon metropolitan area, to request authorisation to launch operations to the public. The official request was granted.

The results presented above are given in the form imposed at the time by the organising authority. It follows the reporting model that was agreed in advance of the start of operations. The targets are based on those agreed for on-board passenger operations.

However, during these test phases, Keolis and SYTRAL did not have the ambition to reach these targets, which are only relevant with passengers on board. The differences between the objective and what was actually achieved are therefore of no value here, since the objective of these tests was to validate the correct operation of the shuttles at the most delicate points on the route.

The follow-up of the operation with passengers on board is given in part 2.4.1 and 2.4.2

In order to prepare for the second phase of the on-demand transportation service, a new deployment work was carried out with NAVYA, to extend the route over approximately 5 km.

This second deployment could only start in August 2021 because prior authorizations from Olympique Lyonnais were required, in particular to validate the access to the T7 podium. This access required the use of the North-West ramp of the Groupama Stadium, and the stadium's insurance company requested a study of the ramp's portability to ensure that it was capable of supporting the weight of the shuttles.

Once all the authorizations were obtained, the feasibility studies could begin and required some evaluation and highlighted some difficulties:

- The GNSS signal under the stadium roof was insufficient. The GNSS signal under the roof of the stadium was insufficient. Special settings had to be set up so that the shuttle could operate on this portion only with its lidars.

- The service around the stadium integrates a risk linked to the limits of the parameters of the autonomous shuttles. Indeed, on a point of the route, the shuttle must make a U-turn with a portion in reverse. This implies to put in "ON" the option UK mode of the shuttle, necessary to make ni-directional displacements. This option being able to be applied only to the whole site, a risk existed that the shuttle leaves the pedestrian podium of the Groupama stadium in the bad direction, with the doors on the left, making impossible the taking in charge of the travelers on the whole route.

- Work was necessary, in particular for the installation of automatic barriers that would allow the passage of the shuttles on the pedestrian podium of the Groupama Stadium, and on the T7 Tramway forecourt where traffic is prohibited, apart from the autonomous shuttle. Requests for authorization to occupy the public domain were necessary. These procedures require an incompressible time of treatment by the services of the metropolis.

Once all of these studies were completed, and these constraints lifted, the deployment could begin in January 2022.

Figure 15 initial situation without barrier, then with barrier installed

Following this new deployment, the first tests were carried out and validated the normal operation of the new deployment, on all origins <-> destinations.

Based on this work, PADAM was able to deploy the fleet management tool and integrate the new stops and routes developed by NAVYA. Once all the field tests were completed, the service was launched and opened to the public on April 17, 2022.

When the service opened, there was no automation of mission management between Padam and NAVYA. Despite our and PADAM's desire to automate the service, NAVYA informed us that only API version 4.X was available, but that this API version only communicated with version 7.X of the shuttle software, and that this version 7.X was not available.

2.4.5 Evaluation

In a normal situation, a public transport operator is autonomous to manage the malfunctioning of its rolling stock. Maintenance teams are trained and available to ensure that the vehicles are in good working order, and the bus, metro and tram fleets are made up of reserve vehicles that can be used whenever necessary. Thus, the service can be operated under any circumstances.

In the case of autonomous shuttles, the situation is more complex. Indeed, Keolis Lyon only has two autonomous shuttles for its OL Park experiment. The maintenance operators are not trained to intervene on the shuttles in the event of a hardware malfunction. No access to the software is authorized by NAVYA. In this context, it is NAVYA's capacity and responsiveness that allows Keolis Lyon to put an inoperative shuttle back into operation.

2.4.5.1 General malfunctions

18/11/2019: Steering rack blockage P104 - 2h interruption of operations on P104

19/11/2019: P104 stopped for 1 hour to extract logs

22/11/2019: P104 immobilized for the whole afternoon due to door closing problems.

23/11/2019: Operation stop at 12:00 (Groupama Stadium match)

27/11/2019: Problems with the doors

28/11/2019: Operation stop P104 due to problems with the doors

30/11/2019: Operation stop at 12h00 (Groupama Stadium match). P104 OUT OF ORDER

02/12/2019: P104 OUT OF ORDER

03/12/2019: Operational stop at 12h00 (Groupama Stadium match). P104 OUT OF ORDER

04/12/2019: P104 OUT OF ORDER

05/12/2019: No operation due to strike. P104 OUT OF ORDER

06/12/2019: No operation due to demonstration in the neighbourhood. P104 OUT OF ORDER

07/12/2019: P104 OUT OF ORDER

09/12/2019: NAVYA intervention on P104 and P108.

10/12/2019: Shutdown due to demonstration in the neighbourhood / No operation in the afternoon - OL match

18/12/2019: Operation stop at 12:00 (Groupama Stadium match)

23/12/2019: Operation stop P104 : return to NAVYA factory

24/12/2019: Operation stop P104 : return to NAVYA factory

25/12/2019: Shutdown P104 : return to NAVYA factory

26/12/2019: Operation stop P104 : return to NAVYA factory

27/12/2019: Operation stop P104 : return to NAVYA factory

28/12/2019: Operation stop P104 : return to NAVYA factory

30/12/2019: Operation stop P104 : return to NAVYA factory

31/12/2019: Shutdown P104 : return to NAVYA plant

06/01/2020: Operation stop due to fog

08/01/2020: Operation stop at 12:00 (Groupama Stadium match)

21/01/2020: Operation stop at 12:00 (Groupama Stadium match)

28/01/2020: Operational stop at 12:00 (Groupama Stadium match)

05/02/2020: OL match: End of service at 12:00

07/02/2020: Maintenance work P104/P108

08/02/2020: Operational stop P108 : Lidar calibration to be carried out

10/02/2020: Operational stop P108: Lidar calibration to be carried out

11/02/2020: Operation stop P108 : Lidars calibration to be done

12/02/2020: OL match: End of service at 12:00 / Operation stop P108: Lidar calibration to be carried out

13/02/2020: Operation stop P108 : Lidars calibration to be done

14/02/2020: Operation stop P108: Lidar calibration to be carried out

15/02/2020: Shutdown P108 : Lidars calibration to be done

17/02/2020: Operation stop P108 : Lidars calibration to be done

22/02/2020: Match OL: End of service at 12:00

26/02/2020: OL match: End of service at 12 noon

29/02/2020: Reduced service due to weather conditions

02/03/2020: Operational stop P104: return to NAVYA factory

03/03/2020: Operational stop P104: return to NAVYA factory / renewal of GNSS base SIM card

04/03/2020: Operational stop P104 : return to NAVYA factory / OL match : end of service at 12:00

05/03/2020: Operational stop P104 : return to NAVYA factory / reduced service due to weather conditions

06/03/2020: Operation stop P104 : return to NAVYA factory / Isolation Log P108 (30mn stop)

07/03/2020: Shutdown P104: return to NAVYA plant

09/03/2020: Operational stop P104 : return to NAVYA factory

10/03/2020: Operation stop. Closure of Avenue Simone Veil due to dismantling of cranes on the leisure center site

11/03/2020: Operation stop. Avenue Simone Veil closed due to dismantling of cranes at the leisure centre site

12/03/2020: Return to the site P104: Test run

13/03/2020: Operation stop P104: Lidar calibration to be carried out

14/03/2020: Shutdown P104: Lidar calibration to be carried out

14/09/2020: P104 OUT OF ORDER due to lidar defect

15/09/2020: P104 OUT OF ORDER due to lidar defect

16/09/2020: P104 OUT OF ORDER due to lidar defect

17/09/2020: P104 OUT OF ORDER due to lidar defect

18/09/2020: P104 OUT OF ORDER due to lidar fault / Operator application malfunction. Passenger counting not available

21/09/2020: Failure of the Metropolitan Connected Infrastructure: Shutdown / P104 out of service due to a lidar fault

22/09/2020: Connected infrastructure failure Metropole : Operation stop / P104 out of service due to lidar fault

23/09/2020: Connected infrastructure failure Metropole: Operation stop / P104 out of service due to lidar fault

24/09/2020: P104 OUT OF ORDER due to a lidar fault

25/09/2020: P104 OUT OF ORDER due to a lidar fault

28/09/2020: P104 OUT OF ORDER due to lidar defect

29/09/2020: P104 OUT OF ORDER due to lidar defect

30/09/2020: P104 OUT OF ORDER due to lidar fault

01/10/2020 Operation cancelled due to a municipal by-law preventing passage along Simone Veil Avenue

05/10/2020: P104 out of service due to lidar fault

06/10/2020: P104 out of service due to lidar fault

08/10/2020: P108 door closure problem

09/10/2020: P108 door closure problem

12/10/2020: 1 shuttle available due to training of new operators

13/10/2020: 1 shuttle available due to training of new operators

14/10/2020: Shuttles unavailable due to new operator training

15/10/2020: 1 shuttle available due to training of new operators

24/10/2020: Malfunction closing of P108 doors

29/10/2020: Service stop due to works on Avenue Simone Veil

30/10/2020: Service stop until 1pm due to works on Avenue Simone Veil

16/11/2020: Appearance of problems with closing the doors

18/11/2020: Appearance of problems at door closure (increase in frequency of occurrence of the problem)

30/11/2020: P108 service shutdown due to door closure problem

01/12/2020: Loss of GNSS

09/12/2020: V2X malfunction on the roundabout. Cause: Roadside Unit

14/12/2020: One shuttle (P108) to NAVYA factory for R10/R100 electrical compliance.

15/12/2020: A shuttle (P108) at the NAVYA factory for R10/R100 electrical compliance.

16/12/2020: A shuttle (P108) to the NAVYA factory for electrical compliance R10/R100.

17/12/2020: A shuttle (P108) at the NAVYA factory for electrical compliance R10/R100.

18/12/2020: A shuttle (P108) at the NAVYA factory for electrical compliance R10/R100.

19/12/2020: A shuttle (P108) at the NAVYA factory for R10/R100 electrical compliance.

21/12/2020: No operation during school holidays

22/12/2020: No operation during school holidays

23/12/2020: No operation during school holidays

24/12/2020: No operation during school holidays

25/12/2020: No operation during school holidays

26/12/2020: No operation during school holidays

28/12/2020: No operation during school holidays

29/12/2020: No operation during school holidays

30/12/2020: No operation during school holidays

31/12/2020: No operation during school holidays

01/01/2021: No operation during school holidays

02/01/2021: No operation during school holidays

04/01/2021: One shuttle (P108) at NAVYA factory for electrical compliance R10/R100.

05/01/2021: A shuttle (P108) at the NAVYA factory for electrical compliance R10/R100.

06/01/2021: A shuttle (P108) at the NAVYA factory for electrical compliance R10/R100.

07/01/2021: A shuttle (P108) at the NAVYA factory for electrical compliance R10/R100.

08/01/2021: Error caused by NAVYA supervision which caused the shuttle to stop in the middle of the track. A shuttle (P108) to the NAVYA factory for R10/R100 electrical compliance.

09/01/2021: A shuttle (P108) at the NAVYA factory for R10/R100 electrical compliance.

11/01/2021: A shuttle (P108) at the NAVYA factory for electrical compliance R10/R100.

12/01/2021: A shuttle (P108) at the NAVYA factory for R10/R100 electrical upgrading.

13/01/2021: A shuttle (P108) at the NAVYA factory for R10/R100 electrical upgrading.

14/01/2021: A shuttle (P108) at the NAVYA factory for R10/R100 electrical compliance.

18/01/2021: Operation cancelled. Path resumption necessary following the new calibration of the lidars which caused too sensitive detections on the right of the shuttle

19/01/2021: Operation cancelled. Resumption of the necessary path following the new calibration of the lidars which caused too sensitive detections on the right of the shuttle

19/01/2021: Operation cancelled. Resumption of the path necessary following the new calibration of the lidars which caused too sensitive detections on the right of the shuttle

20/01/2021: Operation cancelled. Resumption of the necessary path following the new calibration of the lidars which caused too sensitive detections on the right of the shuttle

21/01/2021: Operation difficult due to heavy rain. One shuttle (P104) to NAVYA factory for R10/R100 electrical compliance.

22/01/2021: A shuttle (P104) at the NAVYA factory for R10/R100 electrical compliance.

23/01/2021: No passenger count due to a bug in the operators' application. One shuttle (P104) to NAVYA factory for R10/R100 electrical compliance.

25/01/2021: Operation cancelled due to works on Avenue Simone Veil

26/01/2021: Operation cancelled due to works on Avenue Simone Veil

27/01/2021: Operation cancelled. Blank run due to a software upgrade.

28/01/2021: A shuttle (P104) at the NAVYA factory for electrical compliance R10/R100.

29/01/2021: A shuttle (P104) at the NAVYA factory for R10/R100 electrical compliance.

Phase 2

18/05/2022 P108- Gnss problem (navya asked to check connections/switches/SIM, seen with Adrien everything is OK) P104- Shuttle stop in the middle of the track (pc burning - shuttle stop for 20 minutes)

27/05/2022 P104- Shuttle blocked on the way up to the stadium, switching to manual at each turn/ GNSS loss between 1 and 2 pm on both shuttles

28/05/2022 P104- Numerous GNSS losses preventing the operation of a large part of the service

08/06/2022 Continued problem with the lidar of P108 disrupting the service, tests carried out with navya not conclusive.

10/06/2022 P108: lidar 4 faulty, shuttle could not perform its service - service stop sent while waiting for navya intervention

18/06/2022 P104- Shuttle collides (auto) with T7 barrieere/ GNSS persists several times

24/06/2022 Service interruption of about 3 hours due to gnss problem (connection to navya technical support for investigation + time lost to leave afterwards)

09/17/2022 No service due to NTRIP provider issue

2.4.5.2 Communication with the infrastructure

Three traffic light junctions operate with communication between the shuttles and the infrastructure (V2X). The normal operation of these communications allows the shuttles to send their position to the traffic light controllers, who send the necessary information to the shuttles so that they understand the status of the traffic light. The shuttles can then know whether or not it is safe to enter the intersection.

There are two modes of settings:

Passive operation: The lights are not modified when the shuttles approach. The shuttles adapt their behaviour to the colour of the light.

Active operation: The controller changes the traffic light cycle to facilitate the insertion of the shuttles into the intersection.

2.4.5.2.1 Normal operation

Junction 1: Décines Grand Large bus lane crossing, Rue Francesco Ferrer

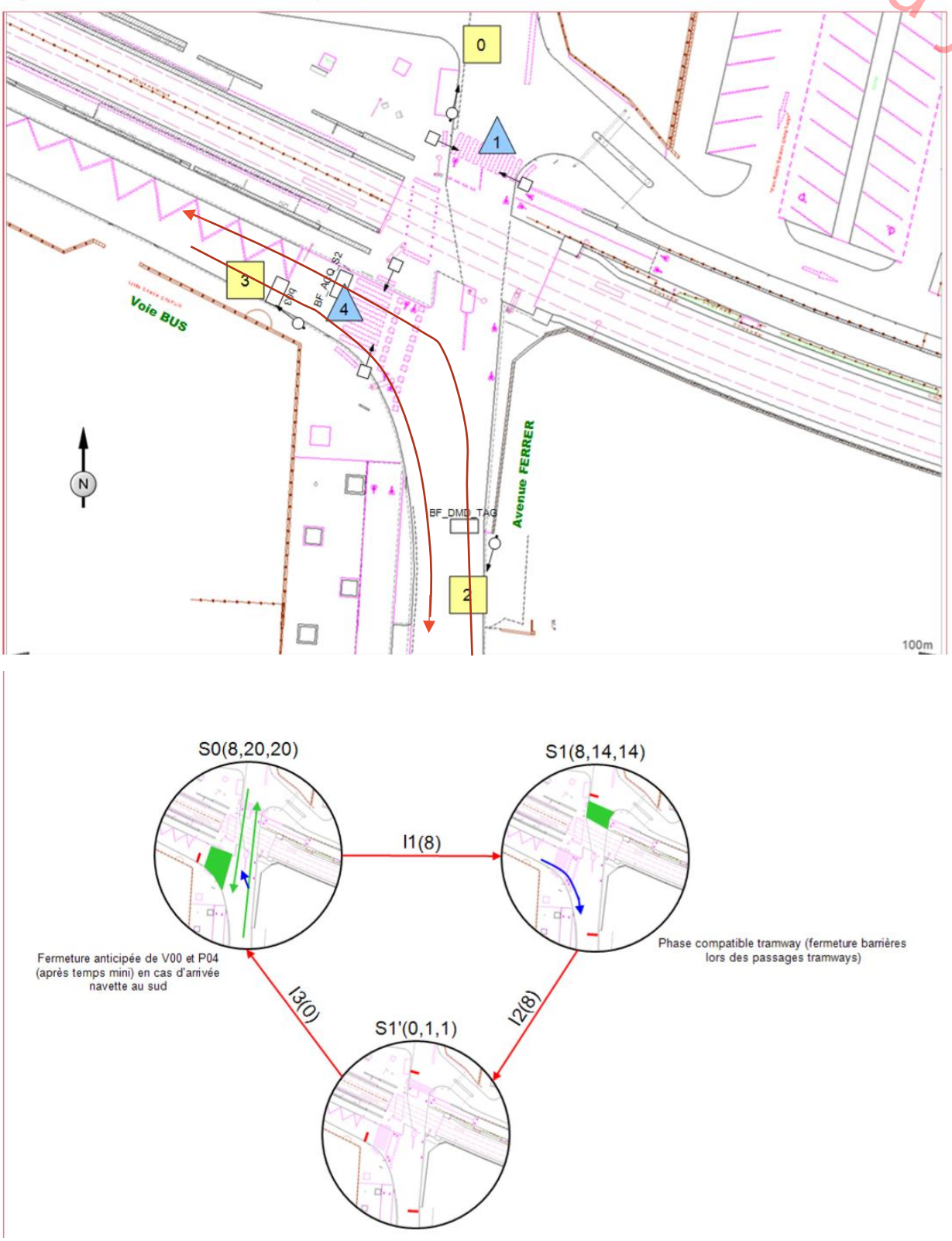
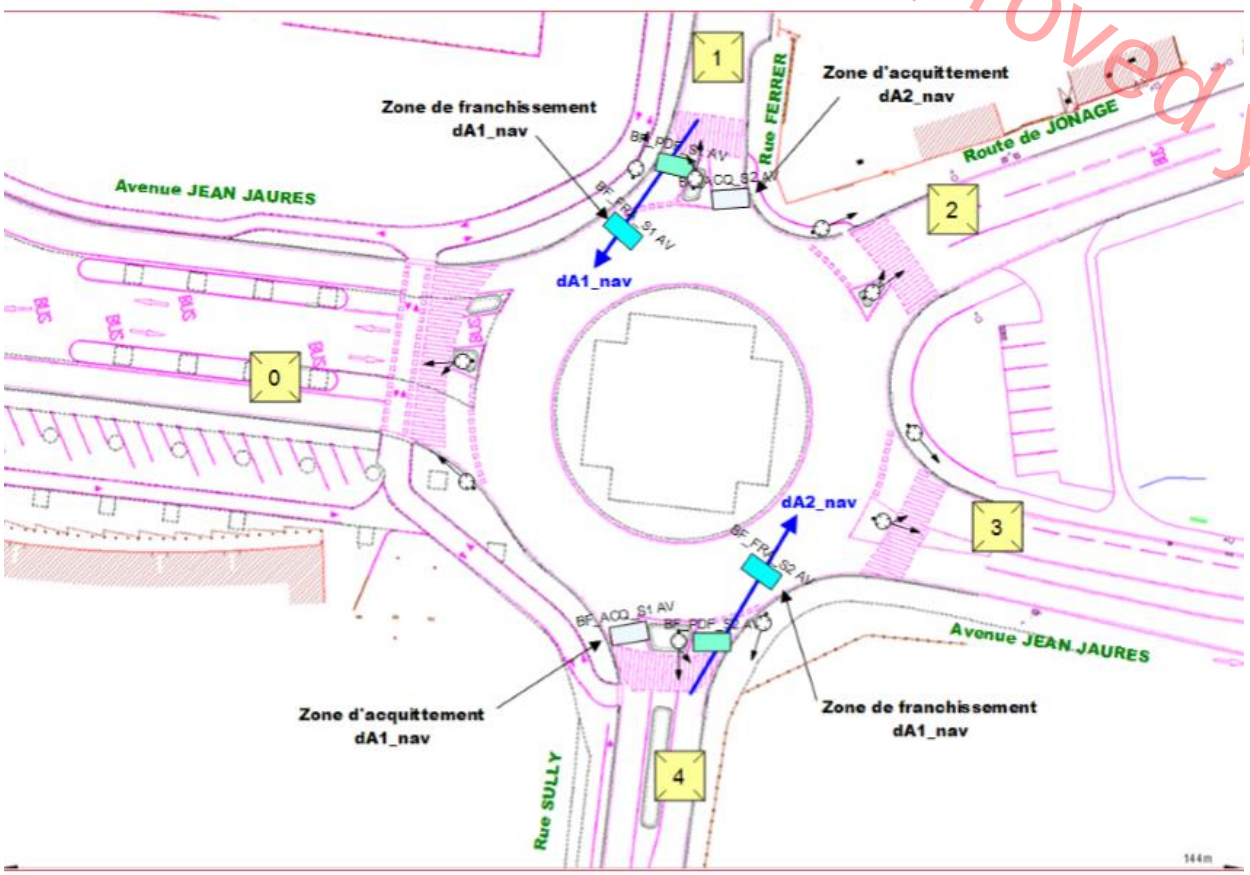


Figure 20: Road geometry and traffic light plan

Junction 2: Roundabout Rue Francesco Ferrer – Rue Sully



OUVERTURE/FERMETURE LIGNES SUR CONDITIONS

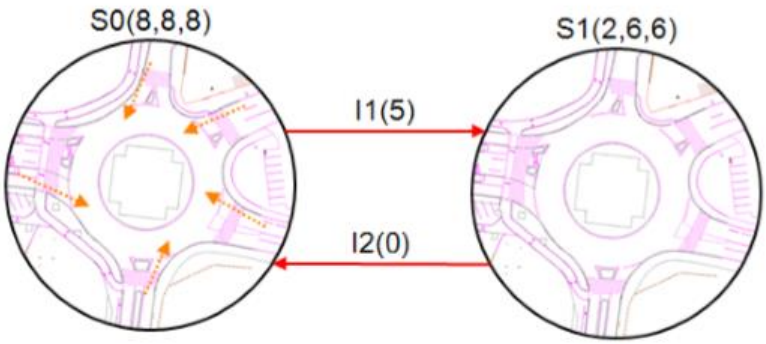
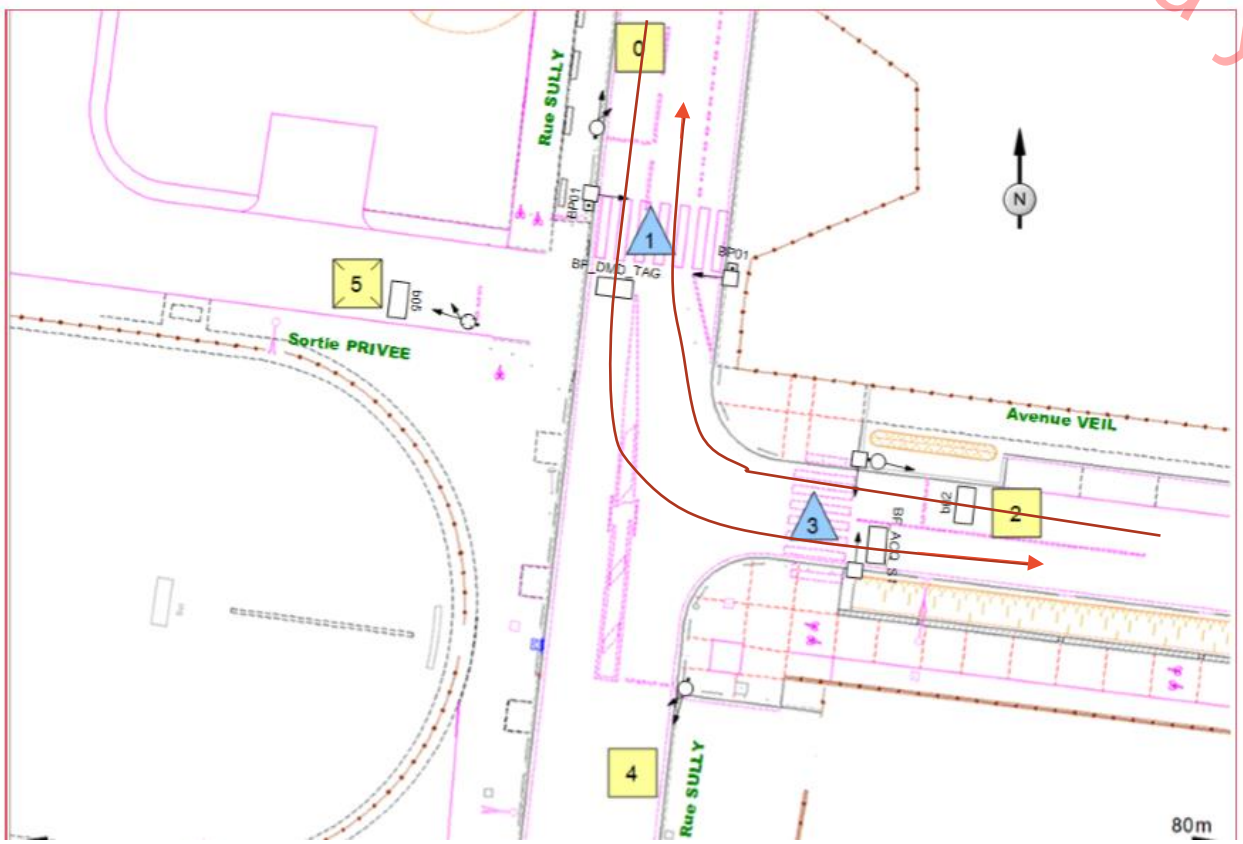


Figure 21: Road geometry and traffic light plan

Junction 3: Rue Sully – Avenue Simone Veil



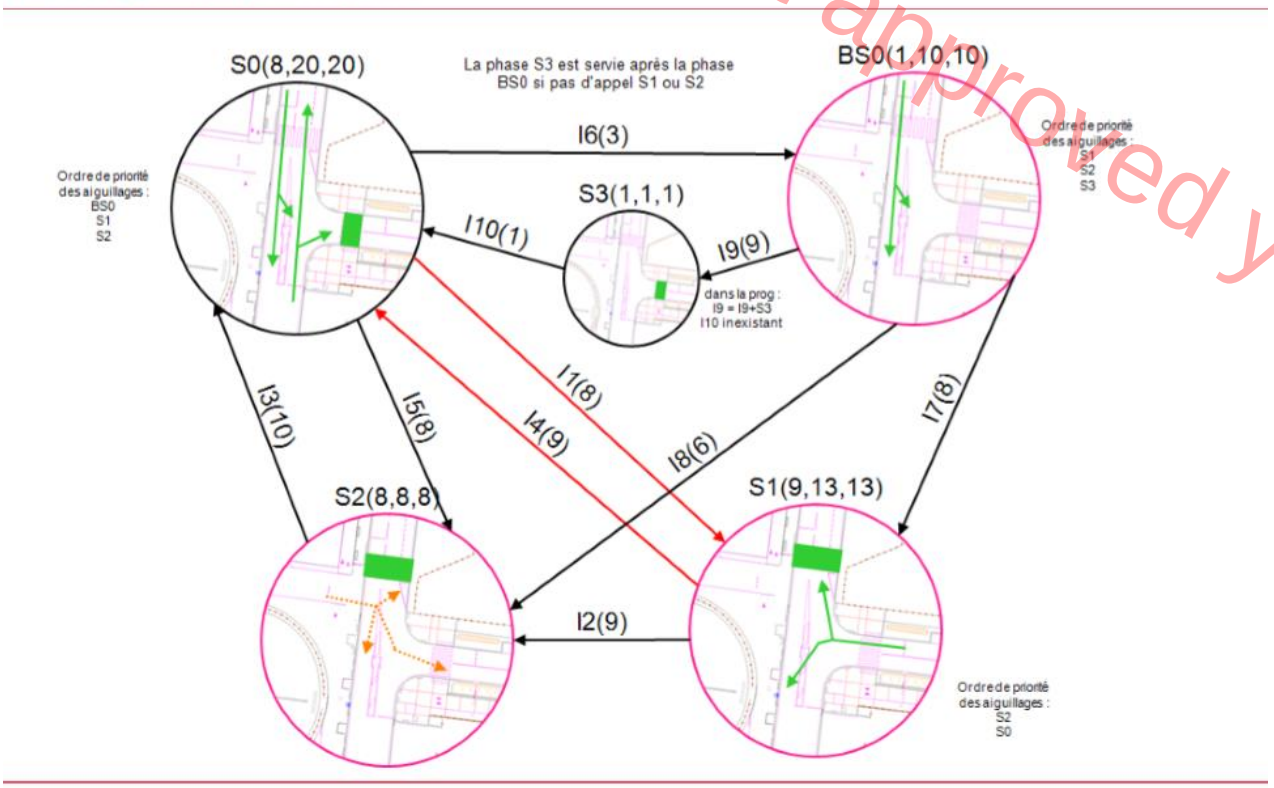
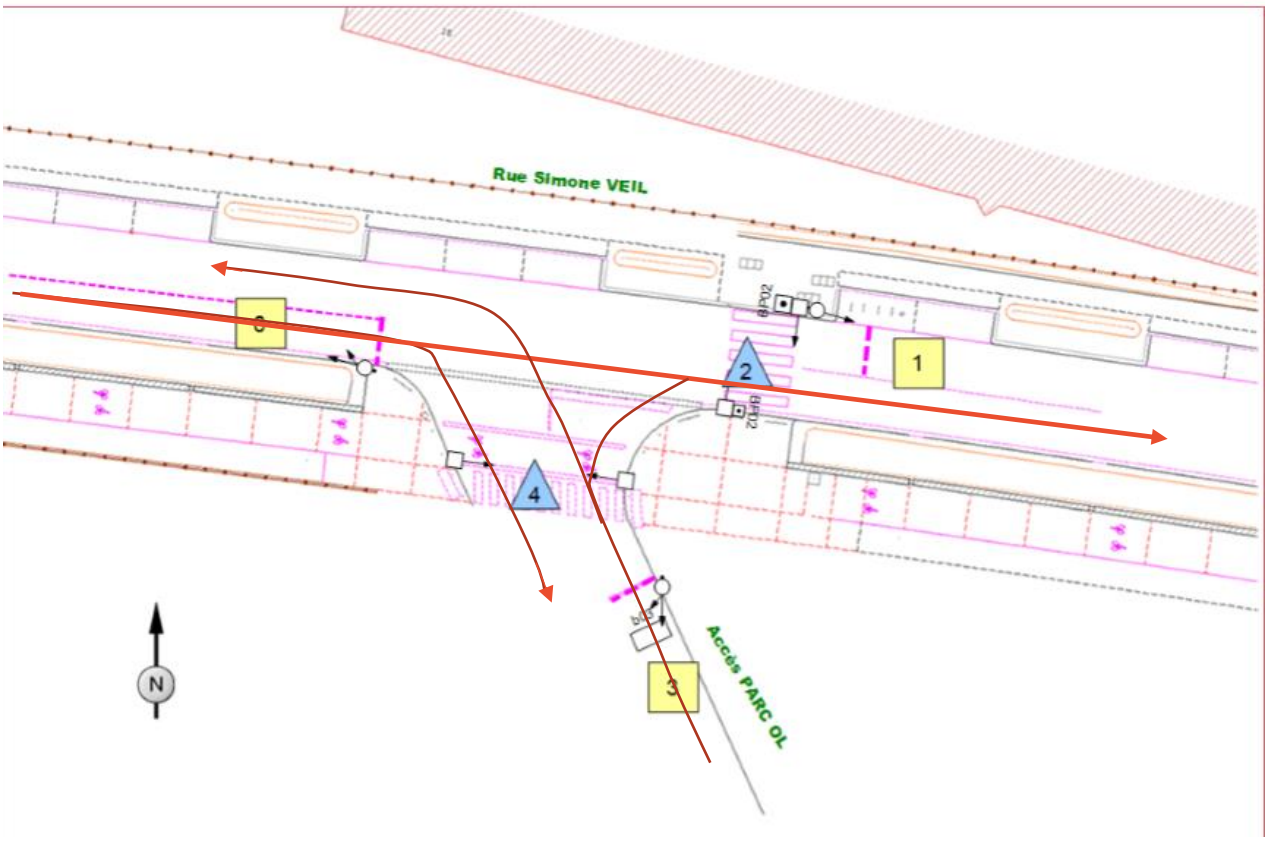


Figure 22: Road geometry and traffic light plan

Junction 4: Avenue Simone – Parking Lane Groupama Stadium



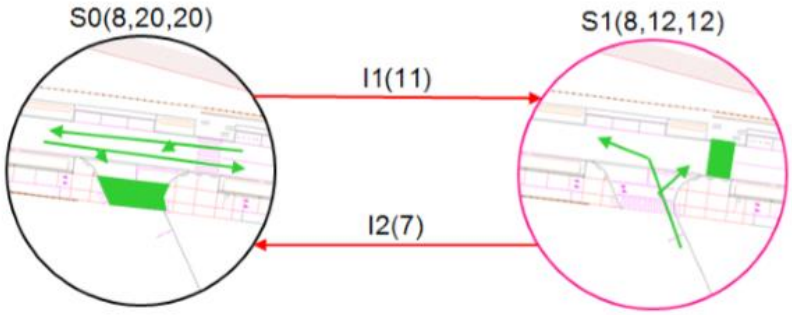


Figure 23: Road geometry and traffic light plan

2.4.5.2.2 Malfunctions encountered

In the early stages of the deployment, NAVYA encountered numerous difficulties in setting up the V2X functionalities. The project schedule had to be rearranged following several problems encountered, which prevented the vehicle - infrastructure communication from working. The functional problems observed were the following:

- No communication between the infrastructure and the autonomous shuttles

- The autonomous shuttles send messages to the traffic light controllers, which modify the status of the traffic lights. However, the shuttle receives messages from the traffic light controller, indicating the status of the traffic light, but is unable to transform this information into a dynamic order to insert itself into the crossroad.

After many hours of parameterization, NAVYA was able to get all the junctions working normally. A full day of testing of the intersections was organized with all the stakeholders (Metropole de Lyon, Fareco, the infrastructure supplier, SEMERU, the traffic light controller maintainer).At the end of this test day, the proper functioning of the autonomous shuttles at the crossroads had been validated by all the stakeholders.

Nevertheless, some points for improvement were noted. The main point of observation was that NAVYA was not able to create different operations for each intersection. In the V2X frames (ITS messages sent by G5 protocols), each possible traffic light state corresponds to a code, which must then be transcribed into DIASER code to be understood by the traffic light controller. A sample of these codes is given in the table

below

Mode carrefour / Etat ligne de feux	Valeur textuelle SPAT	Valeur numérique SPAT
Extinction	« dark »	1
Clignotant	« caution-Conflicting-Traffic »	9
Tricolore / Fermé	« stop-And-Remain »	3
Tricolore / Ouvert	« protected-Movement-Allowed »	6
Tricolore / Jaune	« protected-clearance »	8
Tricolore / Ouvert (jaune clignо bas)	« permissive-Movement-Allowed »	5
Tricolore / Jaune (suite jaune clignо bas)	« permissive-clearance »	7

(les 2 derniers cas correspondent aux lignes dites J-J-R avec un jaune clignotant en bas, au lieu du vert fixe des lignes tricolores V-J-R)

Défaut de communication Diaser	« unavailable »	0

Liste valeurs numéri Ajuster les lignes du tableau état des lignes de feux (par lecture ressources multiples):

Mode carrefour / Etat ligne de feux	Valeur ressource numérique DIASER
Tricolore / Fermé	0
Tricolore / Ouvert	1
Clignotant	2
Extinction	4

The point of improvement that was noted would be to be able to have a different behaviour of the shuttle at each intersection when it receives the same message. For example, on a roundabout equipped with traffic lights, a flashing orange signal can be interpreted as a possibility to insert oneself since a left priority based on the detection of an object by the shuttle is also set.

On the other hand, on a left-turn junction (example junction 3), a flashing orange signal must be interpreted as a shuttle stop because the cars arriving in front also have a flashing orange signal. In these cases, the shuttle's diversion capacity is insufficient, and it must stop in case of an orange signal.

This was reported to NAVYA, but the operation has not been changed to date. We have therefore considered, for greater safety, that the flashing orange signal should be interpreted as a stop on the entire route.

2.4.5.3 Operations related

Month	Year	Operated hours	Km	Average speed	% manual mode
November	2019	223,00 h	1 244 Km	9,60 Km/h	26.05%
December	2019	232,00 h	1 301 Km	9,80 Km/h	26.03%
January	2020	329,00 h	1 906 Km	9,90 Km/h	22.23%
February	2020	291,00 h	1 717 Km	10,10 Km/h	24.09%
March	2020	93,00 h	486 Km	10,00 Km/h	41.44%
September	2020	70,50 h	354 Km	9,20 Km/h	28.23%
October	2020	263,00 h	1 474 Km	9,70 Km/h	38.27%
November	2020	335,00 h	2 039 Km	10,20 Km/h	32.17%
December	2020	105,90 h	501 Km	9,90 Km/h	43.31%
January	2021	128,20 h	620 Km	9,80 Km/h	43.79%
Février	2021	0,67 h	0 Km		-
Avril	2022	24,31 h	34 Km	6,90 Km/h	88.47%
Mai	2022	88,60 h	326 Km	8,10 Km/h	84.95%
Juin	2022	114,00 h	409 Km	8,30 Km/h	89.65
Juillet	2022	9,76 h	35 Km	8,30 Km/h	-
Septembre	2022	127,99 h	376 Km		90,3%

Table 7 Operation report

The % manual mode is indicative of the gap between the current level of technology, and the level needed to consider the withdrawal of the operator (beyond the other technical and safety aspects).

The use of manual mode is necessary for the daily operation of autonomous vehicles.

- To avoid obstacles on the road (e.g. wrongly parked car)

- When a malfunction is observed on the shuttles, and they cannot start up again in autonomous mode, the protocol requires the safety drivers to contact the supervisor to carry out the diagnosis, then to reboot the vehicles. These malfunctions are encountered several times a day (e.g. loss of GNSS, loss of the 3D map background, etc.). The diagnosis and reboot of the shuttles takes an average of 15 minutes, and as our environment is 100% open road, we ask the operators to use manual mode to drive to the logistics areas located at the two ends of the route.

- A manual mode is necessary at each passage of the tramway intersection, whose traffic lights have not been put into operation by the Metropolis, which wished to set up validation by simulation. NAVYA never supplied the simulation module required to carry out this validation.

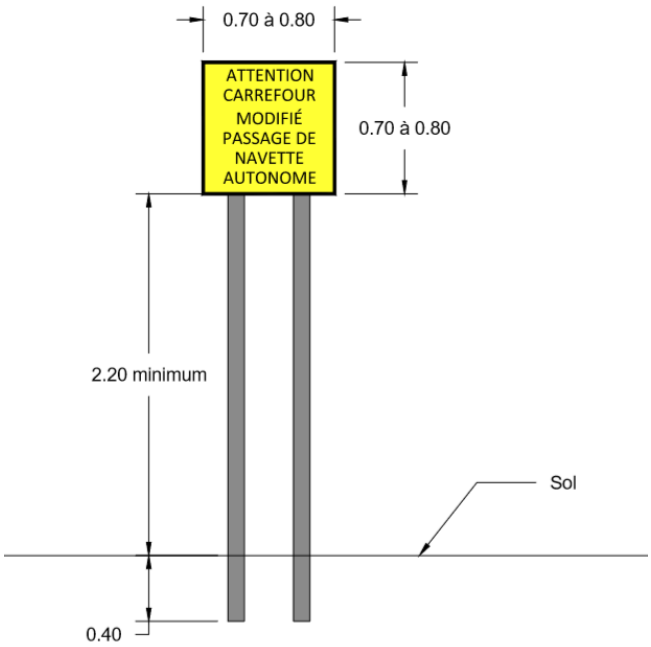
In terms of reliability, over the whole period 2, the overall rate of achievement of the theoretical service is 46%. At least one of the two shuttles was not available for 70 operating days out of a total of 201 operating days, i.e. an availability rate of approximately 65%. In comparison, for the rest of the public transport modes, the rate of completion of the theoretical service is over 99%.

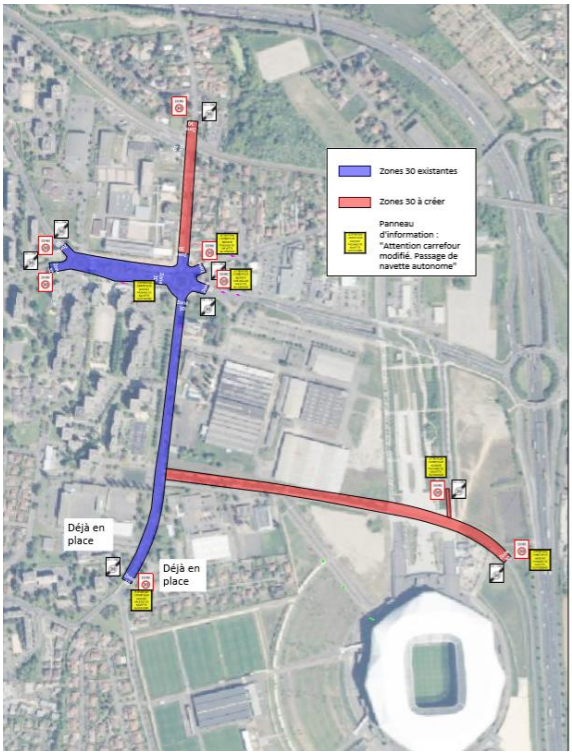
We observe that from April 2022, and the implementation of transport on demand, the rate of automation is much higher. this is explained by the fact that the shuttle makes less km per day because it moves only according to the calls of the customers. the km are thus optimized, and avoids the useless trips. It is also explained by the fact that a part of the new route is realized on an area protected from the traffic, which avoids in particular the resumptions in manual mode to avoid a fixed obstacle.

2.4.5.4 Infrastructure related

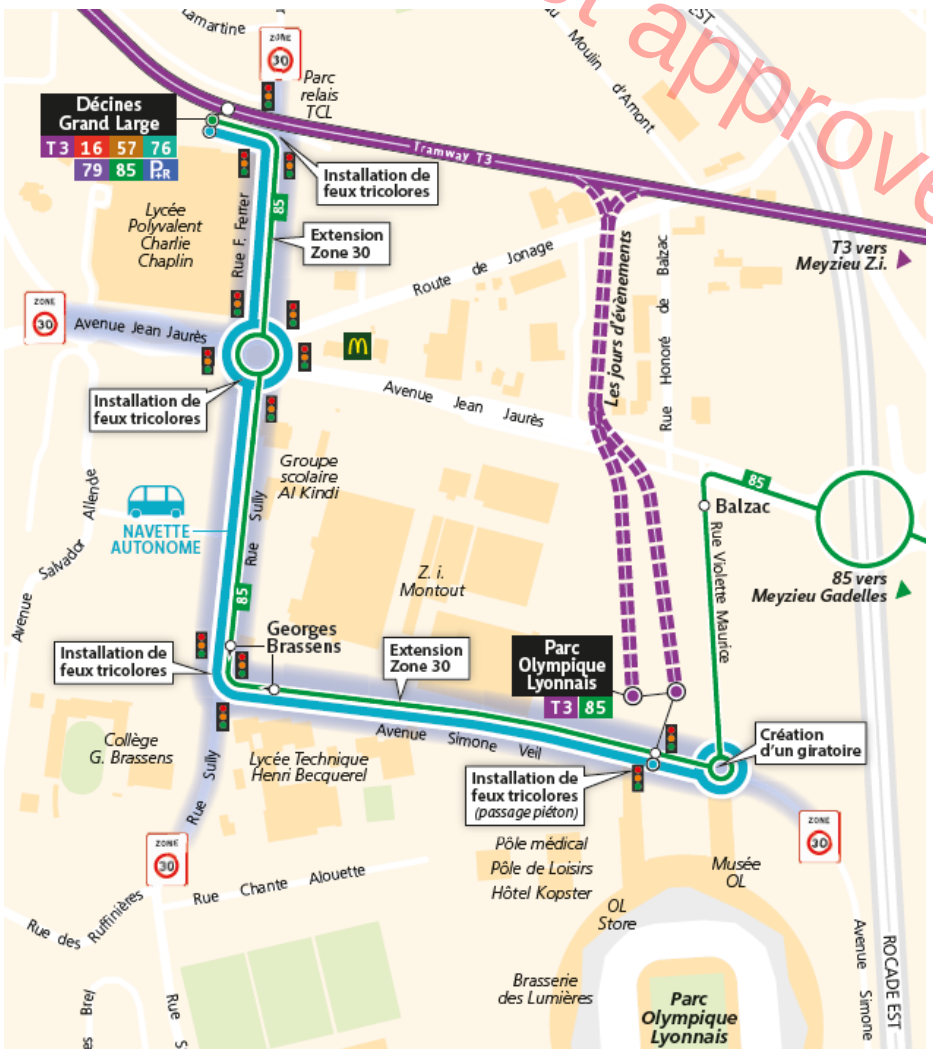
All the roads used by the autonomous shuttles have been reduced to 30 km/h in order to avoid excessive speed differences between the shuttles (maximum speed 20km/h) and the rest of the traffic.

In addition, in order to warn road users of the presence of an autonomous shuttle, signs have been erected throughout the area to warn of the presence of autonomous shuttles.





Dividers have also been placed to avoid dangerous overtaking by other vehicles, and traffic light junctions have been installed specifically for this experiment.



2.4.5.5 Safety operator related

The safety drivers all hold a D licence, which is required for public transport in France, and have received certification training to be autonomous vehicle operators.

All the safety drivers continue to drive buses in parallel with the operation of autonomous shuttles. This is a managerial choice that does not isolate the safety drivers from the rest of the Keolis Lyon driver teams.

2.4.5.6 Covid-19 related

The rules imposed in France to combat COVID-19 have forced a halt to autonomous vehicles. It was not possible to respect the safety distances inside these vehicles for passengers.

For the protection of our employees, Keolis Lyon has put in place a series of measures in the buses, such as the installation of driving cabs with no possible contact with passengers. It was not possible to implement the same measures in the autonomous shuttles, and Keolis Lyon did not want to expose the safety drivers more than the bus drivers.

The autonomous shuttle experimentation was therefore interrupted on 14 March.

When the measures were relaxed in France, Keolis Lyon encountered other difficulties in managing its staff. These measures came at the beginning of the summer, a period during which employees are obliged to take at least two weeks' holiday (labour code), resulting in a reduction in the number of staff available.

In addition, a large number of employees were affected by COVID-19 (positive or contact cases), resulting in a large number of driver absences. All the employees whose health was considered fragile also kept a break from work.

Under these conditions, Keolis was forced to define priorities and to give priority to "normal" operation of the public transport network.

Numerous malfunctions had been noted, and were being resolved before the shuttle buses were stopped. The shuttles were to be restored by NAVYA during the summer of 2020, to allow the Keolis teams to run a dry run during the last two weeks of August. Unfortunately, NAVYA did not start work on the shuttles until the last week of August, thus delaying the resumption of the experiment.

The experiment was able to resume on 14 September 2020.

2.4.6 Recommendations

Keolis, through its participation in numerous events concerning autonomous vehicles, hears many opinions on what should be the future of autonomous vehicles in public transport. In particular, different schools of thought are waiting for new functionalities that should allow autonomous vehicles to fit perfectly into any situation we encounter on the open road. One of the first remarks we can hear on this subject is the need to have a speed equivalent to that which we can have on private cars.

In view of the various experiments conducted by the Keolis group, we believe that manufacturers of autonomous shuttles for public transport should focus on a few basic functionalities, and especially on the ability to remove the Safety Driver from the vehicle.

It is indeed essential to be able to carry out experiments without Safety Driver on board, because without this possibility, the interest of autonomous vehicles is null. Indeed, the business model of this new mode of transport lies in its ability to save on the costs of drivers' salaries.

Even with the capacities of autonomous shuttles remaining relatively limited, but without Safety Driver on board, public transport operators will have the possibility to find particular areas in which the service will make sense. This means that the first generation of autonomous shuttles will not be able to be deployed in every location, and will require PTO's to do some analysis beforehand to ensure the suitability of the location for the autonomous shuttles.

From this point of view, we consider that with the following characteristics (in addition to those already existing), autonomous shuttles will make it possible to provide interesting services for the population:

- Speed 30-40km/h

- Ability to overtake fixed obstacles (autonomously or on request from the remote supervisor),

- Improvement of the reliability of the equipment, and its availability (from a marketing point of view, we consider that a means of public transport must be available at more than 95% if we want to retain new customers who are currently using cars),

- Counting of passengers on board

- Improvement of braking behaviour

This list only focuses on the dynamic aspects of the vehicle.

2.4.7 Preparation and marketing analysis prior to the on-demand service

With the opening of the T3 tramway in January 2021, the service offered by the autonomous shuttles was redundant, which led to the decision to stop this service.

Keolis Lyon has therefore focused on the second phase of this experimentation, which should lead to the proposal of a new on-demand transportation service focused on the various new flow generators within the Groupama Stadium perimeter.

The new mapping will enable the following on-demand service to be implemented, according to the reservation methods initially defined by the Bestmile/Mobile Thinking application. With the bankruptcy of Bestmile, Keolis Lyon chose to integrate Padam Mobility, which was already providing conventional on-demand transportation services in the Lyon area. The choice of PADAM Mobility was driven by a different technical architecture than the one proposed by IOKI.

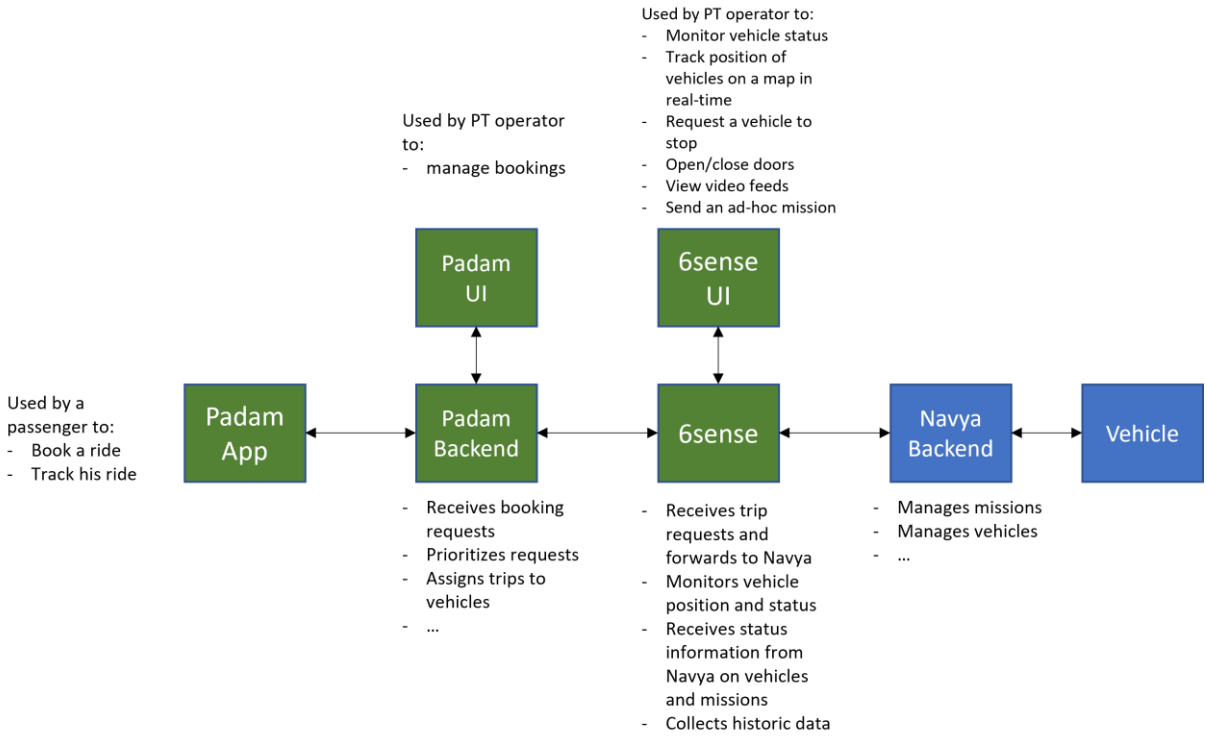


Figure 16 System overview and subsystems

2.4.7.1 Marketing Analysis :

This distribution was proposed following work carried out by Keolis Lyon's marketing department, studying the potential of this new service

A first service for OL Vallée employees that has found its clientele:

- 500 OL Vallée employees in 2019/2020,
- In a non-COVID logic, 1000 theoretical trips, reduced to 800 considering 80% of presence on site (sick, travel, holidays, etc.)
- N1 market share = 6.25%

For this second phase, the new generators could develop a discovery use of autonomous vehicles. On NAVLY, an equivalent use would generate an average of 100 trips/day in 2019, and 180 trips on Saturdays.

The T3 Décines-Grand Large connection still has potential:

- The boarding of passengers from Part Dieu descent from Décines Grand Large (1983 passengers/day on weekdays, including 1762 without connection)
- The boarding of passengers from Meyzieu ZI down to Décines Grand Large (438 passengers/day on weekdays, including 373 without connection)
- Of these 2045 journeys/day, we consider here that 30% of this population could travel to OL Vallée,
- Considering a 5% market share for autonomous shuttles, this represents a potential of 63 trips/day,

Market share projection:

- 1.5M visitors per year (museum/resto/leisure centre/medical centre)
- That is to say approximately 4000 per day (strong day ratio of 360), i.e. a potential of 8000 trips per day,
- Considering a market share of N1 = 5%, potential 400 trips/day,

		2021			TOTAL 2021	2022			TOTAL 2022	TOTAL N1 PHASE 2
		Emplois	Pôle loisirs	Clinique/hôtel/labo		Emplois	Pôle loisirs	Clinique/hôtel/labo		
	Effectifs / Visiteurs annuels	800	600 000	400 000	1 000 800	1000	1 000 000	400 000	2 401 000	3 401 800
	Déplacements	320 000	1 200 000	800 000	2 320 000	400 000	2 000 000	800 000	3 200 000	5 520 000
Hypothèse 1*	Part de marché N1	5%				5%				
	Voyages / 4 mois	5 333	20 000	13 333	38 667	6 667	33 333	13 333	53 333	**92 000**
Hypothèse 2*	Part de marché N1	3%				3%				
	Voyages / 4 mois	3 200	12 000	8 000	23 200	4 000	20 000	8 000	32 000	**55 200**
Hypothèse 3*	Part de marché N1	1%				1%				
	Voyages / 4 mois	1 067	4 000	2 667	7 733	1 333	6 667	2 667	10 667	**18 400**

The project is due to open to the public in the last quarter of 2021. Nevertheless, the modification of the decree governing the authorisation to conduct experiments with autonomous vehicles is causing our application to be processed more slowly than before. Potential delays are envisaged in this case.

2.4.7.2 Operation of the mission management by PADAM Mobility

Thanks to the technical architecture presented above, PADAM Mobility had the possibility not to modify its tools, but only to adapt its operating rules according to the speed limits of the shuttles, in particular for the calculation of travel times.

6sens, which is the intermediate layer between PADAM and the shuttles, integrates all the technical constraints of the two systems and ensures that the subsystems can communicate with each other by transforming the native languages of each tool/API. 6 sens uses the following information from Padam and NAVYA :

1. GEO_POSITION
2. DOOR_STATUS
3. BATTERY_STATUS
4. SPEED
5. MILEAGE
6. ROBOT_MODE
7. BEARING
8. ACCELERATION
9. PASSENGERS_COUNT

Here is the functional diagram of the workflow between the different technology layers :

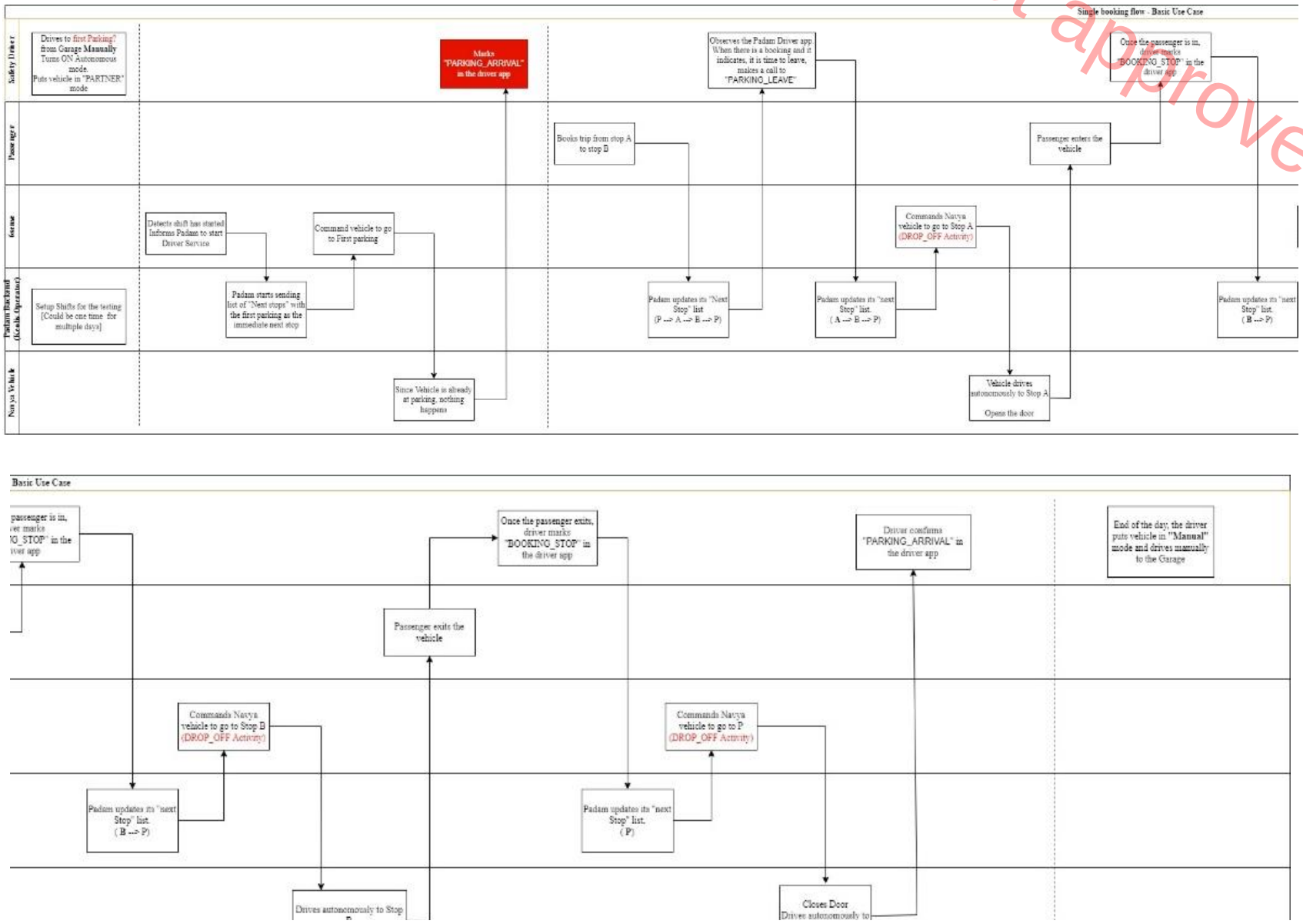
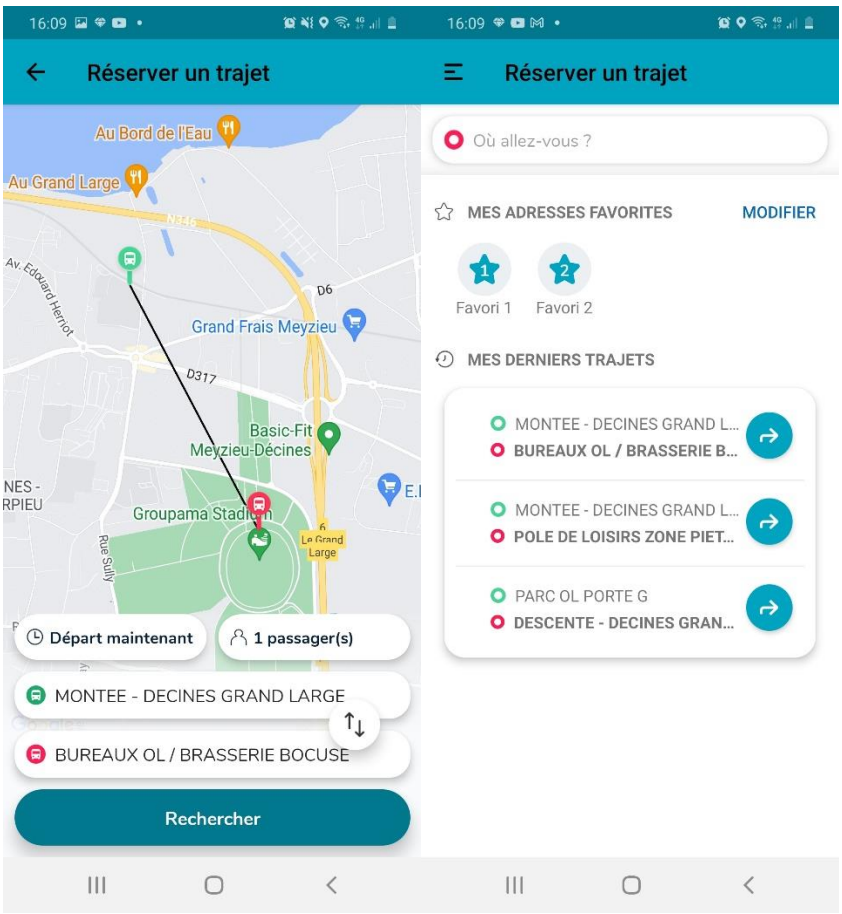


Figure 17 Worklow NAVYA/PADAM/6Sens/Keolis

Since September 2022, a new automated operation is in place to validate the presence of the customer on board. When a reservation is made, the shuttle receives the mission and automatically goes to the pick-up point of the passenger. When the passenger boards the shuttle, the PADAM Mobility application asks the passenger to validate his or her presence on board by scanning a QR Code present in the autonomous shuttles. Following this scan, the system understands the validation of the presence on board of the traveler, and sends the order to the shuttle to close its doors and to go to the drop-off point of the traveler, or to a point of assumption of responsibility of another traveler in the event of voyage regrouping several reservations.

View from the client app :



3 Project homologation

3.1 Ministry authorisation

French government is really interested by AVs project, and is helping operators like Keolis to make this a workable plan. Regarding the requirements of decree **17 of april 2018 « relatif à l'expérimentation de véhicules à délégation de conduite sur les voies publiques »,** Keolis sent authorization dossier with agreement in principle from Lyon Metropole and SYTRAL (Public Transportation Authority). The authorization needed a detailed explanation of the route and roadwork, includes the equipment to control crossroad.

The decree below is the official authorization:

Liberté • Égalité • Fraternité
RÉPUBLIQUE FRANÇAISE

MINISTÈRE DE LA TRANSITION ÉCOLOGIQUE ET SOLIDAIRE

Direction Générale de l'Énergie et du Climat

Paris, le 27 MAI 2019

DÉCISION

Décision ministérielle d'autorisation d'expérimentation de la circulation de véhicule à délégation partielle ou totale de conduite n° 2019-19

Le ministre d'État, ministre de la Transition écologique et solidaire ;

Vu le code de la route et notamment ses articles R. 322-3, R. 221-4 et R. 412-6 ;

Vu l'ordonnance n° 2016-1057 du 3 août 2016 relative à l'expérimentation de véhicules à délégation de conduite sur les voies publiques ;

Vu le décret n° 2018-211 du 28 mars 2018 relatif à l'expérimentation de véhicules à délégation de conduite sur les voies publiques ;

Vu l'arrêté du 17 avril 2018 relatif à l'expérimentation de véhicules à délégation de conduite sur les voies publiques ;

Vu la demande d'autorisation d'expérimentation de la circulation de véhicules à délégation de conduite, accompagnée de ses annexes techniques comprenant un questionnaire dûment complété permettant d'éclairer la typologie des essais, le dossier de présentation de l'expérimentation, ainsi qu'un dossier technique du véhicule, présentée le 11 janvier 2019 par la société Keolis ;

Vu les compléments d'information apportés par Keolis les 11 mars et 3 avril 2019 ;

Vu l'avis du ministre de l'intérieur en date du 15 avril 2019 ;

Vu l'avis du directeur général des infrastructures, des transports et de la mer en date du 15 mai 2019 ;

Vu les avis des gestionnaires de voirie du 3 avril et 7 mai 2019 ;

Vu l'avis de l'autorité compétente en matière de police de circulation du 3 avril 2019 ;

Vu l'avis de l'autorité organisatrice des transports du 29 mars 2019 ;

www.ecologique-solidaire.gouv.fr 92055 La Défense cedex – Tél : 33 (0)1 40 81 21 22 – Fax : 33(0)1 40 81 83 59

3.2 Vehicle homologation

After the signature of the decree, we could ask for the official registration document for the 2 vehicles (document below).

Registration document P108 serial number:

Ministère de l'Intérieur

Numéro d'ordre du certificat
10217966762

Certificat Provisoire d'Immatriculation WW DPTC

(circulation à titre expérimental d'un véhicule à délégation partielle ou totale de conduite)

Autorise, pendant sa période de validité, la circulation du véhicule (Article R.322-3 du code de la route).

(A) Numero d'immatriculation	(I)Date du CPI	(B) Date de 1ère immatriculation
WW-625-SV	15/06/2019	15/06/2019

Numéro de la décision ministérielle d'autorisation exceptionnelle : 2019-19

Date de la décision ministérielle d'autorisation exceptionnelle : 27/05/2019

(H) PERIODE DE VALIDITE : du 01/06/2019 au 31/05/2021 INCLUS

attribué à : (C.1)

KEOLIS LYON
30807755S
19 BOULEVARD MARIUS VIVIER MERLE
69003 LYON

(D.1) Marque	(D.2) Type variante version		(D.3) Dénomination commerciale
NAVYA			
(E) Numéro d'identification du véhicule	(F.1) Masse en charge maximale techniquement admissible (en kg)	(F.2)) Masse en charge maximale admissible du véhicule en service dans l'état membre d'immatriculation (en kg)	(F.3) Masse en charge maximale admissible de l'ensemble en service dans l'état membre d'immatriculation (en kg)
VF9A2CB2C1VB19108	3458		
(G) Masse du véhicule en service avec carrosserie et dispositif d'attelage (en kg)	(G.1) Poids à vide national	(J) Catégorie du véhicule CE	(J.1) Genre national
(J.2) Carrosserie CE	(J.3) Carrosserie (désignation nationale)		
(P.1) Cylindrée (en cm3)	(P.2) Puissance nette maximale (en kW)	(P.3) Type de carburant	(P.6) Puissance administrative nationale
		EL	
(Q) Rapport puissance/masse en kW/kg (uniquement pour les motocycles)	(S.1) Nombre de places assises, y compris celle du conducteur	(S.2) Nombre de places debout (le cas échéant)	(U.1) Niveau sonore à l'arrêt (en db (A))
	11	4	
(U.2) Vitesse moteur (en mn-1)	(V.7) CO2 (en g/km)	(V.9) Classe environnementale	(X.1) Date de visite technique

(Z.1) à (Z.4) Mentions spécifiques

Pour le ministre et par délégation,
Sous directeur de la protection des usagers de la route

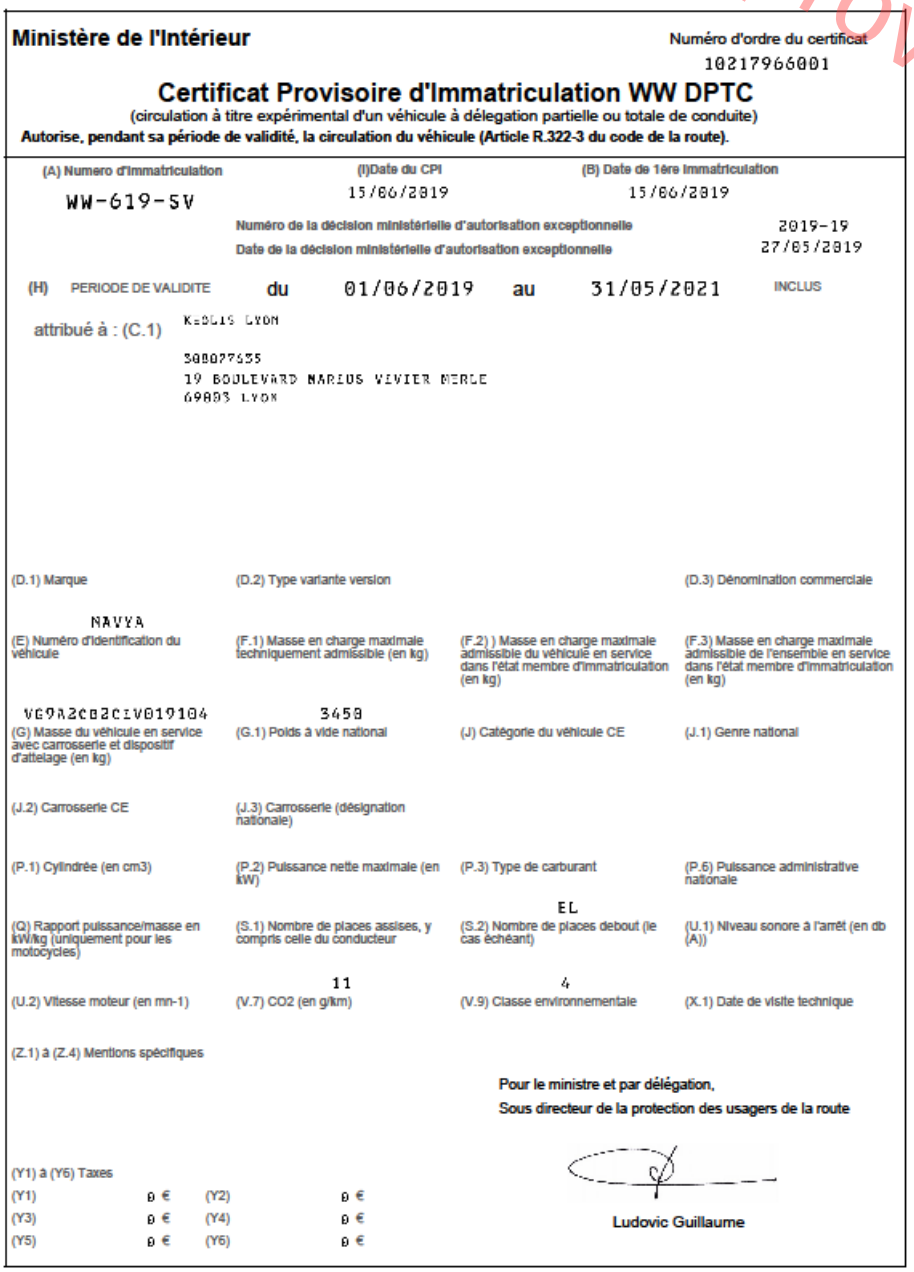
Ludovic Guillaume

(Y1) à (Y6) Taxes

(Y1)	0 €	(Y2)	0 €
(Y3)	0 €	(Y4)	0 €
(Y5)	0 €	(Y6)	0 €

Figure 18 P108 certification

Registration document P104 serial number:



Ministère de l'Intérieur

Numéro d'ordre du certificat
10217966001

Certificat Provisoire d'Immatriculation WW DPTC

(circulation à titre expérimental d'un véhicule à délégation partielle ou totale de conduite)

Autorise, pendant sa période de validité, la circulation du véhicule (Article R.322-3 du code de la route).

(A) Numero d'immatriculation	(I)Date du CPI	(B) Date de 1ère immatriculation
WW-619-SV	15/06/2019	15/06/2019

Numéro de la décision ministérielle d'autorisation exceptionnelle : 2019-19

Date de la décision ministérielle d'autorisation exceptionnelle : 27/05/2019

(H) PERIODE DE VALIDITE : du 01/06/2019 au 31/05/2021 INCLUS

attribué à : (C.1)

K=0619 LYON
308077555
19 BOULEVARD MARIUS VIVIER MERLE
69803 LYON

(D.1) Marque	(D.2) Type variante version		(D.3) Dénomination commerciale
NAVYA			
(E) Numéro d'identification du véhicule	(F.1) Masse en charge maximale techniquement admissible (en kg)	(F.2)) Masse en charge maximale admissible du véhicule en service dans l'état membre d'immatriculation (en kg)	(F.3) Masse en charge maximale admissible de l'ensemble en service dans l'état membre d'immatriculation (en kg)
VF9A2CB2C1V019104	3458		
(G) Masse du véhicule en service avec carrosserie et dispositif d'attelage (en kg)	(G.1) Poids à vide national	(J) Catégorie du véhicule CE	(J.1) Genre national
(J.2) Carrosserie CE	(J.3) Carrosserie (désignation nationale)		
(P.1) Cylindrée (en cm3)	(P.2) Puissance nette maximale (en kW)	(P.3) Type de carburant	(P.6) Puissance administrative nationale
		EL	
(Q) Rapport puissance/masse en kW/kg (uniquement pour les motocycles)	(S.1) Nombre de places assises, y compris celle du conducteur	(S.2) Nombre de places debout (le cas échéant)	(U.1) Niveau sonore à l'arrêt (en db (A))
	11	4	
(U.2) Vitesse moteur (en mn-1)	(V.7) CO2 (en g/km)	(V.9) Classe environnementale	(X.1) Date de visite technique

(Z.1) à (Z.4) Mentions spécifiques

Pour le ministre et par délégation,
Sous directeur de la protection des usagers de la route

Ludovic Guillaume

(Y1) à (Y6) Taxes

(Y1)	0 €	(Y2)	0 €
(Y3)	0 €	(Y4)	0 €
(Y5)	0 €	(Y6)	0 €

Figure 19 P104 certification

3.3 Tramway crossroad authorization Concessions

The most difficult point on our authorization dossier is caused by a modification of traffic lights crossroads with tramway line 3. In France, the competent authority for crossroads between roads and train lines is called STRMTG (Service Technique des Remontées Mécaniques et des Transports Guidés). To be allowed to modify the operation of a train line traffic light, STRMTG has to analyze the security level. Those

evaluations could be long, especially because STRMTG is not use to work with AVs and V2X system. For the Groupama Stadium project, STRMTG sent us the authorization at the end of August, and Lyon Metropole can operate the modification in November. Until this modification is done, a small part of the path will need to be handmade by AVs drivers.

Figure 20 Tramway crossroad

To date, after several working meetings with the technical services of the Lyon metropolitan authority, which is responsible for managing junctions, the only viable method for testing the traffic light junction in complete safety is to carry out initial tests by simulation.

The objective would be to decoy the traffic lights with an autonomous shuttle simulated by a computer and connected to an on-board unit.

Unfortunately, this life situation is not in Navya's technical roadmap for the time bein.

This traffic light junction was never put into operation due to NAVYA's inability to upgrade its model to include simulation.

4 Vehicles

4.1 Keolis Lyon

Type	ID	Type	Funded by	Project	Covering
Navya Arma DL4	P104	Monodirectional	Avenue	Groupama Stadium	TCL

Navya Arma DL4	P108	Monodirectional	Avenue	Groupama Stadium	TCL

Table 8 Vehicles – Operator Fleet

4.2 Technical data

See appendix A

4.3 Options

4.3.1 General

Air conditioning

4.3.2 Seat-belts

The safety belts in the shuttle are not mandatory. Instead, the Safety Operator encourages passengers to fasten their seat belts, warning them of the potential risks associated with heavy braking.

4.3.3 Wheelchair ramp

Keolis Lyon wanted an automatic ramp to facilitate access for people with reduced mobility.

This ramp is an option offered by NAVYA.

.

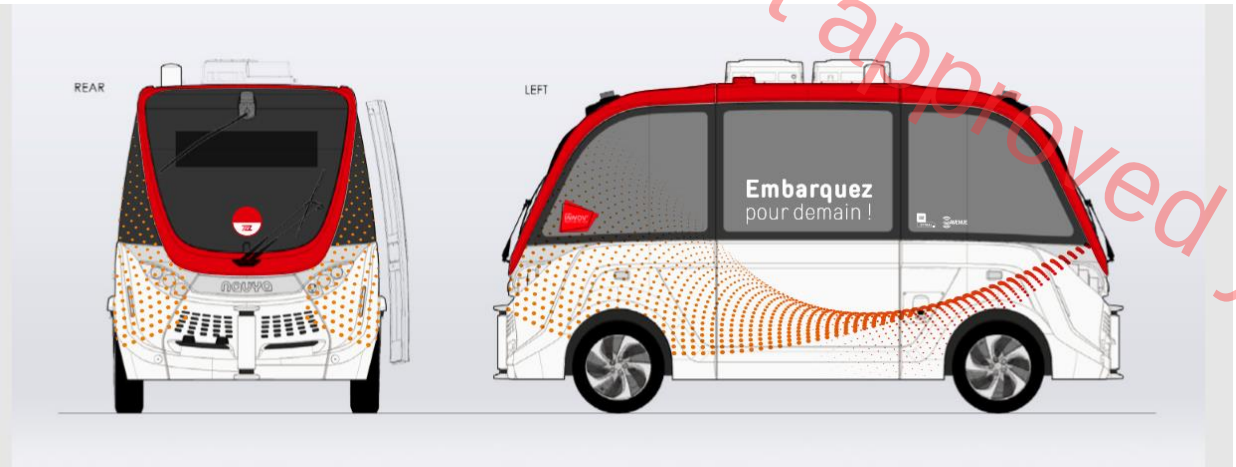
4.4 Covering

4.4.1 Keolis Lyon

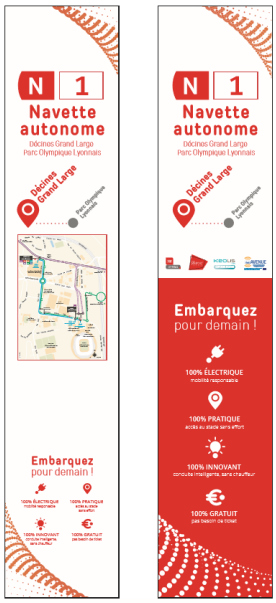
4.4.1.1 Phase 1

As Keolis Lyon is the public service delegate for the operation of the Lyon public transport network (TCL), and as the Groupama Stadium autonomous shuttle experiment is part of the public service delegation contract, the covering had to be in the TCL network colours.

Unlike the rest of the network (only TCL colours), the shuttle also displays the H2020 Avenue logo, and the Keolis Lyon logo



Lyon network colours are also used for AVs stops:



H2020 Avenue logo is included in the shuttle's covering:

Figure 21: Vehicle covering colors

4.4.1.2 Phase 2

With the withdrawal of SYTRAL's participation, the public transport line provided by the autonomous shuttles is no longer part of the Lyon public transport network. It was therefore necessary to modify the colors of the shuttles. Here are the new visuals that have been implemented:

Figure 22 Phase 2 Shuttle covering

4.4.2 AVENUE EU Logo

4.4.2.1 French

Ce projet a reçu un financement du programme de recherche et d'innovation Horizon 2020 de l'Union européenne au titre de la convention de subvention No 769033

Figure 23: Vehicle covering EU Logo French

4.4.2.2 English

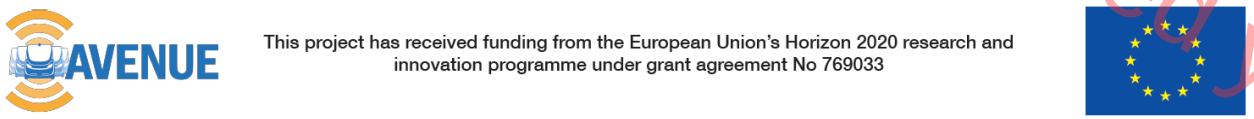


Figure 24: Vehicle covering EU Logo English

4.5 Vehicle inspection

The French state does not impose any particular inspection for non-approved vehicles like this one.

On the other hand, as part of the daily service carried out by the Safety Drivers, a check is carried out every day to ensure that the vehicles are in good condition.

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

Supervision is divided in two level:

- **Keolis Supervision**: The current supervision is made by Kisio, subsidiary of Keolis Group, in order to help safety drivers to operate, and fixe a short list of dysfunction (GNSS signal lost, doors dysfunction, dashboard dysfunction…)
- **NAVYA supervision**: NAVYA's supervision is contacting by Kisio supervision when a dysfunction can't been solve by themselves. They are needed for deeper manipulation (log extraction, API dysfunction…)

5 Personnel

5.1 Supervisor

Keolis delegates supervision to Kisio Services, a subsidiary of the Keolis group.

However, as the two entities are different, no personal information on the supervisors can be disclosed.

5.2 Autonomous shuttle project Staff

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

	Safety Opérator (SD)	SD management	SD director	Project manager
MILLET Laurent	X			
VINCIGUERRA Donovan	X			
GIOVANNONE Fabien	X			
FEKIR Nawel	X			
KNOELL Steven	X			
BOUTAYEB Emad	X			
HARGAS Youssef	X			
LAVIE Adrien	X			
AMIRAT Ahmed	X			
UZTEMUR Mounia	X			
BOUGHANMI Rihab	X			
LIMONES Joseph		X		
LANVIN Jérôme		X		
BABA ARBI Hassane		X		
OUNNALLI Heni		X		
ROLLET Amélie		X		
HIPPERT Audrey			X	
AUSSERT Sylvain			X	
EYMIEU Laurence			X	
BERTONNEAU Jérôme			X	
LAFON Benedicte				X
PATRY Aurélien				X
ZUTTRE Quentin				X

Table 9 Autonomous shuttle project Staff

6 Conclusion

In conclusion, the experiment started on 15 November 2019 has allowed us to validate the possibility of implementing a coherent public transport service thanks to autonomous shuttles integrated in a mixed traffic.

The technical challenge was met thanks to the strong involvement of all the actors concerned, and mainly the Metropolis of Lyon which invested heavily in the V2X communication system. Thanks to these developments, we are convinced that the development of the autonomous vehicle in public transport will have to rely heavily on connected infrastructures, thus allowing not to put all the necessary intelligence on the autonomous vehicles. Between the first trials and the final system, many improvements have been made at junctions to complement the capabilities of NAVYA's vehicles.

However, while there have been significant technical improvements to this new mode of transport, in Lyon we note a danger point that is important to note. Indeed, faced with improvements that are not sufficiently visible, the new political leaders (elected in June 2020) have officially expressed their lack of confidence in autonomous shuttles. For Keolis Lyon, this means a loss of the funding that SYTRAL used to share.

In view of the difficult political context, where the COVID-19 crisis will have a strong impact on the investment budgets of local authorities, we must expect in the future to have to innovate even more quickly to keep the interest of decision-makers. For this, it is absolutely necessary to succeed as soon as possible in achieving the business model of autonomous shuttles: Without Safety Operator! Without this, we risk losing the financial support of public entities, which would put this economy at risk, where the main manufacturers are start-ups that cannot support the R&D investments necessary for the success of these projects. It is therefore important for each project leader to keep in mind that each new experiment must bring us closer to the final operating model for autonomous vehicles.

Ongoing work by the French Ministry of Transport suggests that the methods for approving and demonstrating the safety levels of public transport services operated with autonomous shuttles will be based on the methods we know for the automatic metro. However, to date, the level of reliability and control of the manufacturers of autonomous shuttles is still very far from allowing this demonstration. The safety analysis required for each new line will have to take into account all the risks linked to interactions with the shuttle environment (road traffic, pedestrians, cyclists), and demonstrate that autonomous shuttles have the capacity to manage all these situations, including in degraded mode, with an incidence level of 10^{-9}. With the current level of technology, only dedicated and protected roads will be eligible to operate autonomous shuttles, which makes the business model unsustainable.

The integration in the second phase of the project of new technological links also demonstrate the importance of mastering all the subsystems. Indeed, our work has shown that it was not possible to consider only the validation loop of the presence on board of the passengers. Nevertheless, this type of architecture could make more complex the demonstrations of security necessary because it will require to demonstrate levels of security on all the links of the technological chain. This observation further reinforces the need to choose sites without complexity for the first versions of approved services, moving

away from a largely attractive model, and reinforcing that of a niche model, more applicable to private and protected sites.

Appendix A

Technical data Navya Arma-DL4

Description	value
Capacity	
Passengers	15
Sitting	11
Standing	Not authorised by Keolis for this experiment
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