AVENUE

Autonomous Vehicles to Evolve to a New Urban Experience

DELIVERABLE

D5.5 Vehicle-to-Platform interfaces and protocols

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Acronyms

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

WPL	Work Package Leader

Executive Summary

This deliverable, *D5.5 Vehicle-to-Platform interfaces and protocols*, summarizes the interfaces and protocols deployed in different AVENUE pilot sites for Navya shuttles. This deliverable is the final version of *D5.4 First Iteration Vehicle-to-Platform interfaces and protocols*. The purpose was to make a mapping of Navya's platform enhancements on AVENUE pilot sites.

The Navya software's evolutions that are presented in this deliverable concerns NavyaDrive® and Navya API. Thus, the document is structured as follows: in chapter 2.1, after introduction, are presented the NavyaDrive® versions 4.11.x, 6.0.x, 6.1.x, 6.2 and 7.2.1 and in chapter 2.2 are presented the Navya API versions 3.2.x, 3.4.x and 4.0.x. The new features are detailed from one version to another. The schedule of each upgraded vehicle deployed on AVENUE pilot site is presented in detail in the Table 2.

The Navya's platform enhancements in AVENUE touch the following topics:

- Vehicle behavior improvements.
- User interface improvements.
- Autonomous navigation improvements.
- Diagnosis and safety ameliorations.
- Mission Remote with the On-Demand mode.
- Linux migration for cybersecurity improvements.

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 personalized 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 behavior, 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 behavior safety.

1.1 On-demand Mobility

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

1.2 Fully Automated Vehicles

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

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

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

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

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

SAE INTERNATIONAL

SAE J3016™ LEVELS OF DRIVING AUTOMATION

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

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

1.2.1 Automated vehicle operation overview

We distinguish in AVENUE two levels of control of the AV: micro-navigation and macro-navigation. Micro navigation is fully integrated in the vehicle and implements the road behavior 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 of 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 behavior, in an open street environment. The vehicles are Automatically capable to recognize 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 minibus is able to bypass a parked car, while it will slow down and follow behind a slowly moving car. The AVENUE mini-buses are able to handle different complex road situations, like entering and exiting round-about in the presence of other fast running cars, stop in zebra crossings, communicate with infrastructure via V2I interfaces (ex. red light control).

The minibuses used in the AVENUE project technically can achieve speeds of more than 60Km/h. However, this speed cannot be used in the project demonstrators for several reasons, ranging from regulatory to safety. Under current regulations the maximum authorized 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 minibuses. In table 2 provides and overview of the AVENEU sites and OODs.

	Summary of AVENUE operating sites demonstrators							
	TPG		Holo		Keolis	Sales-Lentz		
	Geneva		Copenhagen	Oslo	Lyon	Luxembourg		
Site	Meyrin	Belle-Idée	Nordhavn	Ormøya	ParcOL	Pfaffental	Contern	Esch sur Alzette
Funding	TPG	EU + TPG	EU + Holo	EU + Holo	EU + Keolis	EU + SLA	EU + SLA	EU + SLA
Start date of project	August 2017	May 2018	May 2017	August 2019	May 2017	June 2018	June 2018	February 2022
Start date of trial	July 2018	June 2020	September 2020	December 2019	November 2019	September 2018	September 2018	April 2022
Type of route	Fixed circular line	Area	Fixed circular line	Fixed circular line	Fixed circular line	Fixed circular line	Fixed circular line	Fixed circular line
Level of on-demand service*	Fixed route / Fixed stops	Flexible route / On-demand stops	Fixed route / Fixed stops	Fixed route / Fixed stops	Fixed route/Fixed stops	Fixed route / Fixed stops	Fixed route / Fixed stops	Fixed route / Fixed stops
Route length	2,1 km	38 hectares	1,3 km	1,6 km	1,3 km	1,2 km	2,3 km	1 km
Road environment	Open road	Semi-private	Open road	Open road	Open road	Public road	Public road	Main pedestrian road
Type of traffic	Mixed	Mixed	Mixed	Mixed	Mixed	Mixed	Mixed	Pedestrians, bicycles, delivery cars
Speed limit	30 km/h	30 km/h	30 km/h	30 km/h	8 to 10 km/h	30 km/h	50 km/h	20 km/h
Roundabouts	Yes	Yes	No	No	Yes	No	No	No
Traffic lights	No	No	No	No	Yes	Yes	Yes	No
Type of service	Fixed line	On demand	Fixed line	Fixed line	Fixed line	Fixed line	Fixed line	On Demand
Concession	Line (circular)	Area	Line (circular)	Line (circular)	Line (circular)	Line (circular)	Line (circular)	Line (circular)
Number of stops	4	> 35	6	6	2	4	2	3
Type of bus stop	Fixed	Fixed	Fixed	Fixed	Fixed	Fixed	Fixed	Fixed
Bus stop infrastructure	Yes	Sometimes, mostly not	Yes	Yes	Yes	Yes	Yes	Yes
Number of vehicles	1	3-4	1	2	2	2	1	1
Timetable	Fixed	On demand	Fixed	Fixed	Fixed	Fixed	Fixed	On-demand
Operation hours	Monday-Friday (5 days)	Sunday-Saturday (7 days)	Monday-Friday (5 days)	Monday-Sunday (7 days)	Monday-Saturday (6 days)	Tuesday & Thursday Saturday, Sunday & every public holiday	Monday - Friday	Monday – Saturday
Timeframe weekdays	06:30 – 08:30 / 16:00 – 18:15	07:00 – 19:00	10:00 – 18:00	7:30 – 21:30	08:30 – 19:30	12:00 – 20h00	7:00 – 9:00 16:00 – 19:00	11:00 – 18:00 11:00 – 18:00
Timeframe weekends	No service	07:00 – 19:00	No service	9:00 – 18:00	08:30 – 19:30	10:00 – 21:00	No Service	On Suterday only
Depot	400 meters distance	On site	800 meters distance	200 meters distance	On site	On site	On site	500 m distance
Driverless service	No	2021	No	No	No	No	No	No
Drive area type/ODD	B-Roads	Minor roads/parking	B-Roads/minor roads	B-Roads	B-Roads	B-Roads	B-Roads/parking	
Drive area geo/ODD	Straight lines/plane	Straight lines/ plane	Straight lines/ plane	Curves/slopes	Straight Lines/ plane	Straight lines/ plane	Straight lines/ plane	Straight lines / plane
Lane specification/ODD	Traffic lane	Traffic lane	Traffic lane	Traffic lane	Traffic lane	Traffic lane	Traffic lane	Open area
Drive area signs/ODD	Regulatory	Regulatory	Regulatory, Warning	Regulatory	Regulatory	Regulatory	Regulatory	Regulatory
Drive area surface/ODD	Standard surface, Speedbumps	Standard surface, Speedbumps	Standard surface Speedbumps, Roadworks	Frequent Ice, Snow	Standard surface, Potholes	Standard surface	Standard surface	Standard Surrface

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

1.3 Preamble

The WP5, *Command-Control-Communication system,* aims the development and the integration of overall service platform. This WP constitutes a central key element of the project because it pays a special attention to the user data and provide services for increased passengers security. AVENUE wanted in this WP to develop interfaces for optimal and integrated services. Thus, the improvements of the existing control systems of PTO as well as the improvements of the management systems of the AVs fleets were targeted.

The deliverable D5.5, *Vehicle-to-Platform interfaces and protocols*, from WP5, describes the interfaces and protocols deployed in different pilot site and their evolution in time. It is related with the task T5.3, *Adaptation of-, and Interfacing with-, existing autonomous vehicle control system*.

When dealing with AVs, i.e. no driver, the requirement to deploy an active management of the autonomous transport system is crucial. The mobility provider expects that the protocols used for the vehicles to be agnostic in order to facilitate the integration of new vehicles to any kind of mobility scenarios.
The communication protocols must allow bidirectional communications between vehicles and the mobility platforms: autonomous vehicles use it to send real-time telemetry and status data (e.g. position, speed, level of battery, alerts) to the platform, while the later use it to send back missions, i.e. indication about the destination point.
Concerning missions, the mobility platform and the vehicles are usually sharing the same representation of the road network: a graph with node and edges uniquely identified. A mission indicates the IDs of edges and nodes that should be followed by the vehicle in order to get to the next stop. If no missions are sent, the vehicle doesn't move. Along with that information, each map section contains the speed points, the waiting time at stops and trip data for vehicle UIs. That data is essential to optimize the system while informing passengers about what actions the vehicle is performing during the trips.

Thus, the deliverable D5.5 will review the improvements of these protocols in the autonomous mobility needed by the market players. Their validation and the confirmation of the maturity level will be correlated with the different AVENUE pilot sites.

2 NAVYA

The autonomous system of Navya shuttles is separated in few blocks: sensors, NavyaDrive®, Navya Operate® and the API that administrate the missions and collect the data. The customer's applications integrate the Navya system by connecting to Navya API.

NavyaDrive® is an embedded software that allows to operate the vehicle. The different versions and configurations of sensors are related to the NavyaDrive and are called, internally, Setups.

The API different versions were developed including various functionalities. The API can provide a limited number of data, because of confidentiality and security reasons. Each customer connexion to the API needs a software development effort and it's related, mainly, to the particularities of pilot site.

Those blocks that form the Navya system are schematized in the next figure.

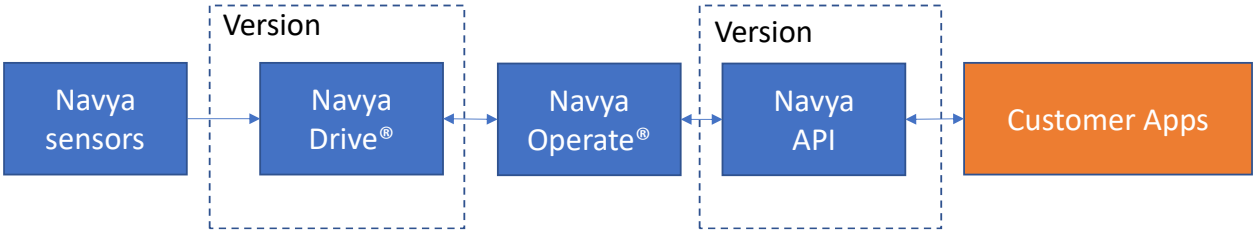


Figure 2: Navya system organigram for AV self-driving platforms.

During the AVENUE project, the NAVYA shuttles were ameliorated following the feedbacks from pilot sites. In Europe, the AVENUE sites where Navya shuttles are deployed are Belle Idée in Suisse (three shuttles), Parc OL in France (two shuttles), Esch sur Alzette in Luxembourg (two shuttles) and Slagelse in Danemark (two shuttles). The next figure shows the repartition of the AVENUE sites on the European map.

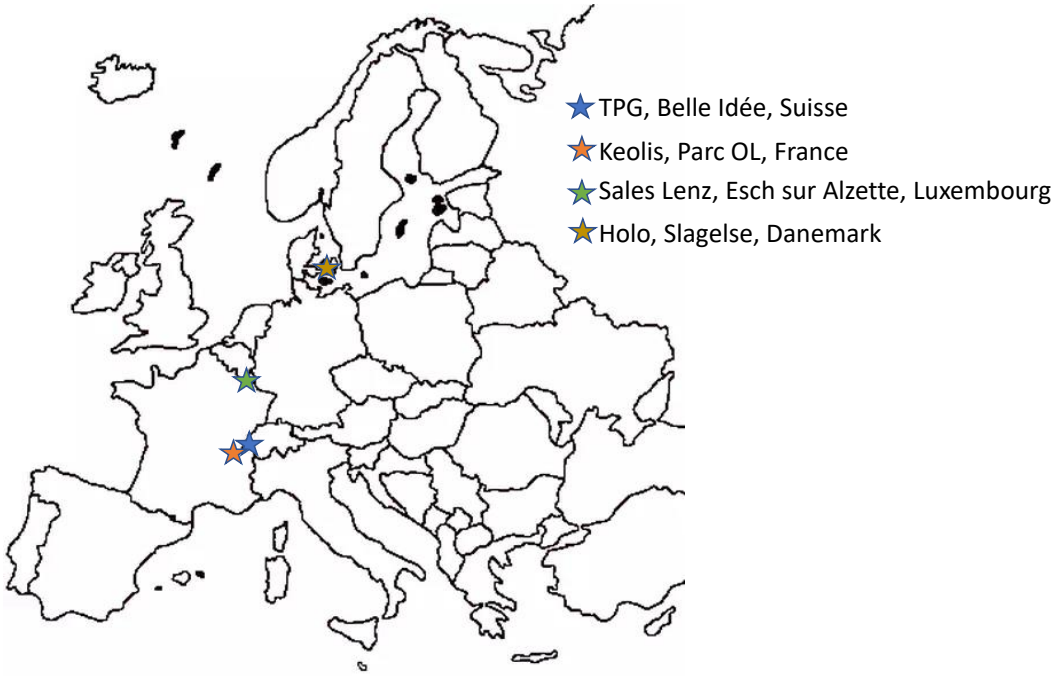


Figure 3: AVENUE pilot sites with Navya shuttles.

The first version of the Setup, the one used at the beginning of the demos period, with which the shuttles were deployed is 4.11.3. Several versions have been created according to the needs and feedbacks of the AVENUE demonstration sites. The last one used is 7.2.1. As for the API, the first version used was 3.2.x and the last one 4.0.x. More details regarding the features covered by those Setup and API versions will be presented below.

We notice that the Setup version 6.2 and the version 4.0.x of API were especially created for AVENUE project.

2.1 NavyaDrive® versions

The NavyaDrive® versions deployed and developed in AVENUE are: 4.11.3, 6.0.x, 6.1.x, 6.2 and 7.2.1.

2.1.1 4.11.x, 6.0.x and 6.1.x

The Setup 4.11.3 it was the first one used on demo sites. Mainly, from 4.11.x to 6.1.x NavyaDrive® versions the improvements aimed the vehicle behavior, the user interface, the autonomous navigation, the diagnosis and safety and the bugs resolution.

2.1.1.1 Vehicle behavior improvement

We are defining as proximity zones, the static zones spread out all around the vehicle. On the DUI (Dashboard User Interface), they are displayed depending on where the obstacle is detected among the 36 zones and trigger a sound in the shuttle.

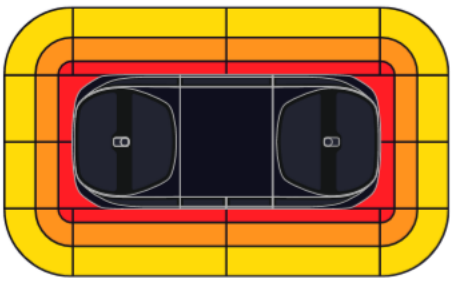


Figure 4: Dynamic display on the DUI.

The safety was enhanced for the operator and the passengers regarding the presence of an obstacle thanks to a buzzer inside the vehicle.

From the field, we were warned on risks of falling inside the shuttle in manual mode because of the detection of the obstacles in in the proximity zones. Consequently, we stopped limiting the speed of the vehicle in AMD (Assisted Manual Driving). Thus, the AMD does not break anymore when an obstacle is close, the decision remains at the level of the operator.

So, a tone signal rings out when an obstacle is detected in one or some proximity zones. The more regular the sound is, closer is the obstacle:

- Obstacle in the “close” zone = continuous tone signal;
- Obstacle in the “middle” zone = very regular tone signal;
- Obstacle in the “far” zone = irregular tone signal.

2.1.1.2 User interface improvement

The field returned us an observation regarding the fact that the functions "STOP" and "GO", served by the same button on the main page of the DUI, need to be separated. Thus, we separated them. The "STOP" and "GO" button are now on the left and on the right of the progress bar. More, the doors states are displayed inside the "GO" button.

Consequently, the layout of the DUI has been modified to be more convenient:

- The "Navigator" buttons are now located on the bottom of the screen;
- The "States" buttons are now located on the center right of the screen.

The color of dynamic points on the Perception Viewer has been modified from yellow to green to increase the visibility and the obstacles are displayed by a red circle according to the direction of travel.

The Hit Ratio percentage is displayed with different color according to its level.

The Arabic language can now be selected on the DUI and the internal screen.

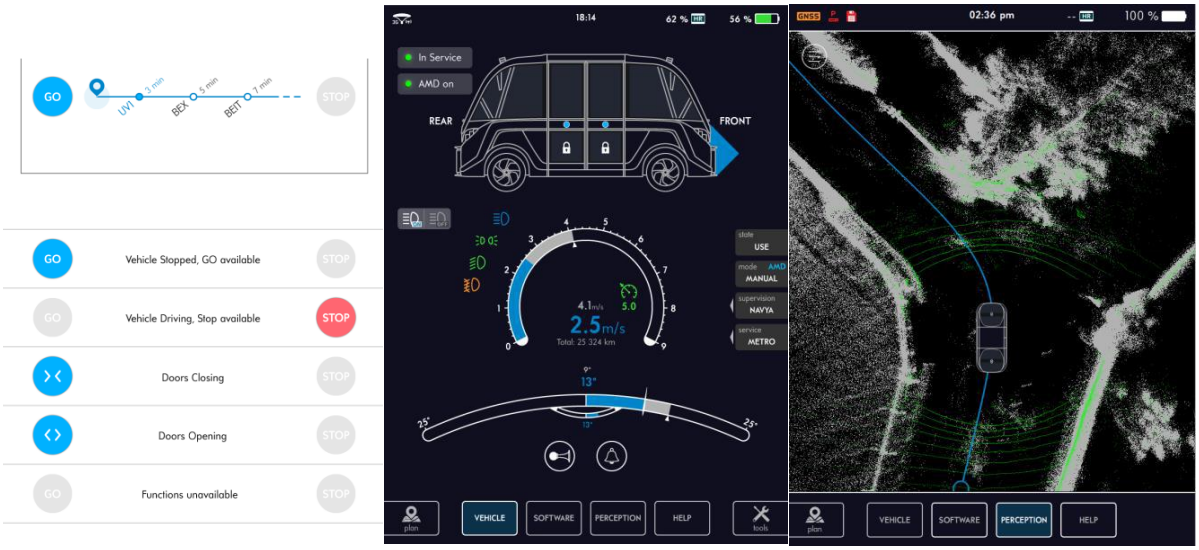


Figure 5: New DUI for user interface improvement.

New pictograms

The operators told us that they need a better representation for vehicle diagnosis. We added new pictograms on the DUI in order to ease the user's diagnosis.

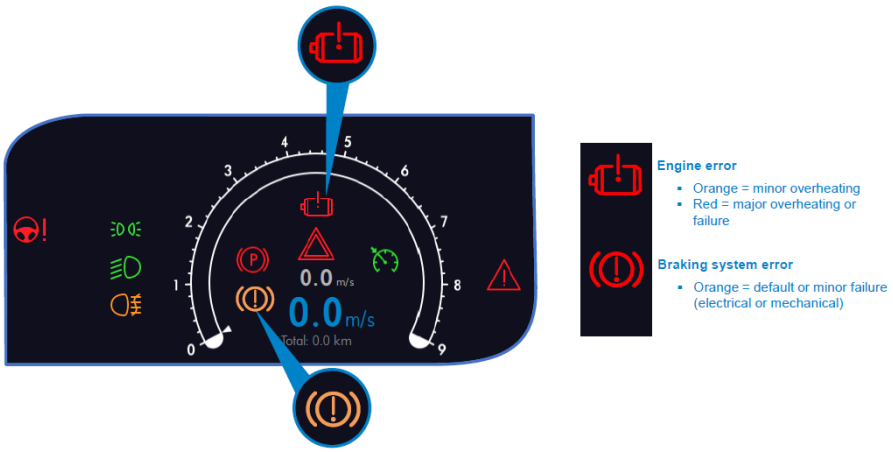


Figure 6: New pictograms for ease the vehicle diagnosis.

Events

A new software display was realized for facilitate the messages understanding, to be more fluent and interactive. We did changes in the “EVENTS” section : a new icon indicates the severity of the event, a short description of the event is automatically proposed and a padlock indicates the impact of the event. We developed the software in order to be able to provide detailed information by clicking on the event. Also, we developed a new feature through which this new software suggests a procedure to be followed by the operator in order to solve the detected event.

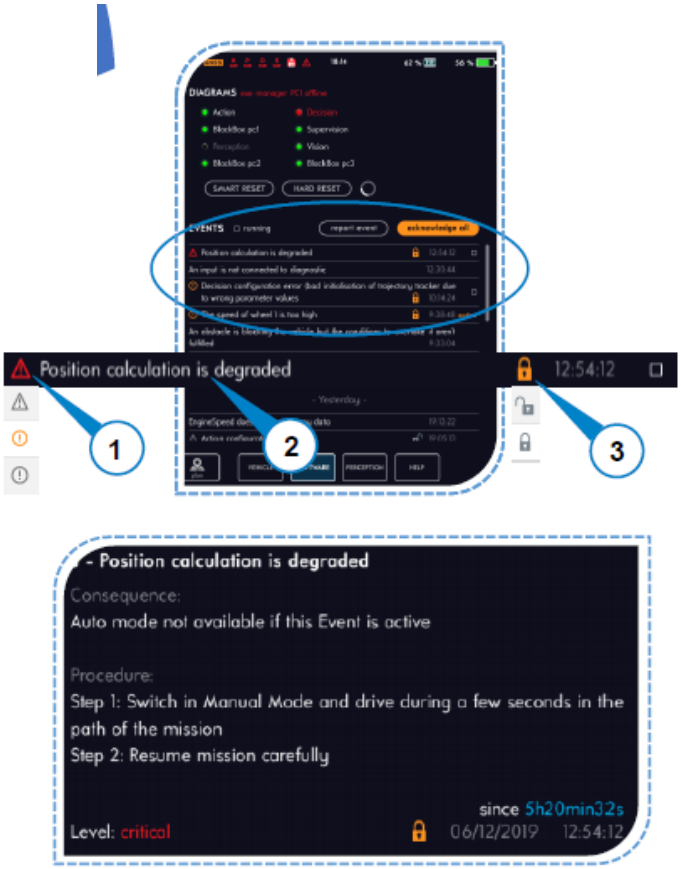


Figure 7 : New software display.

Emergency stop

We developed a procedure for the emergency stop. When an Emergency Stop is pushed, an overlay screen appears on the DUI and can only be removed by acknowledging it. The operator must be logged in to acknowledge the emergency stop. In this way, we ensure that a qualified agent is aware of the issue and that the operator understands the reason its activation.

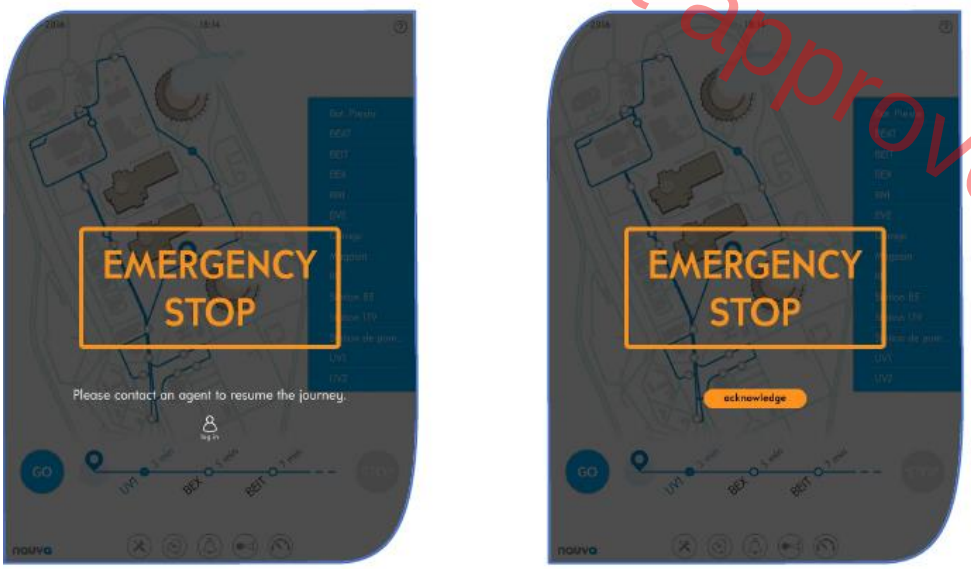


Figure 8 : Emergency stop procedure.

Internal sound

We developed features for the internal sound in the vehicle. Thus, internal speakers in the shuttle broadcast now service information, action validation and warnings. There are voices (ex. greeting message, boarding “metro”, boarding “On Demand”, doors closing, next station, estimate time of arrival and various warnings) and AMD sounds (ex. proximity sound when an obstacle is detected).

Information on the DUI

Navya developed a software through which the door button lights are synchronized with the door lock status (ex. when doors are locked, button light is turned OFF) and a low beam lights systematically when turning on the shuttle.

2.1.1.3 Autonomous navigation improvement

V2X feature

The V2X feature was ameliorated by considering for the traffic light the orange phase. Before, there were considered only two phases: the first one for green light and the second one for red light.

We realized this amelioration for less powerful braking. Thus, the new behavior prevents the vehicle from hard braking if it has enough time to cross intersection in the early stage of the orange status. By taking into consideration the orange phase, the vehicle anticipates better the approach of the traffic lights.
We developed a better V2X communication. Thus, the decision diagram handles every phase of the traffic light (Green/Orange/Red). Navya added new diagnostics and errors codes. As example, if the data received by the shuttle is partially missing or if an error is raised, the vehicle will stop until it has the necessary information to cross the intersection safely and an error message appears on the DUI; in this case the operator can choose to take lead in manual driving.

Behavior at intersection

Navya developed a better handling at traffic lights.
Thus, the vehicle estimates now the time remaining at the red light: either stops before the line of the traffic lights applying the deceleration limit for optimal comfort and informs the operator or regulates its speed to safely cross the intersection at the green light.
Also, the vehicle considers the time remaining at the green light plus the time at the orange light considered as green, the traffic conditions and its speed.
In the event of a flashing orange light, the vehicle stops and informs the operator: “traffic light is not manageable”. In this case, the operator can then either take the lead in manual driving to cross the intersection or wait until the shuttle receives readable information to cross safely.

Line alignment check

The confident departure feature prevents the vehicle from leaving in “AUTO” mode if it is not aligned on the path. The operator is now warned with a status code on the DUI if they must correct manually the position of the vehicle before leaving safely in “AUTO” mode.

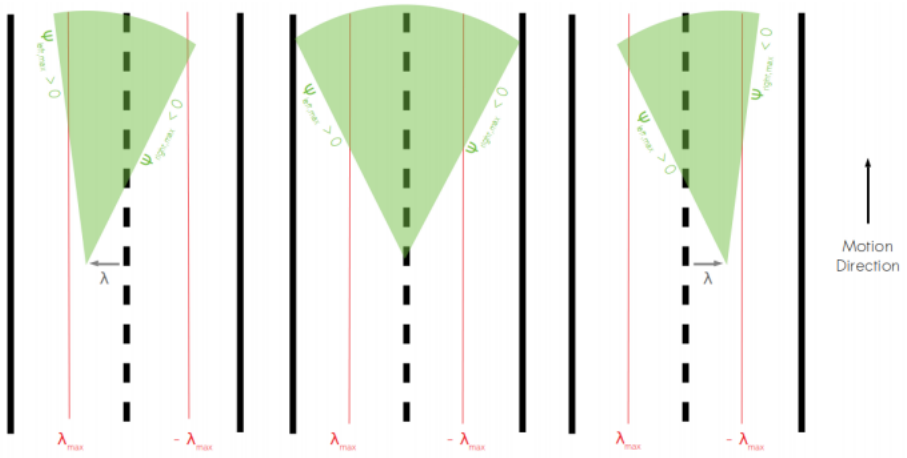


Figure 9 : Median detection for confident departure feature.

The Perception Viewer provides the operator with the exact position of the vehicle. Two errors are taken into account: lateral error (gap in centimeters separating the vehicle from its path) and angular error (offset angle in degrees on the path).

(a) (b) (c)

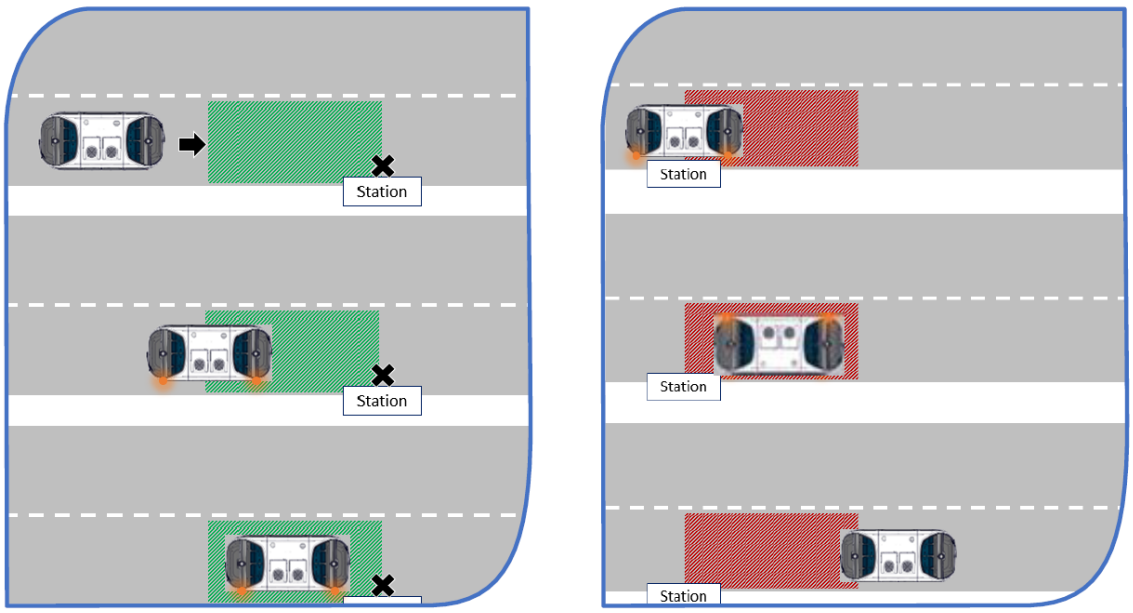
Figure 10 : (a) Confident, (b) partially confident and (c) not confident vehicle positions.

Blinkers Management V1

Navya improved the vehicle's behavior at station's departure and arrival by setting blinking distances (before and after station). Blinkers are set automatically on a given distance to resolve operational problems when leaving a station.

Blinkers stay activated in station on the side of the sidewalk.

At the last station of a path, the blinker is no longer set (mission over). If the shuttle stays at the last station of the path, using the controller, the operator can restart the mission and activate the blinker.



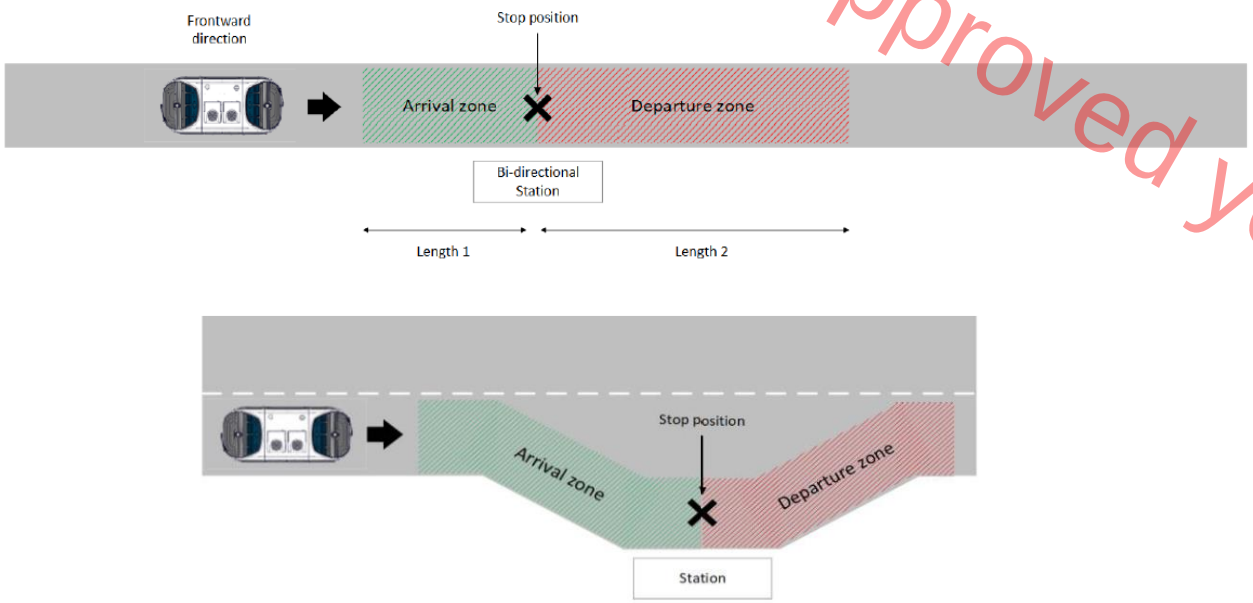


Figure 11 : Blinker management.

2.1.1.4 Diagnosis and safety ameliorations

Supervision

Three supervision modes were developed:

- "PARTNERS" supervision mode
  - This mode is reserved only for operator that have access to the Navya API (or L'APIN). A remote order is used to decide the next mission of the vehicle.
- "STAND ALONE" supervision mode
  - Through this feature, some other supervision solutions can send commands to the vehicle: STOP, GO and OPEN AND CLOSE DOORS.
- "METRO" supervision mode.
  - The supervision can now ask the vehicle to leave a station remotely in "METRO" mode.

Records management

Information about status codes and events is forwarded to Navya API in accordance with the vehicle's display in a two parts section:

- Direct access to the events (active or over), their timestamps and the status code associated to it.
- Access to a static description of the status codes and their information (level, impact, necessary actions…).

Through the AVENUE project we realized that new data were necessary to make easier the log analysis. Navya developed its software in order to make possible the recording of those new data. Thus, new data were made available as: manual velocity (in m/s), driving direction, light status and more data on obstacles.

Vehicle safety ameliorations

In order to increase the vehicle safety a deadman button was developed. Thus, now is necessary to put a deadman button to switch from “STAND-BY” to “USE” mode.

Also, following the filed suggestions, Navya deactivated “by default” the horn when the shuttle is blocked by an obstacle. By doing this, Navya avoids the noise nuisance for the operator and any other road user.

2.1.1.5 Bug resolution

We fixed a series of bugs like:

- #79786 on the acknowledgement of some localization errors on the DUI;
- #63408 on the error appearing when V2X was not installed on the vehicle;
- #54540 the itinerary was made secured in every mode;
- #61671 we removed the error “Stopped Because The Planned Trajectory Contains No Data” in “MANUAL” mode;
- While driving in “MANUAL” mode is no longer possible to modify the service mode from ON-DEMAND to METRO or BUS. The service mode can only be changed in autonomous mode.
- #6638 Navya fixed the error “Steering while Braking” when switching from “MANUAL” mode to “AUTO” mode;
- #54543 Navya fixed a bug which allowed the vehicle to leave without a GO operator in service modes “ON DEMAND” and “STAND ALONE”;
- In autonomous mode in 4.11.x version, the detection zone, limited by a safety radius, limits the detection of the obstacles in front of vehicle. At low speed, the radius does not extend to the width of the vehicle thus the obstacles at the edge of that area are not detected. So, Navya had to make a development and in 6.1.x version: the detection zone now takes the shape of a rectangle and thus facilitate the detection of obstacles both in front of the vehicle and in all its width.

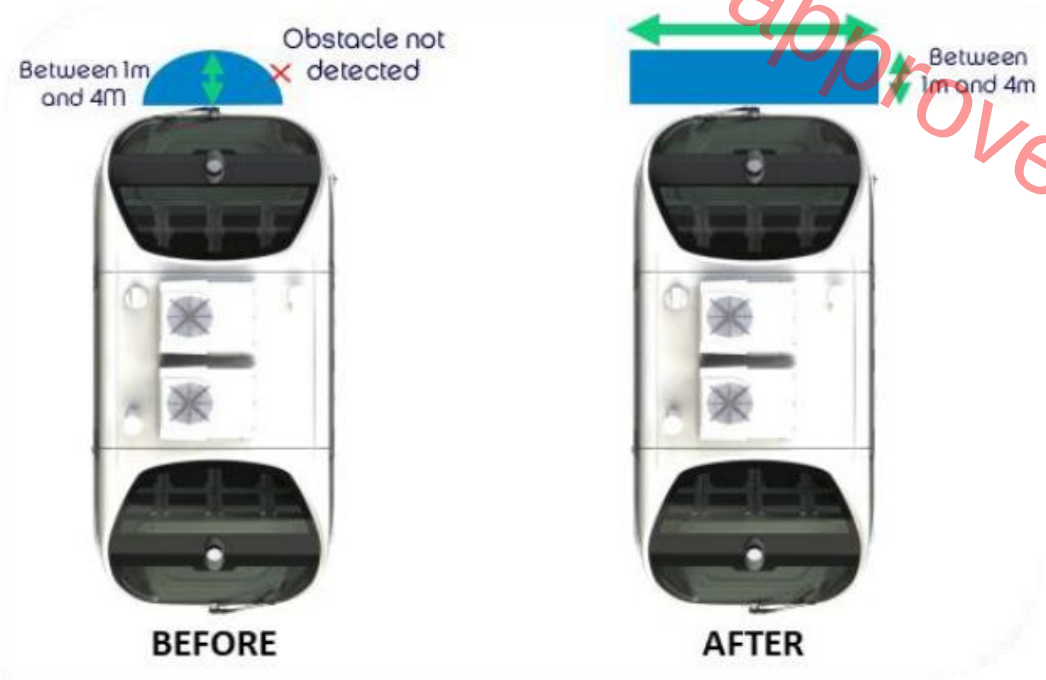


Figure 12: Obstacle detection correction from 4.11.x to 6.1.x version.

2.1.1.6 Setup 6.1.x

In setup 6.1.x, the missions use the starting activities "PICK AND DROP" (ON-DEMAND mode) or "METRO" (metro mode).

Table 1 : Starting activities

Activity	Purpose	Arrival behavior	Departure behavior
PICK_UP	Pick passengers at a station	Open doors when receiving an OPEN command. If no command arrives after timeout(600s), continue.	Close doors and start driving when receiving a START command. If no command arrives after timeout(600s), abort mission.
DROP_OFF	Drop passengers at a station	Open doors after timeout(1s)	Start driving if user closes doors. If doors are not closed after timeout(60s), close doors and start driving
PICK_AND_DROP	Pick and drop passengers at a station	Open doors after timeout(1s)	Close doors and start driving when receiving a START command. If no command arrives after timeout(600s), abort mission.
MAINTENANCE	Go to specific station for a maintenance operation	Keep doors closed	Start as soon as the vehicle receives a mission
PARKING	Go to parking	Keep doors closed	Start driving if user closes doors. If doors are not closed after timeout(15s), close doors and start driving
METRO	Metro-like behavior	Open doors after timeout(1s)	Close doors and start driving after 15s.
BUS	Bus-like behavior	*Expected: open doors if a stop is requested by a customer*	*Not implemented (Expected: Close doors and start driving after a few seconds)*

This setup did not allow the possibility to modify a mission while driving.

Ref.

- Release note Setup 4.11 to 6.1.4. pdf

2.1.2 Setup 6.2

The worked realized for the Setup 6.2 was focused especially on the On Demand (v1) feature. The feature enables, to the fleet Management system, the possibility to modify a mission in execution by the AV.

In the former Navya Setup versions, it wasn't possible to modify a mission while driving.

In 6.2 a new workflow was enabled. Thus, the user defines a new mission for a vehicle through the fleet management interface. This demand is transmitted to the NavyaDrive® using Navya API. The Driving component evaluates the new itinerary and compares it with the current one and give a GO/NO GO to Mission component. The answer is transmitted through the API to the user.

Figure 13: Mission approved.

When updating a mission (remotely on in STANDALONE mode), notifications will appear on the DUI, Internal Stretch and the sound system. These temporary displays will be shown during 1min. The sound notification is customisable like every other sound by creating a sound file named "mission_update_remote_*".

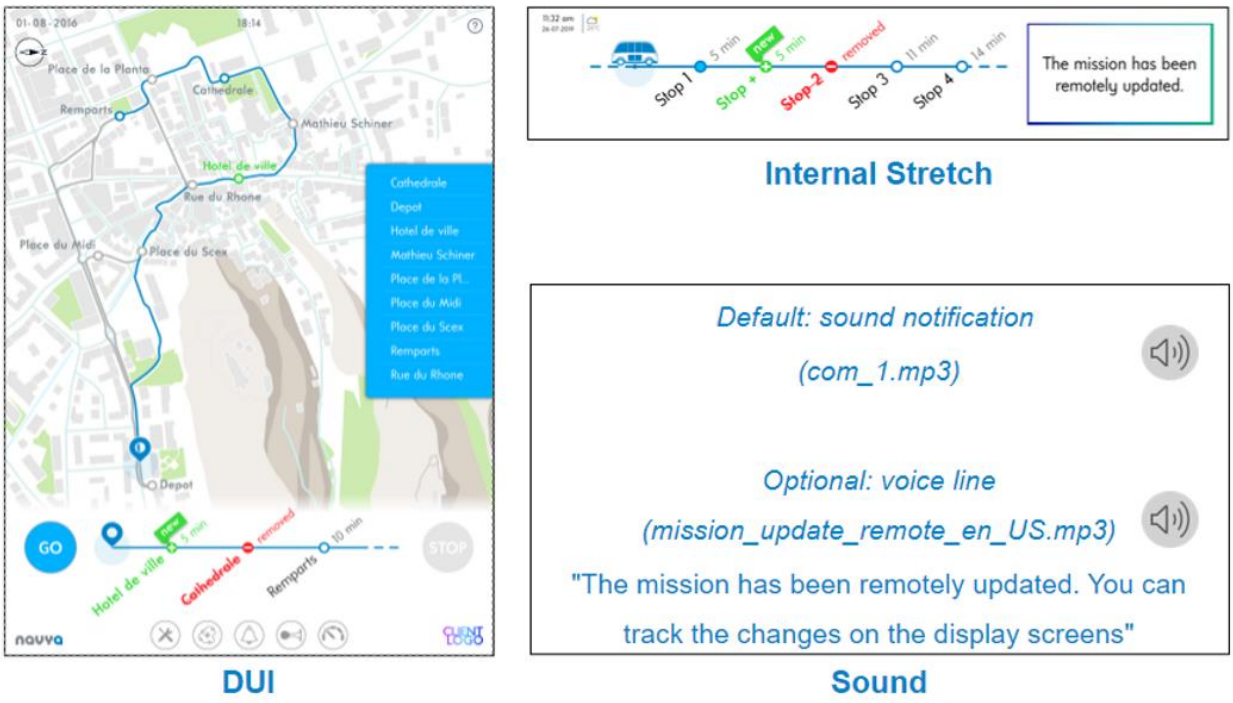


Figure 14 : Mission Remote.

The feature is activated by default and cannot be deactivated. In the future, this feature will be activated or deactivated using a configuration file.

The realization of this feature led to the creation of new data in Decision diagram (i.e. MissionPlayer macrocomponent). This data is out of the communication between Mission Player and the DUI for service description. The data are information about the mission (description, progress, lifecycle etc.).

Ref.

- https://navyatech.sharepoint.com/:u:/s/product-management/ESGE1okEzslBuxxJnLKPxcUBtb25t7FP5BKx3DF9uzVwCg?e=6wVs4e
- Release note 6.2_Autonom Shuttle.pdf

2.1.3 Setup 7.2.1

Linux migration

In order to enhance the cybersecurity of the system Navya realized an OS (operating system) migration from Windows to Linux. Navya targeted a new and more stable OS common with the one used by the routers. The DUI for operator wasn't change. Now, new and a more rigorous supervision tools have been put in place to reduce the number of remote connections.

The update to the Setup 7.2 involved the on-site intervention of Navya commissioning manager. In fact, dry running tests should be done at the end of the update. This update converted the path to a new format. The update to Setup 7.2 involves the replacement of the two PCs and of the router. The archiving of configuration files by Navya Remote Assistance was mandatory before upgrading the vehicle. Now, in 7.2, the utilization of an encrypted USB key is mandatory to recover logs.

The Linux migration is a major step in the development, bringing a more secure architecture and a better cybersecurity: we use signed image, access and profiles management, cyphering and certificates management. This is something highly appreciated by PTOs as soon as they scale up, and operate a fleet and not just some shuttles.

Media System

In this version, new dynamic images have been added to the external display screens: stop at a stop sign or a yield sign, nearing a traffic light, manual driving, obstacle detection, blinkers activated, etc. Each image can be personalized under certain conditions.

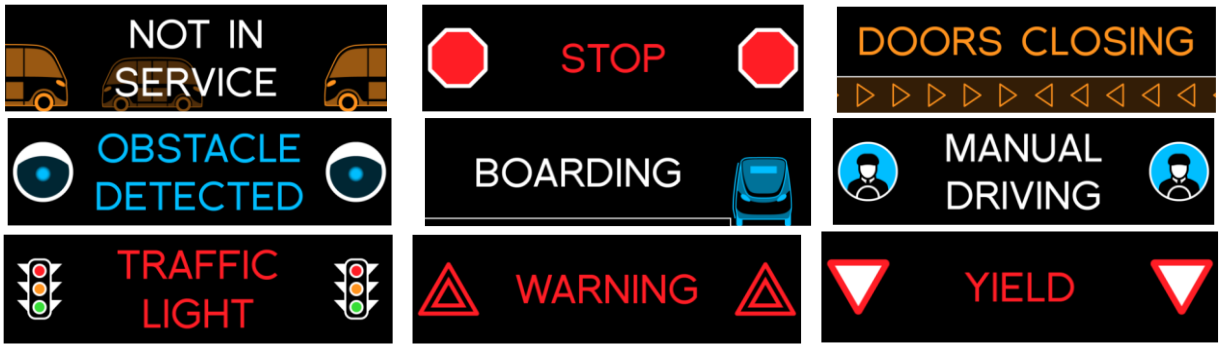


Figure 15 : New dynamic images.

Night mode

Asked by the operators, a night mode was developed. This can be chosen from the main screen of the DUI. Three main possible choices are available: day mode, automatic mode (display of the night mode according to the time of the sunrise and sunset in the geographical area) and night mode.

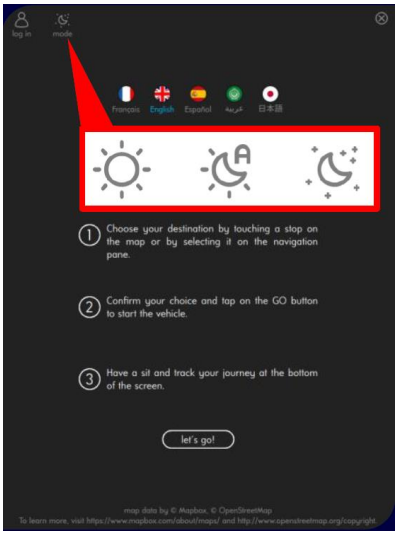


Figure 16 : Night mode.

Dynamic Behavior

Navya realized several developments to ameliorate the dynamic behavior.

Thus, the speed profile was reviewed. The acceleration and the deceleration profiles were adapted according to a new algorithm. The purpose of this algorithm was to ensure the right tradeoff between safety and comfort in the vehicle for the passengers. The acceleration was increased on departure and the crossing intersections was done more efficient. As for the decelerations, they were done smoother, and the abrupt movements were minimized.

The braking distances were slightly modified, depending on the deceleration profile criteria.

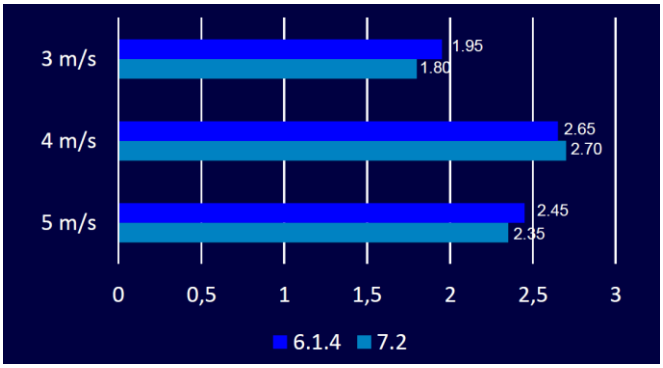


Figure 17 : Distance separating the vehicle and the obstacle (in meters) after an emergency braking (on obstacle detection)

Tools mode

This new feature was done for maintenance and/or deployment training. Thus, new information were made possible on “Mechatronics” page:

- Site name
- Vehicle Techname
- 12V battery voltage
- Outside temperature
- Rear Compartment Temperature
- Front Compartment Temperature

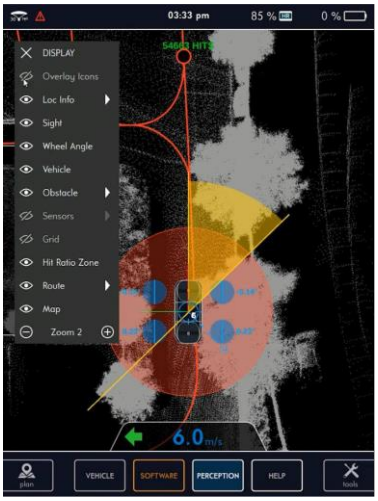


Figure 18 : Tools.

The new “restart” button from this new Tools mode allows to restart the NavyaDrive without performing a full key restart.

Navya improved the Perception Viewer by providing more information like: display of wheels angles, different ways to display obstacles, display customization for LiDARs tablecloths, display of priority zones, etc.

NavyaDrive® Boot

Navya developed for the new boot version a new screen: Splash Screen. It indicates, when NavyaDrive® starts, the steps necessary for the proper functioning of the software and the state of their initialization.

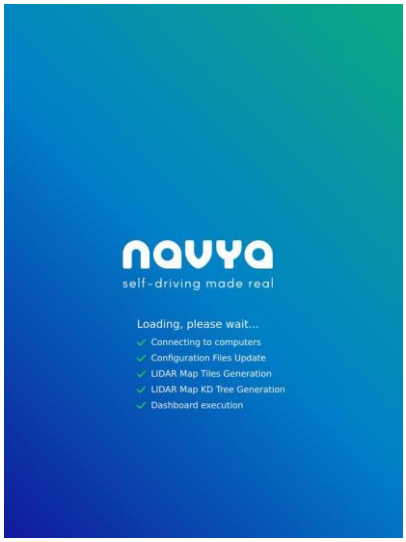


Figure 19 : Splash Screen.

Until the boot is not finished, the DUI and the diagrams will not be launched.

For this new boot version more information is available in order to identify various sources of possible startup errors.

Navya made possible during the boot session the synchronization between the Router, PC1 and PC2.

Other improvements

In 7.2.x version the logs recording is faster than in 6.x. Thus, the vehicle remains immobilized only few seconds instead of 30 seconds previously. This allow a better and faster service, highly appreciated by PTOs.

Now, the status of the Media System (image + sounds) is displayed on the DUI from the EVENTS tab.

The lighting of the brake lights no longer depends solely on the value transmitted by the IMU (Inertial Measurement Unit) to avoid any failure if it reports an error. From now on, the acceleration value calculated by the NavyaDrive® is considered when no information is transmitted by the IMU.

The DUI base maps are generated automatically, when possible, according to the geographical position of the vehicle when it is started.

Ref.

- Release notes 7.2_Autonom Shuttle.pdf

2.2 API versions

Navya API is an interface that enable the communicate with Navya vehicles and system. Navya has chosen to avoid any direct communication to its vehicles outside the API because of security issues, to reduce the number of specific clients embedded for each partner and to reduce the number of parallel protocols that are doing the same thing.
Navya API is the privileged solution to connect a partner to Navya system in order to do a fleet management system, a web application for monitoring, etc.

The API versions used by Navya shuttles on AVENUE demo sites are: 3.2.x, 3.4.x and 4.0.x.

2.2.1 API 3.2.x

Available features when the Navya shuttles were deployed on AVENUE site for the first time:

- Fleet description: list of available vehicles with description, list of available sites. The user can filter for a specific vehicle. Thus, the profiles can be adapted at different levels: application/site/vehicle.
- Available telemetry: engine temperature, GNSS signal, lights and blinkers (only compatible with NavyaDrive® versions from 6.0.x)
- Vehicles monitoring: provide real time information about any vehicle (telemetry at 1Hz and events). Navya shuttles are sharing punctual events describing the important information happening onboard. Share the vehicle's driving direction and direction mode. Limitation:

there is no guarantee that all the events are correctly transmitted from the vehicle (due to a network loss for instance).

- Transmitting commands: control the doors remotely, control the vehicle departure remotely. The format of the vehicle state is harmonized.
- The missions that are stacked in the FM (Fleet Management) can be read and removed.

Features on development when the shuttles were deployed for the first time on AVENUE pilot sites:

- Beta – video streaming: under development at that moment. To provide live streaming of front, back and interior cameras.
- Beta – send missions: under development at that moment. To prepare the user interaction with the mission of the vehicle: to create a mission draft, a mission request, a track of the current mission and to read and remove the mission in fleet manager.
- Beta – vehicle's passengers' counter: under development at that moment.

The concerned API versions: 3.2.0, 3.2.1, 3.2.2, 3.2.3, 3.2.4.

Ref.

- Documentation for partners (Navya API internal documentation for version 3.2.0 from February 19, 2021)

2.2.2 API 3.4.x

The new features that were developed are:

- Navya developed a new WebSocket. It was realized to provide an access to the events for one specific site.
  - It was created to send to the user vehicle information every time a vehicle connects/disconnects. One of the limitations of Navya API is that it shares the vehicle states only for the connected vehicles.
- The rewording of proto messages was realized to be related to:
  - the state WebSocket (to be compliant with the event WebSocket proto messages)
  - the missions (to prepare an upcoming refactoring of the mission features)
- We deprecated the endpoints and proto messages from the control features from the mission (beta) feature. The endpoints stay available, but the clients should stop using them. The end of the maintenance is scheduled for 2021/10/30.
- We developed a new WebSocket for sending to the user of the vehicle information on every time a vehicle connects/disconnects. A mission expires now after 30 minutes and no more after 8 minutes as before.
- We developed a new direction mode for compatibility with NavyaDrive® 6.1.x

The features on development, the beta version, announced in 3.2.x are still in development for this version of API.

Ref.

- *Technical documentation.pdf (manual for a developer that starts the integration of the Navya API)*
- *Documentation for partners.pdf (high level description of the API purpose and content)*

- *Integration guide.pdf (explanation of the integration process at Navya for a project manager)*
- CHANGELOG.pdf (summary of the last modifications of the Navya API)
- version.txt (version of the Navya API is documented here)

2.2.3 API 4.0.x

New features that were developed:

- We developed a new set of commands to handle the alerts: honk and buzz.
- Following the field returns of 3.4.x version, we backported the WebSocket's to a new architecture. The way in which the WebSocket's (vehicle, state and event) were handled was updated with a new architecture for Command and Mission WebSocket's. Thus, we obtained a harmonization of the code and logs and of requests. We obtained an uniformization of http responses and error cases. Thus, we created a unique log format to be used in all endpoints to indicate both the received requests and their associated responses.
- We refactored DAO (Data Access Objects) to obtain a better factorization and robustness. We upgraded the external libraries and we added details to our logs to improve debugging and customer support.
- The major change of 4.0 version was to expose the API to mission creation and tracking (consequence and necessity of the AVENUE project). This new interface completed and replaced the beta version that was partially available in 3.2.x and 3.4.x versions. Clients that were used our beta feature had need to update their interface to adapt to the breaking changes.
    - Thus, the vehicle state NEXT_STATION was considered as deprecated as the mission WebSocket were the only reliable way to retrieve this information. (The final version of this feature was obtained in 7.2.x NavyaDrive®)
    - Thus, we have managed to realize a new vehicle state that described the real time position of the vehicle on the circulation graph. A new PATH_POSITION state has been added to describe the real time position of a vehicle in circulation. On the circulation graph is defined where a vehicle can go, this information is presented in a logical graph that connects nodes and edges. The obtained new data contains two types of position: the waypoints to identify a discrete position on an edge and the nodes to identify a point at the extremity of an edge and to connect one edge or more. Note that this new data is mostly useful for users that are willing to integrate an advanced fleet management system (see the TPG/Belle Idée site were three Navya shuttles are operated in AVENUE). It requires to have our circulation graph.
    - We refactorized the permission management, this modification had no impact for end users.
    - We refactorized the WebSocket services. Mainly, was no impact for end users. The only exception was that the WebSocket's are not closing anymore for a functional reason. Precisely, if a client opens a state WebSocket for an unavailable vehicle, the WebSocket is only sending an error message, but is not closing anymore the WebSocket. The WebSocket stays available, waiting that the vehicle is available again.
    - We added endpoints (WebSocket and REST) to provide command answers from the Navya shuttles. This new feature allowed to the user to get the result of all remote commands executed by the vehicle in a real time and the reasons of the failure if a command failed. It enabled also to the user to get the result of the past commands (bounded by the cache limit size).

- The deprecated features were removed.

Ref.

- RELEASE NOTE.pdf (summary of the last modifications of the Navya API)
- version.txt (version of the Navya API is documented here)

2.3 Overview of Navya's platform enhancements

The history of different versions of the Setup (for Navya sensors and NavyaDrive®) and Navya API are schematized in the table below.

Table 2 : Overview of the Setup and API versions on AVENUE demo sites.

Client	Site	Shuttle	NavyaDrive® versions (Setup)	API versions	Deployment date	Available Feature
TPG	Belle Idée	TPG-GEN-02	4.11.3	3.2.X	10/07/2020	Telemetry v1 + beta missions
TPG	Belle Idée	TPG-GEN-02	6.0.X	3.4.X	01/02/2021	Telemetry v2 + beta missions + stack management
TPG	Belle Idée	TPG-GEN-02	6.2.0	4.0.X	20/12/2021	Telemetry v2 + missions V1 + dynamic update
TPG	Belle Idée	TPG-GEN-03	4.11.3	3.2.X	05/03/2020	Telemetry v1 + beta missions
TPG	Belle Idée	TPG-GEN-03	6.1.X	3.4.X	19/04/2021	Telemetry v2 + beta missions + stack management
TPG	Belle Idée	TPG-GEN-03	6.2.0	4.0.X	16/12/2021	Telemetry v2 + missions V1 +

						dynamic update
TPG	Belle Idée	TPG-GEN-04	4.11.3	3.2.X	10/07/2020	Telemetry v1 + beta missions
TPG	Belle Idée	TPG-GEN-04	6.0.X	3.4.X	10/11/2020	Telemetry v2 + beta missions + stack management
TPG	Belle Idée	TPG-GEN-04	6.2.0	4.0.X	26/11/2021	Telemetry v2 + missions V1 + dynamic update
Keolis	Parc OL	KEO-TRA-01	4.11.3	3.2.X	07/08/2020	Telemetry v1
Keolis	Parc OL	KEO-TRA-01	6.1.X	3.4.X	31/05/2021	Telemetry v2 + beta missions + stack management
Keolis	Parc OL	KEO-TRA-02	4.11.3	3.2.X	27/01/2021	Telemetry v1
Keolis	Parc OL	KEO-TRA-02	6.1.X	3.4.X	31/05/2021	Telemetry v2 + beta missions + stack management
Keolis	Parc OL	KEO-TRA-02	7.2.1	4.0.X	21/06/2022	Telemetry v2 + missions V1
Sales Lenz	Esch sur Alzette	SAL-LUX-03	4.11.3	3.4.X	27/10/2020	Telemetry v2
Sales Lenz	Esch sur Alzette	SAL-LUX-03	6.1.X	3.4.X	11/05/2022	Telemetry v2
Sales Lenz	Esch sur Alzette	SAL-LUX-04	4.11.3	3.4.X	28/10/2020	Telemetry v2

Holo	Slagelse	SEM-DEM-03	4.11.3	3.2.X	06/07/2020	Telemetry v1
Holo	Slagelse	SEM-DEM-03	6.1.X	3.4.X	11/08/2021	Telemetry v2 + beta missions + stack management
Holo	Slagelse	SEM-NOR-01	4.11.3	3.2.X	25/06/2020	Telemetry v1
Holo	Slagelse	SEM-NOR-01	6.1.X	3.4.X	25/06/2021	Telemetry v2 + beta missions + stack management

3 Conclusions

This deliverable, *D5.5: Vehicle-to-Platform interfaces and protocols,* shows the software enhancements realized in the frame of AVENUE project and deployed in pilot sites Belle Idée, Parc OL, Esch sur Alzette and Slagelse. It summarizes the different versions for NavyaDrive®, the embedded software that allows to operate the vehicle, and API, that provide data to customer's applications. Thus, the AVENUE project had a leverage effect on Navya's software's that evolved in time.

The NavyaDrive® version initially deployed on AVENUE pilot sites was 4.11.x. As for the API, the initial version was 3.2.x. The operators on site provided us returns of experience that allowed us to make several technological improvements. Thus, NavyaDrive® and the API evolved, and the versions developed are presented in this document. The NavyaDrive® 6.2 version and the API 4.0.x version were especially developed for AVENUE project. The main feature realized in 6.2 was the On-Demand.

The main challenges were to successfully develop NavyaDrive® and API and to test them in pilot sites and having a good maturity before the end of the AVENUE project. The objectives were accomplished. However, the work will carry on since it is part of the continuous improvements of Navya technology, all specific findings and developments done during the AVENUE project have been injected into the mainstream development of Navya products.

Annex – Confidential information

The annex includes confidential information which can be provided on -demand to selected audience.