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AVENUE

Autonomous Vehicles to Evolve to a New Urban Experience

DELIVERABLE 7.8
Copenhagen Large Scale Pilot Use Case
Demonstration Report
Second Iteration

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

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2.0	12.04	Christian Zinckernagel, Holo	Final report
3.0	04.01.2022	Christian Zinckernagel, Holo	36 month review feedback implemented

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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
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, D7.8, introduces the organisation, the operation and the evaluation of the large scale demonstrator pilot site with automated vehicles for public transport in the Nordhavn area in Copenhagen, Denmark. The route, homologation of it and the challenges will be presented. This report highlights the reason why the site was shut down and introduces a new AVENUE site, that Amobility will be operating in the project.

The Norwegian site that was included in the AVENUE project will be described and learnings will be presented. A data summary of the Norwegian and Copenhagen site will be presented with the purpose of showcasing in numbers some of the experience from the sites.

The e-minbus is operated at low speeds, due to technical limitations and the current risk assessment of the vehicle capabilities and the road conditions for the routes operated by Amobility. The low speeds have shown to be a weighing factor for how people perceive the technology and the service itself. Many of the travellers perceive the e-minibus as too slow to really depend on in daily transport patterns. But sees the technology as exciting and with many potential upsides to society.

This deliverable will also include learnings from other projects with Automated minibuses conducted by AM.

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

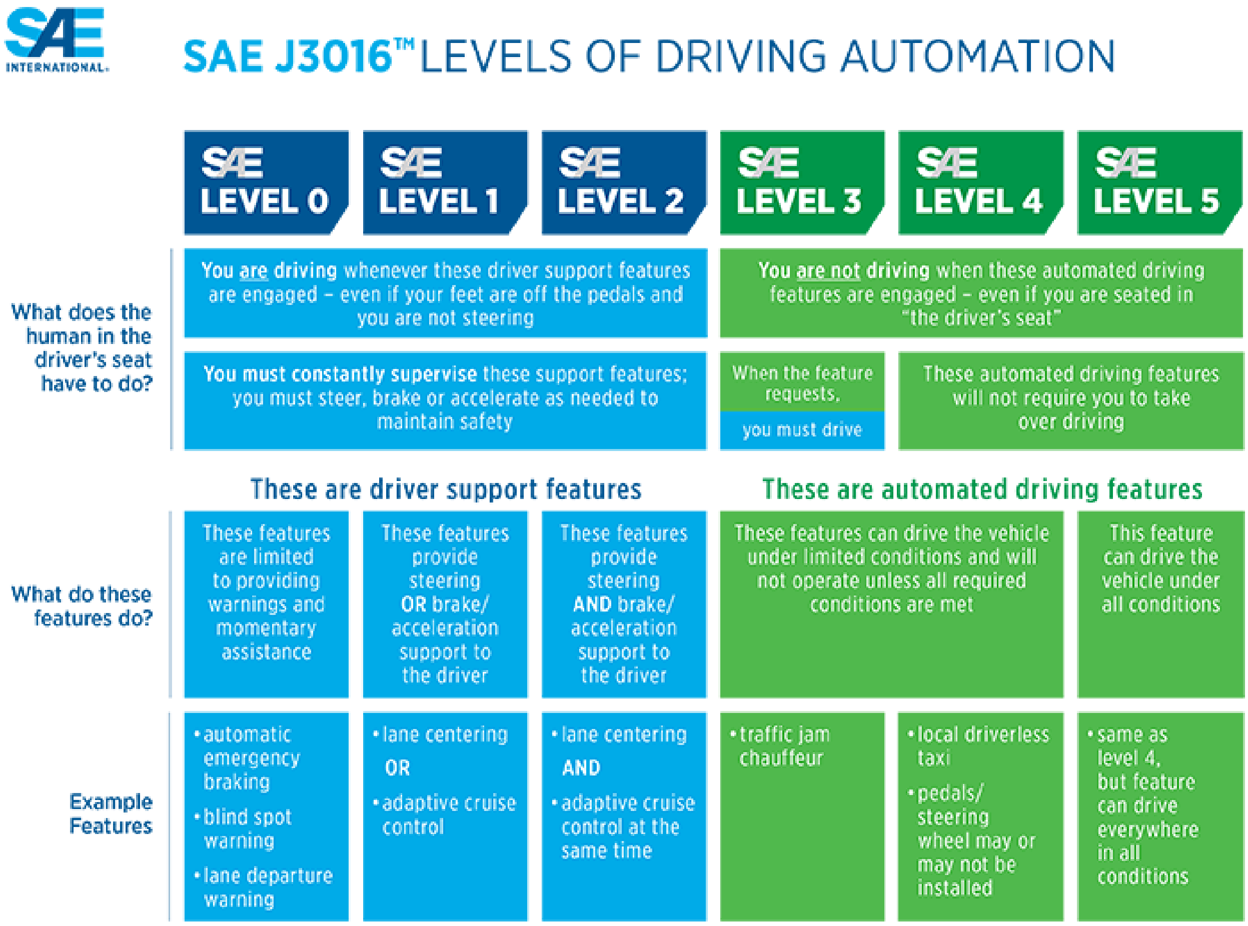
A self-driving car, referred in the AVENUE project as **an Fully Automated Vehicle** (**AV**), also referred as autonomous vehicle, is a vehicle that is capable of sensing its environment and moving safely with no human input.

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 Automated minibuses, 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 technically can achieve speeds of more than 60Km/h. However this speed cannot be used in the project demonstrators for several reasons, ranging from regulatory to safety. Under current regulations the maximum authorised speed is 25 or 30 Km/h (depending on the site). In the current demonstrators the speed does not exceed 23 Km/h, with an operational speed of 14 to 18 Km/h. Another, more important reason for limiting the vehicle speed is safety for passengers and pedestrians. Due to the fact that the current LIDAR has a range of 100m and the obstacle identification is done for objects no further than 40 meters, and considering that the vehicle must safely stop in case of an obstacle on the road (which will be “seen” at less than 40 meters distance) we cannot guarantee a safe braking if the speed is more than 25 Km/h. Note that technically the vehicle can make harsh break and stop with 40 meters in high speeds (40 -50 Km/h) but then the break would too harsh putting in risk the vehicle passengers. The project is working in finding an optimal point between passenger and pedestrian safety.

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

1.1 Preamble

Work package WP7 organises, runs and evaluates these large scale demonstrators of the automated vehicle services for public transport, targeting different user groups, and transport models. The goal is to validate a high quality, safe service, which will enhance the acceptance and adoption of automated vehicles for public transport.

The overall aim of task T7.3 is to test and implement the autonomous mobility Cloud – and thereby creating a better connection between selected areas of Copenhagen and existing public transport solutions.

By offering cloud based AM, Autonomous Mobility (AM) aims at providing a transport service to fulfill the changing transportation at the time users need it. The service is shared and on-demand which is more flexible than we're used to. This will provide a customised user experience of a whole new and better way of getting from A to B. When the autonomous mobility cloud is implemented, the activity of the vehicles will be determined by the users' needs. This will not only reduce the number of parked cars by the street side, it will also optimise the use of capacity in each vehicle and on the lanes.

The mobility cloud will be developed and tested to the extent possible in the AVENUE project. The approach is to build and test critical components with the purpose of testing them and establish a better understanding of what it takes to provide the mobility platform in the future. A very important aspect of the mobility platform is to connect and integrate with påublic transport and in this case Amobility will fully integrate with Copenahgen based large PTA Movia on ensuring on-demand shuttle services at Slagelse Hospital.

1.2 AM

The city of Copenhagen has an overall goal to become the World's first CO2-neutral capital by 2025. AM and the AVENUE project will support this goal by implementing and operating autonomous electric shuttles in Copenhagen and Slagelse as a green initiative to first-mile last-mile public transport.

The overall goal for AM is to implement and test services under the autonomous mobility Cloud on the Copenhagen and Slagelse site. In order to do so, AM aims at deploying up to four vehicles over a period of four years, while working towards expanding and developing the sites. These routes will create a better connection between selected areas of Copenhagen and existing public transport solutions. On the Slagelse site AM will make a public transport integration with Copenhagen based PTA Movia.

During the AVENUE project, AM wants to further expand the portfolio of vehicles and vessels to create more advanced features and integrations with the Mobility Cloud to the extent possible with the technologies available.. The whole system is planned to integrate with existing PTO solutions in the Copenhagen area - such as Movia.

The Am services should be experienced as "Helpful, Simple & Seamless": When automated vehicles become an integrated part of the cityscape, the user will be able to define her transport needs - and order her solution via AM's autonomous mobility Cloud. Shortly after the user will get picked up exactly at his/her location and will be transported to the end destination chosen. The cloud will also be shaped so that it can move goods and parcels - all in various shapes and sizes - around when needed.

At the end of this project, AM aims to have developed, implemented and tested important components of the autonomous mobility cloud to the extent possible, in an on-demand (door2door) autonomous transport system.

2 Project homologation

Danish authorities are positive towards the development and implementation of future transport modes, including automated vehicles. The approval process of AVs falls under the regular legislative framework, which is described below. The process is very extensive and requires a lot of documentation regarding the route, vehicle, safety, risk and so forth.

2.1 Authorities

The approval process for each project testing automated vehicles in DK looks as follows:

1. A single Vehicle Approval for the AV(s) has to be granted by the Danish Road Safety Agency if the vehicle is not EU type approved
2. An impartial third party, called an assessor (appointed by Danish law) has to approve the overall project.
3. The road-owner (typically the municipality) must grant an approval for the project

4. Once Vehicle Approval, Assessor approval and approval by the road-owner has been obtained an application can be sent to Danish Road Directorate. An application must include the three (3) above granted approvals and some additional descriptions of the project.
5. The material has to be processed and commented on by a public Task force, consisting of the Danish Road Safety Agency, Danish Road Directorate, Director of Public Prosecutions and the Danish police.
6. A legal declaration is then made and sent into public hearing for all interested parties, minimum four (4) weeks in public hearing is required
7. The declaration then has to be approved by the Danish Transport Committee (elected politicians)
8. Finally, the Minister of Transport has to approve the declaration and process.

If any changes to the declaration needs to be processed after approval has been granted step 6-8 must be completed again. Major changes could be new/changed routes.

2.1.1 The role of the assessor

The Danish law states that the application to the Danish Road Directorate shall include an assessment of the pilot project by a third party, called an "assessor". The third party is typically an engineering company, which is paid to do their objective assessment. The company applying for approval of the autonomous project is paying the assessor, in this case, AM. The assessor shall through different defined parameters assess that the project can be done within normal road safety risks for that particular type of transport. The defined parameters are; General traffic, IT and data, vehicle technic, infrastructure, organisation and risk management. These are the only guidelines provided for assessors.

The law states that the assessor holds the responsibility for assessing traffic risks in the autonomous pilot project. And with no detailed guidelines, a great deal of time has been spent on agreeing with the assessor and the authorities on a sufficient level of documentation. Hence, AM has spent a large amount of time on application material, including defining and documenting procedures and processes.

There has long been a tradition in Denmark for using assessors in rail projects. And this idea of having experts in the field assessing the risks of an autonomous project might be feasible for high complex autonomous projects. However, it is a time-consuming and expensive setup and it currently does not match well with the low-speed and simplistic projects which are being carried out - with SAE level 3 vehicles.

The law will not undergo review before the spring of 2022 and lawmakers have not shown any willingness to conduct reviews at an earlier stage at this point in time.

2.2 Vehicle homologation

Application to the Danish Road Directorate shall include either a EU vehicle type approval or a single vehicle approval granted by the Danish Road Traffic Authority. Technical vehicle documentation is provided to the Danish Road Traffic Authority for Vehicle Approvals, this also includes specifications for wheelchair anchorage solutions, seatbelt and ramps.

2.3 Test site homologation

Given the Danish legislative framework each route has to be approved with an individual application, including a risk assessment and documentation regarding the implementation, operation, crisis and risk management.

2.3.1 Assessor application

The following table introduces the parts (chapters and information) necessary in the assessor application for homologation of each routel:

Chapter	Information
Project description	- Introduction - Objectives - Methods - Partners
Legal framework	- Description of legal framework - Test-framework
Vehicle description	- Capabilities - Capacities - Technical aspects - Autonomous driving
Vehicle connectivity	- Basestation/N-trip - 4G
Route description	- Route length - Schedule - Garage route - Depot
Bus stop description	- Concessions - Positions - Identification
Organisation	- Roles - Trainers & training plans - Safety operators - Supervisors
Data description	- Data handling - GDPR - API - System descriptions
Risk handling (internal)	- Risk processes - Compliance - Crisis management
Risk-assessment (external)	- Risk identification - Potential pitfalls - Mitigating actions - Risk process

3 Vehicles

AM has been testing AV's since 2017 and owned several Navya Arma vehicles before starting up the AVENUE project. In the AVENUE project AM will operate four Navya Arma vehicles, three of them funded by the AVENUE project.

3.1 AM vehicles for AVENUE

AM has 4 Navya vehicles connected to the AVENUE project as follows:

Type	ID (VIN)	Driving	Funded by	Pilot site	Brand foil
Navya Arma DL4	P109	Mono-directional	AVENUE	Nordhavn	Holo branded
Navya Arma DL4	P111	Mono-directional	AVENUE	Nordhavn	Holo branded
Navya Arma DL4	P112	Mono-directional	AVENUE	Ormøya	Ruter branded
Navya Arma DL4	P85	Mono-directional	AM	Ormøya	Ruter branded

3.2 Navya Arma Technical data

See appendix A

3.3 Options/functionality

3.3.1 Air Conditioning

The Navya Arma shuttles are equipped with air conditioning and heating.

3.3.2 Stickers

Inside the shuttle, stickers are mounted, with the purpose of informing the passengers about hard breakings. This way the passengers are more prepared during a ride.

3.3.2.1 Example of powerful breaking sticker

3.3.3 Seat-belts

The Navya arma shuttle is equipped with seatbelts. Unfortunately, the seatbelts are not approved/allowed in Denmark because the anchorage position is not compliant with standards - hence they are removed from the vehicles. In Norway seatbelts are available in the shuttle and kids and ederly are advised to use them to avoid falling during hard breaks etc.This is approved only because of the low speed of the vehicle.

3.3.4 Wheelchair ramp

The vehicle is required to have a wheelchair ramp in Denmark, as a public means of transportation. The Navya Arma vehicle is equipped with a manual and automatic wheelchair ramp. The manual ramp can be installed by the safety driver and the automatic ramp can be activated by an inside or outside button on the shuttle.

3.3.5 Q-straint

The vehicles are approved to take on wheelchair users. In order to fixate the wheelchairs Q-straint has been installed in the shuttles. Q-straint works simply by having four mounted points in the floor, with seatbelts, that can be hooked to the wheelchair. The seatbelts retract automatically and locks when necessary. When a wheelchair has to board the shuttle, the Safety driver mounts the four seatbelt heads on the floor. This means that the floor is empty when riding without a wheelchair. When carrying a wheelchair user, the three foldable seats cannot be used, and there is room for 8 additional passengers.

3.3.5.1 Q-straint example

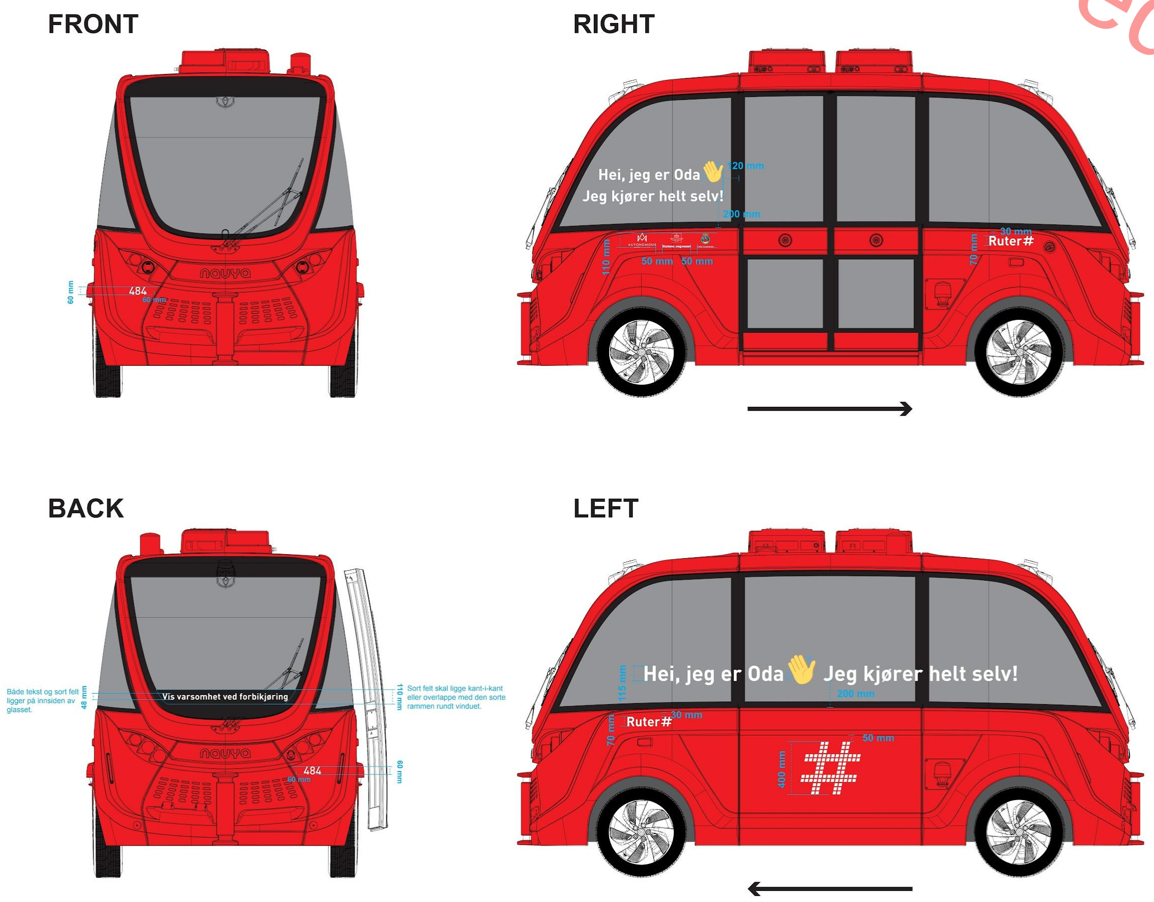
3.4 Vehicle foil (branding)

The Navya Arma shuttles are branded differently at the two AVENUE sites. In Copenhagen they are branded with the Holo sub brand and in Oslo they are branded with Ruter colors (the client in Oslo). The following sections show the two vehicle brandings.

3.4.1 Holo branded

3.4.2 Ruter branded

NAVYA ARMA SELVKJØRENDE BUSS / mads.haraldseth@ruter.no, +47 414 79 303 / Ruter As



3.4.3 AVENUE EU logo

Vehicles in the AVENUE project, hence funded by the EU, are equipped with an AVENUE project sticker/disclaimer in English. The stickers are placed in the front/rear window.

3.4.3.1 English

AVENUE

Autonomous Vehicles to Evolve to a New Urban Experience

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 769033

3.4.3.2 Vehicle example (EU logo)

3.5 Vehicle inspection

Given the vehicle approval in Denmark and Oslo, the shuttles have to undergo a yearly service/inspection, ensuring safety and quality. Local service agreements have been made with official and approved mechanics. The inspection is focused on the mechanical part of the shuttle with focus on robustness etc. The software inspections are done by Navya as a part of the maintenance agreement.

3.6 Vehicle maintenance

For all Navya Arma DL4 shuttles there is a service agreement with Navya regarding service and maintenance of the shuttles. This includes the entire system enabling the operation, hence base station, commission of the route (ensure efficient operation), the shuttles hardware and software. At AM the Deployment and Maintenance Manager has the highest degree of external Navya Maintenance education, allowing AM to do in-house maintenance on hardware parts to the extent possible. When necessary Navya will send a technician to maintain the shuttles. The state of the vehicles, including service, maintenance and driven kilometres are stored and updated in Fleetio, where standard operating procedures are also attached to each vehicle number. Fleetio is an all-in-one fleet management and maintenance solution for fleets of all sizes.

As a part of the service agreement AM has full access to the Navya Supervision Center, within the operational hours. The Navya Supervision center monitors the operation from France and is standby to receive any inquiries from AM's own supervisors.

3.6.1 Sparepart cost

Amobility has driven around 77.000 km in total over the past three years with Navya Arma shuttles. In that time period spare parts have been changed and maintenance of the vehicles have been completed. Amobility has been able to calculate the spare part cost per km driven. The purpose of this is to understand the cost of driving the vehicles but also to be able to compare with other vehicles in the future.

The spare part price per driven km is 3.7 EUR.

The cost per driven km is an average made across all Amobility Navya vehicles during the last three years on all the Amobility routes in Scandinavia.

3.6.2 Amobility commissioning

Commissioning process and information regarding the implementation of self driving vehicles in Denmark. The process involves the vehicle manufactura (Navya), AM and public approval authorities.

The commissioning process typically takes 30 days with 14 days preparation and 14 days on site commissioning and costs around 20.000 - 40.000 EUR.

The entire commissioning process with Navya has to be documented and reported to the authorities before an approval can be issued. Major changes to the approved commissioning report have to be approved again by the authorities before implementation. The commissioning process is conducted in collaboration between Amobility and NAvya. The overall process is presented below.

Prep commissioning

1. Pre-study
2. Site analysis
3. Final route decision
4. Garage facilities
5. PO created and signed
6. Preliminary commissioning plan
7. Initial infrastructure changes
8. Route/vehicle/site preparation
9. Final commissioning plan
10. Base station or N-trip setup

On site commissioning

11. Mapping
12. Cartograph (verification and clearing of map)
13. Route setup testing (initial trajectory)
14. Testing and adjusting trajectory
15. Setup of safety - and priority zones, speed limits etc.
16. Navya API setup

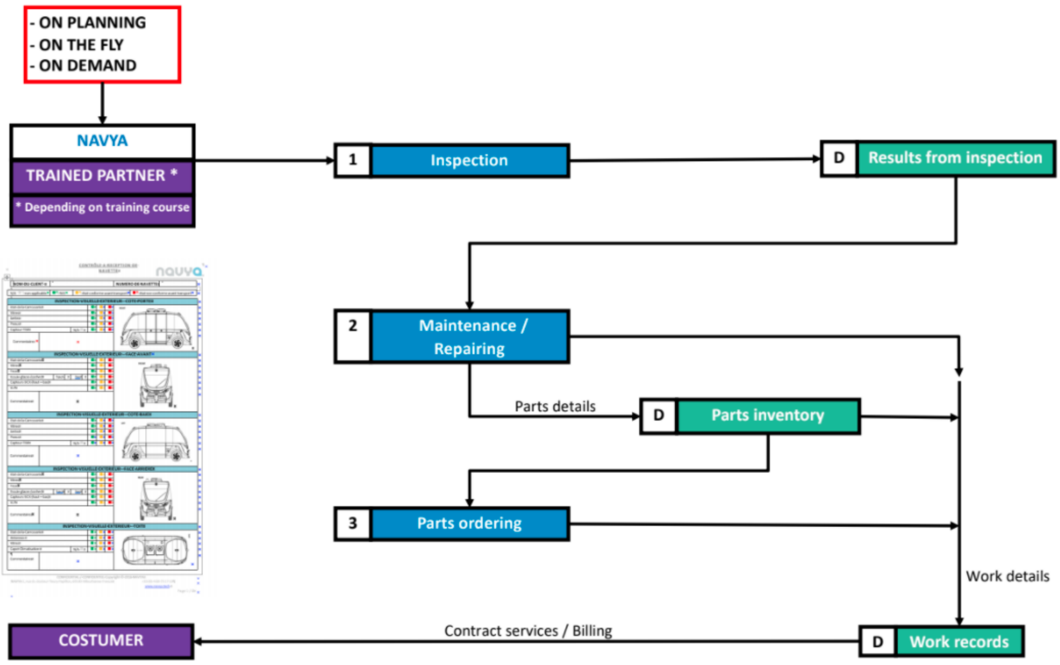
17. Formal hand-over
18. Holo IT configuration
19. Holo internal testing
20. Assessor/authority testing (for approval)
21. Final approval

After commissioning

22. Route adjustments (when necessary)
23. Assessor/authority adjustment testing
24. Assessor/authority approval
25. Route adjustment implementation

3.6.3 Amobility Maintenance

Amobility have been trained by Navya on several maintenance courses in France to do maintenance on our operations to a certain level without including Navya. There are three levels of maintenance that an operator can do, the following shows the levels.



Amobilitys maintenance team has been trained to do all three levels of maintenance, meaning that Amobility over time has developed predictive maintenance, where data from the vehicles (telemetry) is paired with maintenance data (downtime, reasons for downtime etc.) so that Amobility can maintain the highest possible uptime on all sites.

3.7 AM supporting operational functions

3.7.1 Amobility Supervision

Responsibility and mandate

The supervision team helps and coordinates daily operation with safety operators. They are the link between manufacturers and operators and maintain the bigger picture. Their role is to be proactive to the extent possible and reactive when necessary. Data and learnings are constantly stored to avoid future problems. The daily work of the supervision team can be defined as follows:

- Before operation
  - Coordinate and prepare startup of operation
  - Read handover
- During operation
  - Monitor and assist operators on the routes
  - Troubleshoot with operators and manufactures
  - Communicate with project partners
  - Report issues and register downtime
- After operation
  - Coordinate end of operation
  - Hand over information to next Holo Supervisors

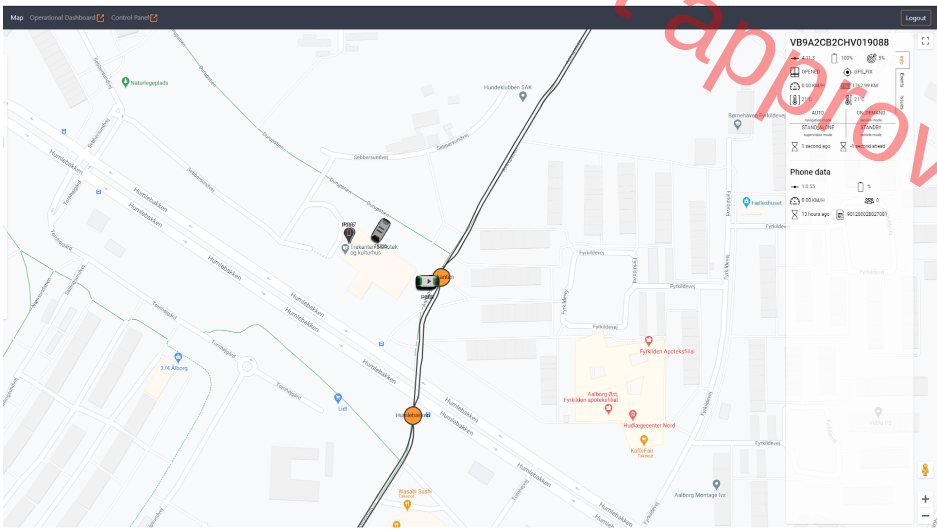
Tools for crisis management

The supervision team has a set of tools they can use when a crisis occurs to ensure that AM handles the crisis to the best possible degree. The process includes securing the site, securing involved parties (safety operator, passengers, other road users etc.) and gathering the required data to understand and analyse the incident, so that AM can avoid making the same mistakes in the future, if the mistake is caused by AM. The following list presents some of the steps and tools used.

- Action cards for incidents
- After action review
- Incident procedures
- Vehicle data analysis
- Incident report(s)
- Final incident assessment report
- Incident interviews
- Incident communication
- Deletion of sensitive personal data
- Incident vehicle assessment

Supervision portal (for monitoring and troubleshooting)

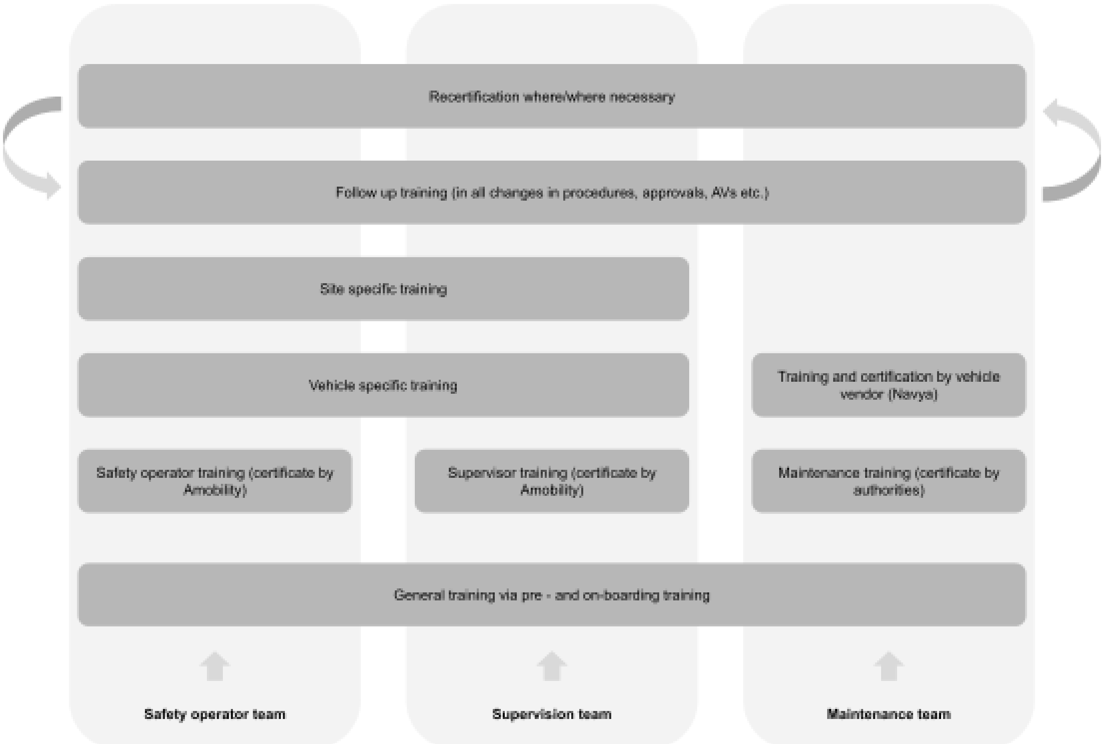
The AM supervision team uses the AM supervision portal to monitor and troubleshoot the vehicles in operation, in collaboration with the safety operators inside the vehicles. The following shows an example of a vehicle in the supervision portal.



The supervision portal is supported by operational data like telemetry, states and events coming from the Navya API and data from the AM operator app.

3.7.2 Amobility training

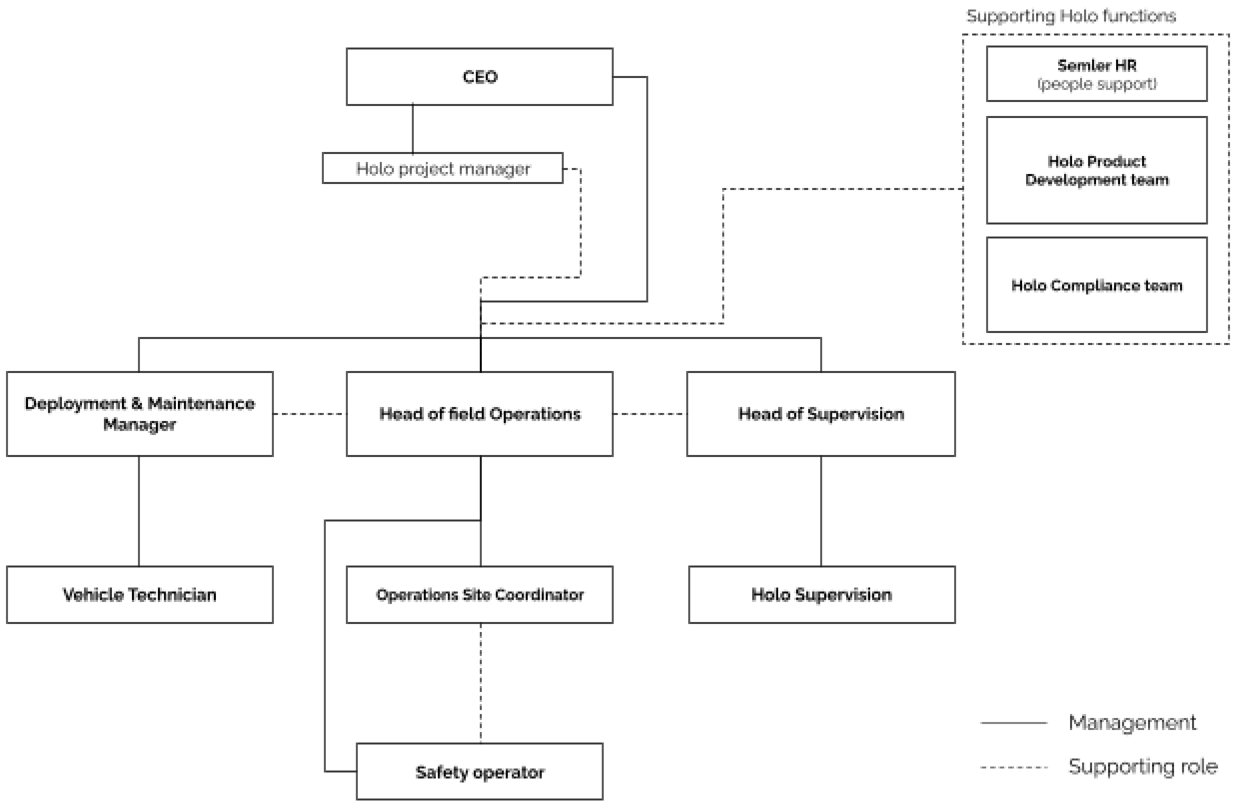
Amobility has received the trainers trainer certificate from Navya allowing Amobility to train and educate operatore to navigate and operate the Navya shuttle. Based on this Amobility has created the Safety operator training program that can be used to educate and prepare new operators for a new site in 4-6 weeks. The training plan consists of the following elements, see below) with the purpose of ensuring that the safety operator team, supervisor team and maintenance team is fully equipped to operate, monitor and maintain the shuttles and feel comfortable in both operating, handling passengers and conducting conflict management and crisis management.



The training plan is approved by the assessor team/authorities and include training for amobility safety operators, supervisors and maintenance personnel. Both supervisors and safety operators have to complete the same vehicle - and site specific training, to ensure in depth knowledge about both the technical capabilities of the vehicles but also the traffic situation and potential pitfall on the site.

4 Operations

The operations of the pilot sites and the different roles are shown in the following organisational chart.



5 AM pilot sites

In the AVENUE project, AM will run three test sites:

- Nordhavn, Copenhagen, Denmark
- Ormøya, Oslo, Norway
- Slagelse, Denmark

The Ormøya route was originally initiated without being a part of AVENUE but an agreement has been made to include the site for 5 months to begin with. The norwegian site ended in December 2020. A new Danish site in Slagelse Hospital will begin in September 2021, with focus on on-demand.

The three routes can be concluded in short as follows:

	Copenhagen	Oslo	Slagelse
Community	Nordhavn (smart city area + residential area)	Ormøya (residential area)	Hospital site
Funding	AVENUE + AM	AVENUE + AM + Ruter	AVENUE + AM + Movia
Start date project	May 2017	August 2019	August 2019
Start date trial	September 2020	December 2019	August 2021
Type of route	Fixed circular line	Fixed circular line	On demand - not circular line
Distance	1.3 [km]	1.6 [km]	5 [km]
Road	Open road	Open road	Open road
Type of traffic	Mixed	Mixed	Mixed
Speed limit	30 [km/h]	30 [km/h]	30 [km/h]
Roundabouts	No	No	No
Traffic lights	No	No	No
Type of service	Traditional bus line	Traditional bus line	Flex: On-demand service
Concession	Line (circular)	Line (circular)	Not circular line
Number of bus stops	6	6	6
Type of bus stops	Fixed	Fixed	Fixed

Bus stop infrastructure	Yes	Yes	Yes
Number of vehicles	1	2	2
Timetable	Fixed	Fixed	Not fixed
Operation hours	Monday-Friday (5 days)	Monday-Sunday (7 days)	Monday-Friday (5 days)
Timeframe weekdays	10:00-18:00	7:30-21:30	07:00-18:00
Timeframe weekend/holidays	No service	9:00-18:00	Only for special events
Depot	At 800 [m] distance	At 200 [m] distance	At 200 [m] distance
Driverless service	No	No	No

5.1 Nordhavn, Copenhagen, Denmark

The Copenhagen pilot site will be situated in an area of the city called Nordhavn. Nordhavn is an active industrial port that is undergoing a transformation – turning into Copenhagen's new international waterfront district offering residential and commercial buildings. When the development of Nordhavn is done, the area will house more than 40.000 residents and 40.000 employees.

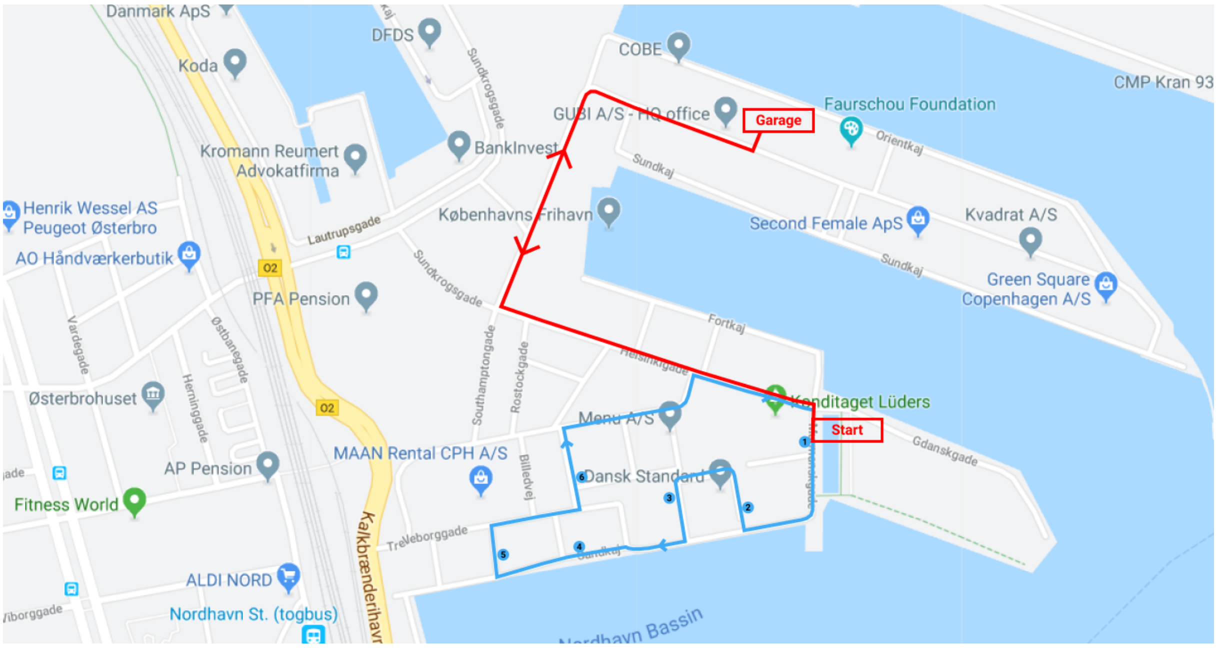
Nordhavn aims at being an eco-friendly neighbourhood and contributes to boosting Copenhagen's image as an environmental metropolis. Renewable energy and new types of energy, optimal use of resources, recycling of resources and sustainable transport will help make Nordhavn a model for sustainable development and sustainable design. A vibrant city: Nordhavn should vibrate with life as a versatile urban area with a multitude of activities and a wide range of shops, cultural facilities and sports facilities. The area is becoming more and more populated, and the needs for local transportation is expected to keep growing.

Currently, the Nordhavn area is serviced by a nearby S-train station (app. 1,1 km away) and bus stops located near the train station. There are however no buses or trains running directly in the area – creating a great opportunity for automated vehicles to function as a new public transport solution, connecting the area much better than it is today. In 2020 two new metro stations will have been built – opening in the periphery of the neighbourhoods.

5.1.1 Route

The first route is placed in the area called Århusgadekvarteret. This area was the first one finished and residents started moving there in 2015. Since then different squares and the harbour promenade and a rooftop gym have been evolved and taken into use. Furthermore, special attention has been on developing local retail, so today there are supermarkets, cafes, restaurants and different specialised retailers. There are several shared space areas on the route including a bathing zone.

The first route is a circle line around the area (blue line on the map below), making it easier to get around and to enter the area from outside Nordhavn. Our garage is located on the next peninsula close to Århusgadekvarteret (the red line on the below map).



The pilot route is going to be in mixed traffic with cars, pedestrians, bicycles etc. The area is, in general, a low-speed area with 20-50 km/h speed limits on the route, and in the 50km/h limit areas, the recommended speed for cars is 30km/h.

Operation facts:

- 2 AV's running to begin with
- Mon-Fri 10.00-18.00
- Loop route with 6 stops

The main expected users of the shuttle service will be the residents of Nordhavn (including families, children, and elderly), commuters working in Nordhavn, and visitors to the area. Several usage scenarios can thereby be anticipated:

- Ease the mobility within the area for the residents and commuters working in the area.
- Used for the first/last mile from the main road/ entry point to the area to the different stops within the area for residents and commuters working there.
- Provide easier access from the main road to e.g. the harbour pool, restaurants, cultural facilities for visitors and families.

Planned services provided for the end-users:

- The shuttles are free of charge during the pilot project in Denmark, so there is no ticketing yet.
- There are static bus stops providing the position of the bus, relative to the given stop.
- Realtime location of busses can be seen in the mobile application.
- Besides the bus stop signs, users can find information about the pilot project at AM website and AVENUE Mobile Application.

During the project period, it is the aim to test the services developed through the AVENUE project e.g. real-time position of the bus, on-demand booking, accessibility for disabled persons.

5.1.2 Bus stops

Stop name	Picture
Murmanskgade	
Gøteborg plads Ø.	
Gøteborg plads V.	

Sandkaj	
Karlskronagade	
Bilbaogade	

5.1.3 Timetable

Timeslot	Mumanskgade	Gøteborg plads Ø.	Gøteborg plads V.	Sandkaj	Karlskronagade	Bilbaogade
A	10:00 10:20 10:40	10:02 10:22 10:42	10:04 10:24 10:44	10:08 10:28 10:48	10:10 10:30 10:50	10:14 10:34 10:54
B	11:00 11:20 11:40	11:02 11:22 11:42	11:04 11:24 11:44	11:08 11:28 11:48	11:10 11:30 11:50	11:14 11:34 11:54
C	12:00 12:20 12:40	12:02 12:22 12:42	12:04 12:24 12:44	12:08 12:28 12:48	12:10 12:30 12:50	12:14 12:34 12:54
D	13:00 13:20	13:02 13:22	13:04 13:24	13:08 13:28	13:10 13:30	13:14 13:34

	13:40	13:42	13:44	13:48	13:50	13:54
E	14:00 14:20 14:40	14:02 14:22 14:42	14:04 14:24 14:44	14:08 14:28 14:48	14:10 14:30 14:50	14:14 14:34 14:54
F	15:00 15:20 15:40	15:02 15:22 15:42	15:04 15:24 15:44	15:08 15:28 15:48	15:10 15:30 15:50	15:14 15:34 15:54
G	16:00 16:20 16:40	16:02 16:22 16:42	16:04 16:24 16:44	16:08 16:28 16:48	16:10 16:30 16:50	16:14 16:34 16:54
H	17:00 17:20 17:40	17:02 17:22 17:42	17:04 17:24 17:44	17:08 17:28 17:48	17:10 17:30 17:50	17:14 17:34 17:54

5.1.4 Stakeholders and partners

In order to get the demonstration site approved and in operation several stakeholders and partners are involved. Some during the whole project period, others only for specific parts of the project. Besides the below entities there are various public authorities involved in granting the permit, these will be described in part 3.1.

AM:
Is the local private operator and the main applicant of the pilot project. AM has the main responsibility to plan and operate the pilot project. AM is the entity given the permit and thereby has the full responsibility for safety and the vehicles.

Copenhagen Municipality:
Is a member of the steering committee for the pilot project. The municipality is also approving the use of the roads under their jurisdiction where their route is located.
CPH City & Port: Is a member of the steering committee for the pilot project. CPH City & Port Development is in charge of the development of the Nordhavn area and assists in selecting the route, risk workshops, getting road permits from homeowner association as well as being a close dissemination partner.

The homeowner association G/F Århusgadekvarteret:
Is a member of the steering committee for the pilot project. The association provides the permit to use the roads under their jurisdiction as well as ensuring that any concerns from the homeowners are taken into consideration.

The Copenhagen Metro:
Is overall responsible for the operation of Copenhagen's metro and the expansion of the metro system including the line to Nordhavn. The Copenhagen Metro assists with the integration to public transport.

Movia:
Is a public company and is regulated by the law about transport companies. According to the law, Movia handles bus operation, local rail operation and transport of disabled persons. Movia assists with the integration to public transport. Movia is also an operational partner in the new Slagelse Hospital site.

COWI Denmark:
Is a leading consulting group, and two different departments (in order to avoid conflict of interest) are hired to do two different tasks:
One department has been approved as the assessor for this pilot project. The application for a permit to test automated vehicles shall according to the law include an evaluation from an approved assessor.
The other is hired to make a risk assessment of the road safety in the pilot. The assessment is done in close cooperation with AM and is part of the basis for the evaluation by the assessor.

Rambøll:
Is a leading consulting group. A road safety auditor from Rambøll has analysed the below list of conditions in the pilot project. The analysis is part of the basis for the evaluation by the assessor.

- The route and surroundings
- Existing traffic conditions
- The speed on the route
- Handling of other road users
- The conditions to give way
- Traffic at the bus stops

Bech-Bruun:
Is a law firm that is hired to provide legal assistance.

AM supervision:
AMs centralised operation center (AM supervision) for the route in Nordhavn will monitor the operation all hours of operation.

Navya supervision:
Is Navya's operational monitoring unit, that is contacted in case of difficulties that can be solved on location, or in case of incidents or accidents. Navya’s supervision monitors all Navya’s vehicles 24/7/365 and AM communicates daily with Navya supervision in connection with the operation of vehicles on other locations.

5.1.5 Status after 32 months in AVENUE

The first 16 months in the Copenhagen demonstration site have been spent on obtaining the permit to drive on the route in Nordhavn. At the same time, AM has tried to get the general approval process changed on a political level, since the current setup is not sustainable to AM.

To provide an overview of the project actions below is listed the highlights from the project timeline. In section 3.1 a more in-depth description of the approval process is provided.

Winter 2017

- CPH City & Port and AM held the initial meeting regarding providing autonomous mobility services to the citizens and visitors in Nordhavn.

Spring 2017

- First inspection of the Nordhavn route

Summer 2017

- On June 1st the law allowing pilot projects with automated vehicles in Denmark was passed
- The compilation of the report for the accessor begins, including obtaining a vehicle approval by the Danish Road Safety Agency. Since this is the first automated vehicle to be approved in Denmark there is not a special type certification for this. According to the law, the Navya bus is then compared to the vehicle type M2, a bus that can have more than 9 passengers including the driver - which means that the applicant has to apply for various dispensations such as not having side mirrors etc.

Winter 2017-2018

- COWI had dialogues with the Danish Road Directorate getting clarifications regarding the role as an assessor.

Summer 2018

- May 1st the AVENUE project begins with Nordhavn as the Copenhagen demonstration site.
- In August COWI and AM host a risk assessment workshop with representatives from CPH City & Port, the Danish Police, COWI and AM.
- In September the final report version 1 based on the vehicles driving SAE 4 is handed to the accessor COWI. The report covered 903 pages including 41 appendixes.

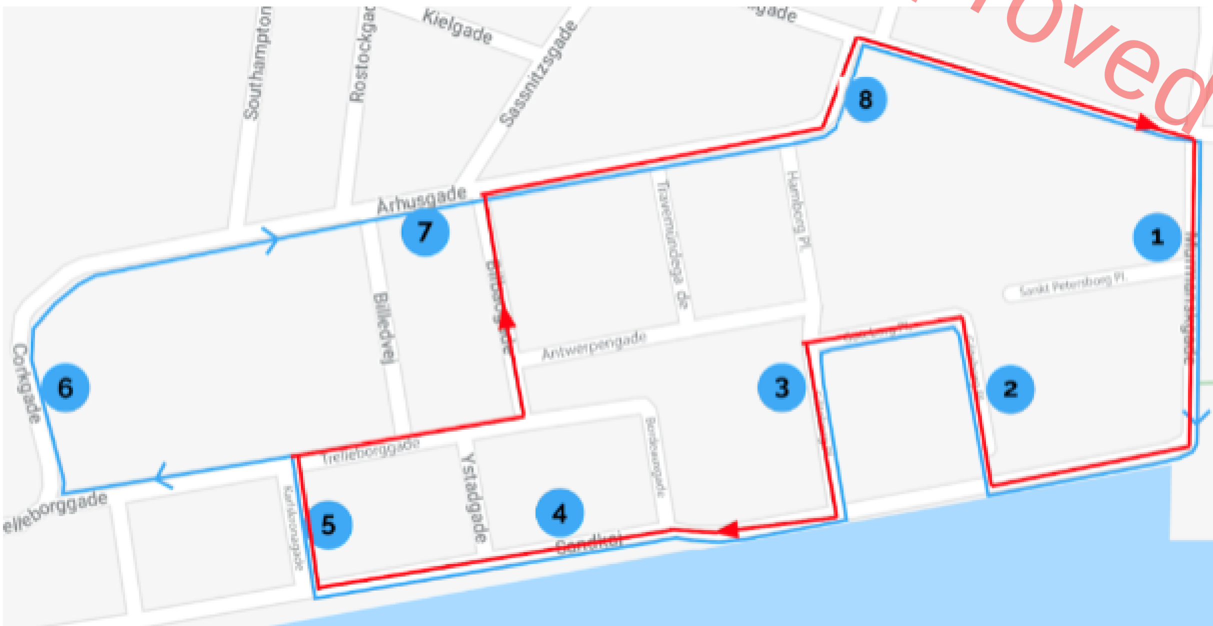
Winter 2018

- In October Navya stated that the vehicles are not able to drive SAE 4 but SAE 3. Due to a blind spot of 30 cm. This meant that AM had to provide revised material for the accessor:
    - Obtain a new vehicle approval by the Danish Road Safety Agency
    - Change the role of the safety operator in the vehicle having to be attentive to the road in the driving direction.

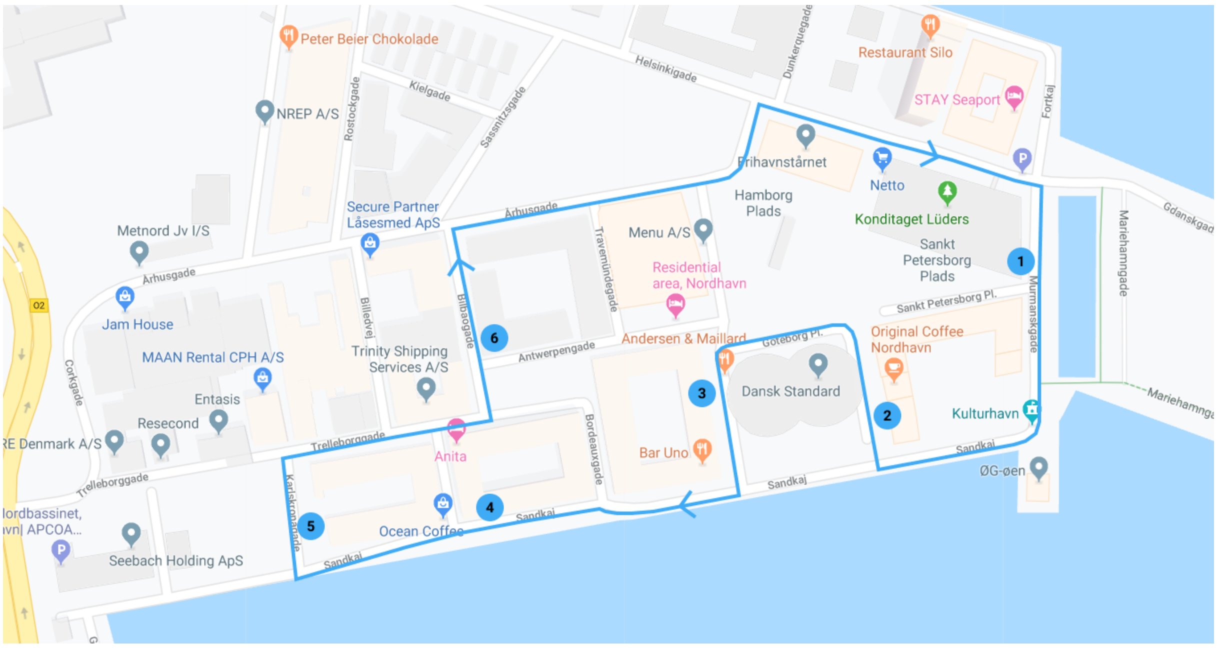
Spring 2019

- 3rd April AM receives the final report from the assessor COWI and thereby closes all 117 questions raised by them.
- 4th April AM hands in the first application for route 1 to the Danish Road Directorate. The application covered 96 pages.
- In May the Danish Road Directorate hosted a meeting with AM, to discuss their first feedback to the application including 11 action points.
- 27th May AM received a formal letter from the Danish Road Directorate, explaining that it will not be possible to perform the necessary political processing of the application. This is due to the announcement on 7th May that the government election will take place on 5th June. During an election period, the parliamentary committees will not hold their ordinary meetings and ministers will not take on new, major political initiatives or decisions in the same period. Originally the first route should follow the blue line on the map below, but due to the time it has

taken to get the route approved, new construction work in connection with the Metro station, demands that the route will be altered a bit from November 2019 (the red line on the map).



- In May it was therefore decided that it would be strategically wise to make an application ready for a revised route 1, so when the parliamentary committees are active again, both route 1 and the alternative route 2 can be approved simultaneously. It turned out though that it would be too complex to apply for 2 routes at the same time, and therefore the further application would only be for revised route 2 (blue line on below map). At the same time the traffic assessment for when the construction starts, recommended some changes in the bus stops, so the route now has 6 stops instead of 8.



Summer 2019

- The application for route 2 included that
    - The CPG City & Port, Copenhagen municipality and the homeowner association should approve the new route 2. This had some small difficulties, due to a playground placed next to the new route.
    - A road safety officer looked at the changes and analysed the impact.
    - The risk assessment was adjusted
    - The assessor assessed and approved the new material.
- In July the final report for route 2 was handed over to the assessor COWI.
- 22nd August AM received the final report from the assessor COWI.

Fall/winter 2019

- It is the aim that the final report regarding route 2 can be handed into the Danish Road Directorate in early September.
- Then the Danish Road Directorate will invite AM for a meeting to provide feedback and maybe some action points, they want AM to elaborate. The dialogue with the Danish Road Directorate will continue until they can make a final approval of the application.
- Based on the approved application the Taskforce will make a draft of the order and send it to be processed by the Transport Committee.
- The Authorities have up to 3 months to process the application including 3 weeks for a public hearing.
- It is expected that AM can start operation in Copenhagen late December 2019 or January 2020.

Spring 2020

- In March 2020 the approval from the Danish Road Directorate was granted
- AM started preparation of commissioning with NAVYA
- Due to travel restrictions from France to Denmark commissioning was postponed until Covid-19 restrictions allowed for NAVYA to come to Denmark

Summer 2020

- The Nordhavn route was mapped and commissioned in July 2020
- Site Acceptance Tests were conducted with COWI (assessor)
- AM launched the site for the public on August 3rd 2020

Fall/winter 2020

- AM conducted scheduled operation with 2 vehicles
- Operations was performed with limited passenger capacity due to Covid-19 restrictions
- AM investigated how to expand the route to meet AVENUE objectives
- AM concluded with partners that the route could not be expanded as a result of construction plans for the area
- AM initiated discussions with AVENUE to shut down the site

Spring 2021

- January preparation with CERHT of test of in-vehicle services with camera and sensor technologies.
- February setup of in-vehicle services in Nordhavn on P109 shuttle
- February test within-vehicle services in Nordhavn

- End of february: End of operation in Nordhavn AVENUE

Summer 2021

- Continuously testing CERTH in-vehicle services on test track in Copenhagen (no operation, just test)
- Approval of new AVENUE Amobility site in Slagelse Hospital site.
- Development and preparation of on-demand with Holo operational platform (supervision, remote control center etc.)

Fall 2021

- Start of new AVENUE site: Slagelse Hospital site (on-demand site with stops)

5.1.6 Operational data summary from Nordhavn

While operating the shuttles, Amobility has been using data from the vehicles and an operational app (developed by Amobility) to improve daily operation and track performance. Data from the vehicles has been received via Navyas API and then categorised and visualised in Amobility Data Analytics tool (Operational dashboards).

5.1.6.1 Data types

The types of data that Amoblity has been collecting are described in the following two chapters; Navya API and Amobility Safety Operator app.

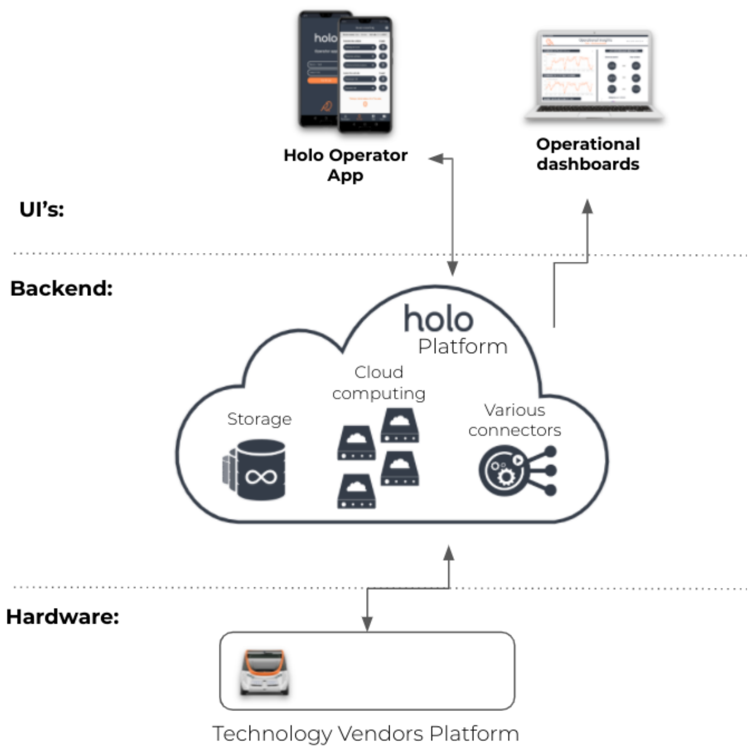
5.1.6.1.1 Navya API

Navya API data sources can be divided into 2 main categories, for simplification, Navya states and Navya events.

Navya states (Telemetry data) contains data indicating vehicle status. This data is received every second as long as the vehicle is turned on. For example this could be: Location, battery percentage, manual/auto mode, door close/open etc.

Navya events (Events) contains data describing events issued by the vehicle at the moment of event occurrence. This could be: Estop button pressed, Arrived at destination, Hard braking occurred, Vehicle is out of path etc.

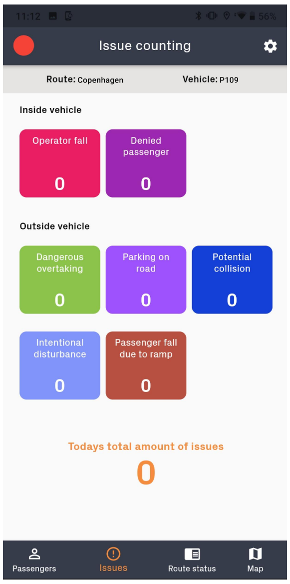
As seen on the figure, data from vehicles are received and stored in the Holo Platform. From here data analytics tools (ex Operational dashboards) are fetching the data.



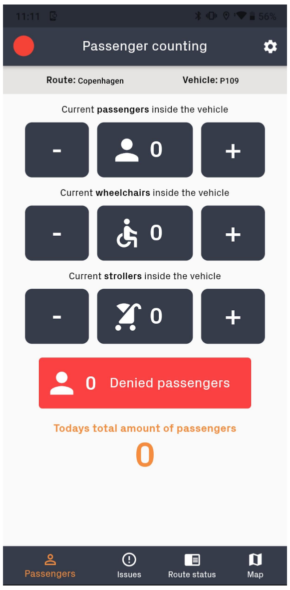
5.1.6.1.2 Amobility safety operator app

The safety operator app functions as a support to the data from Navya by gathering several types of data that are not included in the API. As an operator there are multiple things that you wish to monitor and analyse (both technically and based on client needs). Together the Navya API and the Safety Operator app provide the big holistic picture of the daily operation.

The safety operator app is designed to gather two types of data, Issues and passenger counting.



Issues are related to either outside the vehicle (caused by external factor fx. 'Parked car near trajectory') or inside the vehicle (happen in the vehicle ex 'Denied passenger'). Our operators manually register all issues. The application saves timestamp (time taken from phone device and when registering issue), vehicle id (which indicates what vehicle is in use), and location data (geo coordinates also taken from phone devices) together with the issue description chosen by the operator. The safety operator registers issues like Operator fall, denied passengers, dangerous overtaking, parking on road etc. like seen in the picture for issue counting.



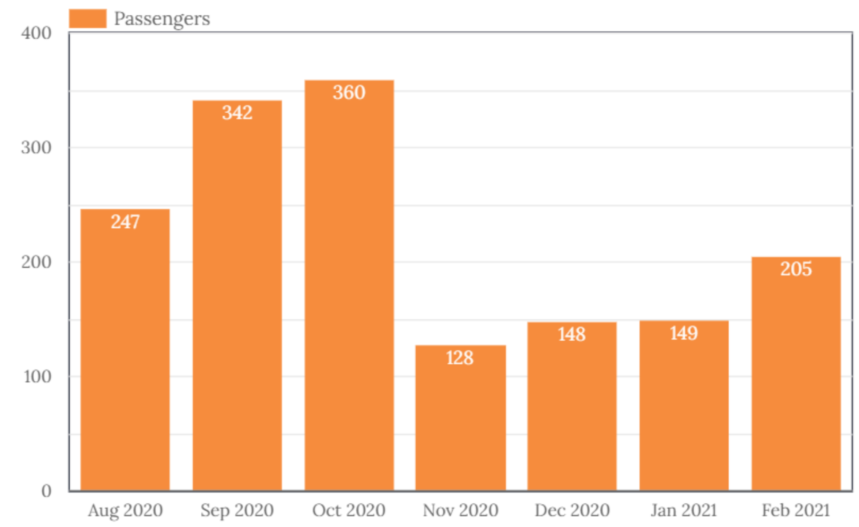
Passenger counting is used for manual counting of passengers during operation. The passengers are logged when entering and leaving the vehicle as a plus going in or minus going out. Besides counting the passengers going in and out, denied passengers are also counted as a result of the COVID-19 crisis. The Safety Operator counts regular passengers, passengers with disabilities and strollers, as an attempt to always assess the capacity of the shuttle.

5.1.6.2 Nordhavn data summary

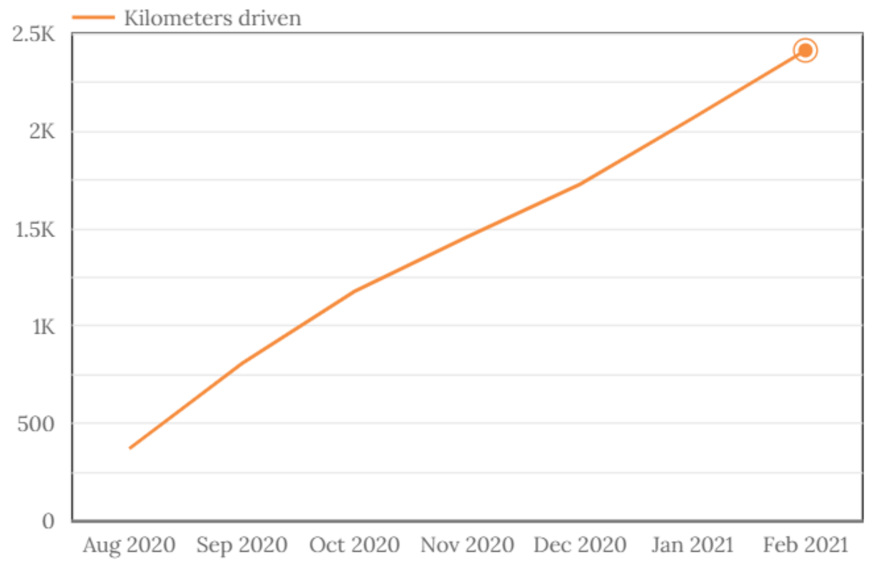
Vehicles on site: P109 and P111

Passengers we counted every day of operation. In total we have transported 1579 passengers. It is seen that most passengers were transported at the beginning of the pilot, possibly due to route location close by harbour popular in summer time. Another possible explanation could be that locals got used to shuttle and as attraction and as time went by a sense of novelty disappeared.

Passenger count per each month of operation



A total of 2.417 kilometers has been driven in Nordhavn. The count can be seen increasing in an almost linear progress since August 2020.



Graph adding up kilometers driven

Driving speed of the Navya vehicles was on average between 7-7.92 km/h. The data used is when the vehicles are in movement.

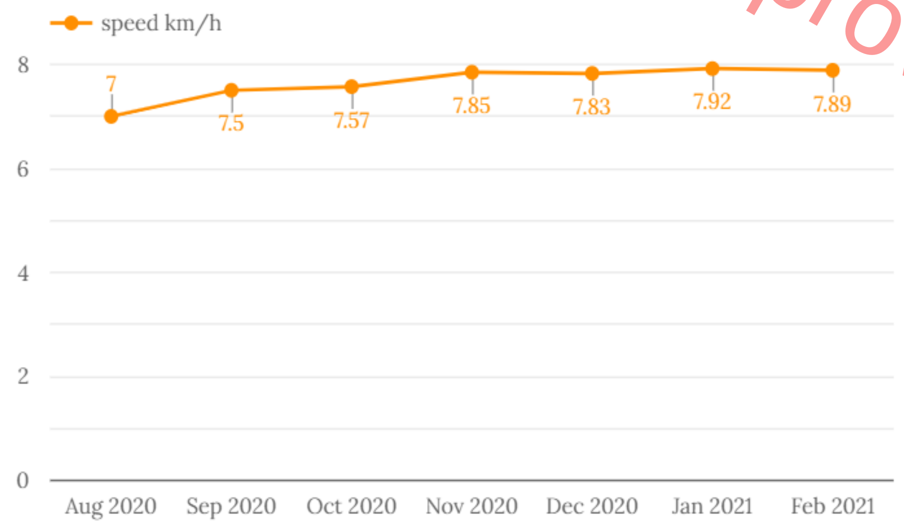


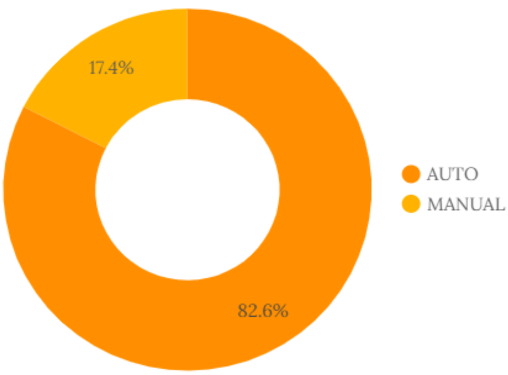
Chart shows average driving speed for each month

In terms of operational time in total, there has been driven almost 992 hours during the pilot.

Score count showing exact operation time (HH:MM:SS)

In regards to the navigation mode, 82.6% of overall driving on the route was driven in Autonomous mode. The rest of 17.4% driven in Manual mode was mostly due to an increased amount of illegally parked cars on the route and due to roadworks. Driving to and from the garage is filtered out.

Pie chart showing distance ratio between Manual and Auto driving



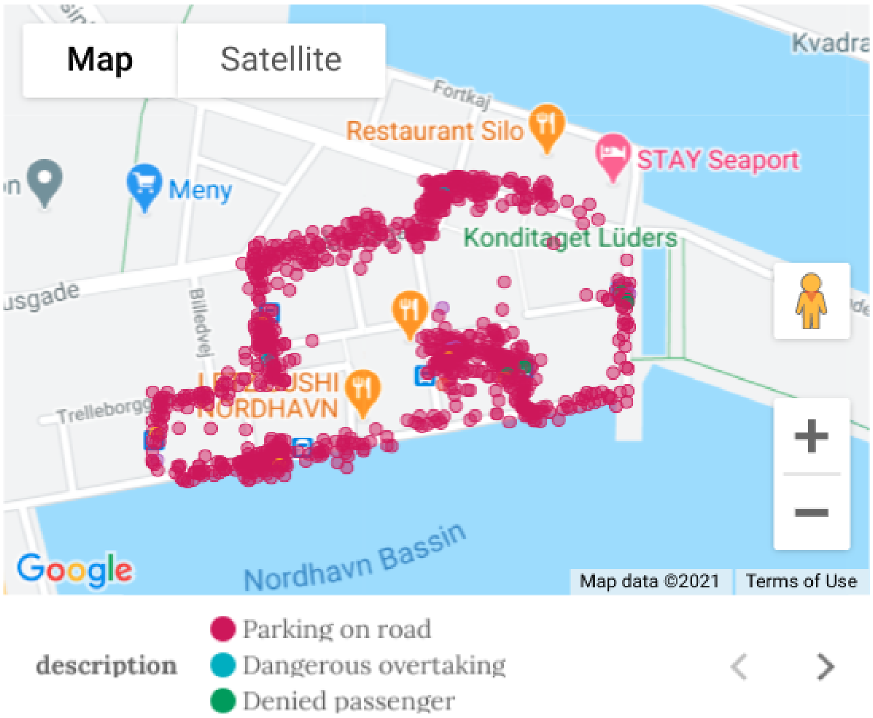
Through the safety operator app. The issue that has been registered much more that the others, are parked cars on road, which disturbs autonomous driving. In total this has been registered 1321 times, distributed around the route through the whole time period.

description	issue occurance
Parking on road	98.4%
Denied passenger	0.45%
Potential collision	0.45%
Intentional disturbance	0.38%
Dangerous overtaking	0.13%
Passenger fall due to ramp	0.13%
Operator fall	0.06%

1 - 7 / 7

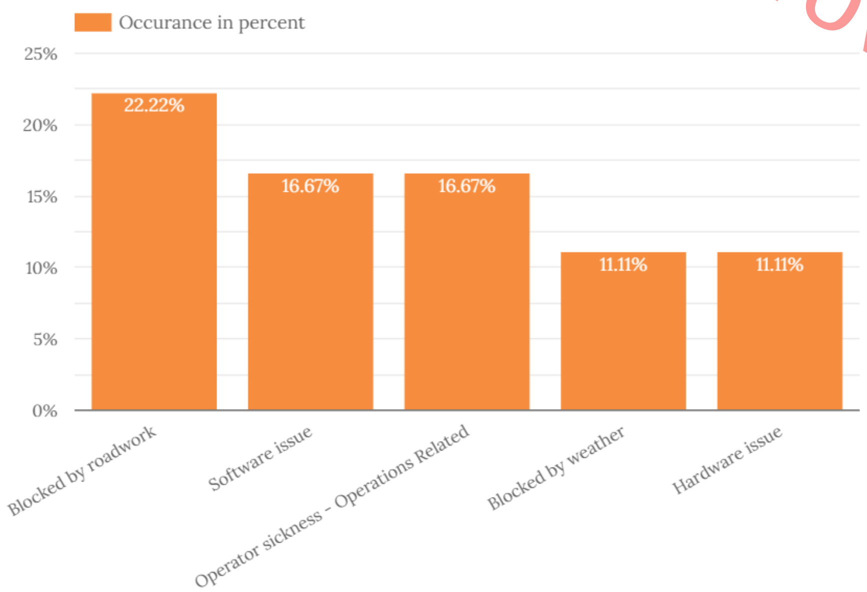
Issues recorded by OP app

Location on the route where 'parking on road' has been reported (Red = 'Parking on road')



Heat map

The following shows the percentile distribution of the 5 most common reasons for downtime / cancelled operation.



Percentile distribution of top 5 reasons for downtime

5.1.7 The process of shutting down Nordhavn in AVENUE

Unfortunately the route in Nordhavn had to be shut down, and AM has investigated several scenarios to still meet the learning objectives for the AVENUE project. In the following the process and reasoning for shutting down the Nordhavn site will be further elaborated.

5.1.7.1 Complications in Nordhavn

In the fall of 2020 AM started to investigate the potentials for expanding the Nordhavn site. AM investigated several routes which could be added to the already active route in Nordhavn. The selection and evaluation was focused on last-mile transportation from the 2 metro stations and to both residential areas of Nordhavn and various business areas.

In November 2020 all the potential new routes were discarded by *By & Havn*, as construction plans for the area would interfere with the Automated minibuses. The area of Nordhavn is undergoing heavy construction and due to delays in the construction work, several roads are unavailable to use for the remaining period of the AVENUE project.

5.1.7.2 AVENUE scenarios

The above challenges in Nordhavn caused AM to seek alternatives for Autonomous Operation in the Copenhagen area. AM has evaluated several scenarios for how to still meet the objectives of the AVENUE project, these different scenarios will be elaborated in detail in the following section.

5.1.7.2.1 Continue in Nordhavn

AM discussed and assessed if the circle route in Nordhavn could continue to operate. With no expansion to the metro station(s), the number of passengers and last-mile value would remain at a minimum. Moreover, the door-to-door on demand service would not create the crucial value, as only 1-2 shuttles could interact on the route, and the fixed route would most likely not be desirable for passengers.

Based on the above evaluations, AM decided *not* to continue the route in Nordhavn. Because of these very limited learnings to be achieved, AM concluded that the current circular operational route was too far from the learning objectives and continuation could not be justified.

5.1.7.2.2 Find new Norwegian project

After reaching the conclusion to shut down the Nordhavn site, AM initiated investigations to find alternatives routes to operate within the AVENUE project.

As the norweigan approval process for autonomous vehicles has proven more flexible and reliable, AM discussed and investigated possibilities for completing the remaining operational months in AVENUE at a site in Norway. This was done simultaneously as the investigation of potential new sites in Denmark, cf. next section; Find new Danish project.

Firstly, AM investigated the possibility to find new routes with an existing customer, the PTA of Oslo, Ruter. However, Ruter and AM had already completed several pilots with NAVYA vehicles. Due to a focus towards new vehicle vendors this possibility was thereby excluded. This decision led AM to discard Norway as a potential place for operating the remaining months of the AVENUE project. The conclusion was based on 1) lack of organisational resources to initiate and pursue new project partners outside of Oslo and 2) establishment of new partnerships and agreements was evaluated to be too time-consuming at such a late stage of the AVENUE project.

AM has continued as an Operator to Ruter and are currently focused on operating new vehicle types from Toyota, equipped with autonomous system setup from Sensible4.

5.1.7.2.3 Find new Danish project

Simultaneously with investigating new sites in Norway, AM conducted several meetings with potential partners for new sites in Denmark. Both discussions with Bispebjerg hospital (Copenhagen) and the municipality of Dragør (near Copenhagen) was immediately very positive towards the project and the potential learnings to be achieved by delivering last-mile on-demand services to citizens. However, both potential sites needed more time, to 1) get political approval to conduct such a project and 2) decide on the actual roads and use-cases for testing.

Ultimately, AM concluded that there would not be enough time to await the decision processes at Bispebjerg Hospital and Dragør Municipality, as the approval process in Denmark easily could take up to a year to get new sites approved. Consequently, AM would not be able to deliver sufficient operational learnings to the AVENUE project, due to a very limited time to operate.

With the aim of achieving a faster decision process with a potential new partner, AM discussed the potential for operating at Copenhagen Airport. AM and relevant stakeholders from CPH Airport conducted a site visit and route inspection. Copenhagen Airport had determined a need for transporting passengers on-demand to and from the main entrance to designated parking areas. However, this route would require operation in a 50 km/h zone with difficult intersections. AM and CPH Airport, quickly determined that adding a low speed vehicle, such as the NAVYA Arma, would not be a good fit, to accommodate the transportation needs for the airport, and thereby the site was discarded as a potential site.

5.1.7.2.4 Use AVENUE shuttles on existing Amobility site

In order to minimize the risk of delaying operations substantially, caused by long approval processes, AM investigated to use an existing site in Denmark for the remaining months of operations in AVENUE.

AM was granted approval to start operations at Slagelse Hospital (Denmark) in March 2020. However, the project had been paused due to Covid-19. In the 4th quarter of 2020 AM and Movia (PTA) decided to restart the project in August 2021. AM and Movia discussed the possibility of integrating AVENUE as part of the Slagelse Hospital site and agreed to proceed with this possibility.

Even though this alternative only can support operations with 2 NAVYA vehicles, AM has identified several crucial learnings in relation to on-demand and integration with PTA for ordering.

5.1.7.2.5 Stop as an operator in AVENUE (continue as research partner)

If none of the above alternatives was possible, AM would have had to stop as an operator in the AVENUE project.

5.1.8 Learnings about the approval process in Denmark

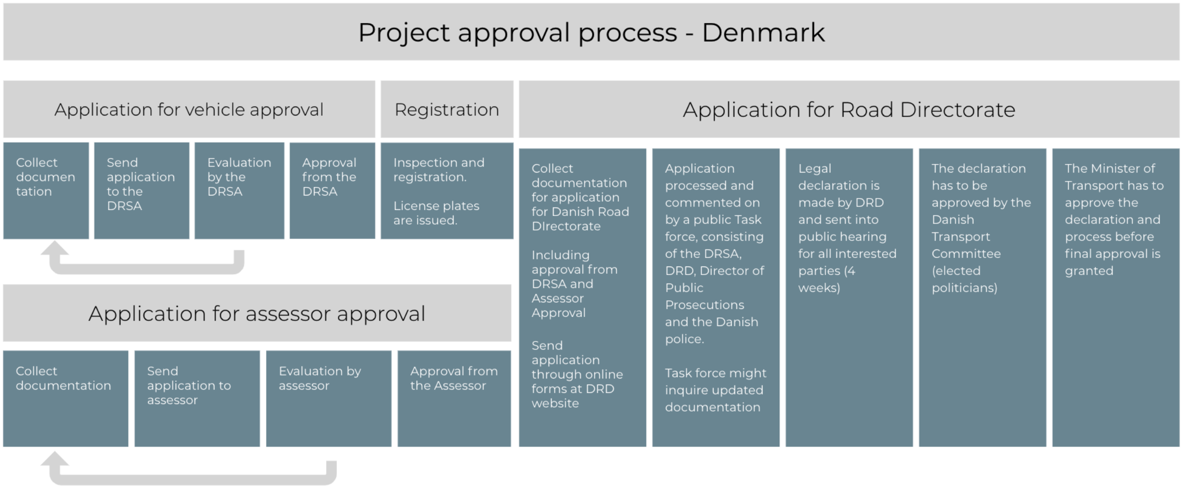
Having applied for autonomous operations in Denmark, now three times, and gotten the approval to operate. Amobility has gathered many learnings regarding the implementations of self driving vehicles in public transport. The following sections will outline the most important learnings from the deployment of Automated minibuses. Based on these learnings, the main recommendations are presented to improve the system and basis for implementation of self driving vehicles.

5.1.8.1 System complications (many approvers)

AM has been operating Automated minibuses in Norway, Sweden, Finland and Estonia. Here AM has been working directly together with the Authorities on the same risk work that is done by assessors in Denmark, resulting in a much more smooth application process. In these countries, the full application process has lasted 2-6 months.

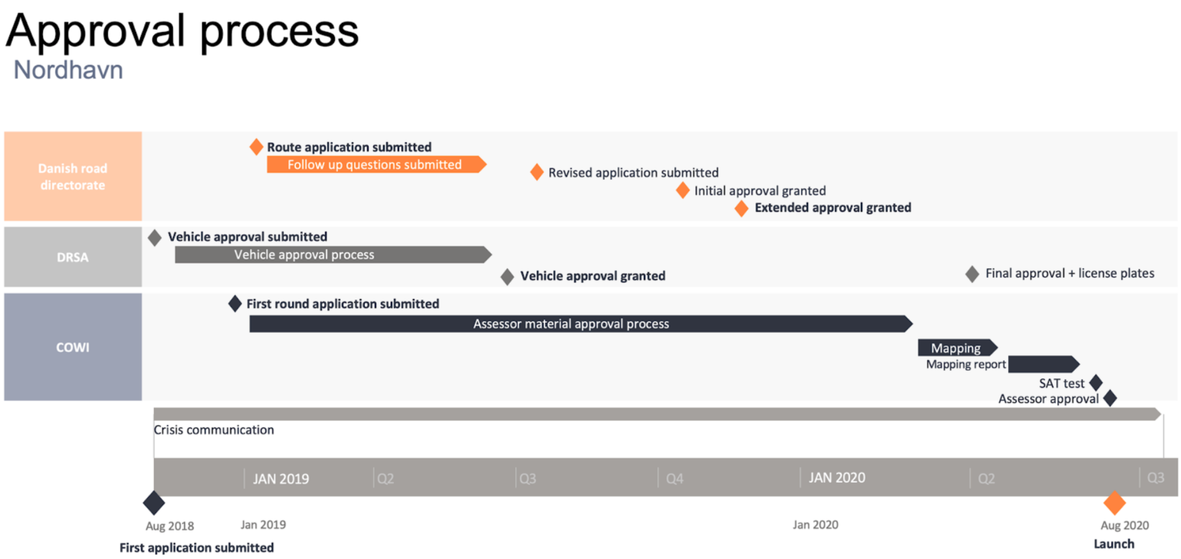
In Sweden, the vehicle approval and risk assessment are done by the Road Directorate, which replaces the assessment done by the assessor in Denmark. In Norway it is done the same way, the Road Directorate approves the vehicle and does the risk assessment.

The challenge in Denmark is not only the amount of time used with the assessors on each project but also the cost to cover this work. It makes it difficult to make a sustainable business model for pilot projects. Moreover, the danish process for approval has several layers of approval, specifically 3 different approvals are needed in order to even apply for a permit from the Danish Road Directorate. Not only does this prolong the process for obtaining approvals, but it also makes the system rigid towards any changes. In Denmark, an approval for an autonomous project is written as an executive order, signed by the Ministry of Transport. This makes the process highly political and with high risk of delays.



5.1.8.2 Time and resource consuming

For the Nordhavn project AM used 24 months for the approval of the project. The specific timeline is shown below.



The timeline would have been even longer if it wasn't for all the work done on the first self-driving project in Denmark that AM got approved in early 2020. Our first pilot gave us a better understanding of the application process. At the same, the vehicles we were using in both pilots were the same type of vehicle, and therefore we had all the documentation needed for the vehicle approval. Without these past experiences getting approval to operate an autonomous project in Denmark would take even longer.

Making changes to the pilot in Nordhavn was also very difficult and time-consuming. In Denmark, all changes in a project with autonomous vehicles must go through and be approved by the appointed accessor before put in use. This slows down the progress in a project and is costly depending on the size of the change. Bigger changes like making alterations to the route or driving schedule must the Danish road directorate as well. This means another approval process, and since autonomous vehicles projects by a specific task force that doesn't meet up every day it can take months to get approval of the changes. Changing our schedule to include operation on weekends took us two months it needed to be approved by both the accessor and the Danish road directorate

In Denmark, the applicant will hold the full cost of the approval process related to an autonomous vehicle project. The Nordhavn project holds high expenses to the accessor, vehicles, operators, consultants, and project management. This combined with all those expenses being needed over a two-year period makes it very costly. And the uncertainties in the timeline of the project make it even harder to get a clear view of the costs.

5.1.8.3 Consequence of the approval process not changing

The consequence of the approval process in Denmark is that we couldn't continue the operation in the Nordhavn project, due to changes that we needed approval for. Further consequences are that only one pilot project in Denmark is currently in operation (Aalborg East). And only two pilot projects are set to go live in the coming year (Slagelse Pilot and Linc Pilot). Furthermore, none other pilots are set to start up in the coming years in Denmark (the SHOW Pilot status is unknown). The resources needed for a self-driving pilot are enormous both in time and cost, changes are very hard and timelines are not foreseeable. All of this makes it almost impossible to make a profitable business case and impossible for most companies or institutions to even apply for a pilot with autonomous vehicles in Denmark.

5.1.8.4 Effect of approval process on Amoblitys objectives in AVENUE

The approval process has delayed and complicated many of the initiatives that were planned for the Nordhavn site and eventually the site had to be closed down due to complications with the area (construction and no flexibility in new approvals). The approval process has indirectly had a huge impact on the success rate of the objectives of AVENUE for Amobility as an operator. The objectives are roughly listed below with a short status on each, with focus on the impact of the legal framework in Denmark.

Objectives	Status
Public transport (other road users)	The Nordhavn site was fully implemented in public transport and drove in a 30 km/h area with all kinds of road users (bikes, trucks, cars, taxies, pedestrians, e-scooters etc.)
Move actual travellers	Being deployed in a residential area the shuttle services moved

	the residents around the area in a loop of fixed stops.
On-demand testing and development	Due to the construction work and delays in the area the route could not be expanded, hence including enough road to test on-demand driving between virtual stops was not possible. Moreover, the legal framework requires a new full assessment and approval for new roads (streets) in the area. With the previous experience of the timeframe (12-14 months) for a new approval, expanding/moving the route away from the construction areas was not possible within the timeframe of the AVENUE project.
Integration with public transport	The plan was originally in the 3rd phase of the Nordhavn deployment to increase the driving area to include the two public metro stations in the area. But again given the legal framework and the timeframe of a new approval, the expansion and relocation of the route was not possible within the project time frame.
Mission integration and adaptation (with PTA and Navya)	As the route was not connected or offered via any public PTA the integration was not possible. The route was integrated with Google Maps allowing people using Google Maps to be redirected to the shuttle when planning a trip in the Area.
Dynamic routing (find the smartest way)	As the routing network in Nordhavn could not be extended the dynamic routing was not tested or implemented. Amobility has performed some testing on the test track regarding the mission control and distribution setup between the Navya vehicle and Amobility as an operator.
Mobility cloud early stage development (SUP portal, data dashboards, operator app, end user app, follow portal, backend API integrations etc.)	One of Amobility's goals of the AVENUE project is to develop the mobility cloud allowing people to seamlessly move from A to B in a geo fenced area (a complete mapped area). The development of the critical components to be able to do this in the future has started and Amobility have developed some of the features necessary to meet the goal. But with the technological barriers and the legal barriers (long approval processes and a very conservative documentation setup) the mobility cloud still needs a lot of work. The experiences from operating in Nordhavn and Oslo have given Amobility knowledge to continue the necessary development.
Drive without an operator in the shuttle (SAE 4)	The Navya vehicles are currently classified as SAE level 3 vehicles. It will not be possible to drive without an operator in the shuttle before the market can deliver an SAE level 4 vehicle, with sufficient documentation. In Danish applications and approvals Amobility expects requirements for documentation to significantly increase in applications for fully driverless operation
Reach higher speeds	The Area in Nordhavn is limited to 30 km/h. The shuttles are currently able to drive a max speed of 18 km/h and have an average driving speed of about 7-8 km/h. If the vehicle vendor (Navya) could provide detailed and accurate documentation for

	how the vehicle is able to drive faster, with improved braking systems and sensor system. Amobility would be able to apply for higher speeds and feels comfortable that it would be approved within the current approval framework. The right documentation is necessary to apply for increased speed to for example 30 km/h.
Automated wheelchair ramp (+ manual wheelchair seat belts)	This has been approved and tested in Nordhavn.

5.1.8.5 Recommendations to the authorities

Amobility would suggest a more flexible and scalable system for approving pilots with autonomous vehicles.

This could be done by adopting the following recommendation for approving projects:

1. When testing/driving in SAE level 3 or lower only approval from the DRSA, local police, and road owners should be necessary. A simple framework for expectations to applicants should be provided, so that requirements for documentation are absolutely clear. Amobility would suggest that a risk analysis should be carried out to ensure the level of risk is kept at the same level as a regular vehicle.

2. In projects with SAE level 4-5 operation, Amobility recommends to have either 1) an approval from the appointed assessor, DRSA, police, and road owner(s) or 2) an approval by the Danish Road Directorate (taskforce), DRSA, police and road owner(s).

   If option 1 is used, Amobility strongly recommends that a clear framework is provided to the assessors, to ensure transparency for applicants. In the current framework, there is no limit to the amount and type of documentation the assessor can request. This makes it hard for the assessor and the applicant to navigate within the framework. Better outlining of the framework would serve both assessor and applicant.

Ultimately Amobility will recommend removing the political approval process entirely. For each project to have their own executive order is completely diminishing the flexibility and innovation for existing and future pilot projects. Firstly, because the process is highly reliant on the political system and Amobility has previously experienced a 6 months delay caused by danish elections, this is extremely damaging to private companies. Secondly, changes to executive orders are time-consuming and frequent changes to projects must be expected in these fast-moving and ever-changing environments.

Continuing this highly rigid and time-consuming approval process will force companies to seek and pursue innovation outside of Denmark in more agile environments, such as Amobility has experienced in both Norway and Sweden.

5.2 Ormøya, Oslo, Norway

Due to the delays in launching the Danish demonstration site, it is foreseen that it will take some time before all 4 busses will be in operation. Therefore in May 2019 AM agreed with the consortium to include our subsidiary in Norway as a third party, so that two of AMs AVENUE buses can be deployed on a route there. This way AVENUE would still gain useful insights into the operation while awaiting the launch of the Copenhagen site.

AM is collaborating with Oslo Municipality, the Norwegian Public Roads Administration and Ruter[1] about a three-year self-driving trial project. The project is an important milestone in the process of getting self-driving buses to the Oslo area. Oslo and Akershus wish to have 0% emissions across their public transportation and this project will test if self-driving buses can support these ambitions for a sustainable public transport system. The end goal is for autonomous buses to be part of Ruter's regular offer in a few years.

Originally the plan was to include the two busses on the route Akershusstranda in central Oslo for 5 months beginning in June 2019. This would be a route with 4 busses running and the service fully integrated with existing public transport in Oslo city. However, due to heavy construction this route had to be cancelled. It was therefore decided to integrate AMs AVENUE buses on the second route 'Ormøya' just outside Oslo center. Ormøya is an Island south of Oslo city connected by a bridge to the mainland and a bridge to a second island called Malmøya.

The main purpose of the project was to investigate what self-driving vehicles can mean for everyday logistics in a neighborhood. By increasing the frequency of public transport by means of small self-driving vehicles the goal was to reduce the need for private cars in the area.

One road leads in and out of the two islands that have a total of around 500 households. The local residents have a 12 meter bus service which departs around once an hour most of the day. On the mainland just off the inland is one of the major through fairs going into Oslo from the south, Mosseveien/E18. This main road has frequent express busses going in and out of Oslo. The autonomous bus service provided a high frequency last mile solution for the residents of Ormøya and Malmøya which connected them to the express service on Mosseveien/E18.

5.2.1 The route

The route is 1,6 km one way (3,2 km round trip) and has 6 bus stops. It runs from Nedre Bekkelaget bus stop which is located near Mosseveien/E18 where users can access high frequency express busses to and from Oslo. Also near this end point is the local area public school which kids from Malmøya and Ormøya attend.

The other endpoint, Malmøya bus stop, is right on the landing on the island of Malmøya where there is a turning place for the vehicles. This bus stop is also located close to a marina, where lots of Oslo residents keep their recreational boats. The four other bus stops are evenly distributed along the two end points.

[1] The public transport authority for Oslo and Akershus counties

The bus stop Mailand is also located close to a public beach/swimming area and a Marina which attracts lots of visitors in the summer. The route can be seen below with the stops marked.

The speed limit on the entire route is 30 kph and it contains several speed bumps which generally keeps the speed in the area low. The condition and build of the road varies quite a bit along the route. Several places are very narrow, only barely wide enough for two vehicles to pass each other and several stretches have poor asphalt quality. There is also a lot of vegetation close to the route.

In order to be able to offer the inhabitants a valuable self-driving travel service, we must ensure high operational stability along the stretch. This has been challenging due to several elements and we have therefore made ongoing adjustments in the offer to explore what it takes to ensure stable and reliable operation. Operational stability will be a success factor in initiating new, more complex self-driving bus lines in the years to come.

5.2.2 Infrastructure

The route required two major infrastructure adjustments to be operational, a purpose built garage and reflector panels along the road for better LIDAR localization.

5.2.2.1 Garage

It proved impossible to find a suitable garage facility on or near the route and the area is a residential area with strict zoning and regulations on what can be built or temporarily placed in the area. Consequently the project had to construct a garage that would meet strict requirements for sustainability, safety and aesthetics as well as for the operational requirements of Holo.

The solution became a design for temporary wood structure with polycarbonate cladding that could be disassembled and moved if necessary. It was quite an expensive solution, but necessary for operating in an area with no existing facilities and with shuttles that cannot move mannually through regular traffic to find a suitable palace further away. See pictures of the garage below:

5.2.2.2 Reflector panels

The route contains two bridges, Ormsundbroen and Malmsundbroen. Both contained stretches where there were very few lidar reflecting objects and thus Navya required that Lidar reflecting panels be put up in their site assessment.

However both bridges are protected buildings under Norwegian law and any infrastructure added had to be made to fit their aesthetic. Therefore the project used sails made using 19th century techniques and hemp road as reflector panels. The sails were also printed with old motifs from the island. The sails were tied to railings on the bridges and in total 52 sails were put up to fulfill Navyas requirements. The sails looked as in the picture below.

5.2.3 Bus stops

- **Nedre Bekkelaget**
  Was created as a new bus stop in a parking lot near the Mosseveien/E18. existing busstops could not be used because they are placed on the main road which has a 60 kph speed limit. In addition the shuttle needed a place to turn around and this solution worked nicely for that.

- **Ormsundbakken**
  Is an existing bus stop used by Ruters line 85. It is placed right next to Nedre Bekkelaget Primary school and because of the large numbers of children moving around in the area it has been constructed as a bottle neck so that no other cars can pass while the bus is stopped here.

- **Mailand**
  Is an existing bus stop used by Ruters line 85 and includes a raised sidewalk for easy passenger access. It is laced right next to the public beach and Holos garage facility. Used as the spot where the shuttles entered and exited autonomous operation

- **Kirkebakken**
  Is an existing bus stop used by Ruters line 85. It has no curb but lots of room for the shuttle to pull to the side and for passengers to enter and exit the shuttle without interfering with traffic.

- **Malmøysundet**
  Is an existing bus stop used by Ruters line 85. It is placed at a narrow part of the road has no curb and very little room for passengers to enter and exit the shuttle. As a result the shuttle would stop traffic while stopped here in both directions.

- **Malmøya**
  Is an existing bus stop used by Ruters line 85, it includes a raised sidewalk for easy passenger access. It has a small roundabout which enabled the shuttle to turn around

5.2.4 Operational hours

Weekdays: 6.30 to 20.30
With departures every 10 minutes during rush hour in the morning and afternoon and every 20 minutes in off peak hours

Weekends: 10.00 - 17.00
With departures every 20 minutes

5.2.5 Learnings from Ormøya (AVENUE shuttles)

5.2.5.1 Public transport in Oslo

The Service at Ormøya functioned as an integrated part of Ruters public transport offerings in the general Oslo area. This meant that the bus required a standard ticket which gives access to the entire network and that the service was included in Ruters overall route planning tools for users. Neither Holo nor Ruter performed checks of valid tickets.

By all indications users did not complain about the ticket requirement, but viewed it as natural for a service in Ruters network.

5.2.5.2 User experience

During the final quarter of operations, Ruter conducted a user survey around the shuttle. The survey was conducted by interviewing people walking or moving around the general area of Ormøya. In total Ruter collected 107 interviews each lasting 5-8 minutes during the weeks 38,39,41 and 42 in 2020. The main purpose of the survey was to evaluate what users and local residents think of the selfdriving bus service

In general respondents were positive towards the tests and felt that it was safe. However the survey also showed clearly that the service was not providing a valuable mobility solution. 82% of passengers took the bus merely out of curiosity while only 12% used the service for their daily commute. And when local residents at Ormøya and Malmøya were asked why they didn't use the autonomous bus for their daily mobility needs, two of the top answers were the low speed and that the bus did not go where they needed to go. Furthermore low reliability was also noted as a reason why the service was not used for their daily mobility needs.

5.2.5.3 Vegetation and snow

The narrow road on Ormøya makes this site especially challenging when it comes to vegetation. There is little to no margin on growth of vegetation. Both vegetation on the sidewalk and overhanging bushes and branches are stretching into the safety zones interfering with smooth operation.

Another issue at Ormøya are the high and low overhanging branches interfering with the GNSS signal. The contact from the vehicle to our base station at Nedrebekkelaget. When the GNSS signal is low or even completely out the vehicle relies on Lidars for obstacle detection and localization.

In the picture below the overhanging branches are within the safety zone, these are then detected by the vehicle causing it to brake or slow down.

The rapid growth of vegetation in the summer months has led to constant interference with operations. In periods operations have been halted until the vegetation has been properly cut. In the summer months, april to september, we have seen the need to cut vegetation up to every second week.

Vegetation related issues have heavily impacted the stability of the operation on this route. Comparing this site to other routes with less vegetation, clearly shows a negative impact on performance of the vehicles. And furthermore sudden brakes caused by vegetation is a major safety concern as well. The sudden braking can cause cyclists, pedestrians and following cars to potentially collide with the vehicle when it makes unexpected and seemingly irrational decisions like braking hard for a small branch near the trajectory.

In the winter months snow and ice proved a similarly big challenge. The ODD for the Navya Arma vehicles states that they cannot operate when snow is falling or when the route is covered in snow. Falling snow proved quickly to be unsuitable for operation. with snow in the air the vehicles makes continuous false obstacle detections and every snowfall resulted in a halt of operations.

2020 did not see very much snow at the Ormøya site and only on a couple of occasions did snow on the ground cancel operations and mainly because snow clearing was not done well enough to clear the vehicles trajectory as highlighted in the image below.

5.2.5.4 Major safety issues

Already in the risk analysis of the route before operation commenced, the major safety concerns were identified as other road users behaving dangerously around the shuttle due to low speed, slow reaction to clear road or similar. Also passengers and operators getting hurt inside the shuttle due to sudden and hard braking were highlighted along with intentional disturbances. These safety concerns proved to have been correctly assessed from the beginning and they were the major safety concerns throughout the operation.

Through the Holo operator app Holo was able to collect data on these most potentially dangerous situations that occurred on the route. The four most important categories that data was collected on are dangerous overtakings of the vehicle, intentional disturbance, operator fall and passenger falls.

These categories were defined in the following way:

Passenger fall
If a passenger falls inside the vehicle due to hard braking, risky overtaking or similar driving behavior.

Operator fall
If the operator falls inside the vehicle due to hard braking or similar driving behavior.

Dangerous overtaking / Potential collision
Dangerous or hazardous events directly caused by our vehicle or indirectly by the presence of our operation.

Example: A car overtakes our vehicle in a dangerous and/or illegal manor (e.g. overtaking by using the sidewalk, passing on a zebra crossing, risk of hitting a cyclist coming in the opposite direction).

Intentional disturbances
If another road user intentionally attempts to test the behavior of our vehicle or intentionally disturb our service.

Example: A bicycle overtakes our vehicle and drives immediately in front only to provoke hard braking - in this case, the operator must be confident that this is done intentionally.

Issue count from January 1st 2020 through December 20th 2020			
Passenger fall	Operator fall	Dangerous overtaking / Potential collision	Intentional disturbances
9	59	189	34

No serious injuries were recorded as a result of these safety concerns, but on two occasions dangerous overtakings of the vehicle caused minor collisions and on several occasions operators were bruised by falls inside the shuttle. Therefore two major safety concerns that remain with an operation like the one on Ormøya is:

1. The operators of Navya Arma vehicles do not have ideal working conditions. Sudden and hard braking has resulted in several mild injuries because of the lack of proper seating and suitable working positions.
2. The low speed of the shuttle does cause other road users to act irresponsibly and attempt overtakings in areas that are not suited for overtaking like areas with bad overview or near pedestrians crosswalks

5.2.6 Operational data summary from Ormøya

While operating the shuttles, Amobility has been using data from the vehicles and an operational app (developed by Amobility) to improve daily operation and track performance. Data from the vehicles has been received via Navyas API and then categorised and visualised in Amobility Data Analytics tool (Operational dashboards).

5.2.6.1 Data types

Described in section 5.1.6.1

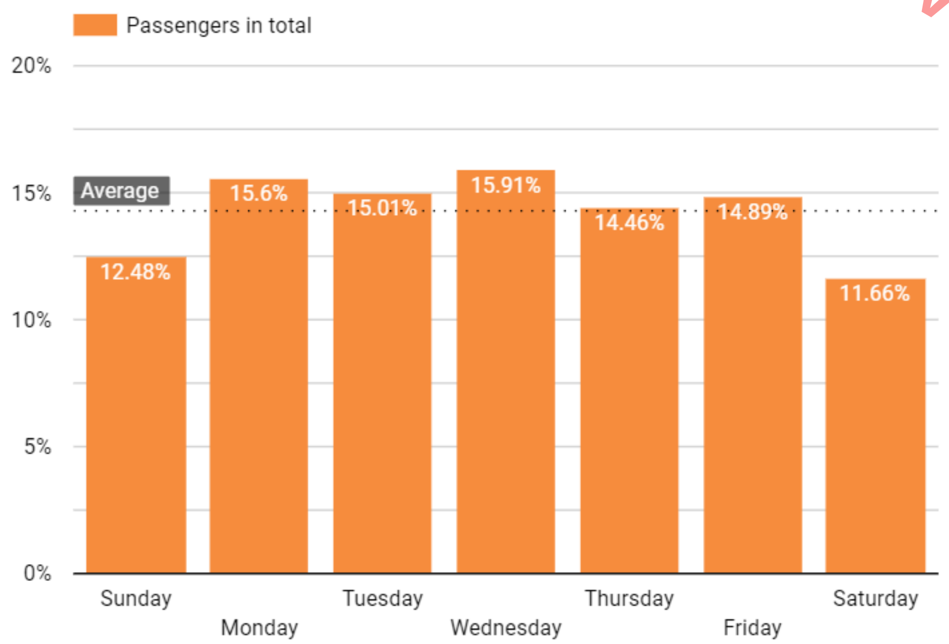
5.2.6.2 Ormøya data summary

Vehicles on site: P85 and P112

In total on the Ormøya route we have transported close to 6500 passengers.

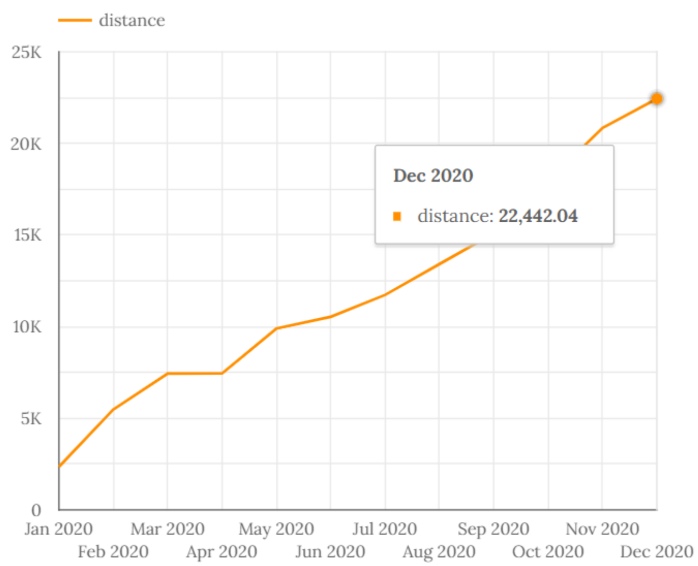
Score count of passengers

Passengers were using our buses for transport on every day of the week. The following shows a a higher number of passengers during the weekday than weekend.



Column chart showing percentage of total passengers per each day of the week

In the period of operation a total of 22.442km has been driven in Ormøya.



Graphs adding up kilometers driven

Driving speed on the Ormøya route was between 9.44-10.53km/h. The overall average speed was approximately 10 km/h. By summer of 2020 a recommissioning was done to improve driving in areas of the route

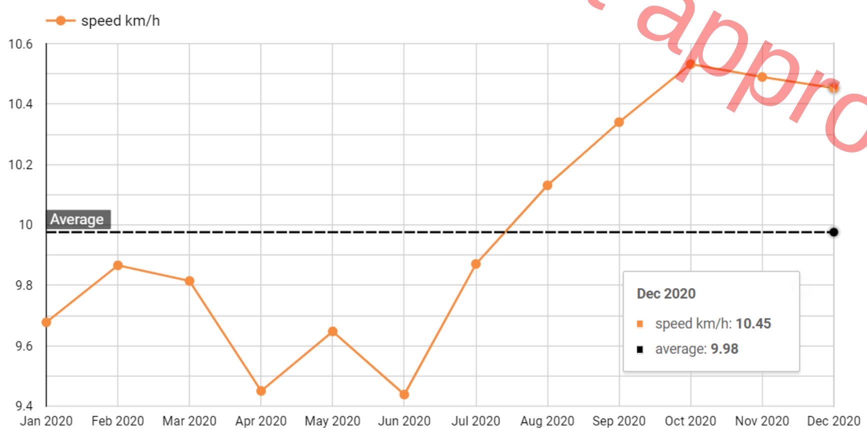
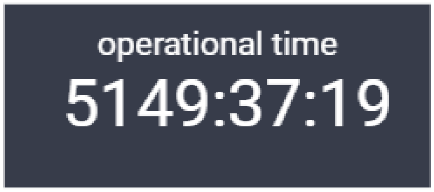


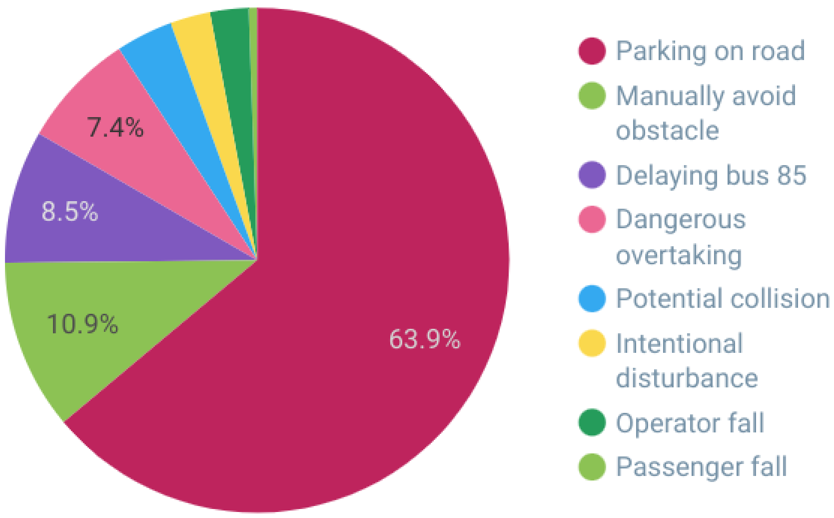
Chart shows average driving speed for each month

During the one-year pilot in Ormøya, there were over 5149 hours of operation (total number when all 3 vehicles are added together). That is equal to approximately 214 full days (1day=24h).



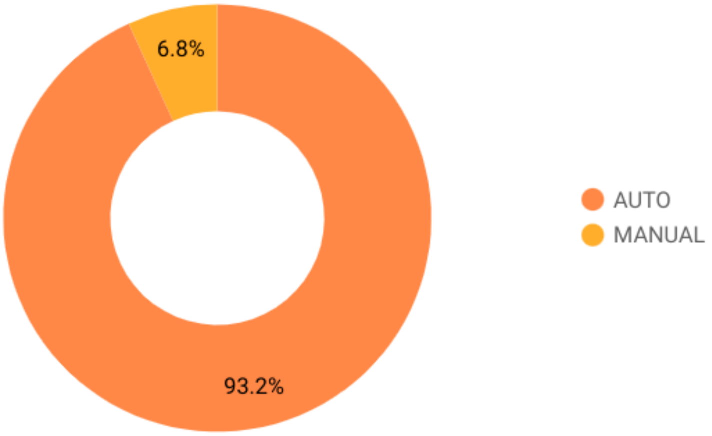
Score count showing exact operation time (HH:MM:SS)

When looking at the distribution of different issues reported by the safety operator. Again for this route the 'Parking on road' is the most frequent issue occurring. With a total occurrence of 1786 times. Passenger-fall 15 times. Operators fall as many as 69 times, signaling a safety issue in the working position of the operators..



In regards to the navigation mode, 93.8% of overall driving on the route was driven in Autonomous mode.

The rest of 6.8% driven in Manual mode was mostly due to technical issues. Driving to and from the garage is filtered out.



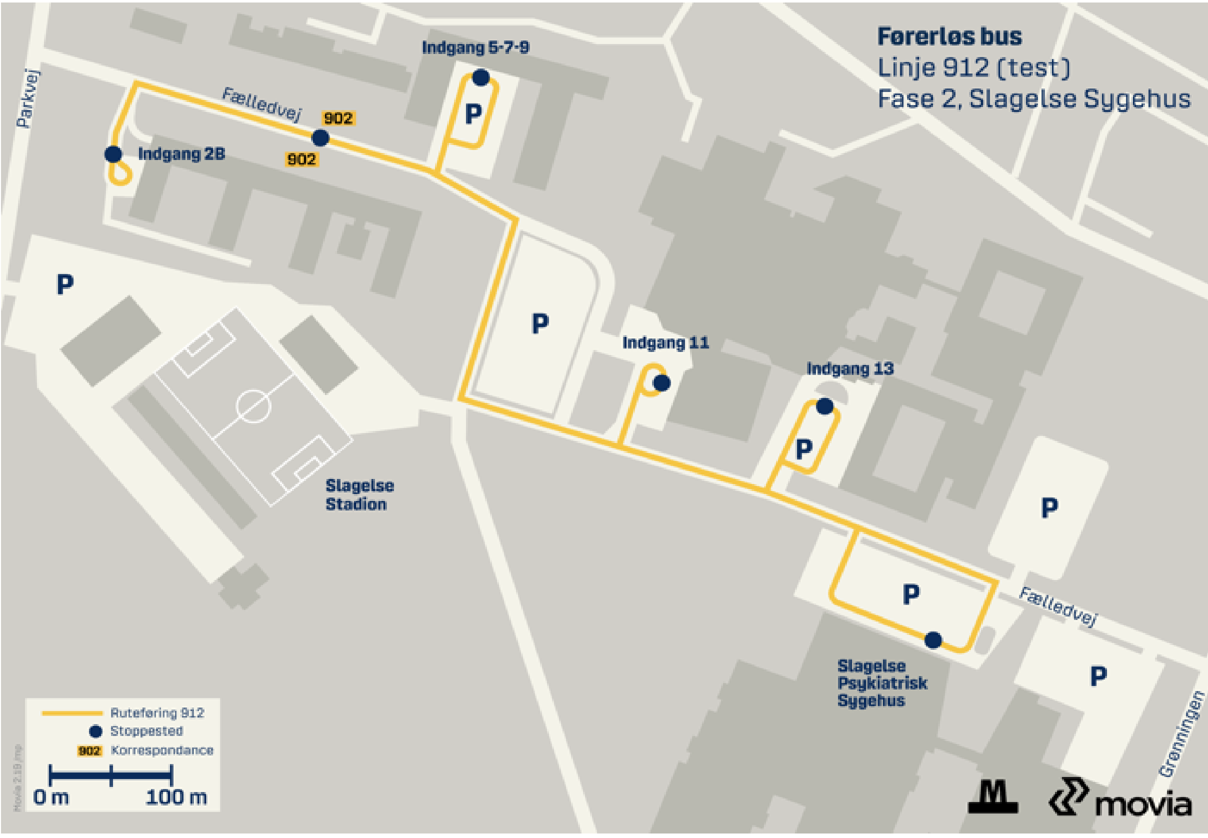
Pie chart showing distance ratio between Manual and Auto driving

5.3 Slagelse, Copenhagen, Denmark

Introduction to the route, project etc.

5.3.1 Route

The shuttle will drive on a 770 m long stretch on Fælledvej at Slagelse Hospital. Besides driving on Fællesvej, the shuttle will drive in 5 parking areas, with multiple stops, to turn the shuttle and reenter the stretch of Fælledvej. The route and the stops can be seen below. Besides the stops placed on the parking areas, the shuttle also stops at the west part of Fælledvej, in both directions.



When driving on Fælledvej, the shuttle will drive on sections of the road with different infrastructure settings. These different sections are shown in the following picture and further described below.

Red section

The red section is a 240 m stretch with parking spots longside the road on the south side, parking booths between the two driving lanes and a double edged bicycling lane on the north side of the stretch. There is a sidewalk for pedestrians on both sides of the road and no facilities for scooters in the eastbound direction. Meaning, scooters and to some extent bicycles must use the road in the eastbound direction. The speed limit for the stretch is today 50 km/h and the red section has a width of 6 m. On the red section there are 3 road connections with an unconditional right of way for the road users on Fælledvej. The municipality of Slagelse has approved the speed limit to be decreased to 30 km/h during the Hospital Pilot Project.

Green section

The green section is a 300 m stretch with parking booths between the two driving lanes and a walking path in the west - and south side of the road, as shown in the picture below. There is no sidewalk in the north side of the stretch (meaning that it is assumed that pedestrians may walk on the roadway on the north side). On the green section there are no implemented facilities for scooters or bicycles, meaning that they will drive on the roadway on the green section. The speed limit for the stretch is today 50 km/h, but it is assumed that the driving speed is lower because of two sharp curves on the stretch, with a small turning radius, which cannot be driven with 50 km/h. The green section has a width of 6 m. On the green section there are 5 entry roads for parking facilities. From the parking facilities to Fælledvej drivers have an unconditional obligation to give way. There is a road connection in one of the sharp curves, where drivers have an unconditional obligation to give way to drivers on Fælledvej. The municipality of Slagelse has approved the speed limit to be decreased to 30 km/h during the Hospital Trials.

Blue section

The blue section is a 230 m stretch with road separating barriers and newly implemented speed signs, recommending 20 km/h on the stretch. There are walking paths for pedestrians on both sides of the stretch. There are approximately 35 m of biking paths on both sides by the exit from entrance 11. On the remaining part of the stretch the road is shared with bicycles and scooters. The driving lane has a width of 3,25 m in both directions and there are 5 cross sections with obligation to give way for the traffic on Fælledvej. Slagelse municipality has approved speed limits of 30 km/h during the Hospital Trials.

A regular Movia bus (line 902) operates on Fælledvej with 30 min intervals during week days. The line has two stops (for each direction) on the part of Fælledvej, that the shuttles will be driving on. At the main entrance of Slagelse Hospital, a patient-bus of the same size as Movia’s regular bus, will depart a couple of times during the day. The patient-bus has a marked parking area in front of Slagelse Hospital, that is placed outside the self driving shuttles route. During entry and exit to/from Slagelse Hospital, the self driving shuttle and the patient-bus can lock. This will require the safety driver to manually take over and give way for the patient-bus.

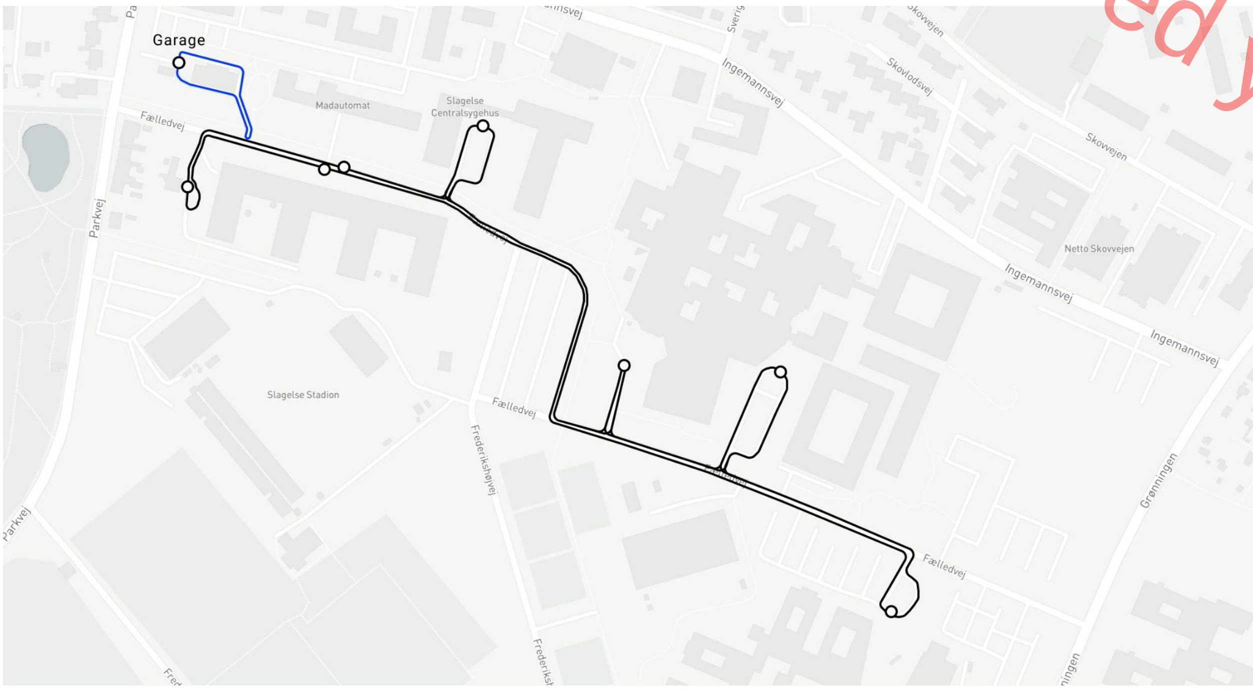
Parking conditions

The area of which the Automated minibuse will be operating has a high density of parking areas. There are parking facilities on Fælledvej, where drivers will dismount their cars directly on to the road way. Further, there are marked parking booths on these parking facilities, which the Automated minibuse has to drive past. Besides parking areas defined by regulation or signs, there is a high degree of parking outside these designated areas, as seen below. Based on this, it is uncertain how much effect the parked cars outside of designated areas will have on the operation of the shuttle. Unwanted stops and brakes may occur if parked cars are blocking the route of the shuttle.



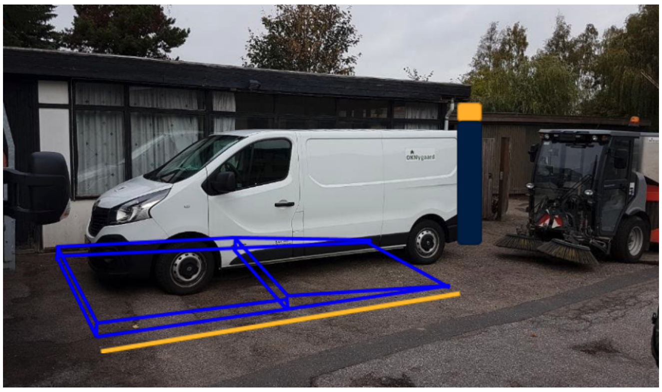
Garage

The following map shows the route including the location of the garage, where the shuttle will be parked overnight. The distance from the garage to route is approximately 500 meters. Driving from the garage to the route is manually in SAE level 0, with a maximum speed of 15 km/h.



5.3.2 Bus stops

Pictures, on-demand virtual stops

Stop name	Picture
Stop 1: Fælledvej 2B	

Stop 2Ø: Fælledvej Øst	
Stop 2V: Fælledvej Vest	
Stop 3: Fælledvej 5-7-9	
Stop 4: Slagelse Hospital, Entrance 11	

Stop 5: Slagelse Hospital, Entrance 13	
Stop 6: Slagelse Psychiatric Hospital	

5.3.3 Project timeline

The Slagelse Hospital project is already approved. The following months will be spent on preparing the site for the operation of two Automated minibuses. Both infrastructure changes and preperational work regarding the deployment has to be done. User surveys and observations have been conducted with the purpose of ensuring the most optimal and user friendly way of ordering a trip. Speed limits are being adjusted by the municipality, on-demand is being tested on the Amobility test track and much more. The following timeline underlines the ongoing and coming steps in order to reach the launch in August/September 2021.

- March 2021
  - Slagelse Hospital site approved in AVENUE
  - Preperational meetings with Movia
- April 2021
  - Certh and Amobility in-vehicle services tested and perfected in Amobility offices
  - Integration test with Movia Planet (being able to receive a mission/trip)
- May 2021
  - On-demand testing with Navya on Amobility test track
  - Certh and Amobility in-vehicle services development and testing on Amobility test track
    - Use case testing

- June - July 2021
    - Integration test with Movia Planet (booking trip → receiving mission → Deploying vehicle)
        - Testing of cancellation of trips, rerouting during trips etc.
    - Integration test with Movia interactive stops for ordering of trips including haptic feedback tests

- August 2021
    - Commissioning with Navya (4 week process)
    - Final on-demand tests
    - Final on route testing of in-vehicle services (Certh / Amobility)
    - Final route test drive (approval for assessor)
    - Project and route communication (Movia / Amobility)

- September 2021
    - Launch of Slagelse Hospital site project
    - National communication about launch (Movia / Amobility)

5.3.4 On-demand testing (technical perspective)

The goal for the on-demand service is 1) hospital staff can book trips for patients and visitors and 2) patients and visitors can book their trip . Transportation between parking lots and other entrances makes good sense because of the large distances in the hospital area. The status of the trips booked will be updated through the tool used by hospital staff, hereby passengers can get info when to expect pickup time. Safety stewards will greet passengers when the vehicle arrives at the pickup point. Without any direct input from safety steward, the vehicle will begin its trip once doors are closed.

The on-demand service will initiate with 1 vehicle. The second vehicle will be included in the on-demand service as soon as possible. If the on-demand service performs well, it is the goal to service both vehicles in on-demand as much as possible.

At this stage, there are some technical activities that needs to be performed in order to prepare the service:

- Update Navya vehicle software to 6.1
- Integrate Holo system with Navya API
- Integrate Holo system with dispatcher at Movia
- Movia to develop UI for booking

There will be full focus on the technical integration and stability/performance in the service created. In order to gain the full learning experience in trying to service a robust on-demand service.
There will be less focus on development of apps and screen content, hereby limiting the investigations into the whole Automated minibus customer journey. This is in order to favor the technical development and achievement on back-end software - customer interfaces are owned by Movia.

This priority is possible because the user who is booking the trips will be hospital staff and the passengers via the Movia interfaces. The passengers will receive the necessary info needed from the hospital staff and the interfaces. Furthermore the safety operator still has to be present in the vehicles, and will be utilized to give the needed information to the user.

The practical test process will look like this:

- Outline vehicle behavior in all possible on-demand situations on Holos testtrack in Copenhagen. SW version 6.1. Holo internally dispatches missions to vehicles.
- Outline vehicle and integration behavior in all possible on-demand situations with missions received from Movia. Still on Holos testtrack.
- Move to Slagelse and perform similar tests on the real route. Reach a satisfactory level of performance before servicing passengers.

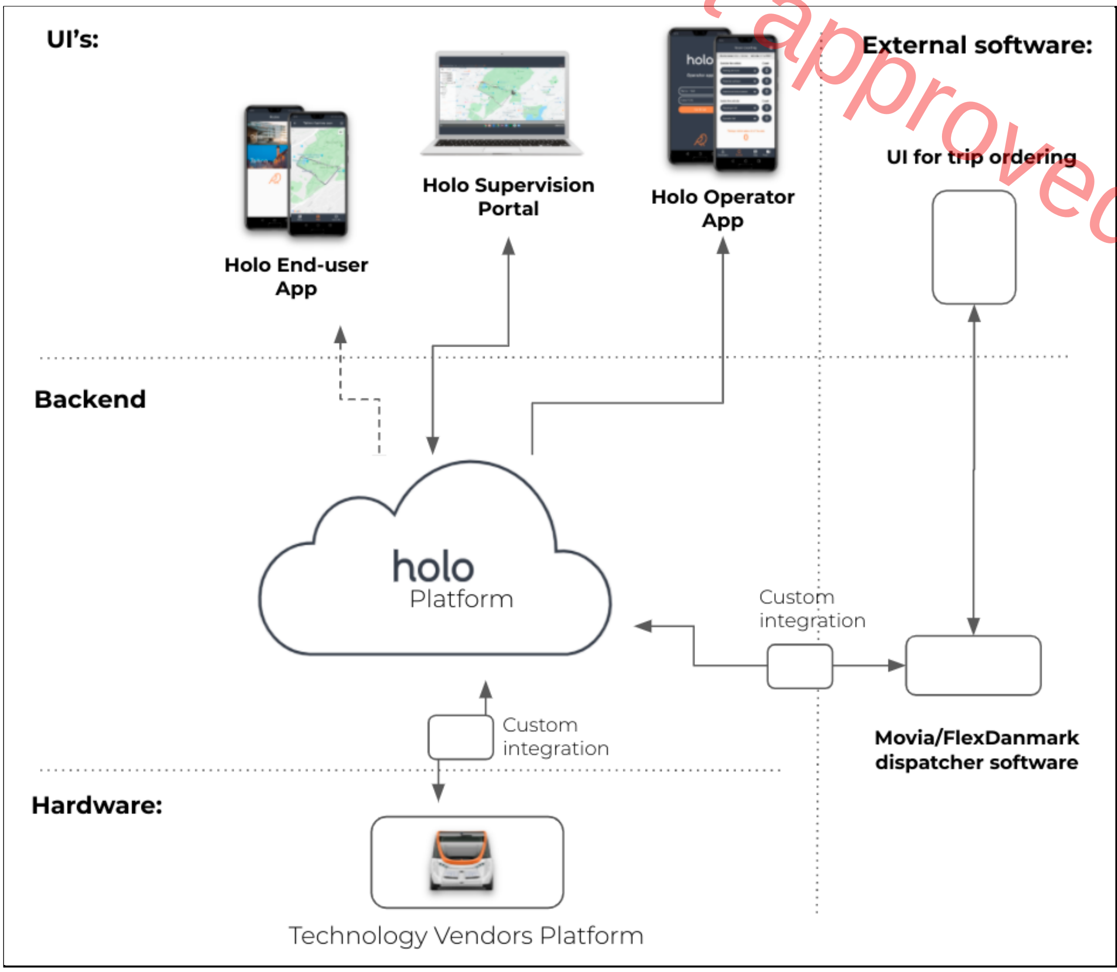
5.3.5 Software integrations

In the illustration below the technical components are presented. A main software component is the dispatcher, who matches passenger request and vehicle capacity, by dispatching missions and thereby fully controlling the destinations of vehicle movement.

The dispatcher used is a piece of software that currently is being used for manual driven transports. From Movias point of view, this is a key point to test and learn about. That is, including self driving vehicles into existing software architecture

A couple of existing Holo products will be used to support the on-demand service.

- Holos operator app in order for the safety operator to be informed about the incoming mission and passengers. But also to report issues manually for data analytics purposes.
- The Supervision portal for remote monitoring and assistance.
- And potentially the End user app for public information about the service and the project.



In the illustration two integrations are shown. This is where most of the development work will take place.

- Navya API <--> Holo Platform
- Movia <--> Holo Platform

The task of coupling an on-demand service to a vehicle demands a series of integrations. A middle layer is in this case added to support and works as a translator. A general purpose dispatcher is used where the missions are translated into vehicle specific language on Holos Platform. Also the support function is placed at Holo, which makes sense as it has the info from all components.

There are many learnings that will be created from this technical setup:

- Introduction of AV's into standard dispatchers. What limitations will be met?
- Outlining the content and dependencies of the integrations?
- With this set up of a on-demand service, how well can it be operated?

Notes: Receive a mission (demand) → forward mission to vehicle → Vehicle execution

5.3.6 Stakeholders and partners

Movia, Region Zealand, Capital Region of Denmark and the Copenhagen Metro have initiated a strategic partnership with the purpose of promoting and shaping the development of self driving vehicles in Denmark. Movia functions as the operational partner in the strategic partnership.

The four partners and supporting stakeholders are described in the following section.

AM:
Scandinavian operator of autonomous vehicle systems. AM has the main responsibility to plan and operate the pilot project in collaboration with Movia. AM is the entity given the permit and thereby has the full responsibility for safety and the vehicles.

Movia:
The client in the project and an operational partner. Amobility and Movia will integrate systems in order to deliver the on-demand driving experience at the Slagelse Hospital site. Movia is a public company (PTA) and is regulated by the law about transport companies. According to the law, Movia handles bus operation, local rail operation and transport of disabled persons.

Slagelse Hospital
The Hospital where the pilot project will take place.

Region Sjælland (Region Zealand)
Strategic partner in the Slagelse Hospital project. Region Zealand is one of the five regions in Denmark. Comprising 17 municipalities. Region Zealand performs two main tasks: Regional development and an operational enterprise in the area of healthcare and social affairs. Region Zealand's vision is to create the best framework for sustainable growth and quality of life for its citizens.

Region Hovedstaden (Capital Region of Denmark)
Strategic partner in the Slagelse Hospital project. The regions are responsible for the transport to and from the stations and for patient-transport internally and to and from the hospitals.

The Copenhagen Metro:
Strategic partner in the Slagelse Hospital project. Is overall responsible for the operation of Copenhagen's metro and the expansion of the metro system. The Copenhagen Metro assists with the integration to public transport.

COWI Denmark:
Is a leading consulting group, and two different departments (in order to avoid conflict of interest) are hired to do two different tasks:
One department has been approved as the assessor for this pilot project. The application for a permit to test automated vehicles shall according to the law include an evaluation from an approved assessor.
The other is hired to make a risk assessment of the road safety in the pilot. The assessment is done in close cooperation with AM and is part of the basis for the evaluation by the assessor.

Rambøll:
Is a leading consulting group. A road safety auditor from Rambøll has analysed the below list of conditions in the pilot project. The analysis is part of the basis for the evaluation by the assessor.

- The route and surroundings
- Existing traffic conditions
- The speed on the route
- Handling of other road users
- The conditions to give way
- Traffic at the bus stops

6 AM learnings from other pilots

AM has currently four non-AVENUE Automated minibuse pilot projects running in Finland, Norway, Sweden and Estonia, where in total across all sites have driven 25.000 passengers by now. Furthermore we await approval of three pilot sites in Denmark.

Tallinn (Estonia) 2019 - Done
The route in Tallinn was part of the Sohjoa Baltic project that researches, promotes and pilots automated driverless electric minibuses as part of the public transport chain, especially for the first/last mile connectivity. The operation will last 5 months and start at the end of August 2019.

Details:
- Vehicle: 1 Navya Autonom Shuttle
- Route: Fixed route and fixed stops, 1 km one way
- Passengers: Students, university employees and local commuters.
- Operating hours: Tuesday-Friday: 10.00-16.00, Saturday-Sunday 09.00-20.00
- With an safety operator on board (required by Estonian Road Authorities)
- Pricing: Free of charge

Oslo (Norway) 2019-2021 - Done
The pilot project in Oslo ran for three years and was a collaboration between Oslo Municipality, the Norwegian Public Roads Administration, Ruter and AM. Oslo and Akershus wishes to have 0% emissions across their public transportation and this project testet if self-driving buses can support these ambitions for a sustainable public transport system

The first route was launched in May 2019 in Akershusstranda. It runs on a route from Vippetangen, to the town hall city square and back again. This takes the shuttle service past the cruise-terminal and along the harbour front.

Details:
- Vehicle: 4 Navya Autonom Shuttle
- Route: Fixed route and fixed stops, 1.3 km one way
- Passengers: Local commuters, tourists
- Almost 19.000 passengers during the first 4 months
- Operating hours: Monday-Sunday 8.20-21.15

- With an safety operator on board (required by Norwegian Road Authorities)
- Services: Fully integrated with the public transport in Oslo e.g. in the RuterReise App and digital time schedule at the two major bus stops.
- Pricing: Same tickets as for other public transport in Oslo is needed to use the ride.

Helsinki (Finland) 2019 - Done

The route in Helsinki was part of the Sohjoa Baltic project that researches, promotes and pilots automated driverless electric minibuses as part of the public transport chain, especially for the first/last mile connectivity. It takes place from June to September 2019.

Details:

- Vehicle: 1 Navya Autonom Shuttle
- Route: Fixed route and fixed stops, 2,5 km one way
- Passengers: Students, university employees and local commuters.
- Operating hours: Monday-Friday: 09.00-15.00, Saturday-Sunday: 12.00-18.00
- With an safety operator on board (required by Finnish Road Authorities)
- Pricing: Free of charge

Gothenburg (Sweden) 2018-2019 - Done

The pilot project in Goteborg was divided into two phases. The first phase of the pilot project took place from May until September 2018 in the Chalmers university area for a duration of 6 weeks.

Details:

- Vehicle: 1 Navya Autonom Shuttle
- Route: Fixed route and fixed stops, 1,8 km one way
- Passengers: Students, university employees and local commuters.
- Total passengers: App. 1500.
- Operating hours: Monday-Friday 07:00-18:00
- With an safety operator on board (required by Swedish Transport Agency)
- Pricing: Free of charge

The second phase took place from April - October 2019 at Lindholmen Science Park for a duration of 6 months. Around 25.000 people travel through the area daily. At one end of the route is a parking area, where the monthly parking permit fee has been reduced, in order to encourage motorists to park there and take the shuttle for the last part of their journey.

Details:

- Vehicle: 2 Navya Autonom Shuttle
- Route: Fixed route and fixed stops, one roundabout, 1.8 km one way
- Passengers: employees at international companies and national authorities, students, scientists and residents.
- Operating hours: Monday-Friday 7-18
- With an safety operator on board (required by Swedish Transport Agency)
- Pricing: Free of charge

Learnings: Driving in mixed traffic provides many learnings regarding how the other road users act, and what obstacles and challenges that occur due to this. How much interference with the service arises when a cyclist or a car overtakes the shuttle. Does the interest in this technology keep interests among citizens; how long does it take for the locals to accept the service as a natural integrated part of the transport services, etc. Furthermore, many technical details regarding operation and the safety operator's functions are obtained.

Køge Hospital (Denmark) 2018-2020 Done

The pilot project at Køge Hospital is divided in three phases. The first phase of the project took place from May until August 2018 in the Køge Hospital for a duration of three months.

Details:

- Vehicle: 1 Navya Autonom Shuttle
- Route: Fixed route and fixed stops
- Passengers: Patients, relatives and hospital staff. Total passengers: > 6500.
- Operating hours: Monday-Friday 7:30-15:30
- With an safety operator on board
- Services: In the non-peak hours on-demand stops on the fixed route were tested, based on the fixed bus stops. The visitor could order the bus through the screen at the bus stop sign post, and then the bus would come to pick them up without stopping at the other stops unless others had made a demand.
- Pricing: Free of charge

Learnings: We gained important learnings about passengers with special needs, e.g. walking frames, wheelchairs, and elderly. The users expressed gratitude and relief due to the service provided, and the hospital experienced the impact of the service and the size of the need among their patients. The on-demand trials indicated the need to find the common denominator when communicating the how-to messages - so that all types of users are able to interact with the service. Furthermore, many technical details regarding operation and the safety operator's functions were obtained.

Aalborg East (March 2020 - December 2021)

The pilot project in Aalborg East is a two year project designed to show how Automated minibuses can provide public transport services in a fastly developing area. The route is on an enlarged bike lane where only self-driving vehicles are allowed to drive alongside with the bikes and pedestrians.

- Vehicle: 3 (2 in operation, 1 spare) Navya Autonom Shuttle
- Route: Fixed route and fixed stops
- Passengers: People in the area around Astrupstien. Still running.
- Operating hours: Monday-Friday 7:00-21:00
- With an safety operator on board
- Pricing: Free of charge

Learnings: The project is still running and learnings have not been evaluated at the moment.

Ski (Jan 2021 - Jan 2023)

The pilot project in Ski is a 2 year project, designed to integrate on-demand last mile services across and around Ski Central Station. Ski Station is located approximately 30 min. outside of Oslo. Residents in the area use the Ski train station for daily commuting to and from Oslo.

- Vehicle: 2-4 Toyota ProAce retrofitted with Sensible4 Autonomous system

- Route: Fixed, but undergoing expansion currently. On-demand functionality will be introduced in Q4 2021
- Passengers: Residents in Ski Municipality
- Operating hours: 11-19, 7 days a week
- With an safety operator on board
- Pricing: Same tickets as for other public transport in Oslo is needed to use the ride.

Learnings: The project is still running and learnings have not been evaluated at the moment.

7 Conclusions

The main conclusion that can be drawn from the Amobility efforts in the AVENUE project and the implementation of self-driving vehicles in Nordhavn, Copenhagen and Ørmoya, Oslo is summarised in the following points.

- The approval process in Denmark has been a slow start where multiple stakeholders in the approval process had to learn the basics of self-driving vehicles, resulting in and approval process with inspirations from the railway approval systems - hence a documentation level out of the ordinary, seen from the perspective of the self-driving vehicles industry, where the technology is still at a low maturity level. A new approval is on average considered to take between 9-14 months in Denmark and the adjustments and changes to and already given approval is rigid and requires a new approval in most cases.

- The entire approval process in Denmark with multiple approvers is very expensive and requires a huge amount of work from Amobility, in terms of documentation, separate approvals, tests, risk assessments and do forth.

- The approval process in Norway is structured in a very different way, allowing for a more dynamic and communicative approach. It is Amobility's experience that the Norwegian system is more agile and ready to adjust to the rapid development of self-driving technologies. A new approval is on average considered to take between 3-5 months in Norway and the adjustestments and changes to an already given approval is seen as dynamic and innovative.

- Based on the experiences and knowledge that Amobility has gained so far, recommendation for the Danish legal framework has been provided, with both direct and indirect changes that can be made to ease up the approval process.

- Inspiration and know-how from the Norwegian approval system has been recommended to the Danish authorities as a comparison - aiming at showcasing the potential loss of innovative projects in Denmark, if the approval system does not adapt to the innovative and rapid developments of self-driving technologies.

- From a technical perspective Amobility has experienced that the technology and industry in general has developed at a slower pace than anticipated and the objectives of AVENUE have been difficult to meet.

- The Navya vehicles are not able to drive in SAE level 4 as there are still many aspects of the safety related features that need to mature before Amobility can take out the Safety Operator from the vehicles. As a part of the risk assessment in Denmark there are certain jobs related to risks in traffic, that the Safety Operator has to perform to verify and support the vehicle in public transport.

- To be able to reach higher speeds with the shuttles the sensory systems have to be improved allowing for a larger safety net of lidars etc. Given the Amobility experience in Nordhavn and Ormøya, the average speed is still as low as 7-8 km/h. The top speed of the Navya vehicle is currently 18 km/h. Is it Amobility's opinion that the average speed is more important to increase than the speed of vehicles as the most important improvement for the operation is to move the passenger faster from A to B and not at the highest top speed. The objective is to try to raise the average speed to 14-16 km/h.

- Driving in snow and heavy rain in Oslo has turned out to be quite the challenge for the Navya shuttles. The big snowflakes are often confusing the lidars and tricking the system into thinking that there is an object that the vehicle has to avoid, hence usually a severe braking causing the passengers and Safety Operator to fall.

- The map of the vehicle (from the commissioning process) does not take into account that vegetation changes from season to season - even from the day the commissioning was executed to the day the operation begins. This has caused many problems for the vehicles that have performed many hard - and severe brakings. Often the branches are seen as obstacles in front of the vehicle in the safety zones. Amobility and the clients have spent both time and resources on keeping the vegetation to a minimum (preferably exactly as it was during the commissioning).

Appendix A:

Technical data Navya Arma DL4

Description	Value
Capacity	
Passengers	11
Sitting	11
Standing	Not included in Denmark & Norway
DImension	
Length	4.75 [m]
Width	2.11 [m]
Height	2.65 [m]
Clearance	0.20 [m]
Tyres	215/60 R17
Wheels	Steel wheel rims
Emphty weight	2400 [kg]
Gross weight	3450 [kg]
Engine	
Drive wheel	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 hours
Charge duration for 90 %	8 hours at 3.6 kW, 4 hour at 7.2 kW
Charging technology	Induction / plug
Charging temperature	0 to +40 degrees

Operating temperature	-10 to +40 degrees
Direction	
Steering wheel	2x2
Turning radius	less than 4.5 [m]
Equipment	
Air Conditioning	Automatic
Heating	Central
Doors	Double wings
Body	Polyester
Windows	Glass
Visual information	15 inch touchscreen
Sound information	Speakers
Lighting	Unidirectional
Sounds warning	Buzzer/claxon
Safety	• Handholds (4) • Supporting bar (2) • Emergency hammer • Triangle • Safety vest • First aid kit • Fire extinguisher • Interior camera
Wheelchair access	Manual ramp
Localisation & object detection	
Lidar 1	Two 360 degree multi-layer lidar
Lidar 2	Six mono-layer lidars
Cameras	Front stereo vision cameras
Odometry	Wheel encoder + inertial unit
Safety2 buttons	
Emergency stop button	
SOS intercom	! button / vi supervision
Emergency brake	Automatic
Parking brake	Automatic