Autonomous Vehicles to Evolve to a New Urban Experience

DELIVERABLE

D7.7 First iteration Copenhagen Large Scale Pilot Use Case Demonstration Report

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

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Autonomous Vehicles to Evolve to a New Urban Experience

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Acronyms

ADS	Automated Driving Systems
AI	Artificial Intelligence
API	Application Protocol Interface
AV	Autonomous Vehicle
BMM	Business Modelling Manager
CB	Consortium Body
CERN	European Organization for Nuclear Research
D7.1	Deliverable 7.1
DC	Demonstration Coordinator
DI	The department of infrastructure
DMP	Data Management Plan
DSES	Department of Security and Economy Traffic Police
DTU test track	Technical University of Denmark test track
EAB	External Advisory Board
EC	European Commission
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	Federal Roads Office
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
OCT	General Transport Directorate of the Canton of Geneva
ODD	Operational Domain Design
OEDR	Object And Event Detection And Response
OFCOM	Federal Office of Communications
PC	Project Coordinator
PEB	Project Executive Board
PGA	Project General Assembly
PRM	Persons with Reduced Mobility
PSA	Group PSA (PSA Peugeot Citroën)
PTO	Public Transportation Operator
PTO	Public Transport Operator
PTS	Public Transportation Services
QRM	Quality and Risk Manager
QRMB	Quality and Risk Management Board
RN	Risk Number
SA	Scientific Advisor
SAE Level	Society of Automotive Engineers Level (Vehicle Autonomy Level)
SAN	Cantonal Vehicle Service
SDK	Software Development Kit
SMB	Site Management Board
SoA	State of the Art
SOTIF	Safety Of The Intended Functionality
SWOT	Strengths, Weaknesses, Opportunities, and Threats.
TM	Technical Manager
UITP	*Union Internationale des Transports Publics*
V2I	Vehicle to Infrastructure communication
WP	Work Package
WPL	Work Package Leader

Executive Summary

This deliverable, D7.7, introduces the organisation, the operation and the evaluation of the large scale demonstrator pilot site with autonomous vehicles for public transport in the Nordhavn area in Copenhagen, Denmark. The route, homologation of it and the challenges will be presented.

AM will briefly introduce the Norwegian project; driving with AVENUE shuttles in Oslo.

This deliverable will also include learnings from other projects with autonomous shuttles 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 autonomous 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 autonomous 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 autonomous 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 autonomous vehicles will become the future solution for public transport. The AVENUE project will demonstrate the economic, environmental and social potential of autonomous vehicles for both companies and public commuters while assessing the vehicle road behaviour safety.

1.1 On-demand Mobility

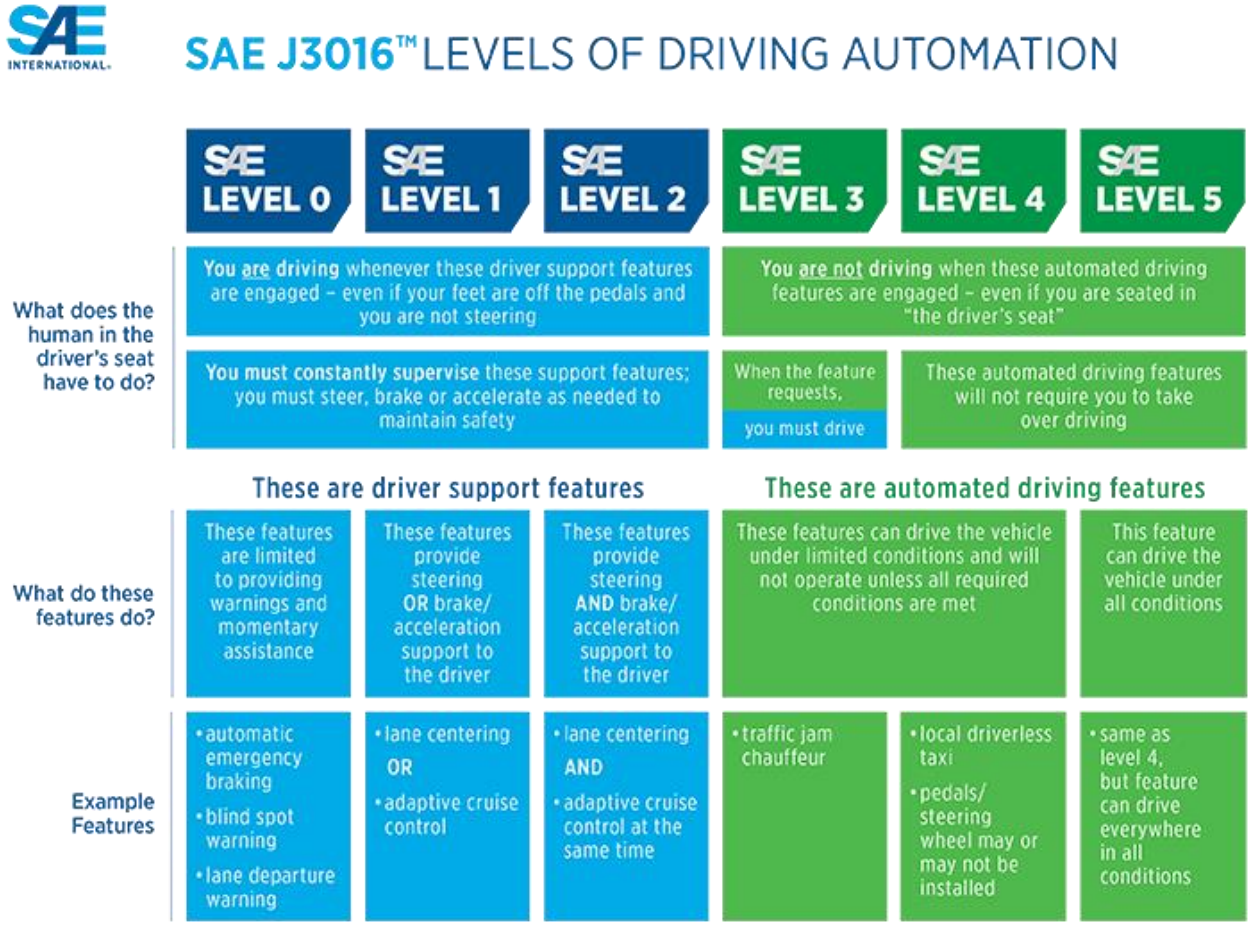
Public transportation is a key element of a region's economic development and the quality of life of its citizens.
Governments around the world are defining strategies for the development of efficient public transport based on different criteria of importance to their regions, such as topography, citizens' needs, social and economic barriers, environmental concerns and historical development. However, new technologies, modes of transport and services are appearing, which seem very promising to 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 autonomous vehicles has the potential to significantly improve services and provide solutions to many of the problems encountered today in the development of sustainable and efficient public transport.

1.2 Autonomous Vehicles

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

vs Automated was made in AVENUE since, in the current literature, most of the vehicle concepts have a person in the driver's seat, utilize a communication connection to the Cloud or other vehicles, and do not independently select either destinations or routes for reaching them, thus being “automated”. The automated vehicles are considered to provide assistance (at various levels) to the driver. In AVENUE there will be no driver (so no assistance will be needed), while the route and destinations will be defined autonomously (by the fleet management system). The target is to reach a system comprising of vehicles and services that independently select and optimize their destination and routes, based on the passenger demands.

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



1.2.1 Autonomous vehicle operation overview

We distinguish in AVENUE two levels of control of the AV: micro-navigation and macro-navigation. Micro navigation is fully integrated in the vehicle and 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 Autonomous 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 Autonomous 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 Autonomous vehicle capabilities in AVENUE

The autonomous vehicles employed in AVENUE fully and autonomously manage the above defined, micro-navigation and road behaviour, in an open street environment. The vehicles are autonomously capable to recognise obstacles (and identify some of them), identify moving and stationary objects, and autonomously 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.

1.3 Preamble

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

1.4 AMobility

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 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 site. In order to do so, AM aims at deploying at least four vehicles over a period of four years, while working towards expanding the route to multiple routes in the Nordhavn area. These routes will create a better connection between selected areas of Copenhagen and existing pvenueublic transport solutions.

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. The whole system is planned to integrate with existing PTO solutions in the Copenhagen area.

Our services should be experienced as "Helpful, Simple & Seamless": When autonomous 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 and implemented the autonomous mobility cloud in Nordhavn, in an on-demand (door2door) autonomous transport system without fixed routes, and with the whole zone mapped & geofenced.

2 Project homologation

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

2.3 Authorities

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

- The AV has to be approved by the Danish Road Safety Agency
- An impartial third party, called an assessor (appointed by Danish law) has to approve the overall project.

- The application + assessor approval then 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.
- A legal declaration is then made and sent into hearing for all interested parties
- The declaration has to be approved by the Danish Transport Committee (elected politicians)
- Finally, the Minister of Transport has to approve the declaration and process.

The Ministry of Justice will at some point during the process be involved, as well as a 3-week public hearing will be held.

2.3.1 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 parameters assess that the project can be done within normal road safety risks for that particular type of transport. There are no further detailed guidelines on how to assess this risk for autonomous vehicles.

The great challenge has been that 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 when enough is enough, in regards to the documentation and descriptions that had to be handed in.

There has long been a tradition in Denmark for using assessors in rail projects. Since there was not provided clear guidelines for the new autonomous pilot projects, the result has been that the assessor has used the framework they know from the rail projects: A very extensive framework, which makes sense, when you assess train projects (high speed, a lot of people, etc.), but does not make a great deal of sense in projects like AM's, introducing autonomous vehicles, going an average 15 km/h, carrying 11 people.

Hence, AM has spent a huge amount of time on the application material. The law is currently being evaluated, and therefore AM has concluded an extensive Public Affairs effort, talking to politicians, lawmakers, interest organizations and other relevant stakeholders in order to obtain another approval setup in Denmark; One that looks like the setup we know from Sweden and Norway, where we work directly with the Authorities.

2.4 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.

2.5 Test site homologation

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

2.5.1 Application

The following chapters and information is included in the application for homologation of each route:

Chaper	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 - 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.

3.3 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

3.4 Navya Arma Technical data

See appendix A

3.5 Options/functionality

3.5.1 Air Conditioning

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

3.5.2 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.

3.5.2.1 Example of powerful breaking sticker

3.5.3 Seat-belts

The Navya arma shuttle is equipped with seatbelts. Unfortunately the seatbelts are not approved/allowed in Denmark because they are mounted wrongly in the shuttle. Nonetheless they are available in the shuttle and kids and ederly are advised to use them to avoid falling during hard breaks etc.

3.5.4 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.

3.5.5 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.

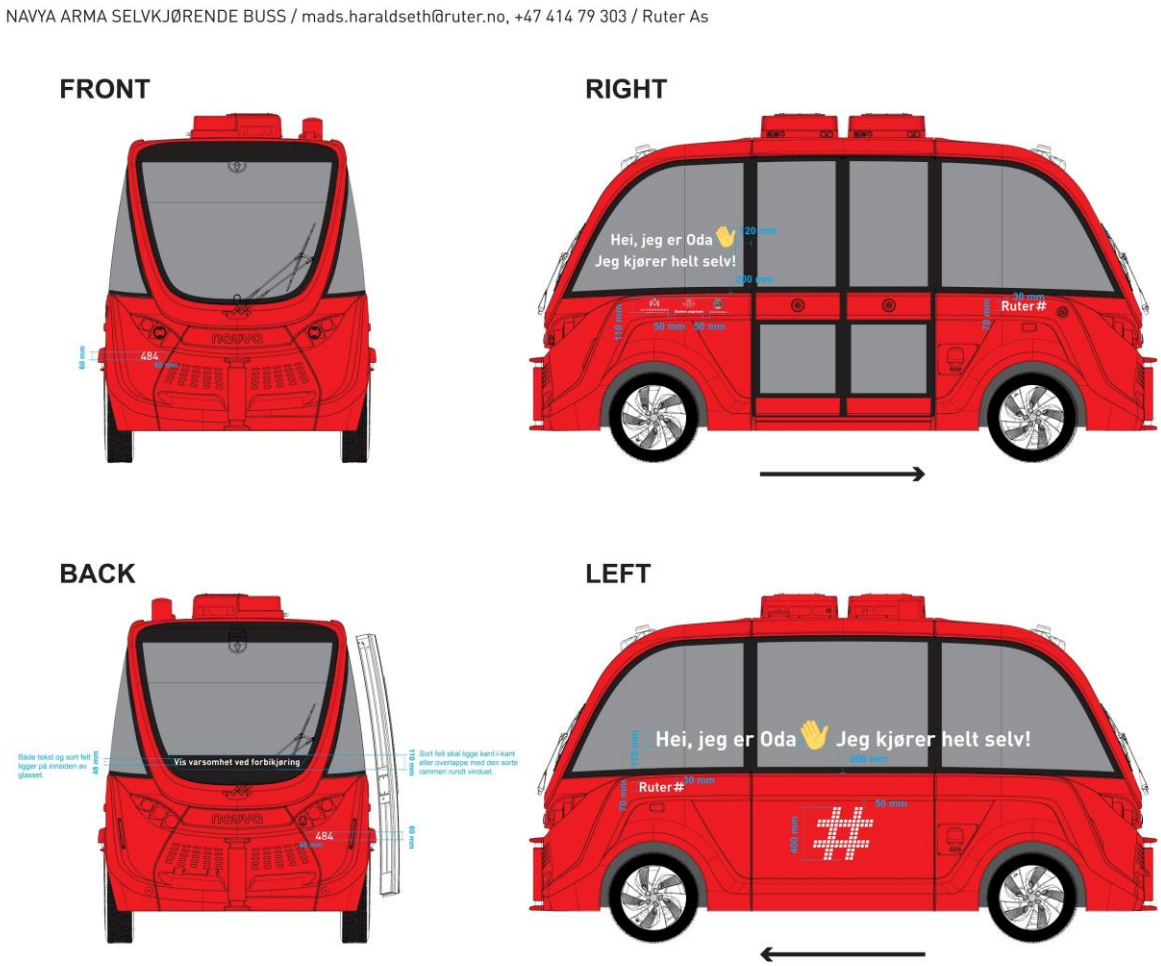
3.5.5.1 Q-straint example

3.6 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.

3.6.1 Holo branded

3.6.2 Ruter branded



3.6.3 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.

3.6.3.1 English

3.6.3.2 Vehicle example (EU logo)

3.7 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.

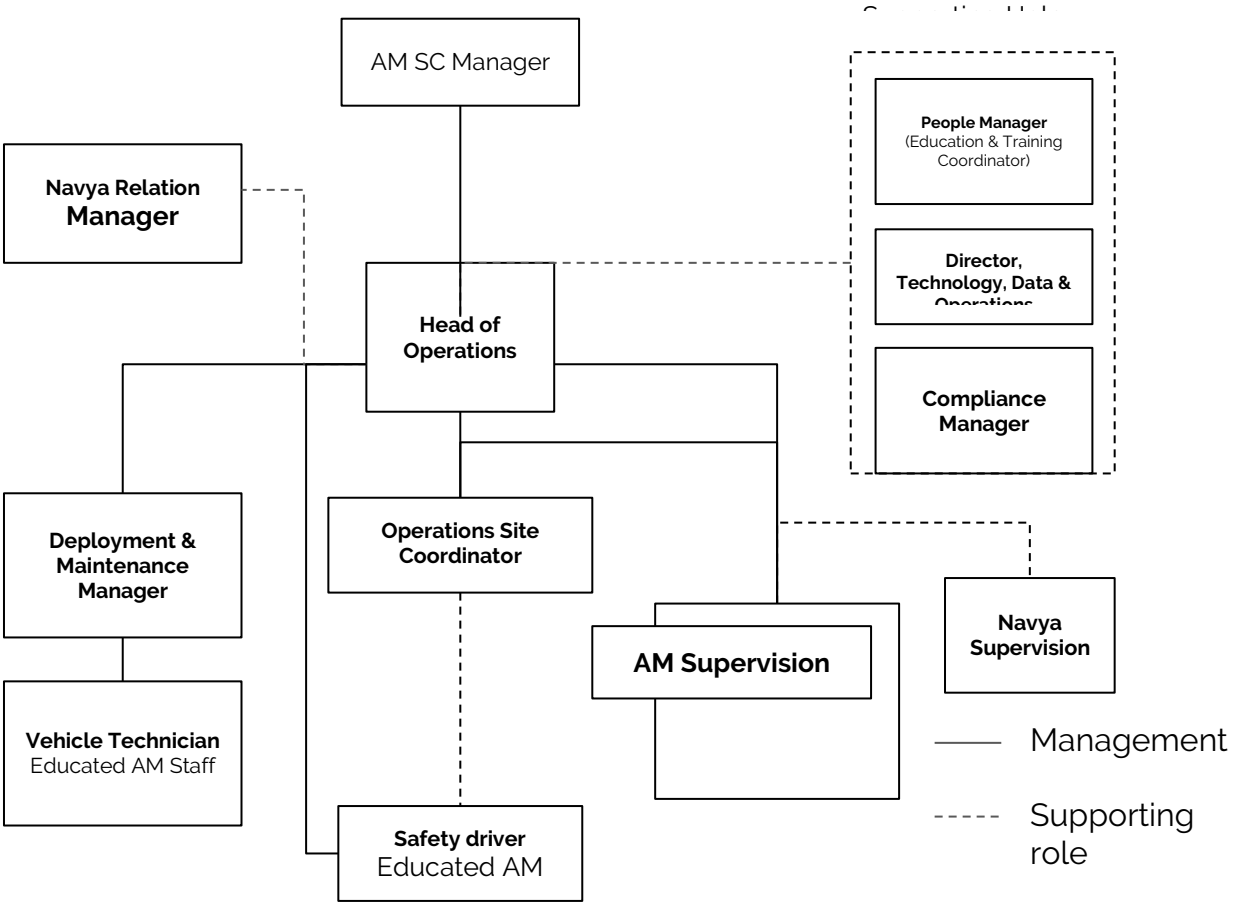
3.8 Vehicle maintenance

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 our 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.

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 two test sites:

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

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 two routes can be concluded in short as follows:

	Copenhagen	Oslo
Community	Nordhavn (smart city area + residential area)	Ormøya (residential area)

Funding	AVENUE + AM	AVENUE + AM
Start date project	May 2017	August 2019
Start date trial	September 2020	December 2019
Type of route	Fixed circular line	Fixed circular line
Distance	1.3 [km]	1.6 [km]
Road	Open road	Open road
Type of traffic	Mixed	Mixed
Speed limit	30 [km/h]	30 [km/h]
Roundabouts	No	No
Traffic lights	No	No
Type of service	Traditional bus line	Traditional bus line
Concession	Line (circular)	Line (circular)
Number of bus stops	6	6
Type of bus stops	Fixed	Fixed
Bus stop infrastructure	Yes	Yes
Number of vehicles	1	2
Timetable	Fixed	Fixed
Operation hours	Monday-Friday (5 days)	Monday-Sunday (7 days)
Timeframe weekdays	10:00-18:00	7:30-21:30
Timeframe weekend/holidays	No service	9:00-18:00
Depot	At 800 [m] distance	At 200 [m] distance
Driverless service	No	No

5.3 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

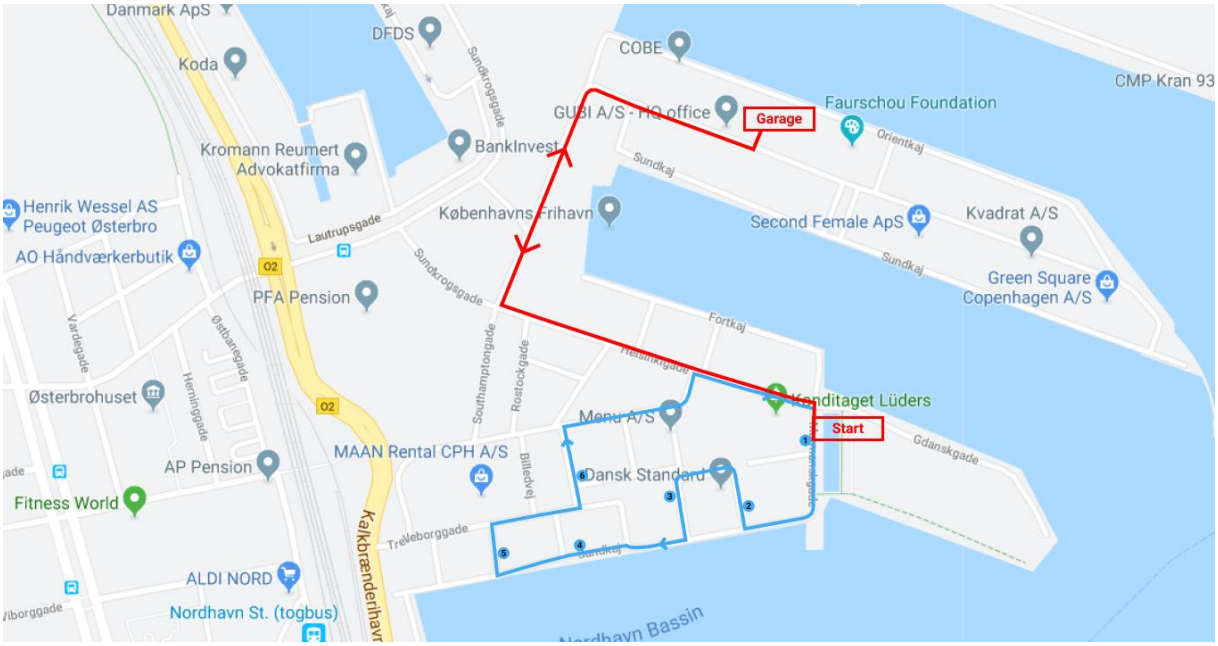
resources, recycling of resources and sustainable transport will help make Nordhavn a model for sustainable development and sustainable design. A vibrant city: Nordhavn should vibrate with life as a versatile urban area with a multitude of activities and a wide range of shops, cultural facilities and 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 autonomous 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.

5.3.1 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:

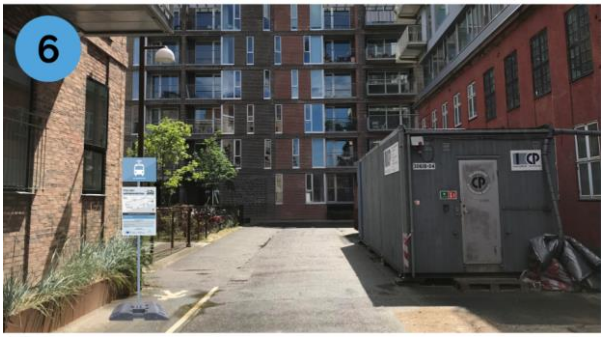
- The shuttles are free of charge during the pilot project in Denmark, so there is no ticketing yet.
- There are static bus stops providing the position of the bus, relative to the given stop.
- Realtime location of busses can be seen in the mobile application.
- Besides the bus stop signs, users can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

5.3.2 Bus stops

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

Karlskronagade	
Bilbaogade	

5.3.3 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 13:40	13:02 13:22 13:42	13:04 13:24 13:44	13:08 13:28 13:48	13:10 13:30 13:50	13:14 13:34 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	16:02 16:22	16:04 16:24	16:08 16:28	16:10 16:30	16:14 16:34

	16:40	16:42	16:44	16:48	16:50	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

5.3.4 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.

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 autonomous 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 local 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.

5.3.5 Status after 16 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 autonomous 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 autonomous vehicle 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

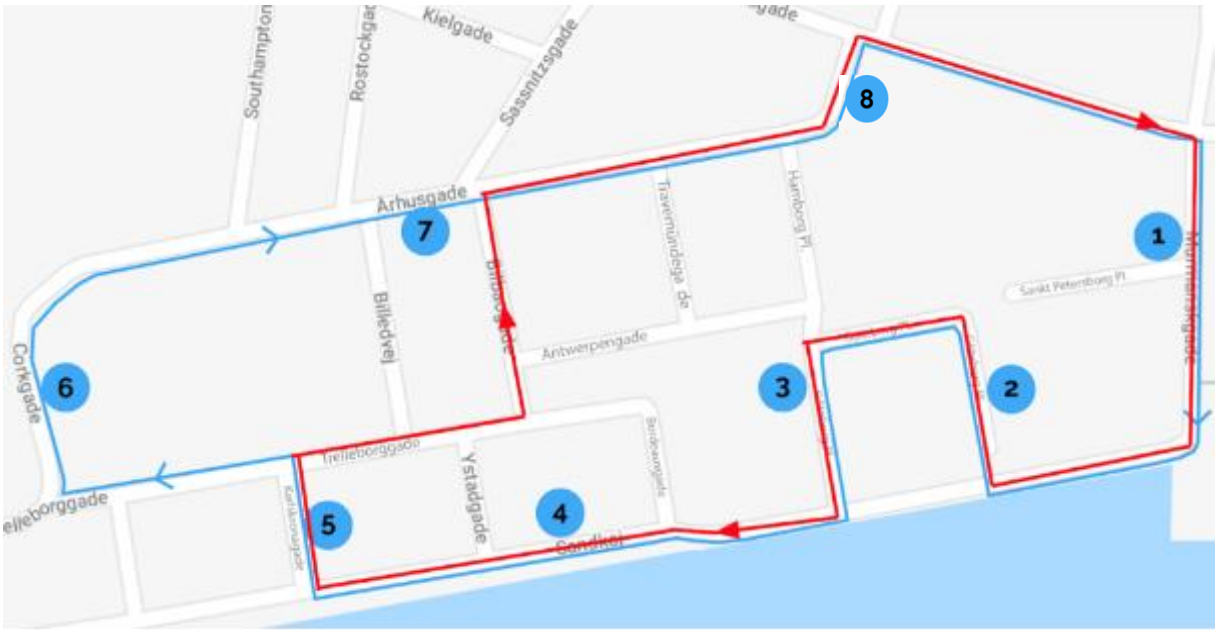
- May 1st the AVENUE project begins with Nordhavn as the Copenhagen demonstration site.
- In August COWI and AM host a risk assessment workshop with representatives from CPH City & Port, the Danish Police, COWI and AM.
- In September the final report version 1 based on the vehicles driving SAE 4 is handed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

Winter 2018

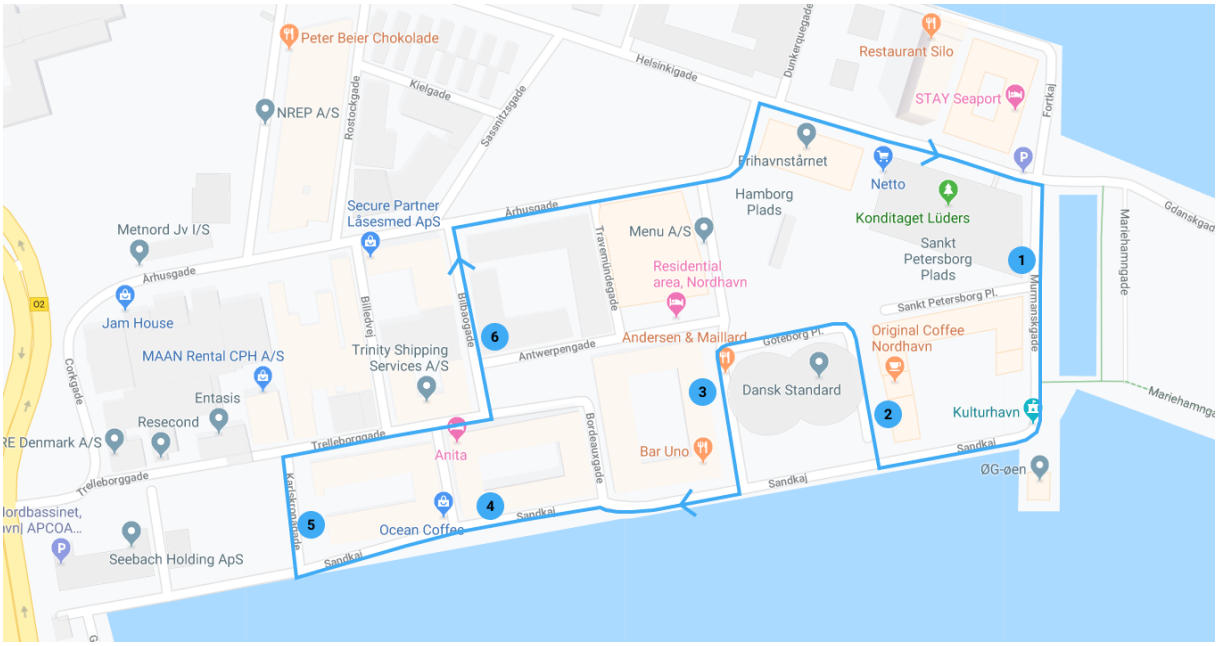
- In October Navya stated that the vehicles are not able to drive SAE 4 but SAE 3. Due to a blind spot of 30 cm. This meant that AM had to provide revised material for the accessor:
    - Obtain a new vehicle approval by the Danish Road Safety Agency
    - Change the role of the operator in the vehicle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

5.3.6 Learnings regarding the approval process

In both Sweden, Norway and Finland, AM is already operating autonomous shuttles. Here AM is 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 the three other Nordic 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.

AM believes that the setup with an assessor does not fit with the wish to have pilot projects testing autonomous driving. A pilot scheme must have a setup where you test new ways to do things - implicitly accepting that learning will be gained and not knowing everything upfront. It should be a setup where things can be changed as the learnings are gained.

It is AMs opinion that the use of an assessor in Denmark is the quite opposite of a pilot scheme. Here you try to uncover all details upfront in order to assess the road safety. The aim is to find all unknowns before the pilot starts, though the fact is that most learning is done once you start the pilot.

Furthermore, once the pilot is running all details and changes to the pilot shall be logged and approved by the assessor. This means that AM shall work continuously together with the assessor regarding many

details during the pilot project, which potentially can become a costly and slow affair. Which in turn will slow down the development of the pilot project once they go live.

Possible solutions
It is AMs overall assessment that the assessor scheme has been the main hindrance to why there are no autonomous pilots running yet in Denmark.

AM has therefore suggested the following two solutions to the Authorities:

- AM recommends that the approval process gets the same setup as in Norway and Sweden. A setup where the assessor scheme is replaced by a risk assessment done by the Road Directorate. Furthermore, should the Road Directorate be able to provide a permit for each pilot project without having to issue a special order and conduct public hearing that prolongs the approval process.

- In case it is decided to continue with the assessor scheme, AM suggests that the Ministry for Transport and the Road Directorate bring relevant parties including AM together to develop a detailed guideline for the assessors.

5.4 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 (see details about the route in section 4) in 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, Ruter was informed that there will be heavy construction on the route in August-September.
It was therefore decided to integrate AMs AVENUE buses on the second route 'Ormøya' in Oslo. Ormøya is an Island south of Oslo city and parts of the Island are protected areas where no adjustments can be made. The route has been in the approval process over the summer, and during the process, the authorities decided to expand the protected area to cover the entire Island. The autonomous vehicles

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

demand a few infrastructural adjustments, and in the case of Ormøya there was a need to install a few obstacles as guideposts for the vehicle. So for now the route can't be approved.

The next step is looking at new potential routes which are done during September 2019. Once a new route is selected the approval process will begin and the aim is to gain the permit so operation on the new route can begin in January-February 2020.

Shuttle service at UITP Stockholm 9-12. June 2019

Together with Navya and Avenue, AM

6 AM learnings from other pilots

AM has currently four non-AVENUE autonomous shuttle 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

The route that is operated in Tallinn is 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 operator on board (required by Estonian Road Authorities)
- Pricing: Free of charge

Oslo (Norway) 2019-2021

The pilot project in Oslo runs for three years and is 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 will test 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 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

The route that is operated in Helsinki is 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 operator on board (required by Finnish Road Authorities)
- Pricing: Free of charge

Gothenburg (Sweden) 2018-2019

The pilot project in Goteborg is 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 operator on board (required by Swedish Transport Agency)
- Pricing: Free of charge

The second phase takes 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 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 operator's functions are obtained.

Køge Hospital (Denmark) 2018-2020

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 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 operator's functions were obtained.

7 Conclusions

It is clear that the process of getting approved to drive in Copenhagen has been very extensive. The amount of documentation and test required to be approved has cost AM many hours of work and resources in the AVENUE project. Compared to the Norwegian site, where the legal framework is different and much more progressive.

It is expected that the approval of the Copenhagen site will be soon.

Next steps:

Further investigate the Norwegian possibilities with Ruter, regarding testing of AVENUE shuttles and service, with the purpose of being able to reach the goals of the AVENUE project faster (maybe even at all).

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