Introduction to PAV

Autonomous Vehicles (AVs), or self-driving vehicles, promise widely available, low-cost, clean, door-to-door transport for people and goods. Widespread use on Europe’s roads is anticipated by the 2050s and is expected this will have numerous societal implications for equity, health, economy, and governance resulting in potential impacts on city development and design (from street to district- and regional development).

Many cities have already started experimenting with AVs in Europe or are planning to in the near future. But AVs have yet to be implemented in local authorities’ spatial planning strategies. This is urgent as cities plan district (re)developments, transport infrastructure and related investments decades ahead.

PAV, Planning for Autonomous Vehicles, is an Interreg North Sea region project aimed to stimulate the adoption of electric, shared autonomous vehicles (AVs) by developing green transport and spatial planning strategies. During the past four years, PAV’s four local/transport authorities (from UK, DE, NL and SE), four knowledge groups and three network organisations worked together to:

- Develop and improve green transport and spatial planning strategies for the four participating local- and transport authorities.
- Prepare a publicly available series of expert analyses on the socio-economic impact of AV.
- Create an open and scalable innovation community connecting cities/regions and knowledge providers on AV;
- Implement 4 urban/regional AV pilots integrated with other, existing transport modes;

Besides the four local pilots, PAV produced a series of reports, methodologies and studies, and had great outreach through local media, international think thanks, conferences and more, and . This document provides a summary of the project’s accomplishments from the past 4 years.
## Objectives

| Objectives | Description | Key Results |
|------------|-------------|-------------|
| To explore the effects and benefits of shared, electric autonomous vehicles to create a sustainable long-term urban and rural planning | This objective aimed to bridge the knowledge gap within the North Sea Region area regarding the impacts of AV on mobility and city/regional planning. | PAV developed a toolbox of resources for urban planners and policy makers. See more about this in the 'Main outputs' section. |
| To assess the local impact of Autonomous Vehicles within the urban and rural environment through 4 AV demonstrators of level 4. | T4 AV pilots of level 4 (driver/steward on board) to assess the local impact of AV on their environment (interaction with infrastructure, ICT, other transport modes and public perception). | PAV local/regional authorities carried out 3 AV pilots of level 4 and one virtual AV pilot to assess the local impact of AV on their environment. See more about this in the 'Pilots' section. |
| To develop green transport and spatial planning strategies that incorporate AV | Using the knowledge and the tools developed in the project and the experience gathered from the demonstrators, 4 mobility green transport and spatial planning strategies (including AVs) will be developed for Varberg, HITRANS, Almere and Hannover Region. | Through the AV-pilot planning and implementation experiences, PAV cities worked with local partners and stakeholders to develop and validate transport and spatial planning strategies and methodologies to address CCAM solutions. 4 reports were produced on the enhanced planning strategies and methodologies for CCAM integration in the pilot areas. |
The PAV partnership consists of 4 local/regional authorities: HITRANS (UK), Hanover Region (DE), City of Almere (NL) and Varberg Municipality (SE) who jointly explore and demonstrated approaches of how to implement shared autonomous vehicles in public roads. The research/academic parts of Robert Gordon University (UK), University of Ghent (BE), the Oslo School of Architecture and Design (NOR) and Halmstad University (SE), who supported the project and the public authorities by developing a toolbox of resources and methodologies. The public authorities and academic partners were completed with Rupprecht Consult (DE), POLIS Network (BE), CLEAN (DEN) and Clean Tech Delta (UK), who supported the development of the toolbox and strategies, as well as the outreach and dissemination of project results.
The success of PAV relied on the engagement and involvement of various stakeholders, including project partners, public authorities, transportation operators, industry experts, and members of the public.

The stakeholder engagement in PAV was designed to provide information and guidance to the partners throughout the project, as well as aiming to support a process of co-design and participation with stakeholders and disseminating project results. Throughout the project, it was essential to ensure that all relevant stakeholders were informed about the project’s goals, objectives, and progress and that their input was considered in key deliverables of PAV.

PAV collaborated extensively with other EU and Interreg projects in workshops, webinars and conferences. Highlighting the presentations at the POLIS conference (2020), ITS Congress (2021), ECOMM (2021) or the CIVITAS Forum (2022), collaborating with key projects such as Dynaxibility4CE, Art-Forum or LEVITATE.
Stakeholder engagement was vital for the PAV AV pilots. The methodology guided the process of engagement, whilst recognising and respecting the different cultural, economic and legal drivers and constraints which will exist. Indeed, by doing this, the project ensured that cross-pilot and transnational learning and knowledge sharing is appropriate and applicable in specified types of context.

*Top to bottom, left to right:*
UGhent led workshop with students, Almere virtual pilot workshop, Hi-Trans pilot launch x2.
The project culminated in a final event that was a highly engaging and productive gathering that brought together a range of stakeholders to discuss the future of autonomous vehicles in urban planning and public transport authorities.

One key theme that emerged throughout the event was the importance of collaboration and partnership in realizing the potential of AVs. Participants emphasized the value of sharing knowledge and expertise across sectors and disciplines to overcome challenges and identify opportunities for innovation and growth. Another important discussion point was the need to ensure that the deployment of AVs is grounded in sound principles and best practices. Speakers highlighted the importance of addressing issues such as safety, accessibility, and public acceptance, and stressed the need for ongoing research and evaluation to guide future decision-making.

Despite the challenges, there was a clear sense of enthusiasm and optimism among attendees about the potential of AVs to transform urban transportation and create more sustainable and efficient systems. Overall, the final event was a resounding success that showcased the power of collaboration and innovation to drive positive change in the transportation sector. The discussions and insights shared at the event will undoubtedly shape the future of AVs in urban planning and public transport authorities for years to come.

Below:

*PAV partner consortium group photo during the event.*
Right and below:

Photos from the PAV Final Event.
PAV's Main Outputs
Social scenarios for autonomous vehicles

Electric shared autonomous vehicles (AVs) can provide green transport and inclusive mobility if implemented effectively by local and transport authorities. AVs will be integrated in our society and this raises some important questions related to the social acceptance of different social groups. To analyse this complex relationship between AVs and social acceptance, there is a need for different social scenarios. Researchers from Ghent University designed four social scenarios for AVs to address this social issue and help local and transport authorities develop and implement pilots with AVs.

Four conceptual social scenarios were designed based on the social key factors 'complexity' (space, time, and AV) and 'social acceptance': Showcase Visitor, Curious Tripper, Easy Rider, and Sustainable PT Commuter. These scenarios respectively approach the pilots in Almere (the Netherlands), Varberg (Sweden), Inverness (Scotland), and Hanover (Germany). The scenarios are quite broad to allow adaptations to the specific local and transport context and different social groups.

The four social scenarios can be the start of discussions with different stakeholders. Scenarios can contribute to identifying social, economic, and environmental effects and assessing their impacts. The ideal outcome for the authorities is to choose the most suitable AV pilot for the local social groups and take strategic actions if necessary.
Combines **low complexity** with **higher social acceptance**. The scenario can be perceived as a pilot with more shuttles that might eventually turn into an actual service. Reliability might be low in the beginning but is likely to improve. The vehicles can operate in less complex environments. The trip can bridge a missing public transport link. Interest might be higher in the beginning because of the novelty and even out in the long term. Acceptance is expected to be quite high. The main goal is to provide an integrated transport solution.

**Easy Rider**

Combines **high complexity** with **higher social acceptance**. The shuttles or buses will drive in more complex spatial environments. Reliability will also improve over time. The service can be implemented as a permanent service, fulfil a feeder function, and enable more complex trips. This facilitates the impact of this service in users’ travel behaviour. It is expected that the acceptance will also be high for this scenario. The aim is also to provide an integrated transport solution.

**Sustainable PT Commuter**

Combines **low complexity** with **higher social acceptance**. The scenario can be perceived as a pilot with more shuttles that might eventually turn into an actual service. Reliability might be low in the beginning but is likely to improve. The vehicles can operate in less complex environments. The trip can bridge a missing public transport link. Interest might be higher in the beginning because of the novelty and even out in the long term. Acceptance is expected to be quite high. The main goal is to provide an integrated transport solution.

**Showcase visitor**

Combines **low complexity** with **higher social acceptance**. The scenario can be perceived as a pilot with more shuttles that might turn into an actual service. Reliability might be low in the beginning but is likely to improve. The vehicles can operate in less complex environments. The trip can bridge a missing public transport link. Interest might be higher in the beginning because of the novelty and even out in the long term. Acceptance is expected to be quite high. The main goal is to provide an integrated transport solution.

**Curious tripper**

Combines **high complexity** with **higher social acceptance**. The shuttles or buses will drive in more complex spatial environments. Reliability will also improve over time. The service can be implemented as a permanent service, fulfil a feeder function, and enable more complex trips. This facilitates the implementation of this service in users’ travel behaviour. It is expected that the acceptance will also be high for this scenario. The aim is also to provide an integrated transport solution.
Local and transport authorities have the important task to integrate autonomous vehicles (AVs) in their transport and spatial plans. An impact assessment can help authorities in their decision-making process. Researchers from Ghent University developed a social impact assessment (SIA) methodology for AVs to help local and transport authorities with the development and implementation of pilots with AVs. Furthermore, the most important social impacts according to the literature are identified and discussed. This will contribute to more inclusive transport and spatial planning.

The social impact assessment (SIA) methodology consists of several processes to foster knowledge and develop strategies. The designed methodology distinguishes between the transport measure and social scenarios. This is followed by an identification phase in which the social groups, social Key Performance Indicators (KPIs), and social effects are being identified. If the social effects are significant, they will be perceived as social impacts and can be reviewed for each social group. From here onwards, the social impact assessment starts complemented by an analysis of the distribution of the impacts. In the end, it is important to provide feedback for the authorities and summarize the lessons learned and possible best practices. Some of the most important social impacts can be analysed within this methodology: accessibility, environment and health, safety, liveability, and employment.
The SIA is a useful tool before, during, and after the implementation phase. Authorities have the power to anticipate and monitor social impacts by mitigating the negative social impacts and maximising the positive social impacts in their decision-making process. This should be aligned with people working in the transport sector. It is crucial to validate and implement the proposed methodology, which can contribute to more social transport and spatial planning.

### Social impacts

#### Accessibility

It is important to have the possibility to access necessary goods and services. One of the most anticipated positive social impacts of AVs is accessibility for all. AVs could become a transport option for non-drivers and especially vulnerable groups like children, elderly, people with physical disabilities, low-income groups, etc.

#### Environment and health

AVs will be electric and probably drive more efficiently, which could reduce energy consumption and emissions and will have a positive impact on the environment and our health. However, if people tend to change their travel behaviour by making more and longer trips and using public transport less in combination with empty AVs and urban sprawl, these positive impacts might diminish.

#### Safety

AVs can help reduce human error, which could improve traffic safety, e.g. fewer traffic crashes, fewer traffic deaths, fewer speeding. Safety can improve for vehicle passengers and more vulnerable road users such as pedestrians, cyclists, and other people around the road. It is crucial that people are convinced of the safety of AVs. A lack of trust in the safety of AVs will limit their uptake.

#### Liveability

Greener and safer AVs are expected to improve the liveability of neighbourhoods and cities. Liveable neighbourhoods can improve societal well-being. Fewer parking spaces could create more space for different functions. It should be noted that the liveability will be negatively impacted if AVs lead to more or induced trips due to the ease of travel.

#### Employment

It is expected that some jobs will gradually disappear (e.g. drivers), others will be maintained (e.g. technicians) while also new jobs will emerge (e.g. trip attendants). Current vehicle services could change in the future, e.g. car dealerships, insurances, road police, parking officers, road emergency workers.

### KEY TAKEAWAY

The SIA is a useful tool before, during, and after the implementation phase. Authorities have the power to anticipate and monitor social impacts by mitigating the negative social impacts and maximising the positive social impacts in their decision-making process. This should be aligned with people working in the transport sector. It is crucial to validate and implement the proposed methodology, which can contribute to more social transport and spatial planning.
Report on the longterm socioeconomic impacts of AV

Introduction

AV promise widely available, safe, clean, door-to-door transport for people and goods. Widespread use on Europe’s roads is anticipated to happen in the next few decades and is expected to have numerous societal implications for equity, health, economy, and governance resulting in potential impacts on city development, infrastructure and design (from street to district- and regional development). However, research and models show that introducing AV would not necessarily lead to an improved traffic situation in the city or to sustainable developments in mobility. As the POLIS discussion paper on AV (2018) pointed out, expectations are being created that self-driving cars will be there tomorrow, will always operate perfectly and will solve congestion and eliminate accidents. While AV may bring some benefits, there is also the possibility that their widespread introduction in urban areas could lead to increased congestion, negative environmental impacts (unless all AVs are electric and/or powered by renewables), increased energy consumption and negative health impacts, if walking and cycling are discouraged and if appropriate regulatory frameworks are missing.

Truthfully, the implications of new technical developments cannot be clearly and precisely predicted today, as many factors enter into consideration. In the future, mobility is expected to be safer, more comfortable, more accessible and, in certain aspects, more efficient. Cities face the challenge of integrating automation in their planning while taking advantage of the opportunities/benefits that autonomous vehicles offer and, at the same time, minimizing the risks and potential negative externalities associated with them. Their introduction therefore needs to be carefully managed in the context of sustainable urban mobility objectives. In other words, even if they prove to be technically and commercially viable, it might be necessary to limit the use of AVs for policy reasons.

To help local and regional authorities need to gain a deeper understanding of the potential paths of development, potential impacts, and chains of causality, POLIS prepared a report examining various potential socioeconomic impacts surrounding the deployment of AV in road transport as well as factors that will influence such impacts.

The report is divided in 4 sections: Scenario analysis and influencing factors, impacts on services, impacts on accessibility and impacts on health and well-being. As many of the sections are connected and related to each other, an order was established to facilitate the reading of the report, with each section referencing or relating to the previous one.
By analysing different scenarios, cities can identify influenceable factors and can be prepared to deal with a range of changes and uncertainties through decision-making processes. This report studies several impacts that could arise from the deployment of autonomous vehicles and points out the different factors or circumstances that will determine them in order to help local and regional authorities to plan for the arrival of the technology and integrate it in their long term strategies.

**Factors influencing impacts of AV**

| Framework Regulation | Cybersecurity | Maturity of telecommunications |
|----------------------|--------------|-------------------------------|
| Politics and political environment | System reliability | Technology development, availability and infallibility |
| Transportation Options | Infrastructure quality | Cost of the technology |
| Human behaviour towards mobility | Traffic rules | Liability and insurance |
| Societal factors | Public acceptance of AV | Social implications, e.g. on workforce |
As part of the project, PAV developed a stakeholder engagement approach, which was co-designed by the partnership under the guidance of RGU. The methodology was applied within the contexts of the four AV pilots and was designed to provide information and guidance to the partners throughout the project.

This approach aimed to guide the process of engagement, whilst recognising and respecting the different cultural, economic and legal drivers and constraints which existed. Indeed, by doing this, the project was able to ensure that cross-pilot and transnational learning and knowledge sharing were appropriate and applicable in specified types of contexts.

**Methodology**

The methodology aimed to be:

- Applicable across borders;
- Helpful in engaging with and selecting required stakeholders for setting up the pilots;
- Of continued value throughout the project duration;
- Useful in targeting groups to include:
  - Local citizens;
  - Interest groups: (elderly) healthcare organisations;
  - Public authorities for legislation (permits, pricing, taxes, etc);
  - Road authorities (monitoring, allowing infrastructural changes, road adjustments, ICT, sensors, camera surveillance, etc.);
  - Safety/health institutions (also for permits and choice of end-user);
With this in mind, local partners engaged with their local knowledge, policy, community and industry networks to reach the required target groups.

It felt by the consortium that the project team could benefit greatly through early reflection on the aims and objectives of each of the planned pilot studies. For example, the pilot studies were likely to be rolled out across a range of scales, each intrinsically connected with the local context (including geographical, social, governance and political and financial considerations).

It is suggested that defining these aims, objectives and contexts early in the project cycle might also enable project teams - beyond PAV - to engage with local and further stakeholders during later stages of the work, to support knowledge sharing and to help facilitate the replication of success more widely.

The approach is arguably novel within the study of AVs, in that our focus was on people and how they might be affected by such new technologies. The work has so far resulted in the preparation of numerous publications, including to academic and industry audiences.

*Bottom left:* Images of PAV’s participation at the International Mobility Summit 2022 in Copenhagen, Denmark

*From left to right:*
Prof Richard Laing (Northumbria)
Daria Belkouri (RGU)
Dr Ditte Bendix Lanng (Aalborg)

*Bottom right:* Logo for the International Mobility Summit 2022
Study and report on innovative AV design solutions

The software and hardware relevant for Autonomous Vehicles are developing fast due to needs in the field of mobility and future marked potentials. Industries and cities in the US and in China seem to be up-front in adapting technologies and launching systems for autonomous mobility. In this study from the Oslo School of Architecture and Design (AHO) 25 different design solutions are presented and categorized according to their functional capacity. The solutions identified supported PAV public authorities when developing their pilots and improving their strategies.

On-demand ride hailing

On-demand ride-hailing, such as Uber and Didi, which allow passengers with smart phones to submit trip requests and match them to vehicle based on their locations and vehicle’s availability. Cities that are fully operating or full-scale testing are San Francisco, Shanghai, New York, Pittsburgh / Washington DC / San Francisco, Phoenix, Boston/Pittsburgh, Las Vegas.

Fixed route stop–based ride sharing

Ride-sharing is a way for multiple riders to get to where they’re going by sharing a single vehicle, usually a bus or shuttle. This mobility makes multiple stops along a fixed route to pick up and drop off passengers, reducing the need for multiple cars on the road.

Top to bottom:
On-demand ride hailing vehicle in Shanghai
Full-size autonomous bus in Singapore
Autonomous Logistic Mobility

Autonomous logistics mobility describes mobility that provides unmanned, autonomous transfer of goods, baggage, and container ranging from last-mile delivery to long-haul transport. Full-scale testing projects in Houston/Silicon Valley/Greater Phoenix. Fully operational forklifts and tuggers on industrial sites. Autonomous baggage tractors in function at Toulouse-Blagnac Airport in France. Testing autonomous short-haul freight system in different US locations. Testing long-haul freight systems from Tucson Arizona.

Autonomous parking

Autonomous Parking is an unmanned car-manoeuvring system either by on-board plug-in or parking robot. It will largely enhance the efficiency of the overall parking system.

Two Autonomous Parking Robots are presented: In Lyon-Saint-Exupery Airport, France and at Düsseldorf International Airport, Germany. Autonomous Parking Plug-in in Merriweather District Development, Columbia Ohio.

Drone technology

Drone related technologies use unmanned drone as main carrier to provide multiple services including last-mile package delivery, agriculture seeding and protection, and inspecting. Drone technology for delivery has mostly been tested out in China. The three design solutions presented in the report shows the Amazon Prime Air delivery project, Shun Feng Full-size Drone Delivery and an Autonomous Agricultural Drone that is an industrial project and fully operating (DJI Agriculture).
Throughout our comprehensive report, we have explored the potential of AVs in various urban logistics scenarios, with a particular focus on the local context of Inverness, Scotland. Our findings emphasize the need for a well-coordinated and strategic approach to integrating AVs into urban logistics. While AVs offer tremendous opportunities, it is crucial to consider their limitations, regulatory requirements, and public acceptance.

To propel this transformative journey forward, we propose a set of key recommendations:

1. **Identify and prioritize use cases**: Determine the most impactful applications of AVs in urban logistics based on local needs, challenges, and opportunities. By focusing resources and efforts on these key areas, AVs can make a significant difference in enhancing urban logistics.

2. **Foster collaboration and partnerships**: Establish partnerships among various stakeholders, including local authorities, transport agencies, logistics companies, technology providers, and community organizations. Through collaborative efforts, knowledge sharing, resource pooling, and the development of comprehensive solutions, we can leverage AV technology effectively.

3. **Invest in infrastructure and technology**: Ensure the presence of necessary physical and digital infrastructure to support AV deployment. This includes charging infrastructure, optimized loading/unloading facilities, robust data exchange systems, and reliable communication networks. Investment in research and development will drive advancements in AV technology, including sensor technology, connectivity, and autonomous capabilities.

4. **Adapt regulations and policies**: Collaborate with regulatory bodies to develop and adapt regulations that facilitate the safe and efficient integration of AVs into urban logistics. This involves addressing liability frameworks, data privacy, traffic rules, and licensing requirements. Promoting regulatory harmonization at regional and national levels will facilitate seamless AV deployment across borders.

5. **Engage in public awareness and acceptance campaigns**: Proactively engage with the public and local communities to increase awareness and understanding of AV technology and its potential benefits in urban logistics. Transparent communication and education initiatives are vital to address concerns related to safety, job displacement, and privacy, ensuring a smooth transition towards an AV-enabled future.

By following these recommendations, we can unlock the immense potential of AVs in urban logistics, paving the way for enhanced efficiency, reduced congestion, and a sustainable transport ecosystem. Together, let us shape the future of urban logistics and embrace the transformative power of autonomous vehicles.
Global Report on drivers and potential business cases

The AV business case assignment consists of the Global Business Case Study for the future of CCAM in Public Transport and 3 Local Business Case Assignments for HITRANS, Varberg and Almere. The study was carried out by Bax&Company.

The AV global study aims to give a holistic overview of the current and future developments of collaborative, collective and automated mobility (CCAM) for public transport. The study provides insights into the state-of-the-art of CCAM, the main drivers and barriers which determine the future of CCAM and provides a framework to define and assess use-cases and business cases of CCAM for public transport. Furthermore, the drivers and barriers in terms of technology, regulation, market, and social acceptance, and how they impact the adoption of AVs in public transportation are assessed.

Expert insights from industry, policy and civil society are used to identify and assess the technological advancements that make AVs possible, the regulatory landscape that must adapt to accommodate them, the market forces driving their adoption, and the social acceptance that is crucial for their long-term success.

Lastly, the global study presents a framework (see figure below) to define the varying use cases of CCAM in public transport. Distinguishing between the deployment area, deployment model and target group, distinct components are defined which combined define the makeup of each use case. Accordingly, the business case of these use cases is assessed based on their profitability, service level and feasibility compared to conventional bus services.

**Deployment Area**

- **Demand**
  - Constant high
  - Fluctuating
  - Constant high

- **Route length**
  - Long
  - Short

**Deployment Model**

- **Timetable**
  - Fixed
  - On demand

- **Traffic type**
  - Controlled
  - Mixed

- **Trip frequency**
  - High
  - Low

- **Fleet size**
  - Large
  - Small

- **Route type**
  - Fixed
  - Area coverage

- **Response time**
  - High
  - Low

- **Shuttle size**
  - Large
  - Small

- **Speed**
  - High
  - Low

**Target Group**

- **Target group**
  - Elderly
  - Employees
  - PRM
  - General public
  - Students

*Left and below: Graphical representation of use case definition framework*
The report

When diving into the state of the art, the report highlights 4 unique projects that have spearheaded the development and use of CCAM for public transport. By illustrating the existing deployment modes and CCAM for AV, the report gives insights into the types of CCAM deployment within public transport and paves the path for what to expect of the mobility mode in the coming decade.

In the 3 local business case reports, the impact of deploying AVs for specific use cases identified by HITRANS, Almere and Varberg are modelled. The model is fed by the use case characteristics, as well as prediction factors that take major sector trends into account such as cost of operation once the driver on board is no longer mandatory and the cost of technology once automated buses are produced at a larger scale.

The outputs consist of quantitative calculations for a range of financial, service level, accessibility, demand, and environmental KPIs. The main insights are the cost projection calculations for both AVs and conventional transportation over the next 15 years for different scenarios. Additionally, sensitivity analyses allow for the many different variables to be assessed and compared, to determine which have a major influence on the overall business case for each specific use case.

Below: Graphical representation of local business case reports assessment framework
To effectively regulate the introduction of Connected and Automated Vehicles (CAVs), minimize potential negative impacts, and influence the shift towards more sustainable urban mobility, a proactive planning approach is required. Authorities must take a leading role in steering the deployment of CCAM services in line with their local policy goals.

Planning for this innovative field involves addressing uncertainties, understanding technological solutions’ functionalities, requirements, and limitations, as well as considering citizens’ and stakeholders’ opinions, needs, and concerns.

To address the deployment of CCAM, robust guidance, tools, and methodologies are required for cooperative action and informed decision-making. A structured planning framework is necessary to ensure the strategic alignment of deployment scenarios with local conditions, policy goals, and societal needs. The Sustainable Urban Mobility Planning (SUMP) concept offers comprehensive methodological guidance for addressing innovative mobility solutions within local planning processes.

With this in mind, PAV has developed a handbook with guidance, best practices and tools to support the integration of AV in urban planning through its inclusion in SUMP processes, following the structured planning framework to address the challenges, key success factors and recommendations to guide effective planning and regulation of CCAM services.

The CCAM planning handbook constitutes a SUMP Topic Guide for CCAM, which builds on previous research, and encompasses results and experience from PAV, as well as other relevant projects such as Dynaxibility4CE, Ride2Autonomy, ART Forum and SHOW, among others. Based on the existent Practitioner Briefing for Road-Vehicle Automation, developed by the CoExist project on 2019, PAV has cooperated with other relevant projects to analyse planning needs, collect recent experiences, research findings and tools developed, enhance the planning guidance for CCAM.

**Right:**
Visualisation of SUMP cycle.
CCAM self-assessment tool

The CCAM Self-Assessment tool simplifies planners’ entry point by supporting the identification of local challenges, opportunities, risks, and requirements for deploying CCAM services. It is an interactive questionnaire that enables public authorities and mobility stakeholders to analyze their status and needs for planning the deployment of Cooperative, Connected and Automated Mobility (CCAM) services. The tool follows the ‘automation-ready framework,’ which proposes three phases of strategic action for CCAM in urban mobility planning processes: Automation awareness raising, Planning for Automation-readiness, and Preparing for the implementation of automation-ready measures. The tool aims to reduce uncertainties and encourage proactive CCAM planning with its structured framework.

Through a scoring methodology, tool users shall be provided with a summary of their results and a series of recommendations and useful references to support their CCAM planning effort. Different weightage shall be given to different categories (question clusters) based on the responses from the users which allows them to compare assessments and identify weaknesses in their CCAM-readiness.

The testing of the CCAM Self-Assessment Tool with the PAV cities provided much-needed valuable feedback to improve the questionnaire in terms of its practicability. This allowed users to better understand how to use the tool comprehensively to evaluate their CCAM readiness status and to better plan their infrastructure to incorporate CCAM in their transport network.

The FAME project (Horizon Europe Coordination and Support Action to build the European Commission’s Knowledge Base for the CCAM Partnership) will integrate the CCAM Self-Assessment tool into its Knowledge Base as an entry point for the target group authorities to support planning for CCAM.

| Mobility Aspect | Automation Awareness | Planning for Automation-Readiness | Preparing for the Implementation of Automation-Ready Measures |
|-----------------|----------------------|---------------------------------|-------------------------------------------------------------|
| Policy          |                      |                                 |                                                             |
| Infrastructure  |                      |                                 |                                                             |
| Planning        |                      |                                 |                                                             |
| Capacity Building |                    |                                 |                                                             |
| Traffic Management |                 |                                 |                                                             |
| User            |                      |                                 |                                                             |

| Policy | Automation Awareness | Planning for Automation-Readiness | Preparing for the Implementation of Automation-Ready Measures |
|--------|----------------------|---------------------------------|-------------------------------------------------------------|
|        |                      |                                 |                                                             |
|        |                      |                                 |                                                             |
|        |                      |                                 |                                                             |
|        |                      |                                 |                                                             |

The FAME project (Horizon Europe Coordination and Support Action to build the European Commission’s Knowledge Base for the CCAM Partnership) will integrate the CCAM Self-Assessment tool into its Knowledge Base as an entry point for the target group authorities to support planning for CCAM.
The Urban Development Solutions report, based on pilot sites in Inverness, Almere, Varberg and Hannover Region, has identified significant opportunities arising from the introduction of autonomous vehicles into the transport system. The report highlights the positive impacts of autonomous vehicles on the community, environment and user experience, as well as the challenges and opportunities encountered in each pilot site.

The report found that in Inverness, the on-demand format of the autonomous vehicle would be more successful in the long term than a scheduled service. Although the pilot took longer than expected to set up, users provided positive feedback and local operators gained skills in the operation of autonomous vehicles.

In Almere, it was concluded that a virtual pilot is an effective way to communicate future scenarios for the public transport system of an urban development and to visualise the impact of autonomous technology. The virtual pilot allowed city planners to discuss the implications of autonomous transport and its requirements at an early planning stage.
In Hannover, it was found that all insurance and licensing challenges were overcome and that the integration and operation of an autonomous shuttle bus into the existing public transport system was successful. However, the shuttle’s maximum speed of 15 km/h caused traffic problems and reduced acceptance by other road users. The report recommends improving the speed and sensitivity of the autonomous vehicle to increase its effectiveness in the transport system.

In Varberg, the report found that the AV Shuttle pilot test in Apelviken was positive in terms of educating the public about the capabilities of autonomous vehicles. However, technical problems and low performance showed that the technology is still immature. The report recommends the use of more reliable and faster autonomous vehicles to increase the efficiency of the transport system.

Overall, it is concluded that there are significant opportunities for autonomous vehicles in the transport system, including relieving pressure on public transport bus drivers, reducing congestion and filling the gap created by the shortage of public transport drivers. However, it is recommended that further improvements to the technology, including increased speed and sensitivity, are needed to increase the acceptance and effectiveness of autonomous vehicles in the transport system.

*Left:*
Image from Hannover pilot
Report over innovative AV products and services tested in the 4 AV pilots

Summary

The PAV project has conducted a series of pilots in various urban environments to evaluate the performance of autonomous vehicles (AVs) and their impact at different levels. The project tested different products and services to assess the viability of AVs in urban environments. These products included innovative procurement and cooperation with second-hand vehicles from public transport operators, innovative procurement of AV shuttles through market consultation and subsequent procurement, a custom-designed delivery robot for outdoor use on islands, and the use of visualisation software to gain insights into future AV deployment and socio-economic impacts.

In addition to the tested products, the PAV project evaluated several services related to the deployment of autonomous vehicles in different urban environments. These services included an AV last-mile connection for tourists, the integration of an autonomous shuttle bus into public transport across city boundaries, an autonomous logistics and delivery system tested in a remote island location, and a demonstration of a new transport service using AVs to connect private sites such as a university campus and a nearby business park. The project also tested a service for the virtual integration of AV technology into the public transport system of a new district development programme.

The report provides an analysis of the impact of these products and services at different levels and a summary of the challenges and opportunities encountered during their implementation. Innovative procurement strategies were found to accelerate AV deployment, while customer acceptance and satisfaction were crucial for the viability of AV services. AV services need to be designed with the needs and preferences of customers in mind and provide a seamless, comfortable, and reliable experience.

Despite the challenges encountered during the pilots, such as vehicle breakdowns, maintenance issues, and adapting to changes in the environment, the opportunities identified provide valuable insights into the future deployment of autonomous vehicles. The project’s findings can serve as a valuable resource for policymakers, transport experts, and other stakeholders interested in the future of mobility and the deployment of AVs. Overall, the PAV project has demonstrated the potential of AVs to transform urban mobility, provided insights into the challenges and opportunities involved in their deployment, and highlighted the importance of collaboration and knowledge sharing among stakeholders.
The PAV Pilots
Hannover

**Duration**: 29 August - 7 November 2022

**Summary**: The pilot in Region Hannover took place on a 1km route in Garbsen, connecting the tram stop, Schönebecker Allee, with the Garbsen campus ("Garbsen-Mitte An der Universität") of Leibniz University. The EasyMile AV was operational from Monday to Friday as the main users were students and staff at the university.

The route was chosen as the short 1km route to the new tech campus which was seen as a good place to test the AV technology. The AV was running in addition to the existing bus line, which provided a good back-up option in cases of technical problems. The pilot route was operating on the road in live traffic with other road users.

**Learnings and challenges**

Through the pilot it became clear that there is still a gap between reality and the scalable use of AVs. The vision of the pilot had been that the AV shuttle could replace the regular bus line outside of peak hours, however, the capacity of the AV was too small, the speed was not high enough, and technical problems as well as lack of drivers caused more periods without service than expected.

*Technology challenges*: The AV shuttle has a capacity of 6 while the regular bus has a capacity of app. 80, and although the shuttle technically had a max speed of 30km/h, it was only practically able to go at 10-12km/h on the route in Garbsen. The infrastructure surrounding the AV would also need to be updated if an AV would be driving permanently. Making the contact between traffic lights and the AV shuttle is challenging and the technical infrastructure and communication systems for this are complicated and expensive.

Likewise, placement of the bus depots would have to be considered. The shuttle cannot return to the bus depot every night (as it can only drive its designated route). Therefore, maintenance has to take place close to the route. This was solved during the pilot, however, new infrastructure is needed to make this work long term.
**Integration with traffic** The AV shuttle was operational on the road with other vehicles, therefore safety measures were introduced to help facilitate the integration of the AV in the regular traffic. The road used usually had a speed limit of 50km/h, however, for the duration of the pilot the speed limit was reduced to 30km/h and advisory signs, letting drivers know they were entering a test zone of the AV, were put up on all streets entering the test area.

At Region Hannover, they have speculated whether the design of the AV could have an influence on how the other road users interact with the vehicle. The shuttle was modern and streamlined in appearance, and perhaps if the design of the future AV shuttles was more like an agricultural machine (robust), looking more strong and bright colors, the other road users would respect the AV shuttle more.

**Stakeholder engagement and learning from experience:** When planning the AV pilot, Hannover Region drew on experience from other pilots conducted in Germany (find names/places of pilots). This framed the key stakeholders to involve, and enabled a positive external engagements. For example, the police and firefighters were invited to see the vehicle and discuss the route and safety.

Also, the cooperation with the transport authorities and local authorities in Garbsen was smooth, especially, the City of Garbsen who was supportive and proud to host the AV pilot in their city. Hannover also had a positive experience with insurance companies as they were very willing to cooperate and to collect knowledge and experience with AVs for their future work with the technology. These successful engagement with many different stakeholders has been a positive experience from the pilot.

**The Future**

The AV shuttle used in the pilot is not suitable or scalable for it in Hannover in its current form. Higher speed and larger capacity are necessary technology developments for the successful integration of the AVs in the transportation system. However, there is currently a lack of bus drivers in Hannover and more AVs as part of the public transport fleet would help alleviate this problem. An ideal vision for the future would be AVs in waiting positions offering on demand services, which both could allow users to go more directly and save bus driver resources, especially at night and early mornings.
Duration: July 2022 - March 2023

Summary: The HITRANS pilot is taking place on a 3km route on the Inverness Campus. The Navya AV Shuttle has a max capacity of 15 (11 seated and 4 standing) and operational from Monday to Saturday from 10:00 to 16:30, as well as an on demand service during the evenings.

The AV shuttle transports people around Inverness Campus, the new development site that has been designated as an enterprise area for life sciences. The route connects student accommodation and the university, with the retail and business park using a new transport only bridge opened in 2020.

Learnings and challenges

The HITRANS pilot had a challenging start with the AV shuttle being out of operation because of a technical issue with a sensor that needed a replacement on the launch day. Most repairs were handled remotely with on-the-ground technicians speaking to Navya technicians in France. However, spare parts were needed to repair the sensor, which highlighted the importance of early diagnose of problems and attention to signs of upcoming breakage to ensure shortest possible time out of operation.

Importance of planning ahead: Planning and preparing for the vehicle to run is a big part of a successful pilot. For HITRANS, especially the decision of where to store and maintain the AV shuttle proved more difficult than expected. The original plan had been to store the AV in the existing bus depot, however, this turned out to be too far away form the AV route.

The solution became building a new temporary garage on the Inverness Campus. This decision and sorting out all the details took longer than expected and many factors complicated the decision. The garage first of all needed to have a charging station for the shuttle. Furthermore the security of the building had to be settled, and because of the weather conditions in Inverness and the Highlands, it was also required to make sure that the garage would stay a certain temperature even if during cold weather and heavy rainfalls.
**Requirements for route:** As the Inverness Campus is a new area with lots of ongoing developments, the area of the route was an empty open space, which made it difficult for the AV to identify where it was. To solve this problem extra signs and landmarks were put up along the route to make it possible for the AV shuttle to identify where it was. However, this meant the roads in the area were all new, so they were in good condition to run the pilot. A new prison is currently being built in the area that further complicated the integration of the AV with the surroundings, as there was an increase of construction traffic during the pilot, that potentially could interfere with the AV.

Extra signage including information signs, priorities, and rights of way signs were posted in the area to help people interact with the AV. Signage was also introduced inside the AV shuttle to remind the passengers to hold on to something when riding the shuttle. As the vehicle drives relatively slow, most people would not think to hold on to something, however, the brake can be quite powerful if it takes you by surprise.

**Communication and stakeholder engagement:** Throughout the pilot HITRANS found that good communication with all stakeholders could be challenging. Making sure that users, manufacturer, operators, campus staff, transport authorities etc. all get relevant information for them at the right time requires a lot of work, but also very important. HITRANS generally experienced good relations, and interest from stakeholders, and they where able to get early approval from the transport authorities which was not expected.

HITRANS also actively tried to involve more local stakeholder groups. The student associations and University were engage when running student awareness and to help communicate on the AV pilot. Local primary schools were also engaged to encourage the scientific and and technical education side of the AV pilot as an opportunity for them to learn, see and ask questions. Also, relations with the restaurants and shops were explored and the possibility of doing joint marketing and advertising.

People are often sceptical and scared of the new technology, and Inverness has also seen this scepticism in the feedback they have received. This has highlighted that the communications and the general messaging is key. It is important to tell people what it is, what the purpose is, and to highlight the innovation and excitement.

**The Future**

HITRANS is looking into new routes to pilot the AV technology, and a number of good opportunities have emerged on the Inverness Campus. A new national treatment center is being built near the campus site, which is expected to open in April 2023. The treatment center has limited parking space but a lot of people with mobility issues as users. The Inverness Campus has a large carpark and the AV shuttle could be used to transport people from the carpark to the treatment center. Currently, HITRANS is looking for funding as well as feasibility studies for this new route. HITRANS are also looking into which added value the shuttle might bring, e.g. considering if treatment center visitors can check in on a screen on the shuttle, get directions for where they need to go when arriving at the center, or if the pressure on the reception of the treatment center can in other ways be eased by the AV shuttle. It is worth mentioning that the idea for this new route came from the dialogue with the campus stakeholders.

For future pilots HITRANS will focus on the added value an AV can bring. This first pilot primarily focused on technical readiness and public perception, and this has paved the way for now being more focused on where an AV can bring the most value and test the vehicle in multiple different locations.
Varberg

**Duration:** Two weeks, June 2021.

**Summary:** The AV pilot in Hannover lasted for two weeks in June 2021. The route was 1 km long and went along the beach from a campsite to a parking lot used by surfers and wind surfers. Initially the route also had a stop at an area with restaurant, but this was terminated as no one used it. Also due to COVID-19 restrictions the EasyMile AV was only allowed to carry 5 passengers in stead of 9. The main users of the AV shuttle were tourists and curios Varberg citizens.

**Learnings and challenges**

*Challenging surroundings:* The AV was operational in very challenging surroundings, with flying sand, wind, rain, and lots of mixed traffic complicating the operations of the AV shuttle. The area had heavy traffic due to ongoing renovation including excavators and tractors, as well as cars, bicycles, and pedestrians. The interaction with bikes was also extremely challenging, and in general this traffic environment was not suitable for the technology stage of the AV which requires a more limited traffic environment.

The sensors of the vehicle were also impacted, especially by the flying sand from the nearby beach. In general the sensors on the AV were almost too sensitive, as such different weeds and bushes had to be removed along the route for the AV to be able to be operational. In addition, the AV model used did not have cameras, meaning that it could not identify flying sand as flying sand, as a result the sand caused the emergency brakes to be used.

Newer versions of AVs with cameras could have reduced this problem. This problem ultimately caused the vehicle to have a major breakdown suspending the pilot one day early due to an especially windy day causing too many emergency brakes. However, an interesting observation on how the AV interacted with the weather was that when raining the wind caused no issues, whilst the wind combined with sunshine caused major technical challenges. The heavy rain would keep the sand on the ground, enabling the AV to run perfectly.
Scepticism and informing the public: The shuttle was used as a leisure vehicle and to give the public an understanding of what an AV is. However, you could often walk faster than the AV Shuttle which significantly decreases the transportation value. Media coverage from local press, radio and TV helped create attention and to get many people to ride it. Many users reported that they had heard about the AV pilot on tv or the radio and brought their families down to the beach to and ride the AV shuttle. In addition, Varberg initially planned to put up information stands about AVs and sustainable mobility, however, these had to be moved online due to COVID-19 restrictions. This naturally decreased the amount of people able to ride the shuttle.

The pilot was met with a lot of scepticism. The local discussion before the start of the pilot was mostly negative, especially, the limiting of traffic and parking was a major concern making local politicians and the public angry. Also the restaurants were concerned that limiting the parking would be bad for business. However, these concerns died out when the pilot started running, and the press was more positive during and after the pilot. This AV pilot has alleviated some concerns, however, due to the somewhat poor performance of the shuttle, people may consider that AVs are a really slow vehicle that brakes all the time and sometimes break down.

Stakeholder relations: Relations were key to getting the pilot up and running. Varberg did not have any problems with the transport authorities, however the local transportation company initially had some concerns. The local transport company managed to connect the pilot to Nobina (transport operator), who already operates AVs in Stockholm. As such the Nobina staff were contracted to run the AV for the pilot period.

The AV stewards were the heroes of this pilot. Most maintenance issues and technical breakdowns were fixed on site by the stewards who were not trained in AV repairs. They were able to fix the AV every time an issue emerged, sometimes aided through phone calls by EasyMile in France or Nobina in Stockholm, apart from the final breakdown at the end of the pilot. The amount of technical issues (and difficulty and slowness of moving the shuttle to a site for repairs), highlighted the need to have support technicians based close to the pilot. However, the fact that untrained personnel were able to handle many of the issues, means that this is not so hard to accommodate.

An unexpected but very important stakeholder was the campsite owner. The camp site owner offered to provide the storage depot, and to provide a place with power available for the AV to charge. The AV was charged there in lunch hours and overnight and this temporary depot solution worked well. Also this provided good publicity for the campsite. The police also assisted by removing wrongly parked cars at the beginning of the pilot. The police showed up and fined 14 cars and the problem of wrongly parked cars has also not returned after the end of the pilot.

The Future

With the current performance and technology of the AV, Varberg currently sees no possibility of scaling. The speed of the vehicle has to be increased significantly, and the integration with other traffic, especially bikes, should be improved. Therefore, future AV pilots are not on the drawing board for Varberg, however they have considered running simulations as a way of looking into next steps. If simulations are promising, then a new pilot could be considered. Something that could be explored further is whether operating the AV shuttle on a straight line, like a bus line, is the best way, or if it is more beneficial to have the AV cover a specific area and work as an on demand service. If the speed of the vehicle is increased, application as a shuttle connecting rural areas would be interesting to explore. However, in Sweden this raises another challenge: how to prepare the AV for the wildlife, such as moose and elks, that suddenly appear on the roads.
Summary: The Almere AV pilot is a virtual pilot, which sets up three different scenarios of integration of AVs in the public transport system of Pampus, a new part of the city currently under development. The virtual pilot sets up the different simulations of how the transport system could look in Pampus with the integration of AVs. The first scenario is similar to what we know today in most cities but with the integration of autonomous or semi-autonomous buses in certain places. The second scenario presents a solution with less bus lanes and bus stops and then integration of AVs for first and last mile transportation. The third and most extreme scenario simulates a completely demand driven and autonomous transports system, with both smaller and larger AV shuttles with no fixed routes but operating on demand from citizens. Both scenario two and three would free up city space for other functions than transport, for example, to be used for parks or recreational activities.

Learnings and challenges

From physical to virtual pilot: The Almere pilot was originally planned to be a physical pilot like the other pilots in the PAV project. In the process of preparing for the pilot, Almere conducted interviews with other cities in the Netherlands who had implemented pilots, as well as with the roads and transport authorities who approved the pilot. They discovered that the necessary processes for getting the approval is a complicated one, involving many stakeholders and taking at least a year from start to approval. Because of this as well as COVID-19’s impact on the work tasks, Almere had to rethink the pilot. An interesting learning in the process was that the transport authorities in the Netherlands are actually interested in piloting and developing the AV technology further, although the rules are strict and the process long. They are focused on the value added from the pilots and want to see pilots not seen before in the Netherlands or Europe.

Due to these constraints, the solution became making a virtual pilot. The development of the area Pampus provided a good opportunity to explore what the integration of AVs in the transport system means for the development of a new part of the city, and to involve city planners in the early stage.
New thinking: The cooperation with the city planners around mobility and AVs at such an early stage has opened up the possibility of considering transportation in a new way and explore how it could be development differently. The simulations allow for discussion and analysing implications of different transportation choices virtually. This opens up the opportunity of really designing the transportation system with the peoples' needs in mind, and addressing the problems and challenges at the start of the process.

The third scenario presents a model where almost no private cars are used, and in general less space has to be taken up by transportation. This is something that could have great implications for the general infrastructure, and free up space for other functions, which changes the way the city planners can think about the public space. In general, the virtual pilot has sparked a lot of new thoughts and the fact that the virtual pilot is not restricted by physical boundaries, might have helped people to think a bit more creatively on mobility.

Relying on data: In order to conduct the simulations, Almere had to rely on data and predictions to make their simulations of how the new area Pampus could look as accurate as possible. Experts on public transport and the mobility department of the municipality made analyses on how many people would live there, the expected employment opportunities and how many would use public transport. Experts on behavioural economy also contributed with input in terms of what people do, what they like etc.

The pilot team worked with the mobility department and had them use their transportation models to predict different scenarios. However, this is a complicated process. Just changing one thing in the model and waiting for the outcome takes a couple of days. A better knowledge of these models at an early stage is something that could be valuable in the future.

The input from different experts in this sense has been key to making a good simulation. The municipality is often split in different islands, not always interacting, and this was the first time the city planners had been engaged in this way. The experience from the pilot has been that it is important to team up across departments and that it has been valuable to have input from different points of view.

For the simulations, data has been collected to make the simulations as accurate as possible, but there is still a need for more data which would be interesting for the next step to make the scenarios more concrete and to make more detailed calculations on what the scenarios would mean for peoples' time and cost of transport.

The Future

Almere believes that the tool of simulations can be a good tool for other cities to use in the future for planning the integration of AVs in a city. It is a good way to start the discussion and thoughts on implications and possible solutions if AVs. In terms of implementing the scenarios proposed in the pilot there is still some way to go. The simulations and data are still being developed and no decision has been made for implementation and technology developments that need to happen outside the simulation.
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