Sohjoa Baltic

The Roadmap to Automated Electric Shuttles in Public Transport

Starting Your Own Pilot

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Credits

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This publication has been made in the Sohjoa Baltic project (2017-2020) funded by Interreg Baltic Sea Region Programme. The aim of the project was to bring knowledge and competence on organizing environmentally friendly and smart automated public transport, provides guidelines on legal and organizational setup needed for running such a service in an efficient way.

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Foreword

The upcoming years are crucial to the development of automated driving in Europe. The technology has great potential to serve public interest by improving the environmental sustainability of traffic and making transit safer and more enjoyable for everyone. Cities are finding solutions for more sustainable mobility in the public transportation sector. The automated (progressing to autonomous) vehicles aim to solve the cities' needs to lower traffic emissions, provide better public transportation services, reduce human-related accidents and save resources. It is believed that once the vehicle technology is mature enough, the piloting proceeds into regular autonomous public transportation services.

Starting Your Own Pilot was co-created with the Sohjoa Baltic partner consortium as a practical guidance and recommendations for future actions in order to progress the Baltic Sea region authorities' regulatory development work that enables the mobility and transport sector to create new service innovations and business opportunities. This publication describes the roadmap for short, medium and long terms and serves the urban planning authorities, urban transport authorities, companies providing public transport, traffic safety authorities and private sector innovation, service developers and academic and research institutions in their work as well as increasing awareness and improving acceptance of current and new users of public transportation.

The current publication provides guidelines for organisations who wish to include automated transport options to their urban public transport chain through the following sections:

- **Chapter II Pilots at a glance** which describes all the pilots of the Sohjoa Baltic project;
- **Chapter III Automated vehicles implementation toolbox for cities** which provides practical insight on how to set up a pilot with automated buses, including information about costs, benefits and safety;
- **Chapter IV Policy recommendations** which provides a number of recommendations at the national and EU level which support the piloting and further development of automated buses in Europe.

The knowledge is retrieved from the implementation processes of six urban areas that jointly decided to run automated mobility trials between 2018-2020 in the Baltic Sea Region, co-financed by the European Union's Interreg (BSR) programme, under the Sohjoa Baltic project. The regulatory requirements and conditions in the partner countries in the project vary greatly for testing autonomous vehicles on public roads.

"What kind of toolkit is needed to deploy an autonomous vehicle pilot?"

"Is it possible to integrate autonomous vehicles as regular service into public transportation?"

"What did we learn from the Sohjoa Baltic pilots in Estonia, Finland, Norway, Poland and Latvia – or Denmark?"

"What policy recommendations can be given?"

About Sohjoa Baltic

The Sohjoa Baltic project developed the knowledge and competences required to organise environmentally friendly and smart automated public transport by researching, promoting and piloting automated (driverless) electric minibuses as part of the public transport ecosystem, especially for the first/last mile connectivity. It also provides guidelines on the legal and organisational frameworks needed to operate a service of this kind in an efficient way. The Sohjoa Baltic consortium has partners from Finland, Estonia, Sweden, Latvia, Germany, Poland, Norway and Denmark with expertise in transportation planning as well as legal expertise combined with a strong technical understanding.

Sohjoa Baltic brought autonomous small buses to drive demo routes in Baltic Sea Region cities. The autonomous bus scans its surroundings and knows when to slow down or stop completely if there are obstacles in the way. During the pilots there was always an operator on board.

With a run time from 10/2017 until 09/2020, the Sohjoa Baltic project was funded by the Interreg – Baltic Sea Region programme.

Info

What are automated vehicles?

Automated vehicles are vehicles that rely on an automated driving system rather than a manual system. This means that they can operate without human intervention (SAE level 3 and higher).

What is a vehicle operator?

The vehicle operator (also known as the ‘steward’ or ‘safety driver’) is a physical person who is present onboard the automated vehicle to guarantee safe operation, even in situations where the automated driving system fails to perform as intended. In such situations, the vehicle operator can override the automated driving functions and assume control of the vehicle.

Executive Summary

The Sohjoa Baltic Roadmap to Automated Electric Shuttles in Public Transport volume **Starting Your Own Pilot** provides an overview and guidance to the practical issues that arise when planning implementation of automated buses as part of public transport.

Cities participating in the Sohjoa Baltic project had their first or one of the first pilots implemented in their country within the project. Practical implementation of the pilots in real city environments proved that automated buses can already be operated on open streets among other road users but there are still limitations for making the service fully viable. These challenges mainly relate to the technology of the buses, legislation and daily tasks that are included in the operational service.

Two of the greatest obstacles to autonomous public transport seem to be the asynchronized development pace of both the legal and regulatory frameworks as well as supply and demand of the novel vehicle types. For cities, to gain practical understanding on autonomous public transport and how it serves the users before investing permanently in these novelties, it is recommended to deploy a pilot in the region. Implementing new technology to different surroundings and for various user groups convey versatile use case data to the vehicle manufacturers and operating businesses, leading to development of technology, product design and services.

This publication was prepared with the input of partners in the Sohjoa Baltic project, which developed (2017-2020) the knowledge and competences required to organise environmentally friendly and smart automated public transport. It also provided guidelines on the legal and organisational frameworks needed to operate a service efficiently.

After the successful national robot bus project SOHJOA in Finland, there was an initiative to share the knowledge and experiences transnationally, and Metropolia University of Applied Sciences, together with Finnish partners, searched for more partners interested in automated shuttle piloting in the Baltic Sea Region. The project consortium was formed and with a positive funding result from Interreg (BSR) supporting the project, Sohjoa Baltic was born.

The project's automated electric shuttle bus pilots were executed as close to real life conditions as the legal framework in each country allowed in Norway, Poland, Finland, Estonia, Latvia and Denmark. The pilots were divided into three large scale (months) and three small scale (weeks) pilots. The large scale pilots were coordinated by the municipality of Kongsberg and the small scale pilots by the city of Gdańsk in Poland.

Table 1: Pilots driven in Sohjoa Baltic 2018-2020

	Year	Months, total	Operating days / week	KMs driven, total	Passengers, total	Max. driving speed for the bus on the route (km/h)**	Length of the route (km)
Kongsberg	2018/2019	9	5	3356	2536	16	5.0
Helsinki	2019	4	7	2596	3932	18	2,5
Tallinn	2019	4	5	4000	3952*	15	1,7
Gdańsk	2019	1	7	632	3325	15	1,8
Zemgale (Jelgava)	2020	0.5	7	618	3817	13	1
Zemgale (Aizkraukle)	2020	0.5	6	432	1877	15	0.74

**Tallinn pilot during Aug-Dec 2019. ** In Tallinn the max speed of the bus was limited by the decision of the Road Administration. In some pilots it was also driven on pedestrian lanes which limited at least partly the driving speed. Otherwise the speed was limited due to bus technology. Speed limits on the roads of the pilot routes varied between 30 and 60 km/h. 18 km/h was however technologically the maximum achieved speed in the pilots, when there were no other specific limitations.*

The large scale pilots in Kongsberg, Helsinki and Tallinn were planned to take 8-12 months each. The small scale pilots in Gdańsk, Zemgale and Vejle were planned to last 1-2 months. Deviations from the original piloting plan occurred in Vejle, Denmark due to not only the short time and service providers' lack of interest but also the complexity of Danish national law regarding this type of activities. In Tallinn, Estonia the piloting ended early in December due to limitations of the vehicle technology but resumed in June.

I. Introduction and methodological overview

1. Roadmap for developing automated first and last mile solutions

Automating transport is already taking place in many cities, starting from driverless metros and trams to tens, if not hundreds, of driverless shuttle bus trials in the urban environment. It is clear that automating urban transport cannot happen without the proactive role of the cities involved. The role of cities can be twofold: 1. cities can invest themselves into new technologies or 2. cities can reduce barriers for companies to test their solutions in an urban environment.

The main aim of the current Sohjoa Baltic project publication is to provide information to relevant public and private sector actors which could help them to bring automated shuttles on the streets. The information is provided in several different ways. First, in Chapter II, the publication provides insight into the successful but also into the failed pilots. By using the PESTEL framework (described below), the pilot descriptions provide information about the different factors that helped or hindered the running of pilots. The chapter includes descriptions about completed and ongoing pilots in Helsinki, Gdańsk, Tallinn, Zemgale and Kongsberg. The latter has been an especially successful pilot and the municipality has managed to establish a stable service. The chapter also describes why Vejle in Denmark did not manage to bring an automated bus to their streets.

Chapter III provides a step-by-step guide - a toolbox - for cities that want to run their own pilots or want to have a stable transportation service provided with automated buses. The step-by-step guide is based on the experiences of the Sohjoa Baltic project but also on past pilots run in Helsinki City.

The aim of Chapter IV is to provide policy and business recommendations which could help to reduce barriers that hinder the wider use of autonomous vehicles. The recommendations are based on the use cases of Chapter II.

2. Methodology and structure

In Chapter II of this publication, the PESTEL framework is used to describe the pilots in each country. The PESTEL framework and variations thereof are often used to evaluate macro-environmental factors that can impact an organisation (or in this case pilot projects) and its specific processes. In the current publication the framework looks at the following factors:

- Political - this factor focuses on the influence of the political environment. In the context of pilots of automated buses, one can look at how supportive the politico-administrative system is towards the technology, its adoption and diffusion.
- Economic - this factor focuses on business models, taxes, innovation, consumers, jobs, trade, etc. In the context of pilots of automated buses, one needs to take into account the costs of operation compared to the gained knowledge, financial sustainability, what the suitable business models for the technology are, how to build the local economic ecosystem around the technology, etc.

- Social - this factor focuses on the demographics, user acceptability, values, lifestyle, etc. In the context of pilots of automated buses, one needs to have sufficient information about the public attitudes towards the technology, including who the potential users are, in what conditions the technology is accepted by users, etc.
- Technological - this factor focuses on the technological aspects which can affect an organisation and its activities. It includes factors such as the maturity level of certain technology, innovation, research and development, patent regulations, technical requirements, etc. In the context of pilots of automated technology, one needs to be aware of the technical requirements the buses need to meet and what limits the current level of technological development sets on pilots (e.g., potential routes, speed limits, etc).
- Environmental - this factor focuses on the environmental factors and sustainability. In the context of pilots of automated buses, the focus is on how technology helps to improve but also hinders environmental sustainability.
- Legal - this factor focuses on legal aspects that can influence an organisation and its activities. In the context of pilots of automated buses, it is important to look at how the technology is regulated, which permits are needed and by whom to operate automated buses on the streets, how legal liability is regulated, and how experienced the public sector is with innovation procurements.

The end of Chapter II tries to answer the question whether the pilots fulfilled their purpose, what should be done differently during the next pilots, and what the lessons learned are.

Chapter III gives detailed instructions on how to organise and run an autonomous last mile pilot. It also informs the reader about the things to consider before organising such a pilot. The main idea of Chapter III is to provide a toolbox for countries and regions and their relevant organisations that have not yet run a pilot but wish to do so in the near future.

Based on the pilot descriptions in Chapter II and the pilot toolkit in Chapter III, Chapter IV of this publication also proposes general policy recommendations for the future. The recommendations will focus on three different stages: planning, short- and long-term pilots, and building a sustainable service.

II. Pilots at a glance

The current chapter will describe the six pilot cases of Sohjoa Baltic project. These include completed pilots in Kongsberg, Helsinki and Gdańsk, ongoing pilots in Tallinn and Zemgale, and a pilot that did not even have the chance to start in Vejle. The descriptions follow the PESTEL framework described in Chapter I and are based on document analyses as well as interviews with people involved in planning and carrying out the pilots. We will first cover the three longer-term pilots and then the three short-term pilot cases.

1. Use cases

a) Estonia, Tallinn

The Sohjoa Baltic pilot was the second automated shuttle pilot in Tallinn which followed the short-term show-case pilot organised by the Government Office of Estonia in summer 2017 as part of Estonia's Presidency of the Council of the European Union. One of the key reasons why Tallinn decided to participate in the Sohjoa Baltic project was the fact that transportation in general is going through a massive digitalisation. The city saw that the participation in the project could help to gain knowledge about the technology and would also help to be at the forefront of its development.

Political factors

Tallinn City was included in the project through Tallinn University of Technology (TalTech). In the city government, the project was initially pushed forward by the Strategy Unit. Over time, Tallinn Transport Department realised that the project gave them an opportunity to see how far the technology has currently developed and how it copes with the local infrastructure and weather. The project also had full support from the Mayor and the Vice-Mayor responsible for transportation.

Economic factors

From an economic perspective, while there are no clear estimates, most participants perceive that in terms of gained knowledge, the actual costs of operation have paid off. Tallinn Transport Department and TalTech have both gained valuable knowledge on how to set up an AV service.

At the same time, one has to be aware that most of the pilots in Europe, including Estonia, have been so far co-financed by different EU funding mechanisms. It shows that the business models for the autonomous (last mile) transportation service are still in a development phase and therefore transport authorities and providers are not willing to make serious investments in this field. In the case of Tallinn, the availability of Interreg funds certainly motivated the city to have a local pilot sooner than later.

At the same time, due to the fact that many cities around Europe are interested in the technology, partly because of the availability of the EU funds, the rental prices of autonomous shuttles have significantly gone up because of the increased demand.

Most of the companies that are developing and/or providing automated shuttles are start-up companies that are still figuring out their exact business model and are very vulnerable to changes in the economic environment. For example, the Navya shuttle operating in Tallinn was initially provided by the Danish company Holo which is owned by Semler Gruppen. However, after the Covid-19 crisis struck, Holo had to stop its operations. The only reason the Tallinn pilot was able to continue was the fact that the used Navya bus was acquired by the Estonian company Modern Mobility which also was the local partner for Holo.

Overall, both the economic calculations of actual pilots as well as the uncertainties related to the collaboration with the start-up sector show that such piloting activities should not be initially treated and assessed as part of traditional public transport services but rather as part of more risky and uncertain public sector innovation and general innovation policy initiatives.

From this perspective, the different pilots have kick-started the emergence of the local innovation ecosystem around the autonomous mobility technologies and services. The first pilot happened in summer 2017 and was organised by the Government Office of Estonia as part of the country's EU presidency. The route had two Easymile buses which were maintained and operated by the local company Milrem (now Milrem Robotics) which develops and produces modular unmanned robots for both military and civil purposes. It was followed by the initiative to develop an automated shuttle for the 100th anniversary of TalTech. The bus was co-developed by a development team from the School of Engineering in TalTech and car distributing company Silberauto. A spin-off company called AuVeTech was later established. The company later became a member of one of the consortias which made it to the last round of the FABULOS project. The project uses a pre-commercial public procurement procedure to support the development of autonomous bus service solutions. The other companies in the Estonian consortium are Modern Mobility, TalTech and Fleet Complete. The consortium has also included Bercman Technologies into their Tallinn pilot. The company develops and produces smart bus stops, intersection control units and smart pedestrian crosswalks.

Social factors

During the first stage of operation between August and December 2019, a survey was conducted among the passengers with an aim to find out: user acceptance, perception regarding traffic safety and personal safety on board the bus, and passenger demographics. Similar surveys were also conducted during other pilots of Sohjoa Baltic project and a separate publication focussing on the aforementioned aspects will be put together by FLOU. In Tallinn, an additional survey was conducted among students who had not driven with an automated shuttle. Interestingly, the comparison showed that people who had first-hand experience with the technology scored significantly higher in traffic safety and personal security. Such results show that pilot projects such as Sohjoa Baltic are necessary for the public to get to know the technology.

Before the actual pilot, Tallinn Transport Department notified the local residents and businesses in Kadriorg about the pilot and traffic changes, which at one part of the route changed the traffic from two-way traffic into one-way traffic. The change was necessary because of a narrow road in that part of the route which caused dangerous situations when heavy duty vehicles such as garbage or street cleaning trucks were approaching. Already before the project, several local residents had turned to the Transport Department so that the traffic would be changed in that area. The project gave an additional argument for such changes. However, not all local residents and businesses were happy about the implemented changes. It shows that a more thorough inclusion of local residents and businesses is needed for such projects. Otherwise, the pilots can have a negative effect on user acceptability without the locals even using the vehicle.

Technological factors

Before starting procurement, the project partners agreed on the technical requirements of the buses. The technical requirements for the buses were developed together with project partners from Kongsberg municipality, Metropolia University of Applied Sciences, Chalmers University of Technology, Tallinn Transport Department and TalTech. This was done to ensure the overall safety of the pilots and that the buses would cope with the local climate conditions. At some point the idea was even to have one single procurement for all three long pilots.

The priority for the Tallinn Transport Department was to run the pilot in open traffic. However, the current development level of the technology set the limitations on the possible routes. The traffic intensity on the streets of Tallinn is high. Many people prefer to use a private car over public transport as the average travel time with the latter is two times longer. In addition, based on experiences of the previous pilot in Tallinn where buses were driving slowly and even on a separate lane, there were fears that a pilot in open traffic with high traffic intensity where other cars drive 2-3x faster would not be safe for passengers. Therefore, the aim was to find a suitable route with low traffic intensity where last mile service would be necessary. The decision fell on one of the most popular leisure places in Tallinn which is Kadriorg Park. The route was planned as a tram extension between the Kadriorg tram stop and the Estonian Art Museum (ca 700 metres). The area has a low car traffic intensity and a large number of pedestrians.

As the route was in the park with a lot of trees standing next to the road, the pilot experienced several technological challenges. The high trees of the park blocked the GNSS signal in several parts of the route which made it necessary to adjust the programming accordingly. In addition, because of the seasonal change and leaves falling from trees, the bus did not recognise the surrounding environment as it did not match the pre-recorded map. The situation jeopardised the whole pilot as recording a new map would have been too expensive. Fortunately, the problem was solved by Navya.

Environmental factors

One of the goals of the City of Tallinn is to become the Green Capital of Europe. The City of Tallinn aims to fully switch to electric transportation by 2035. As the idea of the project was to test electric autonomous bus-shuttles, the city administration acknowledged the potential of this project. However, the main motivation for the city to join the project was to test last-mile mobility solutions.

Legal factors

The Estonian legal environment is very supportive in allowing autonomous vehicles on the streets. In June 2017 the Riigikogu, the Estonian parliament, changed the Traffic Act to allow delivery robots on the streets without a physically present user. Autonomous pilots were allowed without a single change in legal acts. As autonomous vehicles still have to have an operator, either on board or remotely, the liability lies with the operator. However, in the long run, changes in law are required as the decisions made by artificial intelligence are not currently regulated. The legislation to regulate artificial intelligence should be published this year. A more detailed overview about the legal environment of Estonia can be read in The Roadmap to Automated Electric Shuttles in Public Transportation: The Legal Framework (PDF).

The City of Tallinn procured an automated shuttle bus for the first time and this process took more energy and effort than was planned. Ideally, Tallinn wanted to launch its pilot already in late 2017 but this took more time due to weak supply, rental price changes in the market, and also internal procurement capabilities of the city. A more detailed description of the procurement process in Tallinn can be found in the volume Sohjoa Baltic: Procurement Challenges.

The fact that autonomous technology is still in its' early stage of development has also posed legal challenges in terms of the contract between the city and the procurer. Tallinn Transport Department and TalTech did not foresee the technical issues that stopped the operations of the bus for hours or even for days several times. For example, the contract did not describe in too much detail how many hours a bus has to operate on each operational day. Therefore, the definition of 'operational day' remained somewhat fluid. However, as cities are responsible for the responsible use of public money, this issue was a challenge for the Tallinn Transport Department.

Key lessons

The Estonian case further emphasized that for launching autonomous mobility pilots, focus on innovation (search, experimentation, learning) as opposed to traditional public transport service concerns (efficiency, reliability) may provide opportunities to kick-start a broader innovation ecosystem around novel technology and services. Still, the participation of both the city's or government's innovation unit as well as core service providing units is crucial for broader benefits and sustainability of the piloting activities. Also, the cumulative learning effects of several consecutive pilots may enable societal, legal, technological and economic lesson-drawing that may be a key factor leading towards sustainable uptake of autonomous mobility technologies.

b) Finland, Helsinki

After the successful national robot bus project SOHJOA in Finland (2016-2018), there was an initiative to share the knowledge and experiences transnationally, and Metropolia University of Applied Sciences, together with Finnish partners, searched for more partners interested in automated shuttle piloting in the Baltic Sea Region. The project consortium was formed and with a positive funding result from Interreg (BSR) supporting the project, Sohjoa Baltic was born.

Political factors

The Helsinki city strategy, **The Most Functional City in the World (2017–21)** states that Helsinki aims to pioneer an overall smart traffic system and encourages transition into a demand-driven traffic system, as well as serve as a testing platform for new smart mobility solutions enabled by current transport legislation.

This kind of strategy generates good foundations for testing automated vehicle solutions in the city. Companies, and especially small start-ups, need funding for the development through use cases that should be mainly focusing on the technical development of the vehicles and the related services (such as remote supervision and on field activities). The pilot in Sohjoa Baltic was a good example of activity where Helsinki acted as a testing platform of new smart mobility solutions enabled by current transport legislation in Finland.

The Helsinki pilot route planning and operation involved cooperation with the Helsinki city traffic planning: the route was recommended by the city. The route was located to serve passengers of the eastern metro terminus at a busy public transport hub. It was estimated that the chosen route was such that the vehicles could perform successfully during the summer. This highlights the importance of involving relevant parties in the route planning. On a more practical level, the public transit authority, Helsinki Regional Transport (HSL) was collaborating with the route planning. This was one of the drivers to succeed in piloting, as the autonomous shuttle was operating partly on the same route and using the same bus stops as the regular HSL bus traffic. The pilot service was integrated to the HSL's Journey Planner app and had an official line number (90R), following the tradition of regular intercity traffic in the area. All the raised questions concerning the piloting were solved together. The supportive attitude of the city towards experimental culture helped to implement the pilot, as well as creating pressure on the persons responsible for certain areas from the city side.

Economic factors

As the lead partner of the project and with previous experience of automated bus pilots, from route planning to procurements and deployment of pilots, Metropolia University of Applied Sciences was advising and assisting other partners in planning and implementing their robot bus pilots. However, it was not anticipated that between the time of applying for funding for the project and executing the pilots, there had been change in the markets. In just a couple of years, while the vehicle technology was still being immature for regular service in any open road conditions, causing restrictions for the operating environment, the supply of the vehicles had become more service-oriented. Instead of buying or leasing the vehicle, the procurement had to incorporate also the operation of the vehicle, and this changed the nature of the call for tenders and the agreement processes. It also had an effect on the expected cost level. The service providers were still in small numbers and they were pushing to implement longer piloting periods, as the cost of deployment of small scale pilots was not necessarily providing them with sufficient revenues. This led to a situation where the small scale pilot partners were lacking choices - and even large scale pilot partners had to do preliminary work to receive at least one offer. For Sohjoa Baltic, the received project funding was eventually insufficient to cover the originally planned operating time due to higher expenses of the vehicles and services, and the piloting periods were cut back up to 60 % in case of Helsinki. Especially in short-term pilots, leasing a vehicle(s) for a period of time instead of buying is most likely a cheaper and more sensible option for the subscriber as the technology is rapidly obsolete.

Just leasing the vehicles might be a difficult task, and the procurer/subscriber should prepare for leasing the full operational service. This is also the recommended option for a subscriber who cannot easily find personnel to assist with the practicalities of the deployment and operation of the vehicle in the pilot. On the other hand, for instance a local public transport operator company might need to be involved in the process in order to have operators who are able to speak the local language. A procurer should be prepared to assist the supplier, especially if the company is foreign and has no established offices at the place where the activity is conducted, even if the service is procured as a "turnkey" solution, as was done in Helsinki. However, this kind of collaborative work between the procurer of the service and the supplier is most likely already the case to some extent with normal actors in public transport as well.

Social factors

The pilot area was in Helsinki's eastern suburb, Vuosaari, with 35K+ residents and 5K+ workplaces. The chosen route connected the public transport hub and the nearby Aurinkolahti beach area. In total, 3932 passengers took the ride and some of them were interviewed during the pilot, using a survey questionnaire. The answers showed positive feedback. As the pilot was running during the daytime, the majority of users were elderly and families taking a joyride. For the passengers, approaching the vehicle and getting familiar with the technology was mitigated by the safety driver onboard, e.g. a human that could guide and answer questions. Many suggested that this type of "slower ride" would suit to serve the elderly or that it would benefit those in need of assisted mobility. However they were not so certain if they would feel safe and secure if the human safety driver were not inside the vehicle.

On the other hand, people who were driving with passenger cars or other vehicles behind the bus on the route did not share this praise - the frustration of driving behind the relatively slow robot bus was occasionally seen on the drivers' faces - even though these views were not systematically reviewed. According to the operators of the robot bus, some overtakings were also witnessed, which emphasises the importance of the ability to keep up with the traffic flow. Overtakings on an urban district road with several zebra crossings and intersections can be hazardous. The operational areas are also important to choose to match with the pilot vehicles' speed, currently being around 20 km/h at the most. In Aurinkolahti, the area speed limitation was 30 km/h, which can be considered the maximum recommended speed for a pilot area, and the speed difference between other vehicles and the robot bus was then theoretically already around 30%.

Technological factors

Before starting the procurements, the project partners agreed on the technical requirements of the buses. The procurement can not be done based on clear needs of the procurer alone, it still has to take into account the limitations in the technology. The technology of automated vehicles is constantly evolving, there are no complete products on the market that offer more flexible and cost effective solutions for a public transport service than currently exists. Delivery times can be long, due to the limited amount of suitable vehicles and operator staff training needs. The companies are rather small and their production capability is limited. The total market size of automated public transport is still at a very early stage.

The Helsinki pilot's operating services came from Danish company Holo, who used vehicle provider Navya's Autonomous Shuttle robot bus for the procured service. For certain tasks, Holo was dependent on the services provided by Navya, this applied for instance to the route programming. More complicated maintenance services were also the responsibility of Navya.

The duration of the piloting operations was 4 months, from June to September 2019. In addition, Holo reserved circa 2 weeks in May for deploying (mapping and programming) the vehicle on the route. Passengers were not allowed to get on board the vehicle during this time period. After the deployment, the actual pilot service with passengers onboard was arranged so that the vehicle was operated 6 hours per day and 7 days per week.

Towards the end of the operation period, a battery related issue came up, which could not be fixed in time for continuing the operation. A spare vehicle was planned to be kept ready at Metropolia's garage by Holo at the beginning of the operation, which could have been a solution for the issue, but this was not implemented. Due to a lack of necessary on-site technological expertise and spare parts, the bus was operated from the 18th of June to the 11th of September, over a month less (37 days) than initially planned. This highlights the need for locally established offices and vehicle depots as well as availability of technological support near the operational routes when dealing with prototype vehicles.

For planning a pilot, time consuming tasks also include road infrastructure modifications, like stop signs, stop areas, and speed limit changes, which requires cooperation with city and transport planners. It might be necessary to also put effort into marking the bus stop places on the streets, other road paintings, traffic light integrations, warning signs, etc. in order to raise attention (safety and marketing benefits) and succeed with the pilot technically. In the case of the Helsinki pilot, no arrangements other than bus stops were needed, including only reservation of some road side parking places and installation of bus stop signs for temporary pilot use. Leaflets to inform of the ongoing pilot were also laid out at existing official HSL bus stops which were used in the pilot as well.

The pilot vehicle's storage and charging possibilities outside of operational hours were not available near the pilot route by default, but were necessary to be arranged, as it was not possible to drive long distances on busy roads with the robot bus. A suitable place was arranged at a local boat club's (Vuosaaren Urheilukalastajat ry.) yard, where a tent was set up and electricity could be provided. Storing more than one vehicle temporarily would have been a much more difficult task. Having a temporary storage place that was congruent with the outside temperature was also limiting the possible operational period, as it was not possible to charge the robot bus in sub zero temperatures (winter time).

Environmental factors

The City of Helsinki's climate strategy supports actions taken to render the city carbon neutral by 2035. So far, robot buses have been seen to theoretically contribute towards this goal by supplementing the existing public transport network by improving last mile connectivity and in general improve the public transport service level in sustainable ways. However, taking into account the current capabilities of robot buses, so far it has been difficult to find routes in Helsinki, where robot buses would actually bring significant added value to the public transport service. The current public transport network is quite comprehensive and few areas remain uncovered. Serving the current public transport users with an additional mobility solution while replacing walking and cycling on last mile trips is not a sustainable way of deploying automated buses. Future actions regarding the implementation of robot buses in the city should focus on areas where public transport is not already comprehensive and where there is a good potential for affecting private car users while increasing the modal share of public transport.

Electric vehicles also cause CO2 emissions, not locally but at some point of the vehicles' lifespan, either during the production of the vehicle or of electricity. The average CO2 emission factor for electricity production in Finland calculated as a three-year moving average is 141 kg CO2/MWh. In addition, some of the robot buses can use alternative sources of fossil based energy, such as diesel fuel, to heat the cabin, especially in extremely cold temperatures. Within public transport, there are better possibilities to affect what kind of energy is used by the vehicle fleets and how the energy is produced. Also production of near CO2 neutral renewable diesel has made good progress in Finland, which is improving the sustainability of fuel usage. In general, the ambition in Helsinki is to increase the amount of public transport buses with electric drivetrains.

Legal factors

In Finland, pilots in road traffic with automated vehicles have already been run for some years, and the foundations are in good shape legalwise. To operate an automated vehicle in road traffic, a test plate certificate has to be issued. The test plate certificate (including test plates which are mounted on the vehicle) is applied for at the Finnish Transport and Communications Agency (Traficom). Attached to the application are needed: the vehicle technical specifications, a risk analysis, an excerpt from the Trade Register, a route plan and a description of the operation. A compulsory motor insurance for the vehicle has to be acquired as well. Traficom processes the application and if found admissible, issues the test plate certificate and the related test plates to be installed on the test vehicle.

Traficom requires that the person using the test plate certificate is the one to whom the certificate has been issued, i.e., the user is the holder or representative of the test plate certificate. Usually this means an employment relationship, but other agreements between the user and the certificate holder have been accepted as well. For the large scale pilot in Helsinki, the certificate was applied for by the Danish service provider Holo, from which the service to operate the bus was procured. It was initially planned to use Metropolia's test plates (already issued earlier) but it turned out to be a more simple solution that Holo applied for the certificate by themselves. With some help from Metropolia, the process seemed to be quite straight forward also in case of Holo and took around one month (including the application processing time).

The Helsinki pilot service provider was Danish company Holo (Autonomous Mobility A/S at the time). Collaborating with a non-national company, assistance was needed. One of the obstacles was the fact that Holo needed to establish a branch office in the Finnish trade register to proceed with the test plate certificate application. Having a Finnish company ID is a prerequisite to gaining the test plate certificate. In addition, it was agreed to have Finnish-speaking operators in the bus, so the first collaborative task was to help Holo with the recruiting process. The simplest way of proceeding seemed to be recruiting Metropolia's students, and 3 students were hired for the task. Assistance for the local salary and contract of employment issues was given as well. A better solution regarding the operators' recruitment would have been to involve local public transport operator companies or some other local organisations with possible interest in developing the capacity for operating automated vehicles and related business.

Key lessons

A systemic experimental culture in government is always an asset for innovation pilots such as running autonomous buses. Yet, the rather long Finnish experiences with different autonomous mobility pilots while constantly facing technological obstacles in fulfilling the desired outcomes from operating new technologies with high potential socio-economic and environmental impact, show that the public sector needs to show some patience in supporting the technological development and maturing of these technologies. At the same time, the Finnish experience also shows that developing local technological and services ecosystems is necessary for the stability and resilience of such technologies and related services.

c) Norway, Kongsberg

The Municipality of Kongsberg decided to establish a national and international test site for autonomy in autumn 2016. As a technology city hosting global high-tech industrial companies, the municipality focuses on business development for international scaling. Against this background, the Municipality of Kongsberg became a partner in the Sohjoa Baltic project, and successfully implemented a sustainable service.

Political factors

While the municipality acted as the project owner, Statens Vegvesen (The Norwegian Public Roads Administration) was the financial partner in the project, contributing 50% of the project funds and making valuable contributions to preparing the pilot. Applied Autonomy as the main supplier took care of the required system integrations.

To choose the partners that were ultimately part of the Kongsberg pilot, Kongsberg municipality took into account the transport system as a whole, as well as its wider context. From the start, the aim was to build a solution centred around profitability, accessibility, security, business development and green transport. In order to achieve a system that would be truly accessible for all, it would have to fulfil a number of geographical and technical constraints, but also be financially affordable for all citizens. In particular, the project enjoyed political support as it fit Kongsberg's "vision 2030", which amongst other things prioritises sustainable transport solutions.

The Kongsberg pilot was marked by the fact that it was built on a partnership between commercial actors, transport providers, the authorities and the university. These partners were – and still are - pursuing common ambitions, wanting the project to succeed while being open to facing the challenges ahead. In 2020, the city will pilot autonomous bus operation without any host on board. The pilot has been a success and represents a big step towards full scale autonomous passenger transport in cities and towns.

Economic factors

The interplay between partners was crucial to the Kongsberg pilot, as the project's ecosystem ensured the focus on business development needed to integrate the service into regular public transport. Statens Vegvesen provided valuable information and input regarding not just ongoing road operations but also regarding maintenance, and plans for future road infrastructure were shared and helped significantly to shape the project. There was also active communication and encouragement between the subcontractors coordinated by Applied Autonomy. In particular, transport provider Vy encouraged public transport company Brakar to join the project from the start which proved very valuable. Having a public transport company on board meant that there was increased focus on pushing forward a technology which was originally not mature enough for the intended purposes.

The focus on a scalable, sustainable and holistic solution in line with national business development efforts led to the Sohjoa Baltic project effecting an industrialised solution with a number of facets. Knowledge was continuously shared between the partners locally and through the website https://www.cityandlab.no/, which furthered Kongsberg municipality's ambition to develop Kongsberg as an international test arena for autonomous driving and attracting companies that develop related solutions. The City&Lab platform has since also been used to coordinate and advertise further projects with similar character, and also inspired other pilot projects in Östersund in Sweden, Salzburg in Austria, Trondheim, and others, covering autonomous transport but also other autonomous vehicles.

Social factors

Statens Vegvesen contributed essentially to the project's social factors. Aside from carrying out and assisting with risk analyses for the project, continued discussions and an ongoing professional dialogue meant that concerns regarding for example road safety or accessibility could be addressed and tackled from the start. This in turn made the entire process significantly smoother, as concerned parties were included from a very early stage, making later adjustments to accommodate for different needs unnecessary. They also gave talks to share their experiences at project seminars and hosted their own forum to facilitate discussions between the project participants in Kongsberg around shared plans, visions and ambitions for the future of transport. Additionally, they promoted autonomous transport at the Arendalsuka event, which brings together businesses, organisations and political parties from all over Norway. In Kongsberg, local business owners were given information in the form of flyers and invited to attend a workshop that let them voice their concerns about this new technology, with questions ranging from safety concerns to the bus potentially blocking delivery access. Additionally, the municipality had an open dialogue with all shop owners in the pedestrian zone where the bus is driving, and invited them to opening events to make sure that they too were included.

Via the surveys conducted by Brakar throughout all stages of the project, it was also established how passengers felt about the project in particular and autonomous transport in general, providing valuable insights. Notably, 8 out of 10 passengers were either very positively or positively minded about the project, and the majority of those answering the survey believed that self-driving buses will be a part of future public transport solutions. It was also noted that more than half the respondents thought that it was important to have an operator on board the bus. User acceptance has thus been very good, and was decidedly helped by the pilot allowing the public to gain hands-on experience with the new technology.

Technological factors

Following publication of the vehicle requirements, Applied Autonomy as the main supplier decided to use a vehicle by EasyMile for the project. The project enjoyed a continued cooperation with vehicle provider EasyMile. Rather than simply providing the vehicle, EasyMile was actively involved in solving technological problems. Having a company with technical expertise in the middle, as well as a tight collaboration between all actors meant that problems were tackled as soon as they appeared and focus on scalability and applicability to business was maintained. Ultimately, it was this short time frame on which progress could be made that allowed the project to be successfully integrated into a regular public transport service. A total of 6 vehicle operators and employees of Vy were trained and certified by Applied Autonomy. The operators had extensive experience with public transport, which proved to be useful as it helped with the evaluation of traffic patterns, quick learning of the vehicle behaviours and good interaction with passengers. The operators also reported any anomalies of the vehicle and the route, and made proposals for improvements.

Another important contribution to the project came from communications company Telenor, who felt that this project was a good opportunity to test their new 5G network. This was the first time 5G was used in Norway, and contributed to both visibility and business relevance of the project.

Environmental factors

As a technology city, Kongsberg has the ambition to be at the forefront of technology with solutions for demanding environments. It was therefore natural to run the pilot in four seasons, summer-autumn-winter-spring, in demanding topography, and in open traffic.

There was an expectation to have to deal with demanding situations with winter conditions, snowy weather and snow banks, which fortunately materialised. The municipality and in particular their maintenance section worked closely with Applied Autonomy, EasyMile, Brakar and Vy. The decision was made to run the pilot in a normal urban operation situation for maximum learning benefit. In addition to providing a winter service and navigating Kongsberg‘s steep hills, the Kongsberg pilot also included different traffic settings driving in mixed traffic but also in a pedestrian zone.

An environmental effect of the project was that due to Brakar deciding to maintain the autonomous bus service, they could eliminate a traditional diesel bus from their fleet, leading to a reduction in their total CO2 emissions.

Legal factors

After establishing requirements in collaboration with Tallinn and Helsinki, Kongsberg published a tender on the national procurement website Doffin on 06.03.2018. There was one offer by Nettbuss AS, based on which a contract was made and fulfilled between 10/2018 and 06/2019.

The vehicle was acquired following a public tender:

- The specification of requirements for the acquisition, based on common requirements established in collaboration between piloting cities.
- Operating company Vy was the only provider who could offer lease of a vehicle.

- The vehicle used in this pilot was an EasyMile EZ10 Generation 2, which was already approved for test purposes by the Norwegian legislation.
- The Lease period was 9 months.
- Applied Autonomy also leased safety operators for the vehicles.

The background for the investment decisions of the project lies in system engineering, that is to say that Kongsberg felt that it was important to understand the proposed autonomous transport system as a whole, instead of focusing on individual parts. Different actors in the project made the following investments:

1) Applied Autonomy invested in an autonomous minibus shuttle: 3.2 MNOK (300k €);
2) Brakar and Vy invested in running two minibus shuttles as a continuation of activity after completion of pilot in Sohjoa Baltic: 2 M NOK (186k €);
3) Applied Autonomy invested in developing a Smart Mobility Management software: 15 MNOK (1.4 M €);
4) ITS projects in Kongsberg as spin-offs after Sohjoa Baltic, made possible by a collaboration and partnership with The Norwegian Public Roads Administration (Norwegian: Statens vegvesen): 10 MNOK (930k €);
5) Vy Group invested in a generation 3 minibus shuttle: 3.2 MNOK (300 k€).

Sohjoa Baltic was one of several projects related to autonomous transport running in Kongsberg, such that the investments reflect interests in the complete transport ecosystem, and the different actors' ambition to be part of and shape the future of public transport. Their interplay has to be underlined here: Just as the Smart Mobility Management software developed by Applied Autonomy was essential to the Kongsberg pilot, so too was the involvement of users in the form of public transport providers Vy and Brakar.

An additional factor worth highlighting was the role of Statens Vegvesen in the legal processes following procurement, as they provided invaluable insights and assistance as to the official requests for driving permits that were required.

Key lessons

Having a strategic approach to technology and innovation (Konsgberg as a technology city, City&Lab platform, etc.) has been crucial for setting-up a functioning innovation system supporting the most advanced deployment of autonomous buses among the Sohjoa Baltic project partners. Over the course of the circa 25 demonstrations and pilots that have been run in Norway, valuable lessons have been learned and the Sohjoa Baltic project allowed increasing and deepening of these insights into the autonomous transport ecosystem. After the Sohjoa Baltic pilot ended, it was decided to continue the activities. After three years of demonstrating, piloting and developing opportunities for self-driving electric shuttle transport, Brakar AS now runs the world's most advanced route for autonomous bus transport, in ordinary scheduled operations in Kongsberg.

d) Gdańsk, Poland

Gdańsk is the first city that has run an automated shuttle pilot in Poland. One of the strategic goals of the City of Gdańsk is to develop environmentally friendly transportation and mobility options for its citizens. Running an automated pilot has been in line with these strategic goals.

Political factors

The city of Gdańsk had the goal to join an innovative project and to be the first city in Poland to showcase an autonomous bus for the last mile public transport, before autonomous private vehicles became popular. As soon as the confirmation of Interreg Funding was received, collaboration with the city's other units began. Cooperation was expected to be crucial in order to organize a pilot and the other units were asked to designate persons to take part/ assist us with the project's implementation. They served as a local steering committee, following the Mayor's designation of certain organisational units and persons. Consequently, the team working on the pilot, besides employees of the Municipal Office of Gdańsk, included employees of: Gdańsk Road and Greenery Administration, The Public Transport Authority in Gdańsk, Gdańsk Buses and Trams company. The cooperation already started in the autumn of 2016.

From the consortium partners, the city of Gdańsk was looking for advice on autonomous bus specifications and feedback on considered route choices. The relevant partner was the leader of the small scale pilots Work Package, which was believed to help with organising a pilot in Gdańsk.

The implementation of the project is a preparation stage for a revolution in transport for Gdańsk. The spread of electric scooters has come as a surprise to many cities around the world. The same can happen with autonomous mobility. Meanwhile, before autonomous cars appear on the streets of Polish cities, Gdańsk aims to be ready to use this technology in the public transport sector, especially for last mile connectivity. Being the first city nationwide to run an autonomous bus line also resulted in very positive publicity.

Economic factors

Implementation of such an ambitious pilot or investment in an autonomous fleet for the public transport in Gdańsk wouldn't have been possible without external funding from the Interreg BSR programme, with a co-financing rate of 85%.

Even though prices of autonomous buses rental and related services had risen from the time the Sohjoa Baltic project application was submitted and the price for the service of organizing a pilot in Gdańsk exceeded the initially planned budget, the Municipality could still afford it due to underspending in previous reporting periods. The cost of the small scale pilot in Gdańsk was 454 485 gross (ca 99 867 €).

Through public and media relations, the Municipality of Gdańsk was prepared to share good practice and knowledge with other local governments, organisations and local companies. To the project partner's best knowledge there are no local companies yet that are strongly involved in automated public transport. However there is a company specialising in vehicle sensor production and the local project coordinator shared the knowledge of the Sohjoa Baltic implementation in Gdańsk and met with the representative of this company.

There is also a National Centre for Research and Development which aims to develop a regular size bus which operates autonomously at a depot and upon the request of the organisation's representatives Gdańsk organised a meeting, shared knowledge and technical specification of a robot bus desired for the pilot in Gdańsk.

Additionally, a Poland-based branch of the Trapeze (Trapeze Poland) having been involved in the Trapezio project in Switzerland was approached by the City of Gdańsk and invited to a tender for the organisation of the autonomous bus presentation in Gdańsk. Trapeze Poland got in touch with Easymile and while Easymile was the bus and service provider for Gdańsk, Trapeze Poland was their technological partner.

The representative of the city of Gdańsk also contacted a Polish company specialising in insurance services for public transport, inquiring whether it would be possible to insure Gdańsk autonomous pilot, but this inquiry didn't result in a clear answer.

Social factors

The Municipality of Gdańsk intended to communicate its plan with regards to small scale pilots as soon and as widely as possible. For this reason, press releases were issued with every Sohjoa Baltic-related news that emerged, e.g., confirmation of funding, launch of the pilot, etc., in order to generate positive publicity for the project and make residents of Gdańsk familiar with the autonomous pilot plan before it started. Sohjoa Baltic activities were also incorporated into wider initiatives and campaigns, e.g., national workshops on legal aspects of autonomous mobility as well as workshops for residents focusing on the pilot route choice were on the European Mobility Week 2018 agenda in Gdańsk.

Besides a paper-based passenger survey released during the small scale pilot (comparable with other Sohjoa Baltic pilot locations), the city designed an additional research tool: an online survey examining Gdańsk resident's awareness and attitudes towards autonomous mobility. This survey was active throughout the whole pilot, that is from the 6th of September to the 4th of October 2019.

The assessment of the trip did not depend on socio-demographic data such as gender, age of the respondent or professional status. One of the most important conclusions from the survey is that the majority of people who drove the minibus were very satisfied and will certainly retain positive memories of autonomous mobility.

- 73% of passengers rated the feeling of safety during the trip as "7" on a scale from 1 to 7.
- 92% consider an autonomous minibus to be an appropriate means of transporting children to school, 49% of which emphasise that additional childcare would be required.
- 54% would use an autonomous daily connection if it were available.

Technological factors

Before starting the procurement, the project partners agreed on the technical requirements of the buses. The Municipal Office of Gdańsk had no intention to become the autonomous pilot organizer. Instead, the city decided to outsource the whole service from an external company, who would not only deliver and programme autonomous bus, but also obtain all the permits, provide insurance, hire bus operators and carry passengers. The service provider had to apply at the road's managing authority.

The service provider was advised to apply for permission to use the road in a special way, or to follow another procedure that, to their knowledge, would be legal and possible. The Service Provider, following the city's advice, requested permission to use the road in a special way, but in the end the road's managing authority suggested the use of the road on an exclusive basis and gave permission for such a showcase.

Environmental factors

The Gdańsk 2030 Plus City Development Strategy sets out directions and development priorities for Gdańsk and identifies challenges and development needs of residents. These directions were determined by measurable development challenges, which in the area of economy and transport concern, among others, is to increase the share of public transport, walking and cycling in the journeys of inhabitants. Challenges in the area of mobility and transport are related to environmental protection, which is one of the broad cross-cutting issues addressed in the strategy.

In the area of mobility and transport the strategy defines the following strategic objectives:

- development of modern, sustainable systems of walking, cycling and related public transport to improve conditions for daily mobility;
- construction and modernisation of communication infrastructure and improvement of transport accessibility conditions in Gdańsk.

One of the instruments for implementing the Strategy are the Operational Programmes, including the Mobility and Transport Operational Programme. Its aim is to provide the citizens of Gdańsk with comfortable, cheap, fast, safe mobility modes to get to work, study, recreation areas and other services in an environmentally friendly way. The aim was to achieve the goal through investments in infrastructure, including: construction and repairs of pavements, bicycle routes, public transport stops and integration nodes, tram, bus and railway lines. The measures set out in the Mobility and Transport Operational Programme also take on an organisational dimension consisting in calming car traffic, favouring public transport and eliminating barriers in pedestrian and bicycle traffic.

Strategic objectives indicated in the Strategy for the Development of the City of Gdańsk 2030 Plus, implemented by the Mobility and Transport Operational Programme:

Strengthening the flow of goods, services and knowledge passing through Gdańsk;

- development of modern, sustainable systems of pedestrian, bicycle and related public transport to improve conditions for daily mobility;
- construction and modernisation of communication infrastructure and improvement of transport accessibility conditions;
- ensuring improvement of energy efficiency, energy security and reduction of greenhouse gas emissions in the city and the metropolitan area;
- strengthening of multi-faceted metropolitan cooperation leading to increased competitiveness of the metropolitan area.

The operational objectives indicated in the Programme include:

- improvement of conditions for pedestrian and bicycle traffic,
- increasing the attractiveness of public transport,
- improving internal and external transport accessibility,
- promoting sustainable transport and active mobility.

Implementation of the Sohjoa Baltic project and the automated pilot is clearly in line with the Mobility and Transport Operational Programme. The pilot itself generated so much positive publicity, that it helped to promote Gdańsk as a City devoted to sustainable and smart mobility and consequently to its environmental aspects.

Legal factors

Regarding the Polish legal framework, some provisions entered into force prior to the pilot, e.g., from July 2019. In case the city would organise a pilot in Gdańsk based on this Act, they would be obliged to obtain a decision on professional registration of the vehicle used in the pilot.

On 11 July 2019, the provisions of the amendment to the Act on Road Traffic Law came into force, introducing a new form of temporary vehicle registration; a professional vehicle registration. A professional registration enables companies to carry out test drives of vehicles not previously registered in the territory of the Republic of Poland or abroad, without the need to register each of them with the office.

A professional registration card and professional plates are to be used by entrepreneurs with a registered office or a branch in Poland (in the case of an entrepreneur with a registered office abroad), dealing with production, distribution or testing of vehicles, as well as authorised units (e.g., Motor Transport Institute) or research units of manufacturers. The vehicle was not registered as this would have been impossible for a vehicle that has neither mirrors nor a steering wheel. The city of Gdańsk checked with legal experts whether 360 degrees cameras could be treated as mirrors, but the lawyers were skeptical. Even if it was possible to register such a vehicle in Poland as a precedent, for a one month long pilot it would be too much of a struggle. These were some of the reasons why the city of Gdańsk decided not to officially test the autonomous vehicle on the basis of this regulation, but to organise a presentation of the vehicle using the procedure of road use in a special way. This was an alternative solution preferred by the local roads managing authority, that is Gdańsk Roads and Greenery.

Key lessons

Having realised that it would be difficult to obtain an offer for a small scale pilot running for one month only, the city representative networked extensively with potential bidders prior to tender announcement. In order to liaise with companies from abroad, the documentation for procurement was presented bilingually – in Polish and in English. The advantageous solution was that the foreign contractor entered into an agreement with a Polish technological partner.

Instead of registering a vehicle, the service provider presented a certificate from the bus manufacturer that he has installed restrictions that do not allow him to exceed the speed of 25 km/h, which proved that the vehicle in use was in fact a slow moving vehicle.

It would have been good to consult the local police earlier to dispel doubts about the use of the road and to ease the service provider's collaboration with local authorities.

e) Zemgale, Latvia

Together with Vejle and Gdańsk, Zemgale Planning Region was one of three partners to host a one-month pilot. Although there were concerns with finding a bus provider, the Latvian project partner overcame this obstacle and ran two 2-week pilots in separate locations: Jelgava City and Aizkraukle municipality.

Political factors

The political environment in Latvia has been favorable for the project. The project partners from Zemgale Planning Region were supported by both the Ministry of Transport and the Ministry of Environmental Protection and Regional Development who are interested in the outcomes of the pilots in Zemgale. In 2017 the Ministry of Transport gathered a working group to develop guidelines for testing autonomous vehicles where Zemgale Planning Region was one of the participants. The working group prepared guidelines for testing autonomous vehicles on a racing track near Riga.

At the regional level, the Council of the Zemgale Planning Region, which comprises mayors of 22 local municipalities, supported the project as it brings positive attention to the region. Zemgale Planning Region has also adopted several strategic documents which favour such pilots. These include the region's **Sustainable Development Strategy 2015-2030**, **Development Programme 2015-2020**, and **Energy Action Plan**. In 2018, the latter was complemented with an additional chapter focussing on sustainable energy in transportation.

Although autonomous driving is not mentioned in these documents, the project still helps to gain knowledge in priority areas such as electric and sustainable transport, and urban planning.

The project has also been supported at the local level by the municipalities where the pilots are running. However, as Jelgava City is the regional capital and much bigger than Aizkraukle, the administrative processes in Jelgava took more time.

Economic factors

The Zemgale pilot faced the same danger which partly made it impossible to have a pilot in Vejle. As Zemgale was also a location of a short-term pilot, there was a high chance that the Latvian partners would not find a bus provider. The fact that Zemgale Planning Region wanted to have two 2-week pilots in separate locations complicated the situation even more as it meant that the bus provider would need to map two different routes which meant extra costs. Fortunately, the tender had one participant, which was the Norwegian company Applied Autonomy which also provided the bus in Kongsberg.

The local ecosystem of companies involved in the development of autonomous solutions is not so developed. Latvian start-up company Pilot Automotive Labs is currently the only company which is actively developing autonomous solutions. Local telecom companies such as LMT and Tele2 are also interested as higher driving speeds in the future autonomous vehicles will require a 5G connection. The hope is that the Zemgale short-term pilots will increase the interest of local entrepreneurs. Zemgale Planning Region also hopes that because of the pilots in the region, the Ministry of Transport will again gather the working group focussing on autonomous transportation.

Social factors

In both pilot locations the local businesses and citizens were not involved with the selection of the routes. However, Zemgale Planning Region's focus has been to have a route where the bus could provide a needed last-mile service. In Jelgava, Zemgale Planning Region consulted with Latvia University of Life Sciences and Technologies. The proposal was to connect the main building of the university with the faculty buildings on the other side of the river Lielupe with a one-way distance of ca. 3 km. The university did not find the route useful because of the lack of demand and instead proposed that the bus should connect the university's dormitories with the faculty buildings on the other side of the river. On the first route the bus would have crossed a bridge which connects the Palace island with the eastern side of the river while on the second route the bus would pass the previously mentioned bridge and also the one which connects the western side of the river with the Palace island. However, the Latvian Road Traffic Safety Directorate did not agree with such routes because they feared the bus would disturb traffic on the bridges. In Aizkraukle, the aim was to connect the local train station with the town center, which are ca. 3 km apart. As the route would have crossed a major road connecting Riga with Daugavpils, the plan was not approved by the Latvian Road Traffic Safety Directorate.

Therefore, Zemgale Planning Region had to find alternative routes in both municipalities. The route in Jelgava is located on Pasta island and connects the entrance side of the island with the beach located on the other side by driving on a pedestrian road. The island is not accessible for cars, except for Municipal Police and service vehicles. The route in Aizkraukle is on a public road and connects Aizkraukle Museum of History and Arts with a parking lot located 350m away.

Technological factors

The technological limits of the current autonomous buses played a major role in the route selection. The initial route proposals would have been good examples of a last-mile service. However, the routes were too complicated from a technical point of view.

In Jelgava, the Latvian Road Traffic Safety Directorate feared that a bus which drives with a speed of 15 km/h will cause dangerous situations such as car overtakings on a bridge. There was also a proposal to extend the route on Pasta island towards the Jelgava palace so that the bus would make a circle around it.

However, as there would have been a couple of small and unregulated intersections on the route, the Road Traffic Safety Directorate set a condition that traffic lights must be installed to regulate the intersections and therefore the plan was withdrawn. Manual control at the intersections was not considered as the aim was to have a completely autonomous route.

Environmental factors

As was already mentioned, the pilots are in line with the strategic priorities of the Zemgale Planning Region and the local authorities at the regional but also at the local level are open to environmentally friendly solutions. As the region is currently preparing its e-mobility plan, the two short-term pilots serve also as showcases for electric mobility. Jelgava City planned to purchase electric buses for its public transport but are now thinking about hydrogen-powered buses.

Legal factors

The exact procedure for getting a Latvian test plate number for autonomous buses and how to set up a pilot in Latvia needs additional attention. For example, the national guidelines for testing autonomous vehicles only provides guidelines for testing at Biķernieki racing track.

The procedure for setting up two small-scale pilots in the Zemgale region has been ad hoc. This is understandable as the two 2-week pilots are the first ones in Latvia. The bus used in Zemgale has a Belgian test plate number which was allowed on the streets by the Latvian Road Traffic Safety Directorate. The reason for such a decision was to avoid additional paperwork as the bus already had a plate number.

However, this also meant that the insurance needed to be bought from a Belgian insurance company as the Latvian ones were not willing to provide insurance for a car which does not have a Latvian plate number. This makes it more complicated to run pilots in Latvia. A procedure has to be put in place for organising future pilots in Latvia.

A procedure which is agreed by the Ministry of Transport, the Latvian Road Traffic Safety Directorate and other involved stakeholders would provide a fertile ground for future pilots in open traffic. In addition, it could also send a message to local companies and entrepreneurs that the country supports local technology development and testing.

Key lessons

Short pilots function as demonstrator projects that help to raise awareness regarding new technologies but also test and reveal local contextual barriers to technology adoption that may be unique to context (e.g., policy interpretations of local regulators, insurance providers, etc). It is more likely that during the short pilots, one will first develop work-arounds for these barriers - for which open and co-creative discussions between all relevant actors are crucial - as opposed to tackling the root cause of these barriers, but these lessons can be taken onboard for planning and preparing future pilots and use of technology.

f) Vejle, Denmark

Denmark is an example of how strict legal processes can hinder the running of short-term pilots. Initially Vejle planned to run its pilot in October 2019. However, due to legal and also economic reasons, the municipality was not able to run its pilot.

Political factors

Vejle had a favorable political environment for running an autonomous pilot. In 2013, Vejle was selected to join the 100 Resilient Cities network and the municipality adopted a resilience strategy for 2016-2020. In this strategy, exploration of the use of autonomous vehicles and its opportunities to address the aforementioned issues was highlighted as one of the actions that needs to be supported.

Economic factors

Financially, Vejle had enough resources to run a 1-month pilot and start the permit application process. The main barrier for the pilot was the amount of information that the Danish Road Administration needed for the permit. The potential bus provider expressed that collecting and putting all the necessary information together is very labour intensive, and a short 1-month pilot would be too short to cover the related costs.

Social factors

The officials of Vejle conducted an analysis on whether the pilot should only be about showcasing the first and last mile public transportation service or where there was additional potential. The proposal was that the autonomous bus should connect different public entities located in the specific city district. The route was supposed to connect a large healthcare centre, library, sports facility and a highschool. The reasoning was that such a route would serve the most people and also give different types of people (young, elderly, disabled, etc.) a chance to experience the autonomous bus. This would have provided information to the city administration on where to apply such buses in the future.

The city administration did not consult with the local citizens. However, there were meetings with different entities such as the aforementioned institutions and businesses that were located right next to the route. During the meetings it was discussed what kind of learnings the pilot can provide and how to promote it.

Technological factors

There were also technology-related issues that hindered the pilot. First, the officials in the city administration did not find a single district in the city where the speed limit is lower than 50 km/h. Yet, due to safety reasons, the preferred speed limit for the potential bus providers was 30 km/h. As the operational speed of these autonomous buses is usually between 12-15 km/h there were concerns that the bus would interfere with traffic due to violent braking.

Environmental factors

Environmental motives played an important role for Vejle to join the project and run a short-term pilot. As was already mentioned, the city was selected to join the 100 Resilient Cities network and adopted the resilience strategy for 2016-2020. The strategy has four pillars: a Co-creating City, a Climate Resilient City, a Socially Resilient City, a Smart City. As Vejle is located in a valley, mobility is one of the key topics of the strategy. As the municipality is expecting to double its population number from over 55 000 to 100 000 by 2050, issues such as traffic congestion and related CO_2 emissions have been identified. The use of autonomous vehicles was identified as one possible future solution to overcome issues related to traffic congestion and CO_2 emissions.

The proposed route was located in an area that is currently under real estate development and will soon experience growth of population. The pilot would have provided a showcase on how to develop that specific area in Vejle.

Legal factors

In May 2017, the Danish Parliament changed the Danish Road Traffic Act to allow testing of autonomous buses on public streets. A permit has to be applied for at the Minister of Transport, Building and Housing. The applicant has to provide information about the test's SAE level, a specific map of the test route, traffic conditions, weather conditions, test organisation, and a plan for processing data collected through the test. In addition, an assessment of road safety issues must be conducted by an approved third-party safety advisor.

The way the whole applying process has been designed hampered the Vejle pilot in two ways. The first issue is related to the third-party safety advisor. In Denmark most of such safety assessments are conducted by private companies. A similar process is also implemented in Norway. However, by contrast to Norway, in Denmark the applicant such as a municipality cannot be in dialogue with the safety assessor. The applicant can only hand over the initial project for safety evaluation. The safety advisor evaluates the project and, based on the result, advises the Danish Road Administration whether to issue the permit or not. As the permit applicant is not allowed to be in dialogue with the third-party traffic safety assessor, this means that the applicant will receive the decision only at the end of the process. This does not allow the applicant to make any adjustments to the project when the traffic safety assessor finds any shortcomings in the initial project.

The second issue is related to the amount of information that is needed to apply for a permit (see above). The process of putting all the necessary information together is very labour intensive. This makes short-term pilots in Denmark financially unviable.

Key lessons

Although there were several political, social and environmental drivers for implementing the automated buse pilot for developing the resilience of Velje, the pilot was not implemented because of the contradictions between strict legal and regulatory safety requirements and the economic incentives of short-term pilots. Hence, one could learn from the case of Velje that short-term demonstrator pilots are often more burdensome and more difficult to integrate into regular politico-administrative routines of cities than longer-term pilot activities mimicking actual public transport provision. The necessary measures for implementing a small scale pilot can be as laborious as setting up a large scale pilot, as the same procedure of planning, applying for permissions and deploying the vehicles on the route may apply in both cases even though the duration of the actual pilot is shorter. At the same time, launch and implementation of novel technology and public services pilots may require a more open and co-creative approach in policy and regulatory procedures (i.e., safety evaluations and similar assessments) than in the case of more mature policy and technology areas.

2. Successes and lessons learned

Did the pilots fulfil their purpose? The short-term pilots in Latvia and Gdańsk have served as good examples of technology demonstrators where the main aim is to raise public awareness. That was the main reason why Zemgale Planning Region in Latvia wanted to have two 2-week pilots in separate municipalities. If we include the canceled pilot in Vejle into the current discussion, it can be said that the whole process of organising the pilot has been a learning moment for all three project partners as it has brought out currently existing barriers in legislation and procedures.

The long-term pilots in Helsinki, Kongsberg and Tallinn had a somewhat different focus. As the pilots lasted longer in these three cities, they enabled deeper learning and capacity building. The aim in Kongsberg from the start was to gain extensive knowledge about the capabilities of autonomous buses in different weather and terrain conditions, and to set up a continuous last-mile service. The bus was tested in all four seasons and both the public and private sector stakeholders made financial investments to develop conditions for continuous service. In Tallinn, the project helped Tallinn Transport Department to better understand how different weather conditions can limit the current technology, especially tricky weather in autumn. Sadly, the partners in Tallinn did not manage to test the vehicle in actual winter conditions due to a warm winter. The project also helped to build additional capacity in TalTech. All the operators in Tallinn were students from the School of Engineering, many of whom linked with the autonomous vehicle projects in the university. Based on the Sohjoa Baltic pilot, in Helsinki the public transport authority (Helsinki Region Transport, HSL) has no plans yet for procuring automated shuttles. During the project, the comprehension of the automated solutions and state of the technology has increased within the city along with an understanding that it will take time to have viable automated public transport services. Hence, in general, the city encourages relevant actors to continue implementing pilots in real urban environments.

What should be done differently when designing consequent pilots?

It is hard to make general suggestions about what should be done differently when designing consequent pilots. One has to understand that countries and regions are at different stages. Some countries and regions are launching or already have launched their first pilot which usually functions as a technology demonstrator (e.g Gdańsk and Zemgale). There are also countries that have hosted multiple pilots which has enabled them to build local capacity in service delivery and technology development, and prepare or already implement changes in legislation (e.g., Estonia, Finland, Norway). There are also countries in Europe that have not hosted any autonomous pilots yet.

Keeping this in mind, the main recommendation for countries and regions is to move towards more complicated pilots step-by-step. This means that project partners from countries such as Estonia, Finland and Norway should move forward with projects where the main aim is to establish a long-lasting service with autonomous vehicles (already done in Norway) and/or push the limits of the technology by having completely autonomous pilots with no operator onboard the bus which in the end is one of the main goals. At the same time, countries and regions that have not hosted any autonomous pilots should start with technology demonstration pilots and long-term pilots. This is a moment where already experienced organisations from countries that have hosted such pilots could provide their know-how through common projects.

Lessons for future full scale automated solutions

Autonomous technologies in general and first- and last-mile autonomous solutions in particular are still in the process of finding correct business models. On a more general level there is still a big debate on whether autonomous driving should be about private or public transportation, individual or shared rides.

From the Sohjoa Baltic project and a first- and last-mile perspective, several lessons can be learned that in the future can help to make full scale automated solutions a reality:

- **Cooperation** is key as active cooperation between all the important stakeholders such as the road administration, local governments, supplying companies, relevant ministries, etc. ensures the necessary regulatory framework and limits possible conflicts which has been the case with ridesharing in several countries. Such cooperation has also enabled running pilots in countries participating in this project;
- **Inclusion** of local citizens and small businesses is necessary for the deployment of autonomous shuttles. During the preparation of the pilot, Kongsberg municipality actively engaged with the local businesses located next to the route to find out their concerns regarding safety and the bus potentially blocking delivery vehicles. In Gdańsk, such consultations actually resulted in choosing a different route. In Tallinn, the local residents were informed about the coming pilot and the related traffic changes. However, some residents expressed their dissatisfaction towards the traffic changes in social media. Workshops with local residents might have prevented this. Active inclusion of citizens is especially important during the period when the first full scale automated solutions are on the streets in parallel with a large number of private vehicles.
- **The technology** is not ready yet. During the Sohjoa Baltic project, the partners had to find a balance between the (potential) demand for the service in a certain location and the capabilities of the current technology. The demand for full scale automated last-mile solutions already exists, but mostly in areas which are too complicated for the current technology.
- **Hardware matters** too. Developers of autonomous solutions have put most of their effort into teaching their software to become autonomous. Efforts should also be put into making the physical vehicle more comfortable and durable. Visible physical defects which are even not related to autonomous technology can decrease public trust towards autonomous driving. Many passengers expressed this during the time when the autonomous bus in Tallinn had serious issues with opening and closing the doors.
- **In addition, the developers of autonomous shuttles have to start thinking about how the autonomous car will interact with others in the traffic such as pedestrians, drivers and cyclists**. For example, how does a pedestrian know that it is safe to cross the road when an autonomous shuttle is approaching? At the moment, the buses have operators on board who can help with this for legal reasons, but at some point they will be removed.
- **It should be considered what the grounds and when the right time is for procuring an automated service for a certain route**. A public transport route is organised due to certain demand and criteria where the determining factors of the service are often price and quality. Grounds for procuring an automated service for a certain route should not come from the mere fact that the service is automated. There has to be proven improvements compared to what exists and how the current services are organised. If the automated shuttle service cannot be organised more cost-effectively than human driven solutions, what is the reason to have this service? Is there some other significant feature that the automated solution can offer instead of lower costs?

III. Automated vehicles implementation toolbox for cities

The main aim of Chapter III is to give practical advice to organisations, especially cities, on how to organise a pilot with automated electric shuttle-bus. The core of this chapter is Section 2 with step-by-step guidelines on how to organise a pilot. Section 2 starts with the description of prerequisites for setting up automated operation which is followed by practical guidelines. The idea of Section 1 is to provide additional background information necessary for organising a pilot. The section is largely based on the other volumes which have been published as outputs of the Sohjoa Baltic project.

1. Things to consider before organising and running a pilot

Every project and initiative means costs for the public sector. Therefore, two obvious questions emerge for every city: where and why to run pilots with automated vehicles? If we look at the larger macro trends in the world, it is possible to identify many good reasons why cities should get involved with the development and deployment of automated vehicles.

According to a study by the Department of Economic and Social Affairs of the United Nations, two thirds of the world population will be living in urban areas by the year 2050. The increased number of people living in urban centers and agglomeration of economic activities will lead to an increasing need for effective modes of urban transport in terms of energy and costs. Such efficient transportation is fundamental to ensuring full accessibility of urban areas. Densely-populated cities are strongly dependent on high capacity trunk lines to be able to sustain the necessary traffic flow rates required to meet the travel demand. As trunk lines are not directly accessible by the whole population in any area, additional, more flexible first- and last-mile solutions are required to feed and complement the aforementioned trunk lines.

The population growth in Europe is slower, which leads to an ageing population. Increased automation, including in transportation, could compensate for the relative decrease in available workforce. The trend will also cause the traffic patterns to shift away from regular morning and evening peak hours, to more steady traffic around the clock as the significance of work trips declines. Automated minibuses and similar automated vehicles can provide flexible and cost-efficient solutions for serving both peak and off-peak demand parallel to the trunk lines while decreasing the dependency on private cars.

The EU has set a target to drop greenhouse gas emissions from transportation by 60% from 1990 levels. Currently, the transport sector accounts for almost a quarter of the greenhouse gas emissions in the EU and is one of the main sources of pollution in the cities. Electrification of road transport is seen as one of the most important steps toward carbon-free transportation as it will help to dramatically reduce local emissions, including noise, particulates and other air pollutants, in densely-populated areas. Indeed, road transport is responsible for emitting over one billion tonnes of CO_2 annually, which accounts for about 24% of global greenhouse gas emissions. Even more relevant is the amount of SOx and NOx emissions.

Wide-scale automation could also increase traffic safety in the future. According to a survey distributed by the U.S. Department of Transportation, the critical reason for accidents was attributed to the driver in a large proportion of the cases. Causes of crash include failure to recognise the traffic situation correctly, poor driving decisions or driver performance drop.

The aforementioned benefits will not materialise overnight. The development of the related technologies will take years to mature. However, this does not mean that cities should wait all these years to finally purchase a ready product. The software behind the technology needs actual experiences to learn and become more efficient and safe. Cities which act as early adopters by providing learning opportunities through pilots will have a competitive advantage compared to late adopters. Such opportunities can also boost the local technological development and economy as the barrier to enter the market is low.

Nevertheless, cities wishing to start their own pilot(s) need to consider carefully which routes are best for piloting. As mentioned at the end of Chapter II, a public transport route is organised due to certain demand and criteria where the determining factors of the service are often price and quality. A balancing exercise must be conducted where the following questions should be asked:

- Is there demand for such a service on a specific route?
- Is using automated vehicles the most price-efficient way to provide the service?
- How complex is the route? The latter means that one should analyse whether the automated shuttles are able to drive on a certain route at the current level of technological development.
- Will the pilot provide a learning moment for the city or any other organiser?

As already mentioned, it is a balancing exercise. There might be a chance that not all of these questions can be answered positively and compromises must be found. All the project partners in the Sohjoa Baltic project have had to adjust their pilot plans because of these questions, starting from Vejle, where the pilot was cancelled due to price issues, to Zemgale, where the initially proposed routes needed to be dropped due to their complexity.

a) Costs

The costs of running an autonomous pilot can be divided into four categories:

- preparation costs for acquiring the service and a bus
- planning and preparation costs of the route
- purchase or lease of the bus
- the running costs of the service.

For a public sector organisation, the preparation costs include the working hours of the officials preparing the documents for public procurement or financial costs if the service is brought in from a law firm and translation costs. These are costs that public organisations are used to anyway and therefore no additional focus will be put on these costs.

The preparation of the route can include several different costs. The most significant cost is related to the deployment of the bus on the route, including mapping and programming of the route. The cost of deployment is one of the main reasons for why the suppliers of automated buses prefer long-term pilots. In some countries such as Denmark and Norway, the public organisation has to order a traffic safety assessment from an independent traffic safety assessor. Costs can also include traffic arrangements, such as the installment of traffic signs if needed (e.g., due to changes in traffic or warning signs) and informing the local residents and businesses about the pilot and related traffic changes.

There are basically two ways to get a bus for a pilot: purchase or lease. The purchasing price of an automated shuttle bus is around 250 000 - 450 000 €. In comparison, the City of Tallinn just recently purchased 100 Solaris gas buses (capacity of 80-150 seats) for 27€ million. Owning or leasing an automated bus also means a number of operating costs such as payments for software license and technical support to the manufacturer and insurance. In addition, owning your own automated bus still means that you have to pay a service fee to deploy the bus for each route. Therefore, it is easier for public sector organisations to lease an automated bus for the pilot. Other operational costs include the cost of electricity to charge the batteries, parking costs if there are no other alternatives, salaries to operators and other maintenance costs, such as cleaning.

Considering running the service, it has to be taken into account that a safety driver is still needed (technically and in some cases also legally) onboard the shuttle in open road conditions, so at this point it should not be believed that there are cost savings regarding the driver's salary. In addition, it might be necessary to set up Remote Control Center (RCC) facilities to supervise the operations remotely, and other premises for accommodating safety drivers and a local incident response team that would be quickly called on site in case of a situation that requires intervention on site (though at this point these actions can be taken care of by the onboard safety driver). Hence it can be considered that at least two persons are currently required to operate one automated shuttle, if having an RCC. The amount of personnel needed and overall costs to run one automated shuttle varies according to expectations and the nature of the pilot. In general, at this point it is more expensive to run an automated shuttle service on open streets than a traditional human driven bus service when thinking of both the fleet and personnel needed. The situation could be different if operating on closed streets where it might be possible to run the service without an onboard safety driver. But still it requires that one remote operator is able to supervise more than one shuttle (and that this is also legally possible) and the on-field actions are kept at a minimum. In addition, both the upkeep and purchase costs of an automated vehicle are significantly higher compared to a conventional human-driven minivan for instance.

b) Procurement of vehicles and services

The procurement of dynamic technologies may be difficult for cities, mainly due to difficulties to specify all requests beforehand in order to mitigate risks. This also applies to the automated shuttle buses market as this technology is under development with a limited but dynamically changing market.

During the procurement of the Sohjoa Baltic project, there were only two companies that were ready to provide automated, electric shuttle buses (EasyMile and Navya), although several companies were and are still in the development stage. As this project was supported by the European Union and the cities themselves, the procurement process was central for enabling successful outcomes. That is, cities faced a question of how to instrumentally procure high-risk technologies like automated electric shuttle buses.

Procurement processes start from a market analysis. Investigating the service provider’s motivation and suitability for submitting tenders help to predict if bids are given. Seeking to open dialogue with a variety of autonomous vehicles, operators or technology providers in the field helps to understand the variety of services, e.g., turnkey solutions, leasing a vehicle or operating purchased vehicles. Several providers aim to commit their customers to longer projects of 1-2 years duration, as shorter projects are not considered feasible.

In the procurement process, it is necessary to identify and specify the requirements for qualifying bids. For example, as the technology still dictates the possible route selection, the customer’s primary choices may be neglected. An easier approach is to collaborate with potential bidders after the market analysis when creating the final tender materials. If the procurement is conducted from public funding, assessing the bids follows the public procurement and EU tender guidance.

c) The vehicle technology

Autonomy and electrification constitute enabling technologies for the next generation of the transportation system. From an environmental point of view, electrification is perceived as a clean solution to help reduce pollution in our cities, whereas automation is perceived as helpful from a safety point of view by reducing the risk of accidents. Even after these years of piloting, the most important question still remains, is it possible to drive autonomously without an operator onboard? In general, it is not possible to drive without a safety operator on board in open road conditions in normal road traffic with today's technology. However, it would be possible to do so with the help of a remote control centre (RCC). To bring down the costs, the vehicles must be certified without a safety operator on board. While waiting for the safety functionality to become sufficiently sophisticated, frameworks and methods must be defined to certify the vehicles for specific use cases. The development of the vehicle software is making fast progress, but the vehicles are surprisingly poorly equipped in terms of mechanical properties and methods for troubleshooting faults, though the mechanics and troubleshooting strongly depend on vehicles' manufacturer, and can be easily overcome with the next vehicle generation. Software and perception capabilities, on the other hand, are still something to work on with the final aim of improving safety and automation level.

Safety requirements

Safety requirements for autonomous buses to run in public roads include on-board tools (safety belts, etc.) and documentation (safety assessments, plans, etc.). The vehicle solution carrying passengers for public transport in urban areas must offer passive and active safety measures that ensure safe traveling. Personal safety for both the passengers, and other people exposed to the vehicle, must be a priority. Furthermore operators and suppliers must show effective safety plans to handle any dangerous scenario. Along with the pilots' procurement, the consortium has developed an effective list of requirements to fulfill in order to be able to run an autonomous pilot. These information can be shared among stakeholders to serve a starting point for future procurements and city-pilot organization. The list is reported below, while more details are reported in the related volume:

- System Architecture Plan
- APIs and communication channels safe and secure by design
- Open interfaces must be separated from safety critical systems
- System verification
- System Architecture documents need to be verified by a 3rd party validator
- Safety Plan & Risk Assessment
- Safety Plan & Risk Assessment verified by an independent safety assessor
- Accidents & Incidents management plan
- Crisis Communication Plan
- Fire extinguishers and first aid kits in vehicle units
- Electro-magnetic compatibility (EMC)

Technical requirements

Building the procurement for the pilots, the consortium has defined many technical and operational requirements for the vehicles provided to be fulfilled. The requirements are divided in vehicle requirements and operational requirements.

Vehicle requirements:

- Automation level 4 (SAEJ3016)
- Usable on open roads with mixed traffic in automated mode
- Access for disabled passengers
- Lithium-Ion batteries
- Electric driving range, at least 60 km
- Onboard charger with standard connectors (SAE J1772)

- Wireless charging
- CHAdeMO battery
- Operating temperature
- Redundancy
- Driving in all weather

Operational requirements:

- Automated and manual mode with onboard remote controller
- Operable on fixed routes with bus stops
- Supervision through cellular network (LTE)
- Supervision API
- Programmable turn-signals
- Data statistic permission
- Programmable side safety limits
- Automatic passenger counter
- Routes and local requirements for testing:
- Popular location
- Real need for mobility
- Preferably no interferences with existing public transport
- Secure storage with charging station
- Reliable GNSS localization of the bus
- Stable environment, no construction sites along the path
- Speed limit of the road at 30 km/h or less
- Wide lanes and preferably no road side street parking

More detailed descriptions of the technical and safety are found in the The Roadmap to Automated Electric Shuttle in Public Transport - Safety and Technical requirements.

d) Legislation and regulations

The different aspects of legislation affect the implementation of autonomous vehicles in public transportation. Aiming for EU-wide implementation, the national laws have to be adjusted and approximated, e.g., by EU directives, in order to harmonise and approximate the legal basis.

In Denmark, Estonia, Finland, Germany, Latvia, Norway, Poland and Sweden, the automated vehicle must be registered, hence the legal frameworks differentiate between the type of roads where the vehicle would be used. In these countries, the operation of automated driverless vehicles is contrary to European, international, and national law. Some, but not all, legal problems can be resolved by placing a vehicle operator inside the test vehicle. In some countries (e.g., Denmark, Finland, and Sweden) the vehicle operator can also be positioned outside the vehicle.

In all mentioned countries, it is possible by law to conduct test operations with automated vehicles. In most countries, such tests require a special permit. Estonia and Finland require a test plate certificate. Poland recently introduced a new form of registration, the professional vehicle registration which enables companies to carry out test drives of vehicles not previously registered in the territory of the Republic of Poland or abroad, without the need to register each of them with the authorities.

In all countries, these exemptions from otherwise conflicting norms can only be granted if the applicant takes sufficient compensatory measures, e.g., by complying with geographic limitations on the test route, providing a precise description of the planned operation, and securing adequate insurance coverage. In most countries, the vehicle operator is considered to be the driver of the vehicle. In Swedish and Finnish law, the term driver is not legally defined; the vehicle operator is a 'road user'.

Commercial transportation of passengers requires a permit in each mentioned country. Many legal systems, e.g., in Finland and Estonia, distinguish between a general passenger transportation permit and a taxi permit. Exceptions that do not require a permit are the transport of employees by their employer (Denmark) or for purposes of tourism (Poland). Basic requirements must be fulfilled to obtain the necessary passenger transportation permit in all participating countries. Among the most important requirements are the adequate competence of the provider in the field of passenger transport, as well as the financial and technical reliability of the service offered. In Germany, the approval regime is even stricter, with the issuing of permits generally limited to certain modes of transport such as line-based traffic.

In all participating countries, drivers need a driving licence. The appropriate licence type is determined by the length and weight of the vehicle, as well as by the number of passengers. In most countries, the vehicle operator is considered to be the driver of the vehicle. In Swedish and Finnish law, where the term driver is not legally defined, this does not exempt them from the obligation to obtain the proper driving licence for operating the automated vehicle. In some countries (e.g. Germany, Denmark, and Sweden), the driver must obtain a licence for passenger transportation, as well as a driving licence. In other participating countries, namely Estonia and Finland, this is not a legal requirement. In Germany, Denmark, Poland, and Latvia, there are specific legal standards for the behaviour of the 'driver' (vehicle operator) of an automated vehicle. The vehicle operator must remain attentive while driving and be able to regain control over the vehicle at any time. In Finland, Estonia, and Sweden only the common due-diligence rules for drivers and road users apply to the vehicle operator of an automated vehicle.

Liability is a widely discussed topic in the context of automated driving. The participating countries have not enacted any specific rules on automated vehicles. The liability relies on product liability law and road traffic law. Possible defendants are the vehicle operator, the owner, or the manufacturer. In all the listed countries, the use of automated vehicles requires regular traffic liability insurance. The liability insurer has a direct claim against the manufacturer if the damage is based on a failure of the automated driving system.

Most participating countries lack specific criminal legislation for automated driving. Only in Denmark does a special procedure apply. In most countries, criminal liability may be ascribed to the vehicle owner; the manufacturer and its employees; the provider of the necessary data infrastructure; officials at the competent authority for vehicle permits; or the vehicle operator.

Estonia is the only country in which criminal liability can be ascribed only to the vehicle operator (i.e., vehicle safety driver). Legally, the subjects of criminal responsibility need to be clarified by separating the responsible persons for the technical maintenance of the vehicles from the responsible persons for the vehicle software.

In addition to guiding traffic legislation, the General Data Protection Regulation (GDPR), the central EU regulation on data protection, poses challenges for the implementation of automated driving, where cameras are used for safe motion of the vehicle. It is necessary to pay attention to data protection, privacy and information regime as well as data analysing rights.

The national transport safety authorities have responsibilities, but other stakeholders must recognise the local legal and regulatory demands. In general, these competencies should build from the government level to personal level.

To gain more detailed insights to legal matters, read the Sohjoa Baltic Roadmap to Automated Electric Shuttles in Public Transport The Legal Framework.

2. How to set up automated operation

Prerequisites for setting up automated operation

An automated last mile shuttle operation can consist of one or several automated vehicles, which are deployed on a route and operate within a fixed route with fixed schedules or on-demand based under certain conditions.

The basis for setting up an automated operation on a certain road traffic route assumes the following prerequisites:

1) Law allows the operating of an automated vehicle in road traffic among other road users and the vehicle meets the national criteria for such activities.
2) The service has a subscriber (funder/organiser of the operation).
3) A supplier is capable of providing the requested/procured operation by the subscriber.
4) The activities are supported by local and national authorities, albeit in collaboration with other parties responsible, e.g., for local road infrastructure, who enable the testing and are capable as well as interested in removing existing barriers within the limitations of the law.

In addition, for succeeding with a viable and sustainable last mile operation, which aims to complement the existing public transport service and to increase the modal share of public transport as well as reduce private car usage, the following aspects should be considered:

1) What is the purpose of the route?
2) What value does this mobility solution create?
3) Who will be the user of the service?

Currently, the actions have mostly focused on providing and setting up last mile pilots rather than real street-ready solutions as part of public transport services. There is a limited supply of viable, cost effective, and approved solutions, which cannot be implemented in all kinds of required environments and conditions.

The introduction of automated last mile shuttles as part of a public transport service is restricted due to following challenges:

- **Technology advances by testing.** In the Sohjoa Baltic pilots, the speed of the shuttles was limited to around 18 km/h and several factors also restricted the selection of routes and conditions for the operation. Shuttles should be able to operate in a variety of environments and all kinds of weather conditions in the same way as regular vehicles. The operational speed of the shuttles should be increased to at least 30 km/h to keep up with the traffic flow in suitable environments. In particular, shuttles should have the ability to overtake obstacles, handle different types of intersections and deal with traffic lights without hesitation. While the shuttles in the Sohjoa Baltic project were able to approach and interpret intersections successfully and safely in several cases, speeding up this part of the navigation routines will ensure smoother integration into existing traffic. The technology should be reliable, regardless of the infrastructure or the environment: it has to mature to allow the service subscriber to plan the route and other operating conditions. The technology developers use pilot projects to test their products in a variety of environments and weather conditions to learn and develop their products/services further.

- **Public transport solutions require near-perfect reliability**. Reliability of a public transport solution should be at least at the same level as the current ones. For instance, the timetables have to be met with a high percentage. While those pilots which have operated according to a fixed timetable have largely done so successfully, difficulties with vehicles' reliability have still occurred and operating conditions as noted above as well as unforeseen traffic circumstances have been challenging. This underlines the importance of building experience from a large number of pilots, as the collected data allows to work towards the reliability required for the shuttles to run as a part of the normal public transport.
- **Changes in modal share from private cars to public transport with help of automated last mile shuttles are progressing, hence many questions remain unsolved**. Special routes for automated shuttles do not exist. There is a need for travelling and this need is remedied with existing solutions with available resources. Nudging the private car users towards using public transport is not expected to be an easy task unless the offered mobility services are reliable and feasible solutions. Adding a short distance last mile mobility solution to the travel chain is increasing the number and need for changing from one mean of transport to another. In this case the functionality of the entire travel chain is emphasized for being potentially able to affect private car users.
- **Onboard safety drivers were required**. Fully remote controlled autonomous shuttles are a fairly recent development technologically, and legislation still has to catch up on this. Taking the safety operator out of the vehicle will result in major improvements in cost-effectiveness and through this in improvement of public transport services through self-driving technology. Moreover, one remote operator should be able to operate at least two vehicles simultaneously to achieve these improvements. Technologically, it has not been possible to remove the onboard safety driver on open street operations and in some countries it is not legally possible yet. Pilots such as those run as part of Sohjoa Baltic are instrumental in illustrating how mature the technology is in this regard. This allows analyses of what kind of systems are needed in a remote control center, for instance, what kind of visual information must be provided for the operators and what is the best way to remotely intervene in the operation of the buses. Simultaneously, the pilots allow for informed policy making and updating rules and regulations surrounding remotely controlled shuttles.
- **Fleet supervision services have been demonstrated but it is not yet fully known how to organise remotely supervised operations and what kind of on-field services are needed.** During the Sohjoa Baltic pilots, fleet supervision systems were used to monitor multiple shuttles, each of which had a safety driver on board, testing the scalability of autonomous transport. When shuttles can be safely operated and supervised remotely, it should be figured out how several shuttles work together and what kind of on-field backup services are needed. Presumably, there will be situations where human intervention is needed on the field in operational areas and routes of automated buses. These can be linked to working outside of operational hours (e.g., driving buses manually to parking depots and carrying out maintenance activities) as well as to issues encountered during the operational hours (when taking passengers onboard). It is not known how many vehicles one operator could monitor and what the acceptable amount of intervention for both the remote operators and local incident response team on site is. This is a matter of how well the vehicles can handle the route and different traffic situations - how often they request takeover. This is strongly linked to the level of autonomy of the vehicles as well as the legislation.
- **Shuttles require infrastructure for charging and maintenance activities.** Where possible, shuttles have been stored and charged in locations close to the operational area (at a maximum distance of around 500 meters), thus avoiding having to drive on unsuitably fast roads. On longer trips shuttles have been transported with trailers because of limited driving features of the shuttles which does not allow driving fast (usually not over 30 km/h).

- **Generally, the storage and charging places have had to be found near the operational area, which can be difficult**. This is, of course, an area- and route-specific issue but can present a challenge that affects the routes that could be implemented with automated shuttles. This is particularly relevant in densely built-up areas, where there is no room to build new depots for the shuttles.
- **In addition, charging the bus** during the winter with no warm garage can be challenging as the current buses used in Sohjoa Baltic require at least above +0C for charging.
- **Liability decisions and type approvals regarding automated vehicles** are still being established. There has to still be a dedicated person in charge of a vehicle. However, this person does not necessarily have to keep their hands on the steering wheel or even be inside the vehicle while it is moving. This is a prerequisite for operating automated vehicles. It is not yet clear if one person would legally be able to monitor several vehicles. If one person would personally have the responsibility of several vehicles that are operated by a computer, who would even want to take this responsibility and be an operator? The liability should be at least a company level, either with the vehicle manufacturer and/or operator company.
- **Depending on the case, the single person monitoring the vehicles** should of course take some responsibility (not being under influence of substances at work, not sleeping, etc.). Regarding the vehicle class, there has still been some flexibility. For instance, in Finland shuttles have been operated in road traffic with test plates granted by the Finnish Transport and Communications Agency (Traficom), and basically the buses have been registered with test plates as passenger cars. On a European level, it is not clear which vehicle class the shuttles fit into, they lack features stated for instance for buses and passenger cars, and therefore cannot be type approved officially for road legal use yet. Current vehicle approval relies heavily on the technological validation of only a vehicle which is driven by a detachable component, the driver. Some changes must be done or new vehicle classes for automated vehicles must be established so that shuttles can be operated as part of an actual commercial and public transport service in road traffic.
- **Operating with automated buses under market conditions requires careful planning**. Depending on the local legislation, official type approval/registration might be required, and in some cases, test plates are needed for operations in road traffic. Test plates are purely for testing and collecting payments from passengers would have to be part of the testing. For paid operations, the operator needs a passenger transport permit. In Kongsberg (Norway), it was possible to establish a fully operational, paid commercial service thanks to cooperation between the road authorities and the transport providers. Also in Finland, this would be possible already now in some cases, but there is still some ambiguity regarding this in different European countries.

The same process of setting up an operation with automated vehicles applies in many respects also when moving from pilots to real service as part of public transport. It is the output of the service that changes - that is to say the viability of the service improves (or has to be improved).

For now it is important to understand the difference between a pilot and a real service, and subscribers should not expect to receive simply a replica of an existing public transport service that is implemented with lower costs. The above points summarise the future steps that need to be taken in order to proceed from pilots to real official operation of automated buses as part of public transport.

3. Role of the service subscriber and supplier

The process of setting up an operation with automated vehicles is a collaborative action between different parties such as:

- service subscriber (usually a city, public transport operator or some other public or private organisation)
- service provider/supplier (manufacturer and software supplier of the provided automated buses and/or an operator focusing on providing and deploying services with automated buses)
- local transport safety agency (granting the permissions to operate automated vehicles in road traffic)
- local public transport authority
- land owner (some private party or city)
- municipalities (city traffic planners or other relevant parties, e.g., road managing authorities) authorising street use or changes to it
- other parties interested in having and supporting (e.g., providing storage and charging facilities for the vehicles) a last-mile service in their vicinity.

The main responsibility for setting up the operation lies within the service subscriber and the service supplier. It can be said that the role of the service subscriber is more focused on preparing and providing the possibility of testing the automated pilot vehicles on the selected route, while the practical steps of implementing the pilot are in the hands of the supplier. These responsibilities may vary depending on the agreement. For example, during some pilots the operators are provided by the service supplier but there are instances where operators are provided by the subscriber.

More precisely, the main tasks of the service subscriber on setting up the automated operation can be usually listed as follows:

- Steer the supplier in the right direction of applying permissions and support in the process wherever local help and lobbying is needed.
- Select test route (if possible, together with supplier) and provide detailed info about the route.
- Provide detailed information and contact points at actors responsible for the public transport systems, and APIs needed.
- Work as a local contact point for city traffic planners, public transit authority and other relevant authorities possibly involved in planning and implementing the automated vehicles in road traffic at said test route.
- Assist in planning perspective traffic arrangements and bus stops.
- Arrange overnight storage and charging facilities for pilot vehicles, and assist with possible daytime charging arrangements.
- Arrange remote control center facilities (if located in the vicinity of the route) and local response team facilities for the operators/safety drivers and other personnel.
- Provide passenger information and decide the operational schedule of the service.

The role of the service supplier in setting up the automated operation can be described in more detail as follows:

- Apply for permissions and necessary insurances for testing.
- Provide the vehicles, necessary equipment and other related services (such as remote control center) for the operation.
- Investigate the selected route and note potential points of issues.
- Inform the subscriber about potential issues with the proposed route and suggest possible improvements and arrangements regarding the infrastructure.

- Provide detailed information about the vehicle and other equipment needed for storing and charging it.
- Work collaboratively with the service subscriber.

When getting closer to the real supply and locally established official services of providing automated vehicles as part of public transport, the tasks may change to some extent, reducing the subscriber's participation and actions regarding the arrangements.

Apart from setting up the operation, it has been possible in recent years that the subscriber themselves carries out the daily operations by training capable operators with help of the manufacturer's.

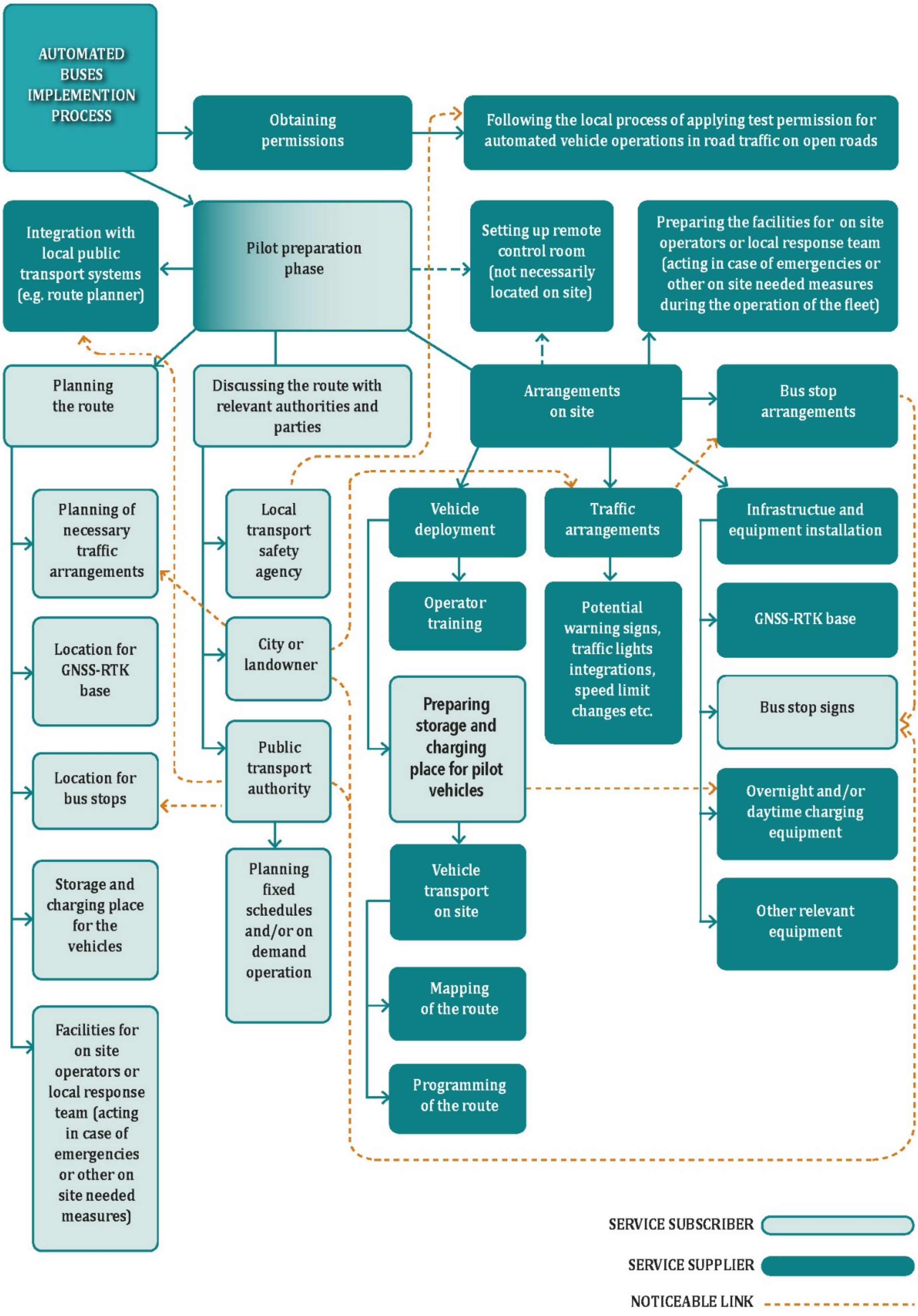
The manufacturer of the supplied vehicle(s) then usually only provides the vehicle(s), its deployment (mapping and programming of the route) on the selected route, related maintenance, software licensing and simple remote supervision to assist with daily tasks.

However, the nature of the supply has been changing lately, with all-inclusive service becoming more similar to what current official public transport operators provide as new operator companies have been established around the business.

4. Setting up the operation step-by-step

Even though the tasks are divided between the service subscriber and supplier, collaborative work should be expected in almost every task, and usually the successful deployment of an automated operation requires substantial input from both parties.

The process of setting up the operation with automated vehicles, now focusing on automated shuttles, is outlined in Chart 1. The colours in Chart 1 reflect the main responsibility for each task.



a Chart 1: The process of setting up operation with automated shuttle-buses

Thinking of the process as a step-by-step implementation plan of automated shuttles, it can be divided into three phases:

a) Obtaining permissions
b) Pilot preparation
c) Pilot implementation

Chart 1 focuses on the first two phases of the automated buses implementation plan. These phases are explained in more detail in the sections below (A. Obtaining permissions, B. Pilot preparation).

a) Obtaining permissions

For starting an operation with automated shuttles, it has to be legally allowable to operate an automated vehicle in road traffic in the country concerned. Moreover, the exemption process or the way of applying for test plates should be relatively easy for service providers to gain interest and provide a solution for the procured operation. This applies specifically if the actual pilot is short in duration - the application process should not take a disproportionate amount of time compared to the operational time of the pilot.

More detailed information on legislation concerning each individual country participating in Sohjoa Baltic and the processes of applying for permissions for testing automated vehicles is explained in Sohjoa Baltic Roadmap to Automated Electric Shuttles in Public Transport The Legal Framework.

b) Pilot preparation

After it has been established that a pilot can be carried out legally and that the permission for testing can be applied for, the next phase, pilot preparation, which is described in detail below, can be started concurrently. Of course a supplier for offering the requested service needs to be acquired at an early stage to be sure that they are able to provide the service. The pilot also needs to be planned and prepared in cooperation with the service subscriber and supplier. The numbering of the topics below does not necessarily represent the correct flow chart of the preparations. Many of the tasks can be and should be done simultaneously.

1. Planning of the route
   - ✓ In cooperation with traffic planners and local public transport authority as well as other relevant parties.
   - ✓ Planning the route (the route itself, bus stops, storage and charging place, etc.).
   - ✓ Facilities for Remote Control Center (if located near the route) and safety drivers/local response team.
   - ✓ Presenting the route to the bus supplier (route map, pictures, videos, etc.)
   - ✓ The supplier visits the site if needed to see if the route is suitable.
   - ✓ Finding a place for a fixed Real Time Kinematics Global Navigation Satellite System, (RTK GNSS) base for corrected satellite positioning of the shuttle, if needed; usually on a roof of the highest building or a building with central location by the operational area. The recommended option would be to use a local virtual reference station (VRS) subscription provider. In that case there is no need for installing a fixed RTK base as the satellite corrections come through the mobile network.
2. Discussing the route with the city or landowner
   - ✓ For instance, discuss the possibility of removing parking spaces for the shuttle's bus stops and making additional arrangements that might be necessary for succeeding with the operation.
3. Discussing the route with local public transport authority
   - ✓ If there are other public transport vehicles driving on the same path, public transport authorities usually hope that the robot bus(es) does not disturb the traffic.

- ✓ To avoid this problem, the schedule of the robot bus can for example be synchronised with that of other buses (as was done in Helsinki with HSL buses). The actual schedule for the robot bus can only be planned in detail after it has been programmed and tested on the route, as there are many things that affect the time it takes to drive the full route.

4. Informing local transport safety agency
   - ✓ Informing the local transport safety agency about the planned pilot location and schedule.
   - ✓ Usually, this institution is already involved in the permission process.
5. Planning all necessary traffic arrangements and bus stops for the route
   - ✓ Traffic arrangements plan for possible traffic signs (for instance automated vehicles warning signs) and bus stops, as well as additional infrastructure and other possible changes.
   - ✓ Daytime vehicle charging possibilities alongside the route, if necessary (depending highly on the schedule of the operation).
   - ✓ If traffic lights are located on the route, make sure it is clear if/how they communicate with the shuttles.
   - ✓ Agreement with the city or landowner.
6. Preparing the storage/charging place for the bus
   - ✓ Height of space: make sure the shuttles fit.
   - ✓ Check that there is sufficient space for all of the vehicles.
   - ✓ Safe and secure: make sure it is clear how to gain access and who has access to the depot.
   - ✓ Check that there is water for cleaning.
   - ✓ Check that there are suitable charging possibilities (both overnight and daytime, if necessary).
   - ✓ Some temporary storages, for instance tents, might be used in warm weather conditions (0 >°C).
7. Preparing a place for the GNSS RTK-base
   - ✓ Ensure that the place for the RTK-base is ready for making the necessary measures regarding the installation (e.g., availability of electricity).
   - ✓ Agreement on the permission to install the base with the building owner.
   - ✓ Making sure that the place can be accessed during the pilot (for instance the base might need to be restarted).
8. Implementing all the necessary traffic and bus stop arrangements for the route
   - ✓ Deploying traffic signs and other required infrastructure.
   - ✓ Installation of specific bus stop signs for the robot buses or leaflets at regular public transport bus stops, if these are used as bus stops (schedule can be difficult to know before the actual operation).
   - ✓ If traffic lights are located on the route, make sure they communicate with the shuttles.
9. Setting up the RCC and facilities for safety drivers as well as local response team
   - ✓ As long as some personnel is needed inside the moving shuttles to be able to act in case of some situation where human intervention is needed on site, a facility to accommodate the necessary personnel should be located close to the route.
   - ✓ RCC facilities could be also located next to the operational route. A place for safety drivers and a local response team could be located in the same facility as well. In the future, RCC facilities could even be located in another country than where the actual shuttles are operating, provided that the personnel can communicate in the local language of where the shuttle service is conducted.
   - ✓ Check there are required internet connections and that the quality of the connections is sufficient.

10. Operator training
    - ✓ Even though shuttles are described as autonomous, human intervention is still needed in shuttle operations. For now, the operators have been on board in the shuttles acting as safety drivers. Eventually, it is intended to move these onboard operators to a remote control center. In any case, training is needed for people acting as operators. If capable operators can already be provided by the supplier within the procured service, this step is not relevant for the subscriber.
    - ✓ In most cases, it is probably preferred that operators are provided by the supplier, but especially in the past, they were also provided by the subscriber.
    - ✓ In the case that operators are provided by the subscriber or some other party not directly cooperating with the supplier, additional training is needed. The training is usually arranged by the supplier (bus manufacturer) on site where the route will be while the shuttles are deployed on the route. Some pre-study material might also be provided for studying the basics in advance. It is especially important to train manual driving in a closed area before entering the actual open road route for training necessary measures in automated driving mode. The duration of the training can be a couple of weeks depending on the skill level of the trainee. The recruited operator must have at least a class B driver's license.
    - ✓ If the operators are not recruited directly by the subscriber, the supplier may need help for recruiting local personnel for operations in a foreign country, especially if it is required that the operators can communicate in the local language.
    - ✓ It is possible that some cooperation is established with some local official public transport operator company or some other party interested in such business.
    - ✓ Training to become an operator trainer can be also arranged by the bus manufacturer which can ease the training process in future operations.
11. Fixing the RTK-base
    - ✓ Before the operation with the shuttles can be started, if a RTK-base needs to be installed, the supplier needs access to the building's roof and must have permission to install the necessary equipment. Further access during the pilot may be needed as well.
    - ✓ If a Video Relay Service (VRS) technique is used, there has to be a subscription available to upload VRS data in the bus or to necessary communication services.
12. Transport of vehicles to pilot site
    - ✓ Obtain transportation quotations if needed
    - ✓ Take potentially long delivery times into account
    - ✓ Someone to receive the vehicle(s) and show the storage/charging place and the route if the supplier has not visited on site beforehand.
    - ✓ It should be taken into account that there needs to be a capable person to receive the vehicle.
13. Mapping the route
    - ✓ Mapping the route with the bus itself or a different type of system by using LiDAR radars (used for the vehicles' positioning on the route).
    - ✓ If there is busy traffic on the route, the mapping may need to be done during nighttime, as other vehicles may disturb the map quality.
    - ✓ Mapping can usually be done in one day.
14. Programming of the route
    - ✓ The route is driven along several times and points such as bus stops, intersections and zebra crossings are programmed.
    - ✓ The speed is increased step by step.
    - ✓ Programming can take several days or weeks depending on the route complexity.
15. Integration with local public transport route planners
    - ✓ It is necessary to bring together the supplier and the technological side of the public transport authority for managing the integration with public transport systems.

- ✓ The integration with route planners and other public transport systems can be done by mutually agreeing with the local public transport authority about the route and schedules providing that there is interest in such collaboration.
- ✓ In case of disruptions, the public transport authority should be ready to deal with feedback from passengers and convey the feedback for the party operating the shuttle service.
- ✓ There are open APIs (such as a high-frequency positioning or HFP API) to include the real time location of the shuttles into the route planner to be seen by the passengers.

Time taken for setting up an automated last mile operation

The time taken for setting up an automated last mile operation varies from deployment to deployment. The complexity of the route and the process for applying for test permissions have the greatest impact on the duration of the planning and the preparations. The actual measures on site can be completed relatively quickly if major infrastructural changes for instances to traffic arrangements are not necessary.

Usually, the deployment of a vehicle (mapping and programming of the route) takes around two weeks. If several vehicles are deployed, it may take longer, but each vehicle does not have to be deployed separately including all the phases of mapping and programming as with a single vehicle. The necessary route data can be transferred from one vehicle to another.

After the deployment is completed, it is recommended to test the operation for at least a couple of days before taking passengers on board to note potential issues with the functioning of the vehicle(s).

When and where the operators are trained must also be taken into account. The deployment of the vehicle on the route has to be finished in order to complete the part where it is learned how to operate (and supervise) the vehicle in the automated mode, if already trained operators are not available.

c) Pilot implementation

The pilot implementation phase comprises all the daily tasks that are included in the operation of the shuttles on a route which can be largely outlined as follows:

- the actual driving of the vehicles on the route (still conducted under the control of an onboard safety driver on open streets), following the predetermined conditions (e.g., fixed schedules or on demand)
- monitoring of the vehicles from a remote control center (located in the vicinity of the route or far away from it) and possibly intervening with the functioning of the shuttles (the actions needed during the operations should be assigned to the remote operator as much as possible)
- communicating possible deviations in timetables through relevant channels
- taking care of the vehicles and depot (maintenance, sanitation, charging, etc.)
- instructing passengers, which is still possible to do via the onboard safety driver but could (and should) later be done by the RCC operator, for instance through video stream
- any other relevant actions for making the most out of the pilot (e.g., collecting user feedback and other relevant data of the operations).

The service subscriber dictates the conditions for how, where and when the vehicles should operate. To some extent, it can be considered that the actual deployment of the vehicles and related systems on site, which is carried out a few weeks before the start of the operations (taking passengers on board), is also part of the implementation phase, although already listed in the previous phase (B. Pilot preparation).

Generally, the implementation of a pilot or actual automated public transport service should not be considered to differ to a large extent from traditionally organised operations which are handled by public transport operator companies. However, especially at this point, the differences are obvious and several challenges often arise within the following topics:

Vehicle fleet

The number of available vehicles to be used on the route can be restricted to one or only a few as in pilots only one or two vehicles tend to be used due to limited amount of funds and limited supply of manufacturers. When problems occur, spare vehicles are not necessarily quickly available.

- Solution: Explore the possibility of having a spare vehicle quickly available.

The operational range of the shuttles is currently limited to around 30-100 km or 5-12 h of operational time depending on the conditions (e.g., use of air conditioning or heating and idle time at bus stops). Fast charging options have not yet been explored and the charging has been carried out outside of operational times, usually at nighttime at the depot. The duration of the daily operations with one shuttle has to be planned considering the possible operational time and range.

- Solution: For extending the operational hours, daytime charging possibilities directly on the route could be explored (e.g., use of roadside parking space or other possible space for adding a power supply to a terminus). The schedule of the shuttle could be also divided into two sections between which the shuttle could be charged at the depot for a few hours.

Operational service

Existing public transport operator fleet depots can most likely not be used unless located in close proximity to the operational route. Daily activities to drive the vehicles back and forth to depots might be too difficult and time consuming to be managed.

- Solution: Find an existing depot near the route for storage, maintenance and charging or establish a new one on an open space by using tents or containers. Equip the depot with the power supply required and necessary equipment such as a water supply for cleaning and some maintenance tools. A service crane may come into use at some point as well. In short-term pilots the investments and work for well established and equipped depots may rise to be disproportionately expensive and laborious when considering the pilot's duration. It is possible to transport the shuttle (with a trailer) to another depot located further away for larger maintenance activities as well.

Due to newly formed business around automated shuttles, few established operators and shuttle suppliers exist which leads to a lack of technical support on site in case of problem situations. In practice, this may be reflected for instance in a situation where the route trajectory (virtual rails) of a shuttle should be modified for some reason, e.g., roadworks. Another example could be a technical issue with the shuttle which cannot be handled by regular personnel on site. In these cases, a deployment engineer or some technician of the shuttle supplier is usually sent from abroad to take care of the issue, which can lead to long delays and downtime of the operations.

- Solution: Build capacity for operational support by local operator companies and entities.

Required personnel

For now, a safety driver is still needed onboard in the shuttle. For Sohjoa Baltic pilots in Helsinki and Tallinn, the safety drivers were students and in Gdańsk, Kongsberg and Zemgale region pilots, the safety drivers were professional bus drivers. Including bus drivers as safety operators can ensure a more active involvement of public transport providers.

For advancing into a state where no responsible person is located inside the vehicle, it is recommended to consider how the operations might be handled without this onboard person. In this respect, it would be useful to establish a RCC for gathering experience on how the operations would be organised in practice, even though the actions done in the RCC would mainly focus on supervising the shuttles for now (location, video image and other relevant data). Furthermore, it is presumably that there will be situations in the future which cannot be handled autonomously by the vehicle nor remotely by the operator, which is why it would be useful to gain knowledge on how a local incident response team would act in case of such a situation and when the service will become financially viable considering all of these actors. These additional measures require personnel and facilities. In general, there might currently be significantly more personnel involved in operating one automated vehicle compared to traditional human driven vehicles.

- Solution: Reserve a sufficient amount of funds to realise the operations. Make sure to have social facilities for all of the required personnel near the route. The RCC does not necessarily have to be located near the route, but at this point it could be wise to have the safety drivers, RCC operators and the local incident team in the same facility near the route.

Collecting information regarding the operators' interventions in the functioning of the shuttle and other relevant data is still important at this point, but may be too laborious for the safety driver to do during operation. Any additional tasks may also reduce the safety level as the safety driver has to focus on several tasks while supervising the vehicle.

- Solution: Have additional personnel collecting this information (and possible user feedback).

Operations are handled by specially trained personnel who have to have a driver's license (class B or D) as a basis. Every automated shuttle model currently works differently and requires individual training for approximately a few weeks where the special characteristics of the vehicle as well as manual driving and automated driving modes are learned. Due to the required training, new safety drivers (and operators) cannot be acquired quickly. If the operations have already started and there is only one shuttle available, it has to be taken into account how the training is completed considering the manual and automated driving lessons as the operations have to be ongoing on the route. If an all-inclusive service is acquired, it should be the responsibility of the supplier to provide the required personnel. However, in some cases it might be considered hiring some local personnel who could be provided by the subscriber.

- Solution: Make sure to train and hire a sufficient number of safety drivers and operators before the start of the operations. Training can also be arranged at the suppliers' premises and it might even be possible to arrange training to gain authorisation to train new safety drivers and operators.

IV. Policy recommendations

Our policy recommendations cover short-, medium- and long-term perspectives to remove existing barriers and facilitate autonomous public transportation service. However, these recommendations should be reflected in the context of a particular place, as countries and regions in Europe have been moving at different paces in terms of piloting autonomous vehicles.

For example, in Norway we can see the first attempts in establishing a sustainable service with autonomous buses while some European countries have not hosted an autonomous pilot yet. At the same time,, Lithuania is currently the only country in the Baltic Sea region, where an autonomous pilot has not taken place.

Therefore, we divide policy recommendations into the following three categories, which cover short- medium- and long-time perspectives:

- planning
- short- and long-term pilots
- building a sustainable service.

1. Planning

- Systemic development of experimental culture is essential for launching pilot projects. The public sector has to be patient in supporting the development of essential new technologies that have the potential to reshape service delivery and provide opportunities for local companies as technological obstacles are the rule rather than an exception. However, nurturing an experimental culture in the public sector can be challenging as failure is not tolerated due to the use of public funding.
- Already early on all the relevant stakeholders should be included into the pilot planning process by the pilot organiser. These include universities, road administration, local government and related companies. Early involvement of such stakeholders can provide valuable information and recommendations which is necessary for organising a pilot. The pilot is also a learning moment for them, which can help smoothing the planning process of future pilots but can also spark local technology development.
- Regulatory flexibility is key for adopting new technologies. The examples of Denmark and Norway show how a small difference in regulations, in this case the question of whether a government body can interact with third-party traffic safety assessor, can play a crucial role in the successful organisation of a pilot.
- National road administrations should develop step-by-step guidelines that describe the process of applying for a permit for autonomous pilots on public streets and test plate number for autonomous buses. It also means that the road administrations should develop a procedure for how test plate numbers are issued for autonomous vehicles.

2. Short- and long-term pilots

- The funding of short-term pilots through different EU funding mechanisms should continue. It is justified to not provide funding for short-term pilots in countries and regions where such pilots have already taken place. However, there are still a number of countries and regions in Europe that have not launched an autonomous pilot yet. Organising a short-term pilot would help these countries and regions gather experience for organising longer and more complex pilots, provide insight about the existing regulatory and procedural obstacles which otherwise would remain hidden, and function as technology demonstrations which raise the public awareness.
- Countries, regions and EU funding bodies have to be prepared for higher costs if they want to run short-term pilots. The length of a short-term pilot in the future should be 2-4 months (previously 1-2 months) to give additional incentive for companies to provide their buses. Although short-term pilots are still necessary, one has to take into consideration the current market situation where demand for and rental prices of autonomous buses is increasing. Setting up a pilot also means high one-time costs for the supplier company (e.g., transportation, programming of the route) which makes them prefer long-term pilots. Several companies have already expressed that the preferred length for a pilot is at least 12 months, which might be too long and complex for some regions and countries.
- Long-term pilots provide opportunities for developing local competence in autonomous technology. Autonomous pilots should not only be seen as testing new means of providing public transportation service by public sector organisations. The market and technology are still in the early phase of development which can provide opportunities for local companies and universities. Such a goal requires an early involvement of all the relevant stakeholders already during the planning phase.

3. Building a sustainable service

- Involve the entire ecosystem around the transport service, especially businesses. By involving businesses and creating an atmosphere where all parties pursue a common goal, it is possible to solve problems quickly and avoid the long time frames that risk making the project unattractive for actors who are interested in business development. Additionally, having a common goal encourages collaboration but also facilitates acceptance of the project on all levels. Involvement of public transport providers, for example by training bus drivers as safety operators, results in positive connections with important actors needed for a successful sustainable service.
- Focus on scalability of an initial project. While there is great merit in starting off with a pilot project and learning valuable lessons from it, it helps to keep the focus on wanting to achieve a fully functioning, scalable solution as much as possible from a very early stage. This ensures that the project as a whole stays tangible for business developers and potential investors, who can then take easily the results of the pilot and convert them into a sustainable solution. Particularly in view of the fact that investments from private investors were essential in realising the Kongsberg pilot, it's important to also concentrate on the profitability of the project.
- Ensure continued communication between all actors involved in the project. It is to be expected that a project involving cutting edge technology will encounter a number of challenges, both technological but also legal. That is why it is important to ensure that there is efficient and good communication between all the parties involved, from the vehicle provider to the national authorities: that way, obstacles can be identified and removed quickly, and the lessons learned can be fed back into an improved solution that everyone will benefit from.

Volumes of the Sohjoa Baltic – The Roadmap to Automated Electric Shuttles in Public Transport

1. The Legal Framework
    - What is the current legal status of automated driving in different European countries of the Baltic Sea Region? Sohjoa Baltic presents the relevant legal information for implementation and provides policy recommendations for the future.
2. Technology and Safety Requirements
    - What are the current relevant technological and safety challenges to be taken into consideration in the implementation of automated shuttle buses? Sohjoa Baltic provides information from Germany, Denmark, Poland, Norway, Finland, Sweden, Estonia, and Latvia.
3. Starting Your Own Pilot
    - How to deploy an automated vehicle pilot in a city? Sohjoa Baltic provides a practical toolkit with recommendations based on the practical experiences from automated shuttle bus pilots in Norway, Poland, Finland, Estonia, Latvia and Denmark.
4. Procurement Challenges
    - What are the barriers and enablers of autonomous vehicle procurement in public transportation? The experiences of Sohjoa Baltic's automated shuttle bus pilots in Estonia, Denmark, Finland, Latvia, Norway and Poland describe the complexity.
5. User Experience and Impact on Public Transport
    - How and why should cities prepare to implement automated public transport? What is the role of automated shuttle buses? Sohjoa Baltic provides views based on experiences from pilots in Norway, Poland, Finland and Estonia.