Policy paper

Deliverable 5.6 - Future application and impact of project results and learnings

Project Acronym:	FABULOS
Full Title:	Pre-Commercial Procurement of Future Automated Bus Urban Level Operations Systems
Grant Agreement No.:	780371
Work package No.:	5 - Impact assessment and Recommendations
Responsible Author(s):	Eetu Rutanen, Marika Koskinen, Eero Tuuliainen and Oscar Nissin (Metropolia University of Applied Sciences)
Responsible Co-Author(s) and contributor(s):	Renske Martijnse-Hartikka and Suvi Vähä-Sipilä (Forum Virium Helsinki), Johann Peetre (MKM Estonia, Tallinn), Carlos Abreu (STCP, Porto), Fotis Gogoulos (Municipality of Lamia), Marcel Unterberg (City of Helmond), Trond Hansen (City of Gjesdal)
Date:	31.3.2021
Status:	Final version
Dissemination level:	Public

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 780371.

Table of contents

1. Introduction 4

1.1 Purpose 4

1.2 Target Group 4

1.3 Background 4

1.3.1 Pre-Commercial Procurement (PCP) 5

1.3.2 Phase 3 consortia and test sites 6

1.3.3 Piloting in Phase 3 7

1.3.4 Field test vehicles 9

1.4 Lessons of the Pre-Commercial Procurement model 11

1.4.1 The Buyers Group's view of the usefulness and success of the PCP process 12

1.4.2 Linking the FABULOS project to the innovation strategy of organizations and its role in project commitment 13

1.4.3 The impact of EU funding on the decision-making of organizations in the implementation of innovation projects 14

1.4.4 Experience of Preferred Partners representatives in the PCP process in the FABULOS project 14

2. Analysis of defragmentation of the market 15

2.1 Market analysis 15

3. Main learnings from the Buyers' Group 17

3.1 Forum Virium Helsinki 17

3.1.1. Helsinki pilot: Political findings 21

3.1.2. Helsinki pilot: Economical findings 22

3.1.3. Helsinki pilot: Social findings 23

3.1.4. Helsinki pilot: Technological findings 24

3.1.5. Helsinki pilot: Environmental findings 25

3.1.6. Helsinki pilot: Legal findings 26

3.2 Tallinn (MKM) 27

3.2.1 Tallinn pilot: Political findings 29

3.2.2 Tallinn pilot: Economical findings 29

3.2.3. Tallinn pilot: Social findings 29

3.2.4. Tallinn pilot: Technological findings 30

3.2.5. Tallinn pilot: Environmental findings 30

3.2.6. Tallinn pilot: Legal findings 31

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 780371.

3.3 Municipality of Gjesdal 32
3.3.1. Gjesdal pilots: Political findings 35
3.3.2. Gjesdal pilots: Economical findings 35
3.3.3. Gjesdal pilots: Social findings 35
3.3.4. Gjesdal pilots: Technological findings 36
3.3.5. Gjesdal pilots: Environmental findings 36
3.3.6. Gjesdal pilots: Legal findings 37
3.4 Municipality of Helmond 37
3.4.1. Helmond pilot: Political findings 39
3.4.2. Helmond pilot: Economical findings 40
3.4.3. Helmond pilot: Social findings 40
3.4.4. Helmond pilot: Technological findings 41
3.4.5. Helmond pilot: Environmental findings 42
3.4.6. Helmond pilot: Legal findings 43
3.5 Municipality of Lamia 44
3.5.1. Lamia pilot: Political findings 46
3.5.2. Lamia pilot: Economical findings 46
3.5.3. Lamia pilot: Social findings 47
3.5.4. Lamia pilot: Technological findings 48
3.5.5. Lamia pilot: Environmental findings 49
3.6.6. Lamia pilot: Legal findings 49
3.6 STCP Porto 50
3.6.1. STCP Porto: Political findings 51
3.6.2. STCP Porto: Economical findings 52
3.6.3. STCP Porto: Social findings 52
3.6.4. STCP Porto: Technological findings 52
3.6.5. STCP Porto: Environmental findings 53
3.6.6. STCP Porto: Legal findings 53
3.7 Summary of the main learnings 53
3.7.1. FABULOS: Political learnings 54
3.7.2. FABULOS: Economical learnings 54
3.7.3. FABULOS: Social learnings 55
3.7.4. FABULOS: Technical learnings 57
3.7.5. FABULOS: Environmental learnings 58
3.7.6. FABULOS: Legal learnings 58

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 780371.

4. Challenges to commercialisation **59**
4.1 Technical challenges 60
4.2 Legal challenges 63
4.3 Operational challenges 65
4.4 Summary of the noted challenges 69

5. FABULOS' Contribution **70**
5.1 FABULOS' contribution to solve the technological challenges 70
5.2 FABULOS' contribution to solve the legal challenges 72
5.3 FABULOS' contribution to solve the operational challenges 74
Examples of FABULOS's local impact 75

6. Considerations for future development of provided solutions **76**
6.1 Considerations for overcoming technical challenges 76
6.2 Considerations for overcoming legal challenges 77
6.3 Considerations for overcoming operational challenges 78
6.4 Considerations for procurement 79
6.5 Expected development of automated shuttle solutions 80

7. References **82**

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 780371.

1. Introduction

1.1 Purpose

This policy paper serves as means to make the target group presented below more aware and informed of automated public transport. It also presents policy-related considerations and recommendations for the future development of automated shuttle services.

1.2 Target Group

This paper is targeted at city public transportation planners, area development specialists, public transportation agencies and operators, traffic safety agencies and companies providing technology and services related to automated means of transport.

1.3 Background

The FABULOS (Future Automated Bus Urban Level Operation Systems) project focused on how cities can use automated buses in a systematic way. The goal was to procure the operations of autonomous bus lines and to accelerate the introduction of new types of automated last-mile solutions entering the European market. Self-driving minibuses had already been tested in technical demonstrations in various countries, but a proof-of-concept for the management of autonomous fleets as part of the public transportation provision was not yet available.

Furthermore, some parts of the driving automation needed to reach a more mature stage in their development in order to be employable in normal urban settings, such as open roads. In other words, a demonstration of the economic, technical, societal and legal maturity of the solution needs was required. This needed to be carried out in a real-life setting, integrating automated minibuses into the public transportation ecosystem.

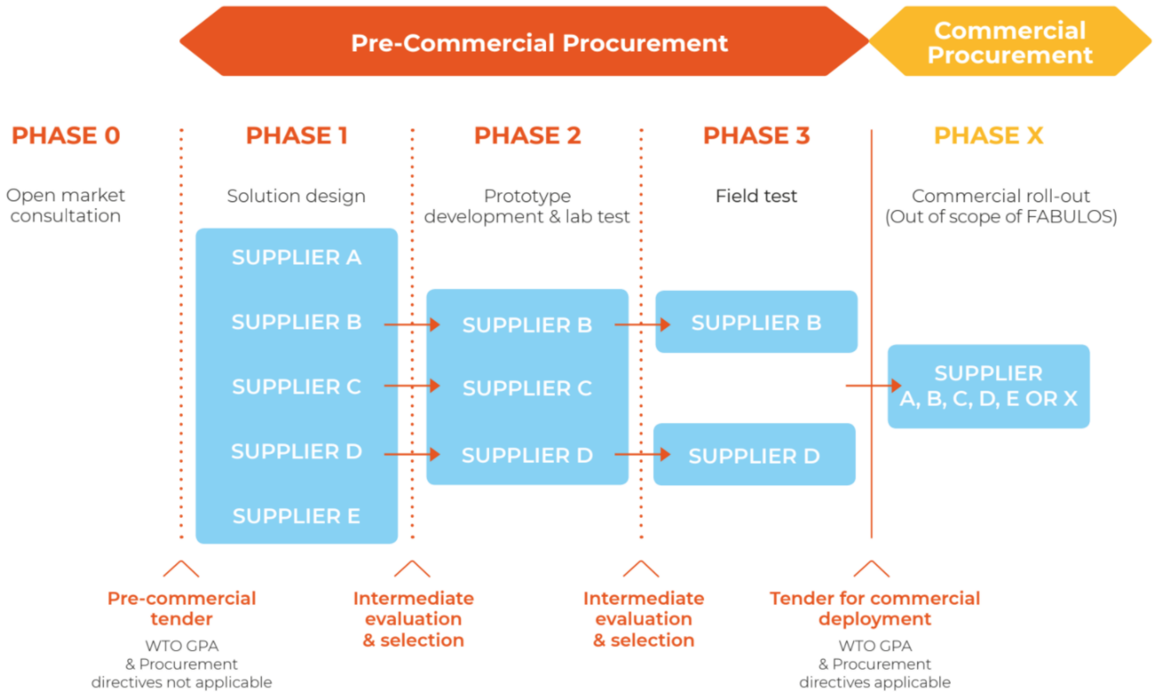
The six partner cities participating in FABULOS were embracing this challenge by collectively procuring R&D for the prototyping and testing of smart systems that were capable of operating a fleet of self-driving minibuses in urban environments. These solutions needed to be all-inclusive: software, hardware, fleet and services. The cities played an important role by combining their efforts in supporting the market to develop such systems. This kind of intelligent transportation system and integrated transportation approach is key to facilitating the sustainable development of public transportation and for cities to be able to become free from private cars in the foreseeable future.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 780371.

1.3.1 Pre-Commercial Procurement (PCP)

The type of procurement described above is called **Pre-Commercial Procurement (PCP)**. Pre-commercial procurement is a method for public sector procurers to buy R&D from several suppliers in parallel, to steer development of solutions to meet their needs. The end result, including the intellectual property rights (IPR), remains with the contractors. Pre-commercial procurement is exempted from the WTO Government Procurement Agreement [Agreement on Government Procurement], the EU public procurement directives and the national laws that implement them. This is because it concerns the procurement of R&D services where the benefits do not accrue exclusively for the contracting authority.

The pre-commercial procurement process depicted in Picture 1 below consists of three clearly defined phases: Concept design, Prototype development and Field testing. In each of these phases significant budgets are available for suppliers to support their work.



Picture 1: Graphical overview of the Pre-Commercial Procurement process.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 780371.

Prior to phase 1 is the Open Market Consultation in which the scope of the FABULOS request for tenders was refined. In FABULOS this consultation was set for April and May 2018 and the actual request for tenders launched in September 2018. This was followed by phase 1, the concept design phase. Phase 2 was the prototype development phase, in which the most promising concepts were developed into working prototypes. Then, in the final field testing phase (Phase 3), after nearly 2 years of developing autonomous robot bus solutions in the FABULOS project, suppliers that successfully participated in the prototyping were selected to execute a series of large-scale pilots in urban environments within the procuring cities.

From spring 2020 onwards, robot bus prototype solutions from three consortia were evaluated in real-life road traffic conditions in five European cities. All the robot bus solutions aim to offer an all-inclusive service for autonomous last-mile transport, while testing the edge intelligence of the vehicles in different driving scenarios, remote control capabilities, on demand features as well as capabilities of adapting to the geographical challenges. Functional specifications that were introduced to the consortia as the procurement challenge, are based on previous experience of the partners from automated vehicle pilots, and from the realisation of the gap between the desired level of operation and the current performance level of the automated vehicle technology.

At the end of the PCP process, the companies or consortia are expected to continue the refinement of the tested prototypes in order to make them into market-ready solutions that can be procured by additional public procurers. That activity falls outside the scope of FABULOS.

In total, FABULOS procurement budget reaches around 5,500,000 Euros (including VAT). The maximum budget for individual suppliers involved in all three phases is over 1,000,000 million Euros (including VAT).

1.3.2 Phase 3 consortia and test sites

During the field-testing phase of the FABULOS pre-commercial procurement – third and final phase of the procurement – selected robot bus prototype solutions were tested as small fleets of shuttles in:

- Estonia (Tallinn)
- Finland (Helsinki)
- Greece (Lamia)
- Netherlands (Helmond)
- Norway (Gjesdal)

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 780371.

Each of the three suppliers chosen for this phase received up to 1 million euros (incl vat) to prepare pilots and implement operational systems to validate their prototypes. The three supplier consortia, composed of a dozen companies representing six nationalities, were:

- Sensible4-Shotl (Finnish – Spanish) - pilots in Helsinki and Gjesdal
- Saga (Norwegian – Canadian) - pilots in Gjesdal and Helmond
- Mobile Civitatem (Estonian) - pilots in Tallinn and Lamia

1.3.3 Piloting in Phase 3

The piloting of the self-driving shuttles firstly started in Helsinki on 14th of April 2020 affected by restrictions due to the COVID-19. Pilots in Gjesdal and Tallinn followed in June 2020. During the autumn and winter of 2020, pilots were launched in Lamia, Helmond and again in Gjesdal. Each of the suppliers piloted their robot bus solutions in two cities.

Table 1 depicts different key performance indicators (KPI) of each Phase 3 field tests in the 5 different cities participating in FABULOS in which the field tests were carried out (Porto is not presented, as the field test was not conducted there due to legislative restrictions). The operational conditions and routes of the field test sites were varying and the consortia also used different kinds of methods to measure the KPIs which reduces the comparability of the data. Thus the table provides general information of the field tests with numbers.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 780371.

Table 1: KPIs of Phase 3 Field test sites.

City	Consortium	km driven bus 1 / bus 2	Passengers	Amount of on demand passengers	Max operating speed / max operating speed by law or due road administration (km/h)	Average operational speed bus 1 / bus 2 (km/h)	Length of the route to one direction (km)	Amount of automated mode / manual mode (%)	Operational hours bus 1 / bus 2	Energy consumption bus 1 / bus 2 (kWh)
Helsinki	**S4 - Shotl**	1026 / n.a.	187	12	28 / n.a.	20 / n.a.	1,2	80 / 20*	270 / n.a.	974 / n.a.
Tallinn	**Mobile Civitatem**	809 / 451	518	n.a.	15 / 15	9 / 9	2,4	94 / 6	256 / 95	n.a.
Gjesdal pilot 1	**Saga**	1507 / 836	1582	338	18 / 18**	12,5 / 12,5	2,7	91,5 / 8,5***	270 / 150	n.a.
Gjesdal pilot 2	**S4 -Shotl**	2534 / 3705	30	n.a.	30 / 30**	18,75 / 18,7	3,3	97,7 / 2,3	700 / n.a.	740 litres as it was used diesel vehicles
Lamia	**Mobile Civitatem**	1410 / 520	399	n.a.	22 / 22	102 / 12	3,1	93,75 / 6,25	377 / 172	13.92 per day and 0.345 per 1 km
Helmond	**Saga**	877,3 / n.a.	91	n.a.	18 / 16	8,7 / ?	2,9	90,2 / 9,8	466 / n.a.	394,52 / n.a.
TOTALS		**8163,3 / 5512**	**2807**	**350**	**n.a.**	**n.a.**	**n.a**	**n.a.**	**2339 / 417**	**n.a.**

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 780371.

** Almost fully automated driving until the last 4 weeks of pilot when automated driving dropped to 80% since road construction/bridge construction site covered 20% of the route and it had to be passed manually to guarantee safety.*

*** The difference in max speed is due to permission from Norwegianian road authorities, which was based on vehicle type and reports of previously carried out tests and pilots.*

**** >91.5% autonomous. Includes all time between 9am and 3pm with the vehicle turned on. This is logged from Spare platform and broadcast of drive mode from Navya during shift hours 9-15 (meaning if vehicles have been driving after 15 in manual mode, this has not been counted).*

During the Field tests the aim was to pilot a fleet of up to three autonomous vehicles in open road conditions with speed limitations up to 50 km/h. The different pilot routes included several crossroads with traffic lights, different types of intersection (such as roundabouts) and street-side parking. Bus stops were located at spots, which were cooperatively planned with city representatives, public transport authorities and the project partners. On demand capabilities were also tested via different mobile app solutions. Some parts of the routes needed different kinds of traffic arrangements, for instance lowering speed limitations temporarily to better adapt the maximum speeds of the shuttles (around 18-28 km/h) with other road users.

Technologically, the shuttle buses did not need a driver or steward on board if certain requirements regarding the traffic conditions and weather were met. For the first time in Europe, the fleets were monitored from newly established Remote Control Centers. In case of exceptional situations, a remote operator could give permission to pass an object, such as a car blocking the road, through validating the maneuver suggested by the vehicle, or take over the control of the vehicles through direct teleoperation. In teleoperations low latency connections, such as 5G, were necessary.

As part of each 50-day field trial period, the functionality, interoperability and security of the autonomous fleets were assessed. After each of the pilots, representatives of the six FABULOS procuring partners carried out an evaluation process. A pre-commercial procurement does not have one “winner”: all participating robot bus prototypes are expected to be commercialized and could be part of a follow-up procurement launched especially by the piloting cities.

1.3.4 Field test vehicles

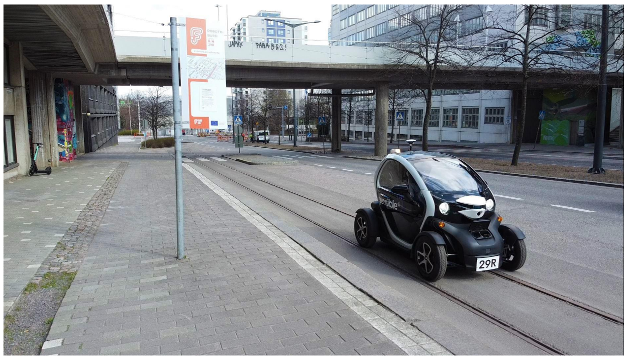
In FABULOS Field tests a total of six different vehicles were piloted:

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 780371.

- **GACHA** shuttle bus (S4-Shotl consortium) (Picture 2)
- **Renault Twizy** two seater minicar retrofitted with Sensible 4's equipment, sensors and software for automated driving (S4-Shotl consortium) (Picture 3)
- **Dongfeng Fengxing CM7** minivan retrofitted with Sensible 4's equipment, sensors and software for automated driving (S4-Shotl consortium) (Picture 4)
- **Toyota Proace** minivan retrofitted with Sensible 4's equipment, sensors and software for automated driving (S4-Shotl consortium) (Picture 5)
- **Navya Autonom Shuttle**/ARMA shuttle bus (Saga consortium) (Picture 6)
- **Iseauto** shuttle bus (Mobile Civitatem consortium) (Picture 7)

All of the vehicles had an electric drivetrain excluding the Toyota Proace vans, which exceptionally had diesel motors (due to poor availability of electric versions at the time of the pilot). Passenger capacity of the vehicles were varying from 2 seats of up to 16 including possible standing places.

Picture 2: GACHA shuttle bus.

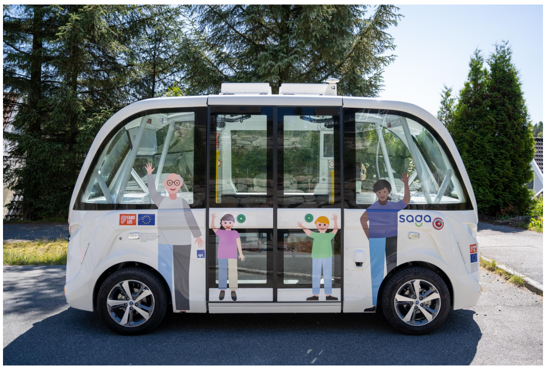


Picture 3: Renault Twizy.

Picture 4: Dongfeng Fengxing CM7 [Credits: Tuomas Sauliala].

Picture 5: Toyota Proace [Credits: Morten . Sivertsen]

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 780371.



Picture 6: Navya Autonom Shutte.

Picture 7: Iseauto.

1.4 Lessons of the Pre-Commercial Procurement model

As a part of the FABULOS project and a separate report [Koskinen 2021], a survey was conducted to find out the opinions and experiences of the usability and usefulness of the pre-commercial procurement in the project. The respondents of the survey represented two groups: the FABULOS Buyers Group and the Preferred Partners. The Buyers Group (or: procuring partners) consisted of the six partner cities participating in the FABULOS project. Preferred partners of FABULOS where organizations who were not acting as lead procurers and were not part of the Buyers Group but have been closely following the project and were interested in the results. They are considering their own pilot or deployment and wanted to follow the technological developments and progress made by the FABULOS Suppliers.

Purpose of the survey was to provide answers to the following questions:

1. How useful and successful do the representatives of the Buyers Group of the FABULOS project consider the pre-commercial procurement process of the project from the point of view of usability?
2. How does the FABULOS project relate to the innovation strategy of the organizations represented by the members of the Buyers Group and what is its role in the commitment to the project?
3. How does EU funding influence organizations' decision-making in the implementation of innovation projects?
4. How does Preferred Partners perceive pre-commercial procurement in the FABULOS project?

The following sections 1.4.1-1.4.4 are a summary of the responses received to the identified questions on the basis of which the survey was conducted.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 780371.

1.4.1 The Buyers Group's view of the usefulness and success of the PCP process

The starting situation for the Buyers Group was that only the project coordinator Forum Virium Helsinki (FVH) had previous experience of the PCP process in the innovation project. However, as the FABULOS project progressed, representatives gained a wealth of experience with the PCP instrument as they worked with a number of international, national and regional stakeholders. Their knowledge of pre-commercial procurement developed and increased due to the lessons learned from the project and the good interaction between the consortia.

PCP was seen as a value-adding procurement tool for organizations, but it was also seen as a challenging and lengthy process. The PCP process provided a lot of new information for the Buyers Group, and the FABULOS project gave them access to industry innovations, state-of-the-art technologies and market pioneers. The PCP was described as an instrument based on the concrete needs of procurers and enabling public sector suppliers to address the challenges of “tomorrow” through international cooperation.

The various stages of the PCP process met the expectations of the representatives quite well. However, the phases also revealed issues that should be addressed in future pre-commercial procurement projects, such as sufficiently clear and consistent rules for all parties to ensure fairness.

The organization and day-to-day operations of the pilots were successful and went well, although the situation of Covid-19 posed additional challenges for the project, e.g. travel and limited staff availability. The three-month extension granted to the project enabled the implementation of all six planned pilots, which was a very good thing for the pilot cities. The extension also ensured that the cities were able to benefit from all the practical lessons offered by the project and that members of the FABULOS Buyers Group had the opportunity to see all the prototypes developed in different environments.

The piloting of the developed prototypes from the cities’ point of view was successful, but they are not yet mature or ready to integrate automated minibuses into their public transport system. Expectations for technology development were not fully met during the project. The commercialization of developed solutions first requires cities to address some technical, legal, economic, and social issues.

PCP was seen as having a clear and important role to play in promoting future innovations and bringing innovative solutions to European cities. The importance of international

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 780371.

cooperation cannot be overemphasised. Working with a variety of stakeholders will accelerate the development and application of innovations.

Members of the buyer group saw PCP as a great way to tailor services of interest to contracting authorities. They felt they had learned valuable lessons from an operating environment where several consortia were working on an R&D-based solution. The different approaches used by supplier consortia to find the requested solution also provided a lot of interesting information and experiences for the members of the Buyers Group involved in the project.

The members of the FABULOS buyer group also recommend the use of PCP to other contracting authorities and, in summary, PCP has proved its worth in the FABULOS project and should be applied more widely by the buyer group members.

1.4.2 Linking the FABULOS project to the innovation strategy of organizations and its role in project commitment

Organizations that have joined the FABULOS project have a strong desire to be at the forefront of adopting the technologies of the future and developing their cities through them. Urban development strategies include responding to the needs of change in the transport sector. With the help of intelligent mobility solutions (e.g. automated vehicles), the aim is to meet e.g. emission reduction targets and to promote the transition to a demand-driven transport system. The FABULOS project is seen as well linked to the long-term development strategy for urban public transport and has served as a research and testing platform to show how intelligent mobility services could be integrated into a holistic intelligent transport system. FABULOS has provided cities with experience and lessons for further development and a solution to be implemented later.

The factors behind the organizations' commitment to the project were among other things the desire to maintain and expand its pioneering role in the field of autonomous mobility and to test how the service concepts developed in the project would be linked to urban transport modernization strategies. Participation in the PCP process of the FABULOS project was seen as an opportunity to work closely with companies in the field of autonomous mobility, to learn more about the risks and opportunities, and to improve the existing state of the art. 90% EU funding has also been one of the influential factors in engaging in the project. The commitment of the organizations to the project was also reflected in the human resources allocated to it.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 780371.

1.4.3 The impact of EU funding on the decision-making of organizations in the implementation of innovation projects

FABULOS is a project funded 90% by the EU's Horizon 2020 research and innovation program. The funding allocated to the project has played a huge role in the implementation of the project and in the involvement of organizations in the project. Without funding, the project would not have taken place. The relatively long time taken for the PCP process, as well as the uncertainty about the usefulness and value of the solutions developed, make the procedure less attractive to public purchasers than projects that directly benefit them. EU funding promotes the feasibility of innovation projects and enables the participation of suppliers.

1.4.4 Experience of Preferred Partners representatives in the PCP process in the FABULOS project

The starting point for designing the survey was that representatives of the Preferred Partners community had closely followed the PCP process of the FABULOS project, but it became clear from the responses that this was not the case in most cases. The representatives had not followed the project as closely as had been assumed. However, a more general survey was used to map the opinions of Preferred Partners representatives as well as experiences with the pre-commercial procurement process.

Coordinating the development of standards, technical information and solutions, as well as the unclear legal framework for PCP contracts, were seen as challenges in the pre-commercial procurement process. In addition, the ambiguity of the PCP process about the new kind of partner / supplier role in it emerged. However, perceptions of the FABULOS project were positive and the pre-commercial procurement process used in the project helped followers to understand the level of maturity of the market as well as supplier structures. According to the respondents who followed the project from outside the project, the management and administration were successful.

The project proved challenging to the respondents, but well prepared, which succeeded in introducing different pilots and technologies. Cooperation and communication with various actors went well and sufficient information was available. The FABULOS project has attracted the attention of industry and is believed to provide valuable information for the future. Awareness of the opportunities offered by the PCP instrument increased and the FABULOS project provided successors with tools for possible future projects of their own.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 780371.

2. Analysis of defragmentation of the market

Implementation of shuttle pilots and complete uptake of the solutions face challenges as motivation to shift towards new technology and the availability of desired technology do not always complement each other. Local public transport authorities would have the most potential role in becoming the large-scale assigners/procurers of autonomous shuttles. However, the public sector innovation promotion is based on mitigated risk strategies promoting safe and planned outcomes instead of risky and dynamic test and fail approaches. Automated shuttles have not yet proved to be a viable complementary solution as part of public transport which is why large investments and permanent decisions are pending. Pilots are arranged and deployed in environments and conditions that have been designed for previously existing solutions which is why viable use cases for shuttle operation can be difficult to arrange. The suppliers and developers are looking forward to long-term and large scale pilots while the demand side is caution with investments and long-term commitment.

2.1. Market analysis

As part of FABULOS, a market analysis was conducted within the smart mobility industry [Tuuliainen 2020]. The analysis was based on a survey which was focusing on the smart mobility industry from supplier side and demand side. The supplier side consisted of operators of automated buses or related software. The demand side consisted of public transport operators involved in FABULOS project. Respondents were involved in the FABULOS project. The demand side was represented with a possible of 10 participants, and the supply side had 13. Sample count totaling 23.

Research questions were:

- supplier-side, what kind of players are there in the automated bus industry?
- demand side, what kind of expectations and requests has the demand side set for the supplier side?

Survey respondents represented six European countries: Denmark, Estonia, Finland, Netherlands, Norway and Portugal. Supply participant's revenue within smart mobility ranged from 0,1 to five million, and demand-side project budgets ranged from below 0,5 to over five million. Participants were in very different smart mobility stages. It seemed that dispersion was relatively high, based on how much money is involved.

Considering smart mobility maturity, most participants thought that smart mobility is close to the premature stage, and there are mainly start-ups operating markets. 80 % of

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 780371.

the participants stated that markets are close to the start-up stage. The more developed market was seen as the only minority.

For future plans, the supply-side seemed to be more optimistic towards smart mobility. They were anticipating fast growth. The demand-side was not that excited about the future; nevertheless, future budgeting was mostly neutral. It seems promising that only a minority of the participants considered lowering smart mobility development or budgets in the future.

Overall conclusions based on the survey are that smart mobility is a relatively small market based on revenues and project budgets. The smart mobility market is close to the premature stage, with many young companies such as start-ups. Start-ups might not have big companies' resources and a limited amount of capital, supporting the view of a small market. It seems that change is coming in the future; the supply-side will increase development fast, and the demand-side is at least providing stable budgeting for the coming years and, that way, funding supply-side. Survey respondents estimated that new suppliers will enter the smart mobility market and as a result, the markets will expand and more financing will be available. According to the respondents, the most important aspects of smart mobility are cost savings for communities, development of Intelligent Transport Systems as well as reduction in pollution and improvement in health and safety.

Open-ended questions provided some insights for the supply -and demand-side. It was intended to find out the foundation of smart mobility and questions for both sides were formed: "what does smart mobility mean to your company / organization?" smart mobility seemed to mean many things depending on the participants's opinion. The answers can be summarized as: "smart mobility is a technological solution for various modes of sustainable and flexible transportation." For another open-ended question, "What kind of expectations do you have towards the demand side (public transport operators) / supply-side (vehicles/software providers) of smart mobility?" Both participant groups wanted personal car-free cities with new technologic solutions. Participants were confident that the development of smart mobility solutions would be accelerated within the coming years. The supply-side was worried about the risk of early adopters. The demand-side was worried about suppliers' lack of funds, and the demand-side has to carry a financial burden.

For the supply-side, it is recommended to keep on investing in the smart mobility industry. Demand for smart mobility solutions is expected to be stable or increasing soon, based on demand-sides answers related to their investing willingness. The balance between parties' financial risks are one major issue to look at. For the supply-side public investors, such as

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 780371.

public transport operators, it seems to be an attractive business partner as financial risk might be lower than the private sector's.

To achieve sustainable and flexible transportation solutions that demand-side desires, the public sector needs to invest in smart mobility projects. The private sector solely will not provide enough solutions for public transportation. Public transport operators should express their wishes and expectations to the supply-side as they both have similar views of smart mobility's future.

3. Main learnings from the Buyers' Group

In the following chapters it is analyzed whether the field test phase in FABULOS fulfilled its purpose as well as take a stand on what were the main learnings from the FABULOS Buyers' Group in relation to political, economical, social, technological, environmental and legal point of view.

3.1. Forum Virium Helsinki

Purpose of the field test phase of FABULOS project was to evaluate the established functional and non-functional requirements of the pre commercial procurement in the project in real life conditions. Field test site in Helsinki provided an opportunity for the chosen consortium (S4-Shotl) to test the solution and different functions in open road conditions thus fulfilling this general purpose. The consortium's vehicle fleet consisted of three vehicles: the GACHA shuttle bus, a Renault Twizy and a Dongfeng CM7 retrofitted with necessary equipment and sensors for automated driving. The vehicles drove along a circular route in Eastern Pasila, going from the Pasila station next to the Mall of Tripla, then turning north to circle back to Messukeskus Fair centre as seen in Picture 8 below. A video of the Helsinki pilot was produced as a part of the project communications and can be seen here.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 780371.

Picture 8: Field test route in Helsinki.

The route itself was quite short (circa 1,2 km) but offered a selection of different kinds of intersections such as roundabouts as well as intersections with traffic lights, hence having the possibility of testing the functions under varying conditions. Though the traffic lights on the area were not equipped with necessary communication modules, which is why this functioning could not be properly tested. Upgrading the traffic lights with necessary modules would have been too laborious and financially heavy to be completed in the timeline of FABULOS field test. Other traffic on the route created a sufficient amount of challenges without compromising safety for instance due to overly large differences in the driving speeds.

Field testing in FABULOS presented the opportunity for the first time in Finland to demonstrate a complete automated bus service system with both automated vehicles and relevant background functions (e.g. remote control center) in open road conditions. In more detail this included:

- the operational vehicles on the route,

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 780371.

- remote control center with personnel (operators) remotely supervising the vehicles,
- facilities and presence for an onsite local incident team that quickly responds to issues encountered on the field, and
- charging facilities for 3 pilot vehicles.

All the functions could be tested during the field test in Helsinki with the exception of the autonomous vehicle's ability to communicate with traffic lights. However, the evaluation proved challenging, since there is no possibility to clearly see and analyse how the onboard safety driver and remote operator interact with the automated vehicle. Basically the safety driver had always control equipment (or steering wheel and pedals) in one's hands to, among other things, steer and control the speed of the vehicle in case needed. Passenger requests and operations on the route were also artificially demonstrated which does not correspond to real situations and in some cases does not clearly present what has to be done by the onboard safety driver or remote operator to complete the action and arrive at the destination.

Due to COVID-19 pandemic, the intended on-site evaluation of the solution was canceled and the evaluation was done remotely by watching videos and reading reports of the consortium further complicating the thorough evaluation of the solution. COVID-19 affected also to some extent in the performance of the consortium as for example the remote control center facilities near the field test site had to be changed for another, increasing the amount of additional work. Other restrictions, such as travel restrictions, did not affect to a large extent the performance of the consortium, as the field test could be carried out in Helsinki with local personnel.

Remote evaluation cannot be considered to fully compensate the on-site presence and not all of the functions could be evaluated on the level that was wanted. On the other hand, while testing the different solutions in open road conditions in different cities and conditions, it is difficult to evaluate the solutions completely equally. To be able to do this it would be necessary to have a controlled environment to some extent.

Nevertheless, the solution has to be able to operate similarly in different conditions and the basic deficiencies of the solution will be present on every open road site where it is operated if the general aspects of urban road conditions are present on the site.

The general aspects of urban road conditions can be listed out as follows:

- Different types of intersections, both controlled and uncontrolled (traffic lights, roundabouts, T-junctions etc.).
- Interference with other road and rail vehicles (trams).
- Interference with pedestrians and cyclists.
- Roadside parking.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 780371.

- Need for diverting from the lane possibly on the lane of oncoming vehicles due to a narrow street area or some stationary obstacles (e.g. vehicles) on the roadside.

Besides evaluating the single functions of the solution during the field test, the overall process of the implementation of the solution in real life traffic revealed other challenges in the field, which could have not been noted in the lab testing environment of the previous phases. Though these challenges were already known to some extent beforehand. In Helsinki these challenges were mainly:

- difficulties in finding a suitable depot for charging and storing the field test vehicles (in relation to height and steep ramps) near the route
- difficulties in finding facilities for the safety drivers, local incident team (acting whenever human support with the vehicles is necessary on-site while operating) and remote operators near the route which was further complicated due to COVID as the use of already agreed facilities were denied - a secondary plan had to be invented
- the need for providing and finding a charging place for day time charging of field test vehicles
- an unexpectedly established construction site that covered around 20 % of the route almost right from the start of the field test.

The unexpectedly established construction site only confirmed what has been noted in previous pilots of automated buses implemented in Helsinki: construction sites on roads are more the rule than the exception. They can be expected to happen at any time and anywhere, even though an intense information change is practiced between the pilot implementer and relevant actors from the city. A solution to overcome these has to be developed. Now construction sites and any other situation that requires diverting from the regular trajectory are invariably handled by the onboard safety driver and it is not yet fully certain if the necessary measures can be done remotely.

In the field testing social aspects were also included to evaluate passengers' experiences of travelling in an automated bus. Among other things questionnaires were filled by the passengers to gain views regarding these aspects. Issue with the Helsinki field test route was that it was not truly answering to a great mobility need thus not providing significant value in addition to the mobility solutions already existing in the area. But for instance one recognized potential user group would have been fair center guests with luggage coming from from the airport train, but these users were not present due to COVID. The route itself was only around 1,2 km long which is a distance that could be quite easily also walked by the majority of people. In addition there was still a responsible person, an onboard safety driver, inside the vehicle which does not give the real influence of a driverless vehicle and certainly affects the passengers' perception on how the trip in an automated vehicle is experienced. Moreover COVID-19 had its own effect on the field testing while limiting the

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 780371.

amount of allowed passengers that could simultaneously ride in the field test vehicles (only GACHA shuttle took passengers, 2 at a time). From the social point of view the experience of the field test was therefore somewhat inadequate.

All in all the field test and its evaluation was enough to show the current maturity level of the technology and it quite clearly showed the aspects which need to be developed. It is clear that a proof-of-concept for the management of autonomous fleets as part of the public transportation provision was not yet demonstrated. The consortia are expected to continue the refinement of the tested prototypes in order to make them into market-ready solutions that can be procured by additional public procurers after FABULOS.

3.1.1. Helsinki pilot: Political findings

The Helsinki city strategy, the Most Functional City in the World (2017–21) states that Helsinki aims to pioneer in overall smart traffic system and encourages transition into a demand-driven traffic system, as well as serves as a testing platform for new smart mobility solutions enabled by current transport legislation. [The Most Functional City in the World: Helsinki City Strategy 2017–2021.]

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 of automated vehicles through use cases that should be currently mainly focusing on the technical development of the vehicles and the related services (such as remote supervision and on field activities). The field test in FABULOS 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 route planning of the Helsinki field test involved cooperation with the Helsinki city traffic planning and the route was recommended by the city from the beginning. The Helsinki city traffic has been involved in some previous automated bus pilots and they already know to some extent the capabilities of the technology. They were capable of recommending a route that could be possible to operate with automated buses and knew how the environment would develop in the near future (though in spite of that an unexpected construction site was established on the field test route). This highlights the importance of involving relevant parties to the route planning. All the raised questions concerning the piloting were solved together and the supportive attitude of the city towards experimental culture helped to implement the field test.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 780371.

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 the same bus stops as the regular HSL bus and tram traffic had been using. The pilot service was integrated to the HSL's Journey Planner app and had an official line number (29R), following the tradition of regular intercity traffic in the area. Establishing a route with an official HSL route number can be seen as a major step towards the integration of automated solutions in the city's public transport.

3.1.2. Helsinki pilot: Economical findings

As a technical innovation and development project such as FABULOS it is difficult to compare it to previous pilots in Helsinki where the main goal has been the implementation of a mere pilot with research perspective. In FABULOS, several vehicles were piloted and a remote control center was established near the field test site which had not been done before. If thinking of the costs of the field test compared to gained knowledge, for Helsinki, the practical learnings of planning and implementing the field test was not that great, as previous pilots had been done in real life environment. The focus was after all more on providing the field test route for the consortia for proceeding in the technological development of the solution. Valuable and deeper learnings was of course also gained from the present state of the technology in the case of the city as well.

If speaking of public transport, the most potential adaptor of automated shuttle solutions in Helsinki in the near future is HSL. Normally HSL procures bus traffic from external operator companies but in the case of electrical normal sized buses HSL has exceptionally purchased a fleet of Linkker buses in the past for themselves as retaining the risks of the new technology for operators companies would have been unreasonable. This arrangement enabled HSL to test and develop new passenger services and carry out various test installations at an early stage in the electric buses which it owns.

In the case of automated shuttles such a purchase of a fleet has not been yet done nor is it seen viable as the offered solutions are still in a too early prototype phase. Basically it would require that a successful pilot without an onboard safety driver would be implemented and the overall robustness would be improved as well as speeds of the shuttles increased to arouse more interest in HSL in the field of automated shuttles. For comprehensive uptake of shuttles in Helsinki it would require that the shuttles are able to replace the current fleet at least partly and when designing new routes for conventional buses, shuttles should be able to cover these routes as well with the necessary quality and price.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 780371.

Currently the operation of automated shuttles is not financially nor technically viable. Perhaps it could be introduced in near future also some kind of hybrid solution, where the purchased automated shuttle solution would be partly owned by HSL and partly by an operator company but it also requires that a sufficient demand for the service would be seen. One option could also be that the price for the service would be a bit higher than a normal HSL ticket which would make the service more profitable. In general the city encourages relevant actors to continue implementing pilots in real city environment and external funding for these activities should be also applied, for example through EU projects.

3.1.3. Helsinki pilot: Social findings

As already explained, the social aspects of the field testing in Helsinki were left lacking. The route was quite short and was not truly answering to a great mobility need, passengers were mostly trying out the shuttle service. This could lead into a situation where the passenger had already a positive mindset towards the technology and issues encountered during the ride as well as delays in the service did not really affect on the experience. The presence of the onboard safety driver certainly affected the feelings as well. On the other hand the COVID-19 limited the number of passengers during the field test and not as many passengers could enter into the shuttle as was initially hoped. The bus operated from 9AM to 4PM which meant that the service was available to only a certain group of passengers who could step onboard during office hours. Longer time of operation would have been unreasonable to demand from the consortia.

Though at this stage of development an important aspect is to gain passengers' feelings and perceptions of the future automated service. Only a fraction of people in Finland and Helsinki have stepped into a driverless vehicle. The pilots have attracted all kinds of people from children to elderly as well as people with visual disabilities or other impairments. In total 184 passengers entered the S4-Shotl consortium's GACHA shuttle during the FABULOS field test in Helsinki and following comments were gained through a survey, which was filled onboard in the shuttle by passengers:

- "Dynamic routing would be nice".
- "Seats need headrests if the speed is increased".
- "The bus breaks very rapidly if it sees obstacles, which decreases comfort".
- "Difficult to use with a wheelchair, too wide gap between the stop and bus".
- "Larger route numbers and clear markings for visually impaired passengers".
- "App doesn't support text-to-speech for the visually impaired".
- "It is difficult to observe the elevated rear floor, it needs better markings".
- "Needs button to notify when a disabled passenger boards the bus".

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 780371.

- “Softer seats and suspension would make the ride more comfortable”.

As the maximum speed of the shuttle (28 km/h) on the route was approaching the speed limit on the area (40 km/h), other vehicles could drive more patiently behind the bus without need for overtaking. The frustration has been seen previously and the pressure of overtaking has increased in pilots where the maximum speed of the shuttle has been at max around 18 km/h. Overtakings on an urban district road with several zebra crossings and intersections can be hazardous, which emphasises the importance of an ability to keep up with the traffic flow.

Certainly there are areas and capabilities where the automated buses are lacking behind conventional public transport buses but in general it can be anticipated that people will use automated buses in the future in Helsinki as long as the route, schedule and quality of the service meets one’s demands. Quality (e.g. amount of space for one passenger, reliability) of the service should not be inferior compared to the public transport buses existing now.

3.1.4. Helsinki pilot: Technological findings

Representatives from Helsinki in FABULOS project, Forum Virium Helsinki and Metropolia University of Applied sciences, were in the main position to establish the functional requirements used to procure and evaluate the different solutions in the project. The formal requirements of the technology are just being formed (such as requirements for cyber security) and general guidelines for the procurement are being established. Currently an automated solution cannot be procured with clear demand of the procurer, it has to take into account the limitations in the technology.

The functional requirements in FABULOS were established with having previous knowledge of the solutions currently existing on the market while giving space for development work. Many of the functions were such that it was known that solutions at the time could not meet them but could be potentially possible to execute in a couple of years in the field test phase of FABULOS.

Followed by the field test in Helsinki it was unfortunate to see that some of the functions were clearly overambitious. These relate especially to the several actions that are still carried out by the onboard safety driver and it seems that the safety driver will be inside an automated vehicle for some time when driving on open roads. These actions can be related to ability to deviate from the programmed trajectory, so to speak the overtaking of obstacles as well as giving permission to get moving from a bus stop. On the other hand it was promising to see that the speeds of the pilot vehicles could be increased to almost 30

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 780371.

km/h, even with passengers on board. This is a proof that the solution provider (as well as the road authority providing the permission) is trusting its own technology. In Helsinki the maximum allowed speed of automated vehicles is not limited, which is a good thing.

As the safety driver is onboard in the vehicle, it increases the temptation to interfere in the functioning of the vehicle, as it is more simple than waiting for response from the remote operator and further actions of the vehicle. While having an active safety operator onboard in the vehicle, it generally slows down the development work as it can be trusted that the safety operator will interact with the vehicle in case needed, rather than developing more quickly a solution to pass these actions to the vehicle itself. This also affects on determining the state of the operational service, as it is not known how often the local incident team would be needed on site. For having a viable automated solution, these onsite visits should be reduced to minimum. It seems that the solution providers give too easily too much responsibility for the safety driver. On the other hand a person is still deemed as the legal responsibility of the vehicle, which is why it is understandable that this person does not want to take responsibility for the actions of another person or the vehicle. Usually this responsible person is the onboard safety driver.

The technological understanding of the automated solutions have been increasing in Helsinki step by step through collaborative work between different parties and city departments. The foundations for implementing pilots are in a good shape, as even the city representatives can suggest potential pilot routes, while knowing the current limitations in the technology.

3.1.5. Helsinki pilot: Environmental findings

The City of Helsinki's climate strategy supports actions taken to lead the city carbon neutral by 2035 [The Carbon-neutral Helsinki 2035 Action Plan 2018]. So far robot buses have been seen to theoretically contribute towards this goal by potentially supplementing the existing public transport network and improving last mile connectivity as well as 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. Large scale implementation and future uptake of robot buses in the city should focus on areas where public transport is not already comprehensive and/or where

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 780371.

there is a good potential on affecting private car users while increasing the modal share of public transport. In addition, there are many areas which are covered by the public transport network, but with a low service level only. There, automation can improve public transport user experience (frequent service during the entire day) and can encourage shared mobility.

Electric vehicles do cause CO_2 emissions as well, not locally but surely at some point of the vehicles lifespan, either during the production of the vehicle or electricity that the vehicles are using. Average CO_2 emission factor for electricity production in Finland calculated as a three-year moving average is 141 kg CO_2/MWh [CO2-päästökertoimet 2021]. In addition some of the robot buses can use alternative sources of fossil based energy, such as diesel, to heat the cabin especially in extremely cold temperatures. Though within public transport it is better possibilities to affect on what kind of energy is used by the vehicle fleets and how the energy is produced. Also production of near CO_2 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 drivetrain and robot buses on the market and under development are almost without exception contributing to this.

3.1.6. Helsinki pilot: Legal findings

In Finland pilots in road traffic with automated vehicles has been done already for some years, and the legal foundations are in good shape. To operate an automated vehicle in road traffic, test plate certificate has to be issued. The test plate certificate (including test plates which are mounted on the vehicle) is applied from Finnish Transport and Communications Agency (Traficom). Attached to the application are needed: vehicle technical specifications, risk analysis, excerpt from the Trade Register, a route plan and description about the operation. A compulsory motor insurance for the vehicle has to be acquired as well. Traficom processes the application and if sufficient, issues the test plate certificate and the related test plates to be installed on the test vehicle. After the necessary information is provided to Traficom, it will take around two weeks to receive the certificate. It is a transparent and fast process.

The field test in Helsinki was implemented by a Finnish-Spanish consortium, which made it easier to apply for the permissions. Basically S4-Shotl had already applied the permissions to the vehicles (which they already had) during previous phases of the project. If a foreign company is applying for the test plate certificate it should be taken into account that a Finnish company ID is a prerequisite to gain the test plate certificate. This means that a branch office would be needed to be established to acquire the test plates.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 780371.

Alternatively cooperation with a local company could be established and the test plates acquired by this local company.

Operating with automated buses under market conditions requires careful planning also legalwise, as in Finland test plates are meant 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. A fully commercial uptake of automated buses would require that the vehicles would be possible to type approve. Type approvals of automated vehicles are pending for EU regulations. Current vehicle type approval relies heavily on the technological validation of only a vehicle, which is driven by a detachable component, the driver. With automated vehicles, the validation would have to include also the driver, which would be in this case the vehicles automated driving system, a computer software and related hardware, to be clear.

3.2. Tallinn (MKM)

The pilot route in Tallinn, Estonia (Picture 9) ran from Tallinn Ülemiste City E-Estonia Briefing Center to the International Airport and from there to a Ülemiste shopping center. Connecting Ülemiste City – the biggest privately owned business campus in Northern Europe – with Tallinn International Airport and Ülemiste shopping center gives an opportunity to test new mobility service with a large number of passengers. The length of the route was appr. 2,4 kilometers. The pilot was carried out by the Mobile Civitatem consortium. The pilot was launched on 18 June 2020 and the three Iseauto shuttle buses were operational for 50 days until September 2020. A video of the Tallinn pilot was produced as a part of the project communications and can be seen here.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 780371.

Picture 9: Field test route in Tallinn.

The field test succeeded in demonstrating how a fleet of autonomous buses could work in live traffic and help the business district of Ülemiste in their everyday movements during the work day. However, it could not be demonstrated in a sufficient manner how to integrate the vehicles with the rest of public transportation – the vehicles provided connection with the tram line and also stopped in one same bus stop as the normal city bus line, but they were not integrated in the city's public transport schedules nor to the national one. The consortia did the integration too late, so it could be operational only for a day or two.

Also since the demonstration took place during the summer, it would still need to be proved how the vehicles function in the winter. This could be potentially interesting not only in the technological aspects (how the sensors work in snow etc.), but also in a societal context – it may even help to popularize the service as people might opt to move in a vehicle that protects them from the elements.

To conclude whether the pilot has been successful, it has to be waited some time to see whether there are any municipalities who will further pilot or whether any consortia will participate in a public procurement to operate and if they will win or not.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 780371.

3.2.1 Tallinn pilot: Political findings

The political environment in Estonia is supportive of new technologies, including automated vehicles. No resistance is found politically in implementing the pilot. Since the basic legal framework was already in place, the technical details and the more specific regulations were already delegated to the experts in Road Administration.

3.2.2 Tallinn pilot: Economical findings

The question of economical sustainability is straightforward and without bias. Majority of Estonian public transportation is organized via public service obligations through competitive tenders. The tenders are aimed to be technologically neutral and describe the service via outputs. E.g. it is not described that the service needs to be provided with battery electric buses, but it is said that the fleets emissions need to be 0 – whoever provides the cheapest offer which also meets all the requirements, wins (currently a large part of new tenders has been won by companies driving with biomethane since its cheaper but still is zero-emissions). This principle should be followed and there is no reason to make exemptions whether the buses have drivers or not.

Although it has to be conceded that other support measures may be needed and also logical, to help a technology forward, to help eliminate market failure. But this is the reasoning for these kinds of projects such as FABULOS.

3.2.3. Tallinn pilot: Social findings

The user acceptance survey conducted by the MC consortia is of limited use due to the small number of participants. According to its results:

- people would be willing to use self-driving minibuses daily;
- it would mainly replace their route by foot, by bicycle or by public transport;
- there was a critical attitude towards low speed as well as user experience, including the lack of information like timetables, which is a typical problem elsewhere in public transport;
- people wanted the service to be available on demand (this function was developed, but not used yet in the pilot).

These results are not surprising as the main motivators for people to opt for mode of transportation for their daily movements are:

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 780371.

- suitable routes and schedules (i.e. the more the service is according to their demand, the more likely they are to choose it);
- connection time (i.e. how competitive it is compared to other modes);
- comfort and ease of use (i.e. common ticketing, available information etc.).

To summarise this issue – the manufacturers of autonomous vehicles need to further develop their technology, so that it would have an edge in one or more of these criteria in specific operational domains, for people to actually opt for using them instead of other means of transportation.

3.2.4. Tallinn pilot: Technological findings

The biggest innovation in regards to technological maturity in Estonia was getting the vehicles approved for traffic by the Road Administration (see also chapter 3.2.6 Legal). Since it was chosen to ask for the vehicles to adhere to the type approval legislation as much as possible, the MC consortia needed to focus on raising the vehicles safety levels by introducing new materials and equipment that was type approved. This is something that would be wished to also see in the future. There is no reason to give exemptions to vehicles in parts that are not innovative or that are not tested. I.e. automated driving does not mandate that the vehicles' chassis should not be safe and adhere to normal legislation.

If looking at the pilot conducted in Ülemiste, it can be seen a difference of what functionalities the team actually developed for the vehicle and what functionalities it used on a daily basis on the route. I.e. even though dynamic routing or automated obstacle avoidance was developed, they opted not to use them on the route in real traffic, but rather relied on the safety drivers/operators to make difficult decisions. This is understandable as it is up for the consortia to assess risks and choose the safest way to operate, but on the other hand this proves that more development is needed from the technical point of view. That being said, if looked at the budget and what the MC consortia has achieved in this very ambitious timeframe (building more than 4 vehicles from scratch, developing their automated driving algorithms from naught etc.), then they have been very good and have achieved a lot during this pilot in terms of their technological development.

3.2.5. Tallinn pilot: Environmental findings

Automated vehicles should not become alternatives to active modes of transportation, like walking or cycling. The only way for the society to win environmentally is when automated vehicles would replace trips that would have otherwise been made by personal cars. Also a

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 780371.

key moment here is that the automated vehicles need to be shared i.e. be a part of the public transport network for them to make sense environmentally.

In current technological readiness the automated vehicles do not provide practical use cases for reaching these goals yet. They may have practical uses in the near future in suburban areas, connecting bigger public transit trunk lines, which may reduce motorization. This will not be achieved however without improvements in technology and holistic approaches to improving user experiences (see also chapter 3.2.3). People will not shift modes just because they have an alternative way to move. The connection as a whole needs to be competitive for it to be a real alternative.

3.2.6. Tallinn pilot: Legal findings

Legal framework and needed activities for testing an autonomous vehicle and conducting a pilot in Tallinn were carried out first via the Road Administration. The Road Administration tested the vehicle in order to register it before being allowed to operate in traffic. Vehicle needs to be registered according to certain criteria, e.g. how many passengers it transports. The vehicle will be issued a temporary license plate costing 205 euros. Operation is allowed when the operator has the relevant driving license (i.e. if up to 8+1 places, B category).

A human being designated as responsible is a must. Traffic Act § 2 (41) states that "driving a power-driven vehicle means [...] any activity of a person (which) influences the driving direction or speed of the power-driven vehicle with the help of control devices [...]".
In other words, the designated responsible person is responsible for any accident and must be diligent. Remote operation is allowed, but the designated person is liable for accidents. In practice, the operator is liable for any harm caused by the activities.

The vehicle needs to be insured. Insurance market in Estonia is free, so the company needs to insure the vehicle themselves from insurance companies. Insurance does not have to be from an Estonian company, but needs to be valid in the EU. Also, the applicants of such permissions should follow the "Guidelines on the exemption procedure for the EU approval of automated vehicles"

Seat belts onboard are mandatory. When using small vehicles, the analogy of M1 vehicles applies and means that seat belts are mandatory. Also, emergency braking in autonomous buses is a practical reason for having seatbelts onboard.

In order for the vehicle to be registered, a technical check is carried out to verify the compliance to the requirements of the Directive 2007/46/EC. These requirements state

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 780371.

that the components that are not linked with automated driving should be safe and according to existing regulation and those that are redundant (e.g. parts about the field of view for the driver if there is no driver) will be disregarded. Components that are automated (e.g. steering is done via technology such as lidar, radar) will be given an exemption.

The testing of the vehicle is done as a closed area test with a demonstration of driving in manual mode and showcasing how the driver can take over driving function from automated mode. Tests are carried out to check how the vehicle reacts to stationary and moving obstacles as well as system failures. Currently, if there are some functionalities that the vehicle is unable to perform up to standards, the speed is limited to under 20 km/h. This is a decision made ad hoc by the Road Administration upon the inspection of the vehicle and the driving tests. In Estonia, the land owner decides if they allow a vehicle to make public transit rounds, i.e. the city of Tallinn when on city territory and a company when on its territory.

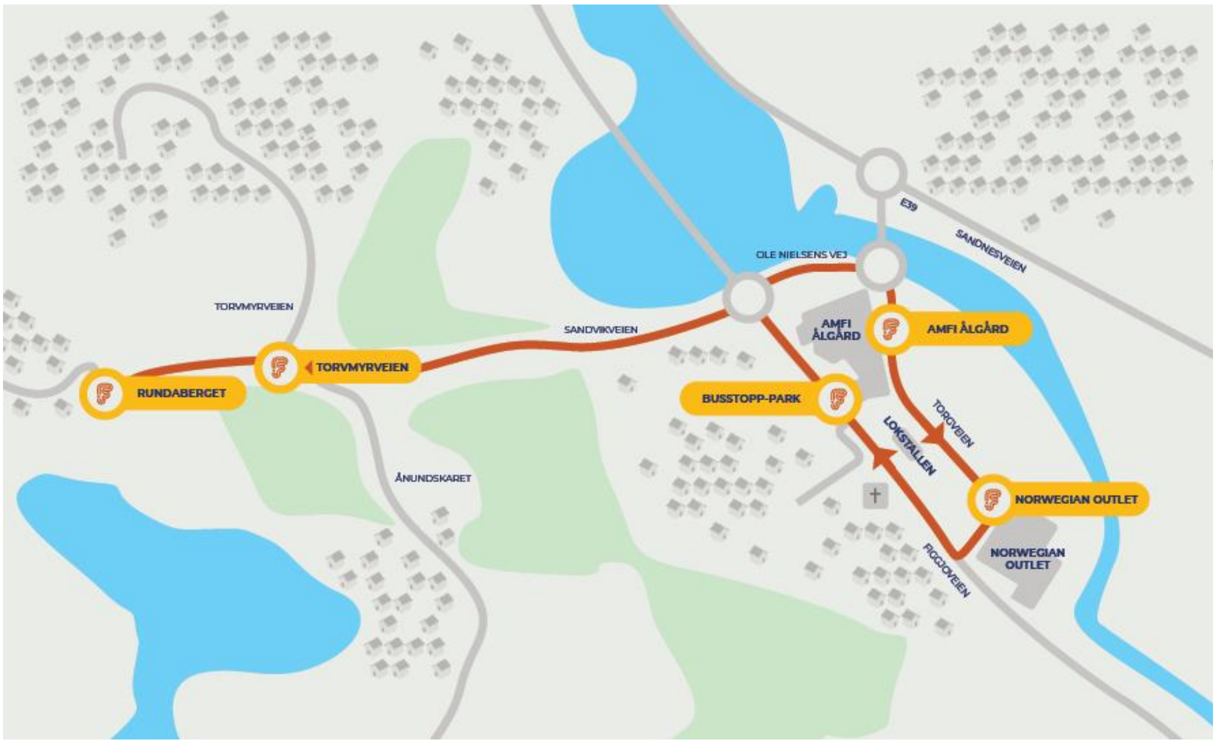
Final examination of the vehicle on the track is made before the vehicle can operate autonomously on track. There, the applicant should demonstrate that the vehicle operates safely in traffic and prove its capability to carry out all the functions as on the actual route (if a left turn, then demonstrate a safe left turn etc.).

Application with all technical information is mentioned in the Guideline to the Road Administration).

3.3. Municipality of Gjesdal

Gjesdal had two different pilots, one in summertime and one in wintertime. The summer pilot was carried out by the Saga consortium and it attracted many passengers, more than 1500 during the 50 days in operation. It was the most of all 6 FABULOS pilots. The pilot was operated with two automated shuttles from Navya operating up to 18 km/h. In addition, a Tesla was added to the fleet, driving only on-demand trips. The second pilot took place between January and March 2021 and was carried out by the Sensible4-Shotl consortium with 2 Toyota Proace vans that were converted into autonomous buses. The Field test routes in Gjesdal seen in Picture 10 and 11 were in total around 3,3 km long and the idea was to connect a residential area to the city center. Height difference up to the residential area is almost 90 meters. A video of the Gjesdal pilot 1 was produced as a part of the project communications and can be seen here.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 780371.



Picture 10: Gjesdal route in Field test 1.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 780371.

Picture 11: Gjesdal route in Field test 2.

Integration to existing public transport was done through a new mobility hub with connection both to the pilot test route and to the larger cities Sandnes and Stavanger where lots of inhabitants in Gjesdal commute to.

Winter pilot was done mostly without passengers due to COVID-19 related restrictions from the national Norwegian authorities. This pilot was tested with heavy winter conditions: snow, ice, fog, low temperatures combined with the steep hills and with a speed of 30 km/h.

To find the optimal test route is crucial. It is important to find a route that both has a practical value for the users and also challenging with some technical difficulties but still doable. The route was the least “urban” one from all the 6 FABULOS pilots. The route in Gjesdal has steep hills, mixed traffic, roundabouts, some narrow roads that were challenging for the pilotists, but doable. And to have an offer for transport between the residential and the city center was very popular.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 780371.

3.3.1. Gjesdal pilots: Political findings

The support from administration and local politicians, especially from the Mayor of Gjesdal, was really important to realize the project in Gjesdal. A political decision on Smart City as a development strategy for Gjesdal from 2015 was very helpful. In this document sustainable solutions are described as a necessary goal to secure the best planning for the future. This document is intended as a guideline for both administration and politicians

On a regional and national level, the project has received good support. The regional mobility provider Kolumbus is a good example. Kolumbus was a so-called preferred partner of the FABULOS project and actively followed its progress throughout the years. The summer pilot was integrated in the real time screens on the mobility hub thanks to Kolumbus.

3.3.2. Gjesdal pilots: Economical findings

The costs of the pilots were relatively high. It was necessary for the municipality to make some adjustments along the route with regard to signs, physical adjustments, regulations etc. But it is very hard to compare the costs to the gained knowledge, which was very significant. The benefit of European Union funding is clear and relevant.

Autonomous minibuses for the first mile/last mile can make it much more attractive to use public transport for workers commuting to larger cities if successfully integrated. However, the number of passengers is relatively limited which indicates that shuttle service would need to be available on-demand and fully autonomous.

3.3.3. Gjesdal pilots: Social findings

The field tests in Gjesdal showed that user acceptance level is high. More than 1500 passengers is a proof of that. When the project first was described in local newspapers, municipality websites and social media there were many sceptical voices. Some could not see that these kinds of solutions were necessary and some reacted with fear. But with lots of clear information, dissemination of the project and good dialogue with citizens the sceptical voices decreased significantly.

During the first pilot, the citizens became familiar with the shuttle. The city center is designed with a nice park in the middle and the test route went around this park. This made the shuttle very visible for all the people using the popular park during the summer. The attractive design of the shuttles in the first pilot may have played a positive role too.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 780371.

3.3.4. Gjesdal pilots: Technological findings

Technological aspects of the pilots were many, and most important elements that were discovered are:

- **Speed is crucial**. The first pilot could do 18 km/h and the second could do 30 km/h. This was due to the difference in vehicles. The second pilot had two type-approved Toyota Proace diesel vans that were converted into autonomous vehicles. In the area of the city center lots of things around the bus happen. Other cars, pedestrians crossing roads, roundabouts, pedestrians on separate sidewalks, parked cars along the route etc. Here it is okay with the bus doing 18 km/h. But when it starts climbing up the steep hills and drives on a road with speed limit 40 km/h and no obstacles or pedestrians or crossings, it will lead to impatient drivers passing the bus. Vehicles used in the second pilot could do 30 km/h and this was very much better suitable in the situation up the hills. A lot less dangerous situations were observed.
- **Sensor technology**. The amount of data from cameras, radars and lidar technology are large and must be analyzed very quickly for the vehicle to react in the right way. It seems the technology at state is not mature enough to operate without a person on the bus at the time. Safety comes first and the result is often that the bus makes some sudden stops which is unnecessary. To decide whether it is clear to drive into a roundabout is very difficult as the situation changes very quickly from all angles and the operator must intervene. With snow conditions sensors react to bad plowing as a dangerous obstacle.
- **Incline of the road**. Steep road angle takes lots of energy from engine brakes.
- **Obstacle overtaking** hard to solve in a real traffic situation with cars moving in the opposite direction.

3.3.5. Gjesdal pilots: Environmental findings

Electrical driven minibuses are a very good replacement for fossil fuel-powered cars. Most families have two or three cars and if one could reduce this number by offering an environmentally friendly alternative this could have a great effect in the long run.

Outside the larger cities it is necessary with a change of habits. Or even a paradigm shift. Private cars have for decades been the only choice in smaller places. If such a paradigm shift should be realistic, the alternative offer has to be the best choice not only in an environmental view but also easy and effective to use.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 780371.

3.3.6. Gjesdal pilots: Legal findings

The legal framework in Norway opens for autonomous testing in a new law decided in 2019. Lots of pilots have been done over the last years and with good results. It has been a goal to understand how to work with the future transport solutions. The key to success is to listen to the users needs and experience and have cross sectional cooperation from legal institutions, technology companies, research institutes, and different public stakeholders. Currently, all forms and regulations are in the Norwegian language only. For foreign suppliers this may cause some barriers.

The law and regulation for testing autonomous vehicle (only Norwegian):

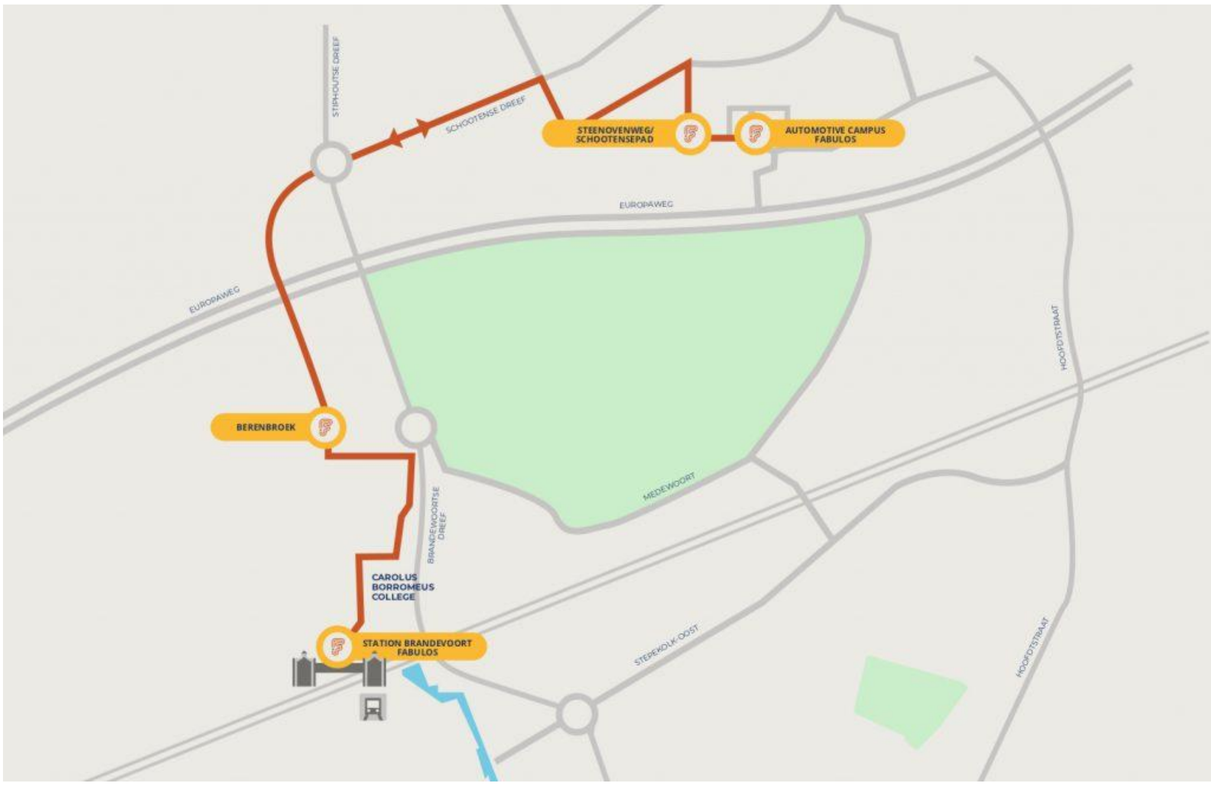
- Law
- Regulation

3.4. Municipality of Helmond

In FABULOS for Helmond, the goal was to create a first and last mile connection with a fleet of autonomous minibuses between the railway station and the Automotive Campus which is an economically important cluster of companies, universities, knowledge institutes and governments, with international allure regarding automotive developments.

The pilot was operated by the Saga consortium, which used a Navya shuttle. The shuttle in Helmond offered a public transport solution for the first and last mile on the connection between Brandevoort railway station and the Automotive Campus. The route seen in Picture 12 was 3 km long with four bus stops (map of the route below). The route was characterised by the presence of a secondary school, two roundabouts, a cycle street, different types of roads and a number of demanding intersections. A video of the Helmond pilot was produced as a part of the project communications and can be seen here.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 780371.



Picture 12: Field test route in Helmond.

When this has been successfully demonstrated it will be time to scale up in Helmond, the Brainport Region and beyond.

But there are more purposes of the Field test for Helmond:

- Learning about the current state of the art
- Creating a network on regional, national and international level in the field of connected automated driving (CAD)
- Showing that Helmond, city of smart mobility, is one of the European frontrunners with regard to innovative mobility solutions
- Gaining experience in deploying these types of solutions on Dutch roads (e.g. how procedures work).

The FABULOS project has been completed with 6 field tests in 5 cities, which can of course be considered successful in itself. One of these pilots was carried out in Helmond. This field test was a great success in many ways. However, this doesn't mean there were no problems and all FABULOS functional and non-functional requirements were fulfilled.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 780371.

In the first place the last mile connection between the railway station (another one than initially planned) and the Automotive Campus was established. The route was the most challenging one for autonomous minibuses in the Netherlands so far. The route actually consists of four parts:

1. An access road with a large secondary school
2. A bicycle street where agricultural vehicles also drive
3. An distributor road with more traffic and higher speeds
4. An access road as part of a business park

The route was further characterized by two roundabouts, easy and difficult T-junctions, interaction with motorized traffic including agricultural traffic and scooters. But also with pedestrians, cyclists and even horse riders.

Based on the field test in Helmond, but also on the other field tests, it has become clear what is technically possible already and what is not. Considerable development is still required before the vehicles can drive fully autonomous in mixed traffic without a steward on board. Nevertheless in Helmond the SAGA consortium achieved to drive with the minibus more than 90% autonomously. In other FABULOS field tests this number was even higher.

By participating in the FABULOS project and the preparation and organization of the field test, it was possible to come into contact with the international, national and regional experts in the field of autonomous driving. It stimulated the municipality's collaboration with companies, universities, knowledge institutions and governments. It has broadened the already extensive network even further. It also positioned Helmond even more as a city of smart mobility and one of the frontrunners in connected and automated driving.

Last but not least it served the purpose of Helmond to gain experience with the necessary (legal) procedures to get these new vehicles on the road. This experience will be of great value to Helmond's plans to actually implement autonomous minibuses on the road. It also became clear what the current differences are with other EU countries and how important it is to develop towards uniform European regulations.

3.4.1. Helmond pilot: Political findings

Smart mobility and specifically C-ITS and CAD are important pillars for Helmond to position itself even more firmly as a city of smart mobility. The political landscape in Helmond is therefore optimally organized for the development and application of smart mobility solutions. And not only in Helmond but as well in the Brainport region and on the scale of southern province(s) where Helmond works together under the flag of

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 780371.

SmartWayZ.NL. This political support ultimately played a decisive role in making the field test in Helmond possible.

And it is not only the support of the authorities, but also the support of, and collaboration with the business community, education and knowledge institutions. It is the drive with which we work together in this region on the mobility of the future.

A good example of this is the public transport operator Hermes, who have made a huge contribution to the success of this field test. Another example is the persistence of the Future Mobility Network to help Helmond through the legal procedure. More examples: Fontys University that have conducted research into relevant technical aspects. TNO, which has provided a parking space to park the shuttle at nights and on the weekends. The automotive campus that has made space available for setting up a control room. And also Breda University of applied sciences and the Technical University of Delft who have conducted important research on the experiences of passengers.

3.4.2. Helmond pilot: Economical findings

When talking about the economic component, it is important to distinguish the effects of this project and the effect on future business models. As for the former, the budget with which this project is financed has resulted in new and further developed technologies to allow minibuses to travel autonomously through traffic and to integrate them into regular public transport. In addition, the participating consortia, procuring partners, preferred partners and all informed organizations via broad dissemination gained a lot of experience about the current state of the art and what it takes to deploy autonomous minibuses. The results of the project therefore represent a value that is many times higher than the investment. Especially in the knowledge that this acquired knowledge will result in new initiatives and follow-up projects that will generate economic value.

Regarding future business models, self-driving (mini) buses will certainly contribute to a more efficient use of available budget. This is mainly because less costs are required for personnel. But it is expected that more will change around the business models. The adoption of autonomous minibuses is just one building block of a greater mobility transition where fewer cars and more alternatives will be used. For example, by saving on infrastructure, more can be invested in mobility services.

3.4.3. Helmond pilot: Social findings

Part of the field test involves research into user acceptance. However, at the time of writing the field test in Helmond is still ongoing. This means that the results have yet to be

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 780371.

processed. Nevertheless, some first conclusions can be drawn on the basis of reactions from people:

- Almost all passengers we spoke to are positive about the shuttle and the project. After some problems with the GNSS causing the shuttle to stop, a few were less positive.
- People along the route are enthusiastic and look at the shuttle and take photos and videos.
- Traffic participants on the route that meet the shuttle almost all respond positively. Of the road users who have to keep driving relatively slowly behind the shuttle, there are a few who react less positively. A bit annoyed about the low speed.
- A number of traffic rules have been temporarily changed for the field test with the FABULOS shuttle, such as lower speed limits on some of the route. Many people obey these temporary rules quite well and take into account the presence of the shuttle.
- In general people react very positively, hearing and reading about this innovative mobility solution.
- The city of Helmond, SAGA consortium and the public transport operator have received 0 complaints.

Also Breda University of applied sciences is conducting research by using wearables. By using wristbands heart rates and stress-levels are measured. Based on this, emotions of passengers and stewards are measured. These results are also expected soon.

It should be noted that the pilot in Helmond took place at the peak of the Covid-19 crisis in the Netherlands. This made it impossible to open the shuttle to the general public as planned. Promotional activities to encourage people to travel with the shuttle was not possible because the policy in the Netherlands was to only travel by public transport when it was strictly necessary. It was only possible to approach a selection of people from the professional world and the network (certainly also people who are less familiar with autonomous vehicles). The maximum number of passengers that could travel per trip was limited to 2.

3.4.4. Helmond pilot: Technological findings

Very ambitious functional requirements were set at the start of the FABULOS project. It was known in advance that some of these would be very challenging. The hope and perhaps also the expectation a few years ago was that the development of the technology would go a little faster than it appears now. Nevertheless, these ambitious goals have ensured that the consortia have taken the technology a really big step forward.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 780371.

The FABULOS project has made clear what is possible with the current state of the art and where further development is needed. But this also varies by consortium. In general, however, it can be said that the following areas in particular still require development:

Driving without a steward is not yet feasible.

- Overtaking (stationary and certainly moving) obstacles is still challenging
- Although speeds in Helsinki and Gjesdal were substantially higher than we have seen before, we saw that in other pilots the speed was still quite slow. This (average) speed needs to increase a bit before the autonomous minibuses can fully integrate with regular public transport.
- The autonomous minibuses cannot handle all traffic situations yet and more interaction with dynamic infrastructure is necessary.
- The autonomous minibuses are still a bit static programmed. More development on artificial intelligence is necessary.

In Helmond it was only possible to drive on the route with the only approved shuttle in the Netherlands. This shuttle still has several shortcomings before it can drive through traffic completely autonomously. This made it necessary to take various infrastructural measures:

- Change of traffic rules, such as a parking ban, lowering speed limits, changing right of way on some intersections.
- To prevent other vehicles overtaking the shuttle on a distributor road is was necessary to place a barrier between two lanes with traffic in opposite directions
- The sensors on the shuttle must have a good view of crossing traffic. As a result, obstacles have been removed.
- Overhanging branches had to be pruned and the grass mowed.
- Autonomous shuttles need more space than regular vehicles because they cannot deviate from the programmed line so easily. This made it necessary to widen some of the curves.

3.4.5. Helmond pilot: Environmental findings

The use of autonomous minibuses will contribute in various ways to a sustainable environment. In the first place, the autonomous minibuses will lead to less harmful emissions but also less noise. After all, the vehicles drive electrically. Secondly, the autonomous shuttles will also promote collective travel, making better use of the capacity of the vehicle and the road. This means that less infrastructure (e.g. parking places) is needed and can be transformed into public spaces to meet or change into green areas. A third point is that it can really contribute to the desired modal shift. As a first and last mile solution it will also make the public transport system as a whole more attractive.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 780371.

Autonomous shuttles can serve several goals. Related as use for public transport it can serve A) as a high frequent shuttle service between two important destinations and B) as an on demand mobility service for low demand zones where in the current situation it is too expensive to drive with regular public transport. This makes it much less necessary to own a private car. In the current situation, the average car ownership is even 2 cars per household. This average car ownership could drop significantly, because of the emergence of autonomous shuttles.

3.4.6. Helmond pilot: Legal findings

The procedure for deploying autonomous minibuses differs per EU country. It would be better if there was one standard in Europe. Not only for the involved local stakeholders such as cities, but especially also for the manufacturers and initiators involved in the use of autonomous minibuses.

There are two procedure in the Netherlands to deploy autonomous vehicles on the road:

- Experimental law (for driving with remote steward)
- BOEV procedure (for driving with steward on board of vehicle)

Both procedures are very extensive and thorough.

The focus is on 3 elements: Vehicle, road and human behavior. Before starting up the process to determine whether the planned field test or structural deployment is under safe conditions or not, the vehicle manufacturer must prove the vehicle meets all requirements set by the Dutch vehicle authority. This organization has a lot of experience and with that also expertise. Netherland's Vehicle Authority in the mobility chain (RDW) not only assesses the physical elements of the vehicle (including also full vehicle EMC test) but for example also the software it uses.

When there is an approved vehicle the applicant has to go through an extensive and thorough procedure to check if it is safe to drive with this vehicle on the intended route or not. The vehicle authority involves specific organizations with expertise in the field of infrastructure and human factors. Also the road authority, for the FABULOS route this is the city of Helmond, plays an important role in the process. The involved organizations assess the risks based on the start document from the applicant. This start document includes a Hazard Analysis and Risk Assessment. Based on their conclusions the applicant must work on mitigating measures until all relevant risks are covered. After all mitigating measures are worked out, the applicant has to demonstrate, during an examination under challenging conditions, that it is safe to drive.

The extensive and strict procedures have the disadvantage that they are also relatively long and difficult procedures compared to other countries. This makes it more difficult to

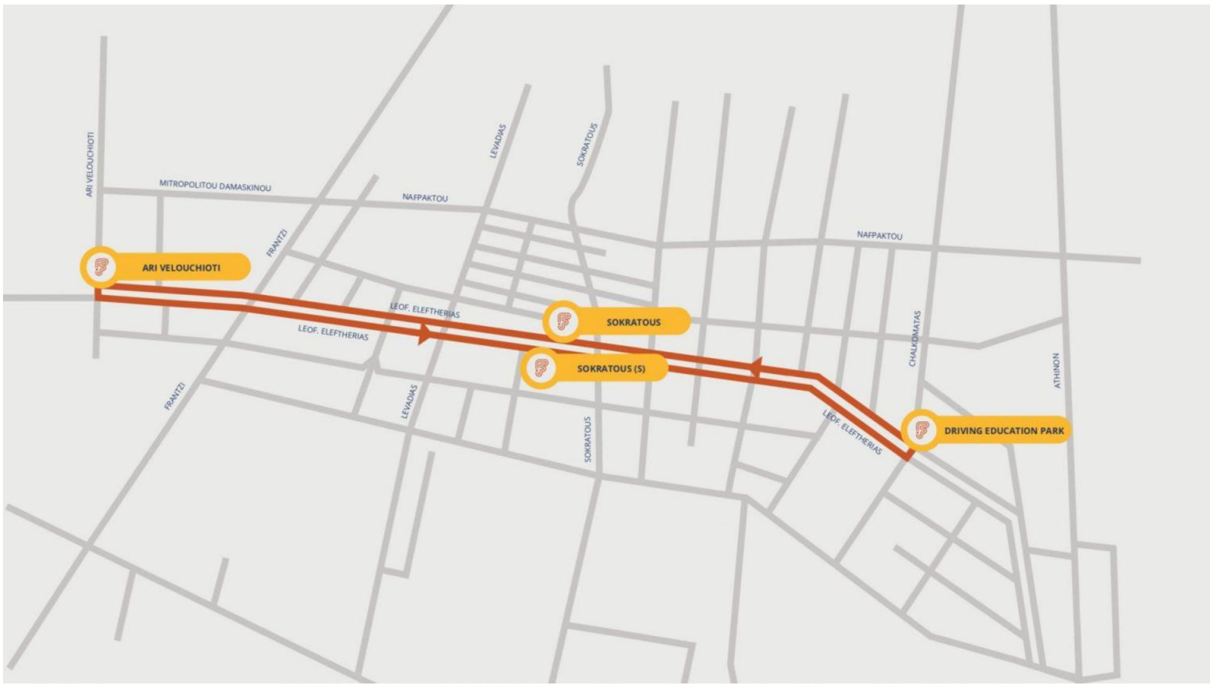
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 780371.

conduct a test in the Netherlands compared to other EU countries. Also relevant to mention are the high costs for the procedure in comparison with other countries. The positive side is of course that very thorough research has been carried out and the safety risks may therefore be smaller during pilots than in other countries.

3.5. Municipality of Lamia

As with the rest of the pilots the purpose of the field test phase in Lamia was to evaluate the established functional and non-functional requirements of the pre commercial procurement in the project in real life conditions in Greece. It was the Estonian Mobile Civitatem consortium that operated 2 Iseauto shuttles from AuVe Tech in Lamia.

The FABULOS Field test route depicted in Picture 13 was 3,2 km long and included a dedicated bus lane with a speed limit of 40km/h. The route was adjacent to busy pedestrian and bicycle routes, thus forming a vibrant multi-mobility zone in the city. Also, the pilot zone included several key city points of interest, such as the Police headquarters, the Driving Education Park and one of the five Secondary Schools in the city. A video of the pilot was produced as a part of the project communications and can be seen here.



Picture 13: Field test route in Lamia.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 780371.

The most fundamental reason behind the specific route selection was the goal of the City officials to test the coverage for specific underserved areas, a problem that the Municipality typically addresses by employing different mini-bus lines and jointly operating them along with the local Transport Operator. The current lack of coverage from traditional public transportation systems is to be attributed to the close distances of the selected pilot zone, which however still leads to an unwanted increased usage of private cars. Due to the geographical location of the route, the links it provided to major City locations and its complementarity to existing traditional bus lines, it was expected to serve diverse target user groups, ranging from bicycle commuters travelling to the city center and people exercising in the nearby sport centers to intercity travelers arriving to or leaving from the City.

It was the first time in the country that such a complex mobility ecosystem was demonstrated, including a fleet of vehicles, a remote operation center, fleet management software and smart bus stops, tested in real conditions. The selected field test site in Lamia provided an opportunity for the chosen consortium (Mobile-Civitatem) to test the solution and different functions in open road conditions thus fulfilling this general purpose.

However, particular technical/legal barriers and other COVID pandemic related restrictions did not allow the pilot to fully demonstrate the functionalities and use cases anticipated.

More particularly, administrative barriers with getting the vehicles registered and licensed to operate in open streets delayed the deployment of the pilot for some months until autumn, missing the opportunity to check the operation of the vehicles in the challenging mid-summer temperatures, which was one of the goals of the pilot. The ability to operate in summer conditions is definitely one of the go-to-market features for AVs in Southern Europe. Moreover, COVID restrictions left the supplier with limited personnel on-site, limiting the available options regarding testing multiple vehicles in parallel operation or demonstrating sufficiently the remote-control center. The latter however was tested and demonstrated during the pilot through a Tallinn-based remote-control center, which although not explicitly defined as a pilot goal was a fruitful experiment. Finally, the underlying legal and regulatory framework allowed the vehicles to operate only on a dedicated traffic lane.

Nevertheless, the provided solution was able to operate in different conditions while all general aspects of urban road conditions were present on the site. These aspects can be listed as follows:

- Different types of intersections, with priority and not
- Crossing an intersection with a high-speed road
- Several pedestrian crossings

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 780371.

- Roadside parking
- Need for diverting from the lane due to stationary obstacles (e.g. vehicles) on the roadside

Eventually, the field test and its evaluation procedure was such that the current maturity level of the technology and that of the legal/social context could be demonstrated. In a nutshell, the results indicated that there is work to be done in certain aspects of the technology as well as on the legislation front before AV could be integrated in public transportation systems in cities, at least in Greece.

3.5.1. Lamia pilot: Political findings

The Municipality is committed to the steady modernization and digitalization of its public transportation services and the systematic minimization of private vehicles usage within the city center. In this context, the Municipality has demonstrated strong political will and determination to successfully host the autonomous bus line. To this end, the City undertook all supplementary side projects that were deemed necessary for the completion of the route (e.g. minor on-site interventions, including signage, smart bus stops installations, traffic lights, security guards among others).

In any case, good collaboration among everyone involved is the cornerstone of any intervention of this scale. In practice, all stakeholders, from the Technical Department of the Municipality to the Regional Administration and the relevant Road Authority, really believed in this project, supported operations and joined forces to make the pilot happen.

Also, Lamia with fellow cities have joined forces to shape the evolution of autonomous vehicles in the country and thus are focusing on expanding the capacity of Greek cities to host autonomous bus lines and upgrading the autonomous vehicles market in the country. In that respect, the city officials had dedicated resources in updating the current legislative and regulative context towards the current state of the art. Already from 2018, the City has been involved in a series of meetings with the General Secretary of the Ministry of Transport, forming a respective dedicated work group. This work succeeded in achieving a legislation update that will drive the further development of the autonomous vehicles market in the country. However, delays, partially due to COVID emergencies, have yet prevented the legislation to be enforced at the time of writing this document.

3.5.2. Lamia pilot: Economical findings

The Lamia pilot was an excellent opportunity for city officials, urban planners and decision makers to become familiar not only with the technological aspects of an autonomous public transport service but also with the financial parameters of such practice. It is clear

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 780371.

that for the time being, the service and its accompanying setup, operation and maintenance costs are considered to be beyond the capabilities of typical mid-sized city budgets, at least when compared with traditional transport services.

It should be noted that, of around 260 million Europeans living in city regions with more than 100,000 inhabitants, only 20 percent live in city regions of more than 2.5 million people, while almost half (44 percent) of all urban inhabitants live in city regions of less than 500,000 inhabitants. Evidently, suppliers need to find more affordable business development strategies to reach this massive target group. Alternatives, such as Public Private Partnerships or EU-funded innovation procurement funding schemes could be the way forward for autonomous vehicles in public transport, until technology costs are normalized to support business models comparable to those of traditional transport services, in a financially sustainable manner.

3.5.3. Lamia pilot: Social findings

The field testing showcased that user acceptance levels were significantly high. User acceptability evaluation covered not only actual passengers travelling with the autonomous vehicles, but local society in general, that is citizens residing nearby the pilot, people passing by the route either on foot or while using other vehicles, public opinion etc. The evaluation was systemized by the utilization of both physical and online questionnaires, which indicated high social acceptance levels. Additionally, the service attracted more than 400 passengers despite the fact that several restrictions were enforced during the pilot due to the COVID pandemic with the country being under lockdown.

Most common passengers were locals 18-45 years old. The questionnaire results indicated an overall experience satisfaction grade of 6.6/7. Regarding the particular aspects that people commented on in a more conservative way in the questionnaire, referred mainly to the steep braking system and the small capacity of the vehicles.

Overall, the field testing served as a point of attraction for the city, drawing the interest of local media, citizens, government and city officials among others, without however illustrating if actual travellers behavioural change could be possible in the long-term. As a matter of fact, there were some voices of concern documented, regarding the suitability and appropriateness of demonstrating innovation under the unfortunate circumstances the pandemic and the underlying socioeconomic context. These debates were mainly raised in online media, among citizens' discussions, indicating that there is still some work to be done until the benefits of the innovation and technology actually influence the daily transportation habits of citizens and thus become clearly identifiable by the public.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 780371.

In general and from the social acceptance point of view the field testing could be deemed successful.

3.5.4. Lamia pilot: Technological findings

The project had set by default technology advancement targets beyond the current state of the art for participating consortia, in compliance with the nature of the pre-commercial procurement framework. As such, expectations regarding technological maturity of the products were significantly high from the start. In this context and despite the consortium's efforts, it was clear that some of the most challenging technical requirements could not be met. Nevertheless, the pilot showcased technology maturity levels high enough to make the integration to public transportation systems quite feasible in the near future.

Particular aspects of the technical requirements that could not be met during the pilot were related mainly to:

- The constant presence of an onboard safety driver in the vehicles. It should be noted that the legislative framework pertaining to autonomous vehicles in the country actually allows their operation without a driver onboard. However, the technological limitations of the solution (not only in the case of the selected consortium for Lamia pilot but also in the solutions provided by the rest of the consortia) imposed a safety driver on board for safety reasons. It is notable that the providers themselves did not feel confident enough to operate without a safety driver onboard.
- Advanced connectivity data usage, mainly upstream channels for storing pilot data, during operations and the instability of WiFi networks required unlimited data plans, that in the case of Greece were not available. In this context, data intensive functionalities could not be tested sufficiently, such as remote operation for the control center, despite the fact that the underlying technology was available.
- The ability to avoid obstacles while driving in autonomous mode was also demonstrated only in lab environment, since the feature did not reach a development status that could enable its demonstration in real life conditions.
- Vehicle-to-Infrastructure (V2I) communication could not be tested since the pilot location lacked any smart infrastructure. The supplier did install smart bus stops, which however did not highlight any important V2I functionality.

On the other hand, the field test evidently showcased that the technology has the maturity required for achieving the following goals:

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 780371.

- Capability to manage a fleet of vehicles, even if the full functionality could not be demonstrated in the Lamia pilot.
- Operating with 4G connections. Indeed, 4G proved to be completely sufficient for ensuring robust, low latency and protected communications. This could be crucial when operating in less developed parts of the city.
- Charging systems were available that could charge the fleet without the need for any on-street or bus-stop charging during the operative hours.
- The vehicles proved to be able to undertake and succeed in all national type approval tests.
- Operational integration to local public transportation systems can be realistic and feasible via the utilization of open APIs and open standards.

All in all, the capacity of all local and regional stakeholders in understanding and navigating through the specifics of autonomous vehicles and their systems has been significantly increased after the pilot. Moreover and from the technology maturity level the aforementioned points indicate that although significant progress has been made during the last year in the field (even during the project lifetime), there are still areas of improvement and consideration.

3.5.5. Lamia pilot: Environmental findings

The transportation sector, as well as private car usage especially for last mile trips, evidently have been considered heavily responsible for Greenhouse Gas emissions for the past thirty years. In this context, autonomous vehicles can be environmentally beneficial only to the extent that the technology can support cities, urban planners and transport operators in influencing transportation decisions of citizens, visitors and businesses in real life conditions. In that respect, the field testing with its limited duration, route length and other restrictions discussed above could not really demonstrate any significant environmental benefit for the city.

Nevertheless, the selected route, located in an underserved part of the city in terms of the available public transport options, showcased that autonomous buses at their current technological maturity level could provide environmental added value in similar contexts, by inducing a travellers' behavioural change and replacing last mile trips.

3.6.6. Lamia pilot: Legal findings

One of the biggest milestones, as well as one of the most challenging tasks, in the Lamia pilot was getting vehicles registered and licensed for operation on open roads in Greece.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 780371.

Regarding the full licensing landscape, Autonomous Vehicles in the country are governed by the Greek Government Gazette, Common Ministry Decision 50308/7695 of 13/8/2015, entitled “Terms and Conditions for Circulating a Bus without a Driver”. In this context, the following phases were the steps that the city with the support of the supplier undertook to reach the full licensing of the vehicles and the eventual development of the field test activities.

- Type approval of vehicles
- Issuance of registration plates issuance for a trial period
- Execution of a trial operation period with no passengers onboard
- Fine tuning of the technology according to trial period findings
- Issuance of registration plates for pilot period
- Insuring the vehicle

Overall, the process is not actually streamlined, with no official document templates or online forms supporting the interested parties. In reality, the legislative framework is rather customized to facilitate the first pilot in the country back in 2015 and thus was found to be outdated to a significant extent. The licensing experience was deteriorated by the inexperience of local road authorities in dealing with the issue at hand and also by the fact that the supplier was an Estonia-based consortium which introduced further language and cultural difference barriers. Nevertheless, the support of the Estonian Road Authorities has been accurate and timely, providing insights about the relative paperwork of the process as executed in Estonia with the same consortium in the first round of pilots. In that respect the full authorization process lasted approximately 3 months.

As previously stated, the pilot has been an excellent opportunity to raise the topic of the much-needed legislation update in the sector, on a central government level. The Municipality of Lamia has been pivotal in the underlying procedures which lead to a legislation update that will drive the further development of the autonomous vehicles market in the country.

3.6. STCP Porto

In the case of STCP Porto, the public transport operator of the greater Porto region, it was not possible to carry out the test in the city due to the lack of any legal framework for this in Portugal. However, STCP defined, with the Municipality of Porto, the implementation of the project and the definition of the place where the test was intended to be carried out with strong acceptance by the municipality.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 780371.

The test development site was located in the Asprela area, establishing a 2.7 km circular line, which was proposed to be connected to an intermodal terminal with connection to the metro and the connection of intercity and regional road connection lines, making then the distribution of passengers to the university campus, hospitals and shopping.

This line had several challenges that were intended to be tested, namely: crossings with and without traffic light control, cycle paths, changing lanes, crossing pedestrians. It was also proposed to verify the capacity of the solution to respond to a public service operation and for that goal was expected maximum speed of the vehicle in a mixed traffic environment, intended to be greater than 35 km/h, and test the acceptance of the concept in society.

Although it was not possible to carry out the test in Porto, the STCP team monitored the implementations in other cities and was actively involved in the evaluation of the solutions, assessing the results of these conclusions that would be wanted to be tested.

The concept was evaluated as positive, since a last-mile mobility solution was seen to bring flexibility and saves in cost when no driver is needed onboard.

3.6.1. STCP Porto: Political findings

There was full collaboration from the local authority and municipality and they revealed a strong interest in the project. Difficulties were felt in streamlining processes with the Central Authorities, for the approval of legislation that would allow the tests to be carried out. An inter-ministerial working group has been created with the mission of studying the legislative changes necessary for the introduction of new technologies related to autonomous driving. One of the main tasks of the Working Group is to present a proposal for the regulation of testing and the respective safety conditions.

The regulation for obtaining licenses to carry out AV Tests that Portugal is developing has been a long and complex process, because on one hand it is a completely innovative process, on the other hand because it is intended to lead to regulations that are not too restrictive, but also not too vague and general. Achieving the right balance between a regulation with high detail and more rigid, or the possibility of having several updates in the short or medium term, in a concept of “learning by doing”, has been an obstacle that is difficult to overcome.

The task of the Working Group is practically completed, and the regulatory proposal to perform AV Tests in Portugal should soon be approved by the Government. In Portugal new legislation is on its way, but it takes time. The different levels of national regulatory

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 780371.

requirements imply the need for European regulation to standardise specifications and facilitate the homologation process for manufacturers.

3.6.2. STCP Porto: Economical findings

From an economic point of view, the use of autonomous vehicles is attractive, since it can be created flexible transport solutions in low-density locations that today are not economically viable to explore public transport.

As a public transport operator in urban areas, STCP's goal is to connect main transport network to less economically profitable lines due to lower demand, through forms of transport without the use of heavier vehicles and without a driver. It should be noted that approximately 60% of operating expenses are spent on personnel.

The implementation of autonomous vehicles will allow a significant reduction in personnel expenses, reducing the number of drivers, although there must be an increase in jobs in the control centre due to the need to operate the vehicles remotely in some situations. It also allows the implementation of last-mile solutions, linking transport modes and complementing the transport network, making the geographical coverage of transport much finer mesh, and increasing the attractiveness of public transport.

This solution also has enormous potential in transport solutions such as Bus Rapid Transit (BRT), gradually implementing it throughout the transport network.

It will reduce costs associated with automobile accidents, all the analysis carried out makes it possible to verify that human error is much higher than any errors associated with autonomous driving.

3.6.3. STCP Porto: Social findings

There was a great acceptance of the concept in the cities where it was implemented. Unfortunately, we were unable to assess the acceptance of the concept in the city of Porto.

3.6.4. STCP Porto: Technological findings

From the technological point of view, there was a significant evolution during the project; however, it did not achieve a final marketable version with a maximum speed level necessary for the use in public transport operation.It should be noted that in the tests carried out from the point of view of safety, there were no noticeable flaws.

With the FABULOS project it was possible to identify some themes, in which further development will be necessary, such as for example:

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 780371.

- Difficulties in dealing with speed, not only the vehicle speed, but also with the different approach speeds of other vehicles traveling in the same direction, either at lower speeds (eg. bicycles) or at higher speeds (eg. automobiles);
- Difficulties with lane changes, on parallel lanes of more than one way, turning left at intersections without regulation by light signals;
- Difficulties in using remote driving without the existence of 5G communications and when this technology is available, is necessary to guarantee their presence without any quality breakdown.
- Vehicles still in a prototype status of development with regard to operational needs for intensive urban use.

3.6.5. STCP Porto: Environmental findings

From an environmental point of view, autonomous vehicles bring great advantages when linked to electric vehicles, allow a much smoother and controlled driving, and above all allow the implementation of transport solutions complementary to current networks, which allows greater attractiveness to public transport opposed to forms of private transport.

3.6.6. STCP Porto: Legal findings

From a legal point of view, there were difficulties that STCP had to publish, in a short period of time, the national legislation that would allow the testing of autonomous vehicles.

The FABULOS project was important to help trigger the legislative process in Portugal.

STCP believes it is essential to have European legislation that creates uniform rules for the use of autonomous vehicles across Europe.

3.7. Summary of the main learnings

Cities proved mature enough to host successful pilots in challenging conditions (e.g. due to Covid-19 constraints), but are not yet considered to be mature enough or ready to integrate automated minibuses into public transportation systems. When the project began in January 2018, expectations for technology development were high, but not all of them were met by January 2021. However, with the FABULOS project, organizations have learned what it takes to integrate autonomous vehicles into public transport, and with this lesson learned, cities can be further prepared for them. Before the solutions developed in the FABULOS project can be commercialized, there are certain technical, legal, economical and societal issues that need to be addressed first.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 780371.

As an exemption, in Portugal there is no legislation yet in place for AV testing on open roads. Thus unfortunately no pilots were possible in Porto at all. The different levels of national regulatory requirements imply the need for European regulation to standardise specifications and facilitate the homologation process for manufacturers. In Portugal new legislation is on its way, but it takes time.

3.7.1. FABULOS: Political learnings

Solid political commitment and active exchange of information between relevant parties on national, regional and local level was needed in order to carry out the pilots in a successful way. The inclusion of relevant stakeholders in the route planning process and supportive attitude from the city administration was also seen as key when solving new challenges together. Integration of the pilot route in the regular routes of traditional vehicles, such as in Helsinki, was a major step towards the integration of automated solutions in the city's public transport.

However, finding a good balance between detailed regulation on autonomous vehicles and a possibility of "learning by doing" was a challenge that should be met in future endeavours. Also, due to differences in national legislations, EU-wide legislation on AV integration was seen important as well as sufficient support from various funding instruments to advance technological innovations and testing. For instance, in Estonia the basic legal framework was already in place and attitudes towards piloting and innovation were positive, the more technological specifications fell more towards the responsibility of the Road Administration. In Portugal on the other hand, the project was a starting point to launch such political and legislative processes.

3.7.2. FABULOS: Economical learnings

At a time when vehicles still have a safety driver on board, cities or public transport operators do not have a viable business model and this is an obstacle to wider deployment. At least for Helsinki, the public transport operator is not yet very interested. The pricing model is also considered expensive and some cities would find it difficult to rent or purchase the service of commercial autonomous vehicles without EU funding. French market leader Navya has done the first test, but it is still unclear exactly when the vehicles are planned to be completely without a driver. Estonian suppliers currently plan to start fully driverless operations in 2024 and Sensible4 level 4 plans to launch their fully autonomous vehicle software as early as mid-2022.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 780371.

The technology is not yet advanced enough to make definite statements on whether the results of FABULOS has some impact on future employment patterns. The effect on employment was not part of the research in FABULOS, but there are no worrying indications that there would be significant job losses due to automation of public transport, not at least at the first stage of uptake of automated small-sized shuttles which are mainly intended to complement the existing public transport. Considering these use cases it can be assumed that only more jobs will be formed.

3.7.3. FABULOS: Social learnings

Reviewing the societal acceptance and attitudes of driverless shuttle solutions in FABULOS project and in the Field test sites were greatly suffering from the Covid-19 pandemic in 2020 and 2021. Nonetheless a survey of user acceptance and passenger satisfaction was conducted putting together the results of individual surveys made in each Field test site, totalling nearly 160 answers. Results of the survey can be read here. In more detail the survey covered the following aspects:

- Pilot passenger surveys from the field test sites
- Online based non-user surveys targeted mostly to persons who had not experienced a ride in a driverless shuttle
- Background from key results from other pilots or projects and comparing FABULOS survey results to these.

Conclusions from pilot passenger surveys from the Field test sites:

- Attitudes towards robot buses were least positive in Helmond and Helsinki, but overall the robot buses were rated positively
- Passengers would use robot buses during the day
- Robot buses could mainly replace other buses, walking, car and taxi. In the pilots they replaced mainly walking
- Passengers wish improvements in ride comfort (suspensions, seats, speed and braking) and hoped for more routes.
- No major differences in ratings between men and women

Conclusions from non user survey:

- Compared to passengers in pilots, non users gave lower average scores for traffic safety and passenger safety.
    - Especially usage during the night raised questions about safety and security, mainly related to misconduct by other passengers
    - Non users also proposed some use cases, which seem realistic in future.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 780371.

- Interestingly, some non-users also raised questions about the same topics as the passengers, such as acceleration, speed and braking.
- Responses indicate that passengers need positive experience with robot buses to be more confident and to use them, although the majority could use them for daily travel if robot buses were to help them in their travel.
- Respondents also have different opinions which modes of transport robot buses could replace based on whether they have experience with robot buses or not.

Conclusions and comparison of FABULOS surveys and results from other pilots

- Results from both FABULOS pilots and non user surveys have very similar results when compared to other studies of user acceptance of robot buses and autonomous vehicles.
    - Demographics, such as gender, seem to have limited effect on the acceptance
- Passengers need some guarantee of personal security when on board (e.g. CCTV, remote security operators, driver or security stewards)
- There may be some national differences in the acceptance
    - It is difficult to pinpoint whether these are due to attitudes towards transport and driving, socioeconomic or caused by different types of routes and pilots organized.
    - In Sohjoa Baltic pilots, Tallinn and Gdansk had the highest rating for overall experience. In FABULOS pilots, most positive experience was reported in Lamia and Tallinn. Other studies have indicated that lower income level or more thrill seeking population may be linked to higher acceptance and positive perception.
- Overall, the acceptance is high and people have mainly positive attitudes towards robot buses, their safety and security, and ease of use.
    - Positive experiences are needed to enforce the acceptance further
    - Autonomous driving technology must evolve to be reliable without human operator and perception of personal security needs to be addresses
- Robot buses mainly seem to replace walking, which may not be favourable in many cases. There is some potential to replace other public transport modes, such as buses and trams but also some potential to replace cars.
- Non users rated the personal security and traffic safety lower than average pilot scores, indicating there might be less acceptance in the general public who is not so keen to test robot buses. When user acceptance is tested in pilots, the samples are often small and biased towards those who have more interest in technology.
- While the user experience is good and acceptance is high, passengers note many areas of improvement.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 780371.

- Based on the passenger comments and responses, the robot buses need to find their place in the transport ecosystem. Further, autonomous driving technology has to prove its safety and be able to match and exceed the performance of human drivers, in terms of ride comfort, speed and safety.

3.7.4. FABULOS: Technical learnings

True driverless remote operations, where a remote operator monitors multiple vehicles simultaneously from a remote control center, require further improvements in infrastructure, such as 5G connectivity and more research and development in general. For many suppliers, vehicle speeds should be higher, but that is also partly a legal issue, not just a technical one. The autonomous vehicles tested in the FABULOS project still lack too many features to be able to drive safely and completely independently in mixed traffic. Software developed for autonomous mobility that takes into account obstacles (e.g. parked vehicles) and overcoming objects (even moving ones - e.g. slow cyclists) should be more advanced and needs more R&D to operate on a commercial scale in a busy urban environment and to communicate with other road users.

With the current state of the art it became clear that the vehicles still miss several essential driving skills that are necessary for integrating the vehicles in regular public transport and in mixed traffic. The main ones are:

1. At the moment there is still a steward necessary to guarantee safety in all circumstances.
2. The speed is too low (however this also depends on the road where to drive; speeds of 30 km/h were driven in some of the pilots).
3. The possibility to overtake other traffic (moving or stationary vehicles or objects).
4. Not able to deviate from a programmed line on the road. E.g. with icy roads it's important that the vehicle can drive a bit more to the centre of the road when there is no oncoming traffic.
5. Vehicles are still a bit too static programmed. Vehicles should know how to react to the actual real time traffic circumstances.
6. Vehicles should get smarter in distinguishing real objects and non-relevant objects such as grass and bushes with their branches.
7. Vehicles could respond better to other traffic approaching from a diagonal direction.
8. Vehicles cannot yet communicate well with other traffic (and do not understand all traffic signs)
9. Vehicles should drive a bit smoother, now it can still be a quite bumpy experience in some vehicles.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 780371.

10. Fogging up of the windows in damp weather in some vehicles.

Because of these shortcomings it can be necessary to realise quite a lot of infrastructural measures to guarantee safety, some examples:

1. Setting several traffic rules (No parking, lower speed limit, etc)
2. Barrier between two lanes (with traffic in opposite directions)
3. Speed bump to slow down other traffic (esp. on distributor road)
4. Creating sufficient view (for sensors) on cross traffic
5. Roads and curves should be wide enough (more than for regular traffic)
6. Pruning and mowing of green
7. Change right of way at some intersections
8. And several specific infrastructural changes to realise a safe and smooth track

3.7.5. FABULOS: Environmental learnings

The Buyers Group presented both critical and positive views of the sustainability and environmental impact of automated shuttles. As a conclusion the pilot stage and mobility use cases that are possible to cover with the present stage of shuttle solutions does not present a reckoned impact towards reduction of CO_2 emissions, pollution and use of private cars. However with efficient and viable use of shuttles in the future it was seen positive impacts:

- Less harmful emissions but also less noise with electric drivetrain.
- Promotion of collective travel, making better use of the capacity of the vehicle and the road.
- Contribution to the desired modal shift as last mile solutions will make the public transport system as a whole more attractive.
- Drop in car ownership due to improved mobility service for low demand zones where in the current situation it is too expensive to drive with regular public transport.

3.7.6. FABULOS: Legal learnings

There clearly is a lack of an EU legal framework for autonomous vehicles and autonomous public transportation. Currently, countries use a customized regulatory environment, which, however, is not sufficient to obtain a real service. The legislation allows for the necessary exceptions to be made for the conduct of pilots, but is not suitable for long-term or permanent services. Nor is it conceivable or desirable that each Member State would regulate autonomous vehicles separately. It would therefore be important for the EU to draw up the relevant rules quickly. For example, real operation without a driver is not yet

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 780371.

possible or in some places even legally allowed. National road authorities and Ministries of Transport play an important role in the European rule-making and cities can contribute by advocating new regulation that is in their interest.

4. Challenges to commercialisation

In general, the FABULOS project accelerated the introduction of new types of automated last-mile solutions entering the European market. New consortia aiming at offering a turn key solution and all-inclusive service for automated last-mile transport were established. Especially after the field test phase of the project and referring to the high end solutions involved in the project representing the top of the industry in the EU, the maturity level of the technology in use could be stated in practice. In this context, the technology readiness levels (TRL) indicating the maturity level of particular technologies is an appropriate tool.. The solutions demonstrated in FABULOS can be all stated to be at TRL 7 - system prototype demonstration in operational environment [Technology readiness levels (TRL) 2014].

Proceeding to the next TRL - TRL 8: system complete and qualified - will require both technological and legislative development. In addition the nature of the whole automated last mile shuttle service is still looking for its final form. That is to say how are the daily operations of the shuttles organized while minimizing the human intervention on site. The service design of the automated solutions plays an important role in making the service attractive, usable and accessible by all. Especially by the ones having moving disabilities or other special requirements who usually need some kind of human aid while using different mobility solutions.

It is not worth organizing automated transport service to a certain route just because it is automated. There has to be proven improvements in the service compared to what exists now on the market or at least demonstrate the same level of service quality and reliability which are achieved not more than with the same amount of financial input. This applies especially within the public sector in public transport where price and quality are decisive factors for procuring a certain fleet and service for a route. A competitive procurement on different routes simply cannot be won by a supplier if not providing service corresponding to the general level and price in the market. For instance just improving traffic safety with help of automated technology as a qualitative factor is not necessary enough, as accidents caused by professional traffic (e.g. public transport buses) is not a major problem, if considering the accidents that have occured in traffic. In 2009-2018 in Helsinki, around 12 % of the respondents to pedestrian accidents were buses. In case of cycling accidents the corresponding number was 3 %. Majority of the accidents - 64 % in case of pedestrians and

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 780371.

71 % in case of cyclists - were caused by passenger cars. [Liikenneonnettomuudet 2020.] That is to say the most predominant effects in traffic safety would happen in case of passenger cars. Of course every saved lives and reduced injuries with help of automated technology matters also in public transport.

At its best automated last mile shuttle operation can:

- be organized to a wider range of areas where public transport has not been possible to arrange by traditional means
- work as an on demand mobility service by reducing the amount of empty seats per driven km
- be organized more cost effectively than current public transport bus lines
- increase the amount of departures and reduce waiting time with less or same costs compared to traditional bus lines
- be environmentally friendly by increasing the modal share of public transportation while reducing trips made by private cars
- be safer than traditional human driven buses or
- all of these or some of these at the same time

However, the ecosystem is not there yet. In FABULOS it was made observations in relation to technological, legal, operational service as well as the ecosystem and market of automated last mile shuttles. Though categorized in different themes, the below listed challenges are all largely interlinked. In the end of chapter 4 it is presented a summary of the noted challenges.

4.1. Technical challenges

Overall technology of the automated shuttles approaches the capabilities of traditional human driven vehicles but the technology is not there yet, it should be more advanced

The noted main issues with the technology in FABULOS have been in relation to the achievable operational speed, which remained around 28 km/h at max and the ability of generally keeping up with the traffic flow in suitable environments. With higher speeds, it should be focused more on how the shuttles brakes to avoid sudden intense stopping, which can be dangerous already at slower speeds. At the moment it cannot be recommended to have standing passengers on board in the shuttles and seat belts can be seen as necessary.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 780371.

Recommended operational environments were focusing on areas with maximum speed limitation of 30 km/h, though in FABULOS it was operated also in areas where speed limit was 50 km/h. In these test sites the speed limitation was lowered temporarily and other traffic arrangements were done as well. However in the future this should be avoided as some of the areas and roads may not even encourage people to drive according to the speed limits and the actual driving speeds are much higher in the area (even though not allowed). Speed difference between the shuttles and other road users may rise very high while increasing the possibility of dangerous overtakings thus accidents.

In the pilots different intersection types were possible to overcome autonomously but especially the communication with other road users and situations where pedestrians were crossing a road through zebra crossing needs to be improved. Most inconveniences causing situations were unexpected changes in the infrastructure, which were lowering the vehicles' ability to act autonomously while increasing the need of operator's intervention. The next steps of technological development should include improving the ability to overtake obstacles (both stationary and on the move), increase the operational speeds, handling of more complex intersections and traffic lights as well as improve the overall edge intelligence of the shuttles.

In relation to technical deficiencies of the shuttles, there are still several domains, which can prevent a route from being realized. These can be in relation for instance to weather, incline of a road, type of intersection, roadside parking and speed limitations. It has to reach a situation where the needs of mobility and the service subscriber can dictate the conditions of the route to be taken, not the vehicle's technology or its supplier. Usually a route that is planned and organized by a public transport authority is procured with certain requirements from different public transport operator companies. If an automated vehicle solution cannot fulfill these requirements, it cannot be procured for the route, nor is it either sensible.

Public transport solutions require near-perfect reliability; current solutions are prototypes whose overall reliability should be improved

High reliability is one of the most demanded and valued features in using public transport. In FABULOS pilots it was established fixed timetables for the services, in addition the pilot vehicles were operating on demand and they could be called to a bus stop. However, not all of the planned departures were able to be met due to technical issues in the vehicles. Lack of onsite technical support as well as locally established offices and depots further complicated remedial actions on site when problems occured. Though for instance while having partly local consortias in case of Helsinki and Tallinn pilots it facilitated the performance of maintenance actions.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 780371.

Both software and hardware Issues with single pilot vehicles were seen in quantities which are not acceptable in official public transport. For instance on an annual basis the share of uncovered departures of all Helsinki Region Transport (HSL) bus traffic is around 0.15-0.17% [Kyllönen 2019]. The pilot vehicle fleets in FABULOS were not able to meet these numbers. Some of the more simple encountered issues could be also noted and solved by the safety driver, while he/she was still located onboard in the vehicle. All in all, a clear picture of the roles and responsibilities of the onboard safety driver and remote operator in terms of reliability was not formed. Also it was not clear how departures could have been organised without an onboard driver.

For validating the quality of the solution in the future, it would be necessary to operate a certain period of time (around 1-2 years) without major issues and involving the safety driver in the functioning of the vehicle as well as actions on site. The reliability would have to match with some average number of public transport authorities' share of uncovered bus departures. The attractiveness and viability of the service may not otherwise be sufficient.

A safety driver is still required onboard in the vehicles to solve issues encountered

Fully remote supervised and controlled automated shuttles are a fairly recent development technically, and for now a safety driver has still been inside a shuttle on open streets, including the pilots in FABULOS. Removing the safety driver out of the vehicle and transferring the necessary actions to a remote control center will result in major improvements in cost-effectiveness of organizing public transport services. As long as the operator is inside a shuttle this is not achievable. Moreover, one person should be able to operate remotely at least two vehicles simultaneously to achieve some improvements.

Within pilots run as part of FABULOS it was noted that the technology is not mature enough in this regard as the suppliers are not yet ready to remove the onboard driver and all of the actions done by the onboard operator cannot be yet carried out remotely. Allowing deviations from the pre-programmed trajectory for overtaking obstacles and driving through temporary traffic arrangements turned out to be the most difficult actions to be handled, both autonomously and remotely by the remote operator. These maneuverings were carried out by the onboard safety driver in all of the cases. Though the ability was demonstrated on closed areas but it was not put yet in action on open street pilots due to safety reasons. Generally by the consortia it was thought that the onboard safety driver has to still be inside the vehicles for some years and further testing is needed.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 780371.

4.2. Legal challenges

Liability issues and type approvals regarding automated vehicles and operations are still unclear

There has to still be a dedicated person in charge of a vehicle. However in several countries the law has been interpreted as that this person does not necessarily have to keep one's hands on the steering wheel nor be at all inside the vehicle while it is moving. This is a prerequisite for testing and operating automated vehicles in road traffic. There has to be also a certain way of allowing non type approved vehicles to operate on open streets. Usually some kind of test plate certificate is applied and the actual test plates later mounted on the test vehicle.

It is not yet clear if one person would legally be able to monitor several vehicles. Most likely a single person would not even want to personally take this responsibility of several vehicles that are operated by a computer. The liability should be at least at some company level, either with the vehicle manufacturer and/or operator company for instance. Depending on the case, the single person monitoring the vehicles should of course take some responsibility (not being under influence of substances, not sleeping etc.).

In FABULOS the participating consortia were responsible for the vehicles and basically the safety drivers on board were liable for the single vehicles they were located in. The actions of the remote operator were focusing more on supervising the vehicles and controlling for instance overtaking maneuvering whenever possible to do remotely. If accidents would have occured, it would have been investigated case by case, but the basic responsibility remained within the safety driver.

Out of the six piloting cities in FABULOS, Porto was not able to carry out the pilot at all due to legislative issues: although under development, there currently is no regulatory provision that allows driving autonomous vehicles in mixed traffic. The city of Helmond faced adversities with the laborious procedure in approving the non type approved vehicles for open road testing but managed to complete the pilot nevertheless. If states and cities have strict test permission procedures, it emphasizes the importance of effective cooperation between the supplier and city and further with the road authorities or traffic safety agencies whom the permission is applied from. It may require laborious exchange of knowledge and investigations of the test vehicles' abilities and functionalities. Even when not using type approved vehicles, there might still be some single functions that have to be met, such as Electromagnetic compatibility (EMC). In short-term pilots these application procedures may affect the interest of the suppliers while it takes a

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 780371.

disproportionate amount of time to meet the requirements compared to the actual pilot duration.

It has not yet been possible to type approve automated vehicles for road traffic use as such approval processes do not exist yet. Depending on the legislation, last mile shuttles have been usually operated in road traffic with test plates granted for instance by some traffic safety agency responsible for that certain relevant country or city. Basically the shuttles have been registered with the test plates as passenger cars (M1 class) or possibly busses (M2 or M3 classes) in some cases. On European level it is not clear, which vehicle class the shuttles really fit into. They lack features stated for instance for passenger cars and buses (e.g. driving control devices such as steering wheel and pedals), and cannot yet be therefore type approved officially for road legal use.

Current vehicle approval relies heavily on the technological validation of only a vehicle, which is driven by a detachable component, the driver. With automated vehicles, the validation would have to include also the driver, which would be in this case the vehicles automated driving system (ADS), a computer software and related hardware, to be clear. Would it be enough to validate just the ADS of the supplier that would be fitted in different vehicles? Or would it be necessary to validate every single vehicle separately? These are questions that should have answers. It is clear that some changes must be done or found out new vehicle classes for automated vehicles so that they can be operated as part of an actual commercial and public transport service in road traffic. In general some kind of driver's license test for automated vehicles would have to be developed to validate the ADS of different vehicles.

Establishing commercial service with automated buses under market conditions is not yet completely acceptable

If an automated vehicle cannot be officially registered for road legal use, test plates are needed for driving in road traffic. Depending on the legislation test plates are usually meant purely for testing and collecting payments from passengers would have to be strictly part of the testing. For paid operations, the operator needs a passenger transport permit. In some countries, it may be possible to establish paid commercial services when using test plates with cooperation of road authorities and transport providers, but there is still some ambiguity on this between different European countries.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 780371.

4.3. Operational challenges

Fleet supervision services and remote control center features have been demonstrated but it is not yet fully clear how to operate and supervise a fleet of shuttles remotely and what kind of on-field services are needed

During the FABULOS pilots, remote control centers were established to supervise multiple shuttles, which each had a safety driver on board. However, the remote operator could not sort out all of the encountered situations and the onboard operator in the vehicle still intervened in the operation. Before a fleet of automated shuttles can be efficiently remotely supervised, the edge intelligence of a single shuttle should be improved. In spite of good progress, it is not yet fully known, 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 shuttles.

Presumably it will take decades (if ever achieved) to create a fully autonomous (SAE level 5) vehicle working in every environment and conditions without need of any human intervention. Despite the pursued future full remote supervision of the automated shuttles, there will most likely be situations, where human intervention is needed to some extent on the field on operational areas and routes of the shuttles. These can include measures to start the day's operation by manually driving the shuttles to the desired location where the public transport service actually starts, and respectively drive the shuttles back to the depot after the service ends. Some local response team to quickly act in case of problems on site is most likely necessary as well at least for some years to come.

Furthermore, it is not known how many vehicles one operator could monitor; this is strongly linked to the level of edge intelligence or autonomy of the vehicles as well as the legislation. After one person can technically and legally monitor at least two vehicles simultaneously, the amount of actions needed on site will greatly determine when the service will become more cost effective and viable than simply having a human driving every single vehicle in public transport.

Shuttles require infrastructure for charging and maintenance activities – where to store and charge the shuttles outside of operational hours?

Where possible, shuttles have been stored and charged in locations close to the operational area, thus avoiding having to drive on unsuitable roads with busy traffic and high speed limits. On longer trips, shuttles have been transported with trailers. This is

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 780371.

because the operational speed of the shuttles in open environments have been limited to around 18-30 km/h in manual mode which is restricting the possibility of using existing public transport bus depots for storing and charging the shuttles outside of operational hours.

This is, of course, an area and route-specific issue but can present a challenge that can affect the routes that could be implemented with automated shuttles. This is particularly relevant in densely built areas, where there is no room to build new depots for the shuttles. Though the possibilities of charging and storing the shuttles for instance by roadside could increase the potential operating environments and ease the use where space is limited. Within pilot conditions the costs of building the necessary facilities may rise disproportionately high compared to the pilot's duration if there is no intention to deploy a long-term pilot.

The potential of changes in modal share from private cars to public transport with help of automated last mile shuttles should be studied more

Special routes for automated shuttles do not exist. There is a demand for travelling which is remedied with existing solutions with available resources. If the current public transport is not used by some private car users, it cannot be expected that these users would start using a service that is not working as well as the currently offered 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.

When able to expand and complement the supply of public transport with automated last mile shuttles, it should be considered the best potential use cases and routes for the shuttles where they could affect on private car users and increase the modal share of public transport. It is clear that the greatest potential lies in sparsely populated areas where public transport does not work so well, and where it could be possible to arrange automated transport which works with lower costs.

Alternatively it should be aimed at a situation, where the existing public transport bus lines are partly or fully replaced by automated shuttles within the possibility of maintaining the current service with lower costs or by generally improving it (e.g. with denser departure intervals or even wider coverage). Working as an additional service for people who are already using public transport while replacing walking and cycling on short distances, automated shuttles only cause more CO_2 emissions, despite having an electric drivetrain and other electrically powered accessories.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 780371.

Around 77% of an average European's energy needs are currently met by fossil fuels such as oil, gas and coal [Energia 2019]. It is also important to note that the production of shuttles also causes CO2 emissions and some of them can use alternative sources of energy, such as diesel, to heat the cabin especially in extremely cold temperatures. Considering this, automated shuttles cannot be considered as a short-term solution for reducing CO2 emissions. Though within public transport it is better possibilities to affect on what kind of energy is used by the vehicle fleets and how the energy is produced. Also for instance production of near CO2 neutral renewable diesel has made good progress in Finland which is improving the sustainability of fuel usage.

Safe, affordable, congestion-free and low-carbon mobility requires a holistic approach and cooperation between different sectors. The hierarchy of mobility decisions is formed from everyday mobility decisions as follows, depending on the region and each person's own opportunities.

1. I walk.
2. I cycle if walking is not possible
3. I travel by rail if walking is not possible.
4. I travel by bus if the other options are not possible.
5. I travel by car, with passengers on board; I lend my car; I take a taxi. [Salonen 2020: 6.]

Based on this, people should be encouraged to walk and cycle especially on short last mile distances, if physically possible. Of course it is important to provide solutions to help those for which walking is difficult or impossible. Though in case of driverless robot buses it is worth noting, that a responsible person (driver) is not intended to be inside the vehicle to physically assist people if needed.

Deployment process of the service and related vehicles is still unwieldy

Deployment of an automated service on a route requires:

- careful planning and plenty of time
- permissions to operate the fleet on the route
- premises for the vehicle fleet (off duty depot and charging facilities) and necessary on site personnel (safety driver, local incident response team and possible remote control center to remotely supervise and intervene in the operation of the vehicles)
- a capable supplier for providing the requested/procured service.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 780371.

After all the necessary permissions have been applied and granted as well as the route arrangements have been completed, the actual vehicles are deployed on the route. The deployment starts usually by mapping the route - creating a virtual point map of the surrounding environment which the vehicles are then using to locate themselves on the route. After the mapping the vehicles are programmed to drive on the route. This includes adjusting and programming of various aspects on the route, for instance the exact location of where the vehicles are driving on the road (trajectory), location of bus stops, speeds in different parts of the route, intersections and pedestrian crossings. A route cannot just instantly be driven by an automated shuttle. In general the process takes time and it requires several measures.

The deployment of the vehicles are currently mainly carried out by the vehicle manufacturers without transferring responsibilities to external parties, such as automated bus operators which are slowly being established. Procedures and systems for deploying the vehicles varies and requires specific competence. If the shuttle service is deployed abroad of where the company is located, it is necessary for them to send employees to carry out the actions which makes the process more complicated and vulnerable to risks of travelling. In FABULOS this was proven in practice especially due to the COVID-19 and the related travel restrictions as the consortia were struggling to send the required personnel to carry out the deployment and the whole operation of the vehicles on the route. Among other things additional subcontracting was necessary to be done to be able to complete the tasks.

The actual deployment of the vehicles on the route takes around two weeks depending on the complexity level of the route (e.g. length of the route as well as type and amount of intersections, bus stops and pedestrian crossings). The necessary preparations before the deployment of the vehicles may take the same amount of time and effort regardless of the duration of the actual pilot. That is to say the preparations for a one day open road demonstration compared to a several month or years lasting pilot may take nearly the same amount of time.

For temporary pilots it may be not possible to establish more permanent storage facilities for the vehicles and other facilities for necessary personnel. Space for temporary built facilities may be difficult to find near the route especially if it is located in a densely built urban environment. Height of the shuttles (usually around 3 m) can restrict the use of normal parking garages in the city.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 780371.

4.4 Summary of the noted challenges

4.4.1 Summary of technological challenges

- Overall technology of the automated shuttles approaches the capabilities of traditional human driven vehicles but the technology is not there yet, it should be more advanced.
- Public transport solutions require near-perfect reliability; current solutions are prototypes whose overall reliability should be improved.
- A safety driver is still required onboard in the vehicles to solve issues encountered.

4.4.2 Summary of legal challenges

- Liability issues and type approvals regarding automated vehicles and operations are still unclear.
- Establishing commercial service with automated buses under market conditions is not yet completely acceptable.

4.4.3 Summary of operational challenges

- Fleet supervision services and remote control center features have been demonstrated but it is not yet fully known how to operate and supervise a fleet of shuttles remotely and what kind of on-field services are needed.
- Shuttles require infrastructure for charging and maintenance activities – where to store and charge the shuttles outside of operational hours?
- The potential of changes in modal share from private cars to public transport with help of automated last mile shuttles should be studied more.
- Deployment process of the service and related vehicles is still unwieldy.
- Lack of on site technical support and know-how leading to delays in the deployment and operation as local operator companies do not necessarily have the required personnel to complete the tasks. Facilities for accommodating personnel needed to carry out the daily operations may be difficult to establish.
- Routes/bus lines which have high demand have been largely already implemented (with regular buses) and routes suitable for the available technology as well as with sufficient passenger demand might be difficult to find - the established routes can be artificial and attract mostly experimenters.
- Traffic hubs which have been conquered by the current public transport fleet and space for temporary pilot use might be limited. When using existing bus stops it should be also considered what additional value can the shuttle service provide.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 780371.

- If completely new routes and bus stops are established it may require changes in the traffic arrangements or infrastructure, e.g. reserving road side parking spaces for the shuttles' bus stops. More permanent bus stop arrangements are not necessarily a viable option in a short-term pilot.

4.4.4 Summary of market and supplier ecosystem challenges

- Working in pilots according to temporary established environments and conditions due to lack of large scale investments and long-term decisions on uptake of shuttles.
- Motivation to shift towards new technology and the availability of desired technology do not always complement each other.
- Ambiguity between the demand of the automated service and planned development trend as well as potential outcomes of the solutions.

5. FABULOS' Contribution

5.1. FABULOS' contribution to solve the technological challenges

Key element of the FABULOS project was to create the functional requirements for evaluating the different solutions and deciding which consortia were able to proceed on the following PCP phases. The complexity level of the requirements were progressively changing between each phase.

In Phase 3, the requirements were finally divided into following 9 functions:

1. Fleet Management System
2. Control room functions and remote operation
3. City Traffic Control System and Traffic Infrastructure Integration
4. Maintenance and Incident Management
5. Integration to the cities' public transport systems
6. Traffic Situation Capabilities
7. Vehicle and fleet requirements
8. Vehicle operational requirements
9. Deployment, setup and service

And the following 3 non-functional requirements (NFR):

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 780371.

1. Safety and technical maturity
2. Societal Maturity
3. Legal Maturity

Nearly each of the above listed functions were further divided into several sub-functions addressing different aspects under the particular theme. These could be in relation for instance to the minimum achievable speed, overtaking abilities, system architecture and weather related issues. The nine functions mentioned above especially aimed to target the development of the noted technical deficiencies (from previous projects and pilots) in the vehicles themselves and ancillary services, such as remote controlling and supervision.

The functional requirements established in FABULOS aimed to develop the solutions in the direction of where the automated shuttle services could be viably taken up as part of public transport. They were formulated based on a true need from procuring organisations. From the beginning of FABULOS the functional requirements were aiming at removing the onboard safety driver from the pilots but it turned out still to be too ambitious. It was allowed to have the safety driver onboard but the consortia were advised to transfer the related functionalities to the remote center as much as possible. Thus the onboard safety driver should only act in case of necessity. In addition, for instance, the speed of shuttles have been largely below 20 km/h in the past few years which is not suitable for road traffic and limits the potential operational areas. Within FABULOS the speed of around 30 km/h in Phase 3 open road field tests was achieved in 2 of the 6 pilots.

To be able to more efficiently handle the daily operations during the pilots, facilities for remote control centers and local response team were provided for the consortia near the routes by the pilot cities. This is how the consortia could react and fix the encountered issues rather quickly.

While different cities with distinct climatological conditions and traffic culture took part in FABULOS and provided use cases for the participating consortia, the solutions could be tested in a variety of environments and different weather conditions in the final phase of the PCP process. Fulfillment of the functions could be verified in practice in real driving environments, though this is how the deficiencies were again noted but also development witnessed compared to past. Through operating the vehicles in real operational environments it was possible to gather data and improve the overall functionalities as well as work towards the reliability required to run officially part of the public transport. Though the COVID-19 outbreak had a substantial impact on the live evaluation of the solutions on pilot sites, the evaluation was mainly based on reports and videos provided by the consortia.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 780371.

It turned out that some of the requirements had not been even considered yet by the consortia, but seen relevant for a complete solution. The overall effect was that the development of certain functions or features were even sped up and shifted in the more near future of the consortias' development roadmaps due to FABULOS. It seemed that overall ambition of the project was very high and in some cases the bar was set clearly too high as not all of the functions were able to be fully met in case of any of the consortia.

Examples of FABULOS's local impact

Modern Mobility (Estonia):

"Estonian public sector transport specialists and businesses in the sector see the testing in Ülemiste as a valuable experience to pilot new technological solutions in real-life environments. Also Lamia Municipality is interested to launch future pilots and carry out additional testing."

5.2. FABULOS' contribution to solve the legal challenges

The prototype lab visits as part of the Phase 2 in FABULOS could be described as the first concrete steps towards a driver's license test of automated vehicles. A list of different functions were gone through in the consortias' premises both by verbally explaining the solutions and physically driving the vehicles in different driving situations while demonstrating the features in practice as well as showing simulations. Of course in test environments with little or no other traffic at all the tests were not complete but provided insights for what this kind of "automated vehicle driver's license" (AVDL) test could look like.

FABULOS lab visits were also short in duration which complicated the systematic and thorough validation of the individual functions. No actual baseline or standards for validating the functions and comparing the different solutions between each other did not either exist. The validation was based on what could be seen from the demonstrations and learned about the explanations - a need for an official systematic AVDL test was noted in practice.

Examples of FABULOS's local impact

Fotis Gogoulos, Municipality of Lamia:

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 780371.

There was not a clear licensing pathway for AVs in Greece. Legislative and regulative framework was outdated at the time, since it was formulated in 2015 and had never been updated. Regional Road Authorities had limited experience in dealing with AV licensing procedures.

In our case the cooperation with national authorities on issues with regulations was very good; Greek law is in process of being updated; MC first had its pilot in Estonia, then in Greece: cooperation between Estonian and Greek national authorities has been very helpful; some procedures were copied etc. The support of the Estonian Road Authorities has been accurate and timely, providing insights about the relative paperwork of the process as executed in Estonia.

Overall, the pilot has been an excellent opportunity to raise the topic of the much-needed legislation update in the sector, on a central government level. The Municipality of Lamia has been pivotal in the underlying procedures.

The relative national authorities (Ministry of Transport) have been really cooperative in this process and willing to proceed with the alignment of the framework with the state of the art. Unfortunately, this didn't materialize in time for the Lamia pilot.

Eetu Pilli-Sihvola, Traficom, Head of Analysis, Trials and R&D (Finland):

I think one of the most important contributions of FABULOS is the set of supporting documents, requirements and materials to help public transport organisers and/or operators consider purchasing AV shuttles or AV-provided PT services. I would highlight this as one key result, although I'm not quite certain what is the full set of materials that will be made public in the end.

Another contribution has been help in identifying both practical and regulatory issues related to providing commercial PT services using automated vehicles. This will help to advance and develop international regulation related to commercial passenger transport.

AuVeTech (Estonia):

For future pilots, follow the Fabulos example of the safety and structure documents.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 780371.

Mobile Civitatem, FABULOS consortium (Estonia):

As the result of 2020 self-driving vehicles testings in Estonia, Road Administration took into use from 2021 a new traffic sign (see Picture 14 below). Previously only yellow-based traffic signs with exclamation marks were allowed. Automated vehicle test section -the warning sign will warn of approaching a section of road where unmanned vehicles are being tested.

Picture 14: Automated vehicle test section -warning sign.

5.3. FABULOS' contribution to solve the operational challenges

As FABULOS wanted an all inclusive self driving shuttle solution, aspects related to the operational service were also taken into account. In the different field tests carried out it was taken into account:

- Planning of the pilot routes.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 780371.

- Planning location and establishing the facilities for remote control center, local incident team and on board safety drivers.
- Storage and charging facilities for the pilot vehicles.
- Planning and setup of necessary route and traffic arrangements.
- Applying for necessary permissions and deployment of the vehicles on the routes.
- Operations of the vehicles upon agreed conditions during the pilot periods.

Therefore a comprehensive look at the routes, vehicle fleets, personnel and facilities needed for operating an automated shuttle service were taken into account in the field tests. Procuring cities participating in FABULOS were in the special position of providing the possibility of field testing for the consortia and the responsible persons also worked as a contact point to the city's different departments and authorities as well as necessary permission procedures for the open road testing of the pilot vehicles. Even though a proof-of-concept for the management and operation of autonomous fleets as part of the public transportation was not yet fully demonstrated, FABULOS offered for the consortia the first opportunity to test and develop their solutions in open road conditions both in their local countries and abroad proving the scalability of the service. In addition many of the participating cities had an automated shuttle service running on their streets for the first time and could see how this kind of service works currently in practice.

Implementation of automated pilots and service in general suffer from unfinished technology and legislation as well as the lack of surrounding required infrastructure such as storage, charging and remote control center facilities. In addition, current public transport operators have often not purchased automated shuttles nor have capable personnel to fully take care of the operations locally. In FABULOS the shuttle service suppliers, consortia in this case, had mainly internally the capability of carrying out the pilots and responsibilities were not externalized to a large extent. At least for the second pilots the essential parties of the consortia travelled abroad and established temporary operations in the designated location. Due to COVID travel restrictions additional subcontracting had to be done which provided by force the chance of building local competence for operating an automated vehicle in the field test city in question. Subcontracting also speeded up the process of handing out certain tasks of the operation to external parties. For having viable operational service in the future it requires that local offices and competence for deploying and operating automated shuttles is established.

Examples of FABULOS's local impact

Modern Mobility (Estonia):

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 780371.

"FABULOS project provided a good experience in setting up pilot projects. In the future, we intend to further implement and develop these experiences."

6. Considerations for future development of provided solutions

Implementation of automated smart mobility transportation in modern cities has to overcome several challenges regarding the technological, legal and operational challenges. Considerations for overcoming these challenges are presented below.

6.1. Considerations for overcoming technical challenges

Considerations for public authorities:

- Cities and public authorities to dictate the use cases as well as features of automated shuttles with help of other R&D partners and authorities; and suppliers to develop the technical capabilities according to these needs.
- Cities to provide potential use cases for testing fleets of automated shuttles in a real operational environment and supporting the development through understanding the current limitations in the technology.
- Cities to provide smart traffic lights with certain communication modules and other smart infrastructure (in discussion with technology developers about the standards etc.).
- Suppliers need funding to the development work of the automated shuttles. The PCP process is a good example of providing direct financial support for companies developing technological functions.
- Consider if passengers are necessary to be taken onboard as part of technological R&D pilots.

Considerations for technology developers:

- Focus on overall technological development of the automated shuttles, especially the edge intelligence of the vehicles.
- Have clear goals on what functions specifically are developed within a pilot. Aim at clearly showing the improvements compared to the past.
- Develop vehicle reliability towards numbers of official public transit bus fleets.
- Develop automated vehicle solutions where new hardware and software can be easily retrofitted (possibility of adding and replacing new sensors, radars etc.).

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 780371.

- Consider energy consumption and means of charging without human intervention as well as pay attention to energy efficiency of the vehicles.
- Aim for honest representation of capabilities of the provided solution (deficiencies and benefits) - empty promises may affect negatively in the parties acquiring the service and interest in the solution may decrease.
- Consider vehicles' safety features.

6.2. Considerations for overcoming legal challenges

Considerations for public authorities:

- Establish a harmonized and systematic way of approving the provided automated vehicle solutions to road traffic use uniformly between different EU countries for both piloting and future real use cases.
- Develop type approvals of automated vehicles and "driver's license test" for automated vehicles.
- Clarify liability issues and other legal aspects in case of one person monitoring one or several automated vehicles remotely and simultaneously.
- Clarify what is the maximum number of vehicles a single person can simultaneously supervise remotely.
- Understand that while supervising several shuttles simultaneously it is unreasonable to expect that an operator could act fast enough to prevent an accident from happening, for instance be able to stop a shuttle remotely in time if something unexpected happens and the shuttle deviates from the programmed path to an oncoming lane for instance. A vehicle that is driving only 30 km/h is moving 8.3 meters during one second.
- Allow commercial operation and collecting payments also in the piloting stage with non type approved vehicles (if passengers are considered relevant for the outcome of the pilot).
- Liability issues in case of accidents remain open. It is highly questionable whether a single person would like to take responsibility for several vehicles that are operated by a computer. The liability should be at least at some company level, either with the vehicle manufacturer and/or operator company for instance. Depending on the case, the single person monitoring the vehicles should of course take some responsibility (not being under influence of substances, not sleeping etc.).
- Validation and regulations on software updates on automated vehicles should be refined.
- Establish safety standards for automated shuttles or consider if these should diverge from type approved vehicles.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 780371.

Considerations for technology developers:

- Develop remote control center functionalities as well as minimize onboard operator actions and intervention to see possible number of vehicles that a single person can simultaneously monitor. Or provide an estimation on what are the desired numbers to gain advantages compared to conventional bus traffíc.
- Work together with road authorities to gain mutual understanding of what is required from automated vehicles for being able to operate legally (without specific exemptions) in road traffic.
- For faster market entry, consider using and developing vehicles such as minibuses that are already type approved instead of building completely new shuttles. Already existing type approved vehicles have sufficient safety features and can be driven at high speeds.

6.3. Considerations for overcoming operational challenges

Considerations for public authorities:

- When automated shuttles are implemented as part of the public transport of a city, it should be considered how the solution is supporting the city strategies in particular towards sustainability: e.g. what kind of numbers would like to be achieved in case of emission reduction and how this is achieved.
- In general the operational service has to meet the basic requirements set by a local public transport authority to have viable operations as part of other public transport. There is no reason to procure an automated service if it does not meet these generally set requirements of the service quality (reliability, passenger capacity, accessibility etc.) and price. No exceptions should be made whether the buses have drivers or not - technology neutrality should be applied. In case of some certain service bus lines it may be even necessary to have a driver on board to be able to assist passengers.
- Responsibilities of providing the facilities and charging equipment for the vehicle fleet and required personnel should be transferred slowly to cities and public transport authorities if the automated shuttle solutions are seen to contribute to the city's goals.
- Investments on more permanent or long-term shuttle operations and facilities should be planned and increased. It is not necessary to deploy several vehicles on a route but to refine the operations of one or few vehicles and background services step by step.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 780371.

- Clarify use cases and conditions where the demand for automated shuttles have been seen (e.g. speed limit of the operational are, lengths of the desired operational areas and routes, passenger capacity)
- Consider the price per passenger km that is currently achievable within public transport and other competitive means of transport (such as taxis, e-scooters etc.) within acquiring an automated shuttle service.

Considerations for technology developers:

- Through pilots local competence of organizing automated vehicle transportation should be built.
- As long as a human is needed to drive a vehicle in some tasks, it would be more sensible to fit the vehicle with a proper driver's compartment and equipment. In addition, a drivetrain and other properties which would allow the vehicle to be driven in high speeds (around 100 km/h) in road traffic would significantly ease transporting of the vehicles for longer distances (no trailers etc. needed) and already existing public transport bus depots located further away from the operational area could be potentially used the same way as with existing bus fleets.
- Clarify in what kind of use cases, routes and conditions the provided solution is intended to be used. Clarify what benefits can be achieved in these use cases with the provided solution compared to conventional means in the near future and beyond.
- Consider the price per passenger km that is currently achievable within public transport and other competitive means of transport (such as taxis, e-scooters etc.) within developing the solutions.

6.4. Considerations for procurement

- A viable and cost effective complete solution for automated public transport cannot yet be procured and the procurement cannot be drawn based on clear needs of the procurer.
- The procurement must be based on known facts of the technology while pushing the limits of the current state-of-the-art (e.g. speeds, remote control features, overtaking of obstacles)
- Functional requirements established within FABULOS may work as a good startpoint for drafting the technical and non-technical requirements for a procurement of an automated shuttle bus (pilot) service.
- Within an automated shuttle bus service procurement, consider if there are some specific field of development targets to be addressed and how is the continuity of the service ensured - taken into account that most likely the service would be more

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 780371.

cost effective and efficient to arrange with traditional human driven vehicles still for some years.

- Automated shuttle bus service providers are interested more in long-term pilots rather than short-term (duration of few months) pilots which also would provide better possibilities for developing the functionality of the fleet and background services (such as operations in a remote control center and on field actions for keeping the service running) step by step and in a more systematic way.
- The arrangements, such as traffic arrangements, depots and charging facilities for the vehicles, and one-time payments, such as route programming, are pretty much the same nonetheless how long the pilot duration is. In addition the driving permit process may take a disproportionate amount of time compared to the duration of a short-term pilot.

6.5. Expected development of automated shuttle solutions

At the moment it is still impossible to say what is the timeline for a complete cost effective and efficient automated public transport shuttle solution where both the technological and legal challenges have been solved. Most likely the first solutions are focusing on low speed areas (max 30 km/h speed limit) where shuttles would be complementing the existing public transport network. These solutions could be seen already within a decade. However it is also a question of efficiency, even though shuttles would be technologically and legally able to operate in road traffic without a safety driver on board - they have to offer something better than is currently existing.

In general the operational service has to meet the basic requirements set by a local public transport authority to have viable operations as part of other public transport fleets. There is no reason to procure an automated shuttle service if it does not meet these generally set requirements of the fleet, service quality (reliability, passenger capacity, accessibility etc.) and price. Moreover the goal of having automated solutions as part of public transport should be the possibility of offering at least the same service level and efficiency with lower costs. Exemptions should not be made on the basis whether the vehicle has a driver or not. Quality of the service should not be lowered just for the sake of having a driverless solution. This applies also to the first/last mile use cases with slow speeds and relatively short routes in which the automated shuttles have been intended to be used in the first place.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 780371.

For broad uptake especially in densely built areas where public transport is already working well it will require that shuttles are able to replace the existing fleet partly or fully as few areas remain uncovered. This is why the features of the shuttles should be designed to match with the requirements of the organizer of public transport. On these routes operated by conventional fleets the speed on the roads may easily rise up to 50 km/h in some parts of the routes, also in case of feeder traffic use cases. By not having the ability to operate on such routes restricts the potential use cases and usability of automated shuttles in the transport system. In practice this means that the need for changing from one means of public transport to another will increase as not the entire route can be operated with a shuttle.

Even though a fully workable and complete solution would be invented now, it can be presumed that it will take a couple of years to validate the functionality of the service and be sure that any onboard human intervention is not needed for safe and efficient operations. Within FABULOS pilots, the participating consortia thought it was still necessary to have the safety driver onboard in the vehicles and some tasks were still carried out by the safety driver. On the other hand it was not legally possible to operate the vehicles without the safety driver on board in some cities.

The majority of the automated shuttle prototype solutions used in FABULOS were designed from the start to not have a driver's compartment and traditional driving equipment (steering wheel and pedals) for the driver. Thus the safety driver was onboard in the vehicle in the same space with the passengers and controlling the vehicle with specific equipment which can not be considered as a safe and most efficient way of carrying out the operation. Safety drivers should be fully concentrating on monitoring the vehicle and its operation, while passengers can distract this task. As long as a human is needed to drive a vehicle in some tasks, it would be more sensible to fit the vehicle with a proper driver's compartment and equipment. In addition a drivetrain and other properties which would allow the vehicle to be driven in high speeds (around 100 km/h) in road traffic would significantly ease transporting of the vehicles for longer distances (no trailers etc. needed) and already existing public transport bus depots located further away from the operational area could be used the same way as with existing bus fleets.

As a conclusion, the PCP process was found as an efficient way to bring the development of driverless shuttle solutions forward. Together with its field tests, the Pre-Commercial Procurement process allowed practical insights and information for policy-making as well as updating rules and regulations surrounding remotely controlled driverless shuttles.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 780371.

7. References

Agreement on Government Procurement. The World Trade Organization (WTO). <https://www.wto.org/english/tratop_e/gproc_e/gp_gpa_e.htm> Read on 17.3.2021.

CO2-päästökertoimet. 2021. Motiva Oy. <https://www.motiva.fi/ratkaisut/energiankaytto_suomessa/co2-paastokertoimet>. Read on 18.3.2021.

Energia. 2019. Web article. European Environment Agency (EEA). <https://www.eea.europa.eu/fi/themes/energy/intro>. Read on 8.6.2020.

G. Technology readiness levels (TRL).2014. HORIZON 2020 – Work Programme 2014-2015. Online material. <https://ec.europa.eu/research/participants/data/ref/h2020/wp/2014_2015/annexes/h2020-wp1415-annex-g-trl_en.pdf>. Read on 2.7.2020.

Koskinen, Marika. 2021. Pre-Commercial Procurement (PCP) process usability and impact analysis.

Kyllönen, Essi. 2019. Transit planner, Helsinki Region Transport, Helsinki. E-mail discussion 15.1.2019.

Liikenneonnettomuudet. 2020. Helsingin kaupunki. <https://www.hel.fi/helsinki/fi/kartat-ja-liikenne/kadut-ja-liikennesuunnittelu/tutkimus-ja-tilastot/liikenneonnettomuudet/>. Read on 9.7.2020.

Salonen, A. 2020. Policy Brief 2/2020. Metropolia University of Applied Sciences, p. 6. <https://www.theseus.fi/bitstream/handle/10024/282923/2020_TAITO_46_The_need_for_reform_of_mobility_choices_is_urgent.pdf?sequence=2&isAllowed=y>. Read on 5.6.2020.

The Carbon-neutral Helsinki 2035 Action Plan. 2018. City of Helsinki. <http://carbonneutralcities.org/wp-content/uploads/2019/06/Carbon_neutral_Helsinki_Action_Plan_1503019_EN.pdf>. Read on 18.3.2021.

The Most Functional City in the World: Helsinki City Strategy 2017–2021. 2019. City of Helsinki. Online material. <https://www.hel.fi/wps/portal/HelsinkiV2/!ut/p/z1/04_Sj9CPykssy0xPLMnMz0vMAfIjo8zizQwtzAwNLYx8LUJDTQwcnTz8jCxDXIwNDIz0C7IdFQHz8e60/?current=true&urile=hki%3Apat

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 780371.

h%3A%2FhelsinkiV2%2Fen%2Fadministration%2Fstrategy%2Fstrategy%2Fcity-strategy#luku3> Read on 14.12.2020.

Tuuliainen, Eero. 2020. Smart Mobility market analysis FABULOS report.

World Production. 2018. ACEA. <https://www.acea.be/statistics/tag/category/world-production>. Read on 24.7.2020.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 780371.