Chapter 10
Mobility in Smart Cities: Will Automated Vehicles Take It Over?

Ralf-Martin Soe

1 Introduction

Many foresight-looking scholars tend to see autonomous vehicles as an inevitable development. For example, Yuval Noah Harari in his book *Homo Deus* compares autonomous vehicles and human-driven vehicles to the horses and human-driven vehicles. Late-nineteenth-century people could not imagine changing their flesh-and-blood emotionally and behaviourally responsive horses to manufactured non-personalised automobiles. According to Harari [1], this switch from horses to cars was an inevitable development as motorised vehicles are significantly more effective and the same outcome will eventually happen to human-driven vehicles that will be replaced by automated vehicles as superior technology. According to innovation researchers (e.g. [2, 3]), this is still not a straightforward process: in some cases superior technologies indeed replace non-superior ones, although it is not automatic and there are several cases, often driven by economic or business reasons, when superior technologies do not make it to the market.

In any way, over the past 100 years, the automobile industry has gone through many incremental and radical innovations but the main concept of a vehicle has remained the same. It is now that the automotive industry is facing one of the biggest revolutions in the history: driverless control of vehicles. There are first elements of computer-assisted driving already in mass production (e.g. adaptive cruise control, parking-assist systems) and there are first city pilots with passenger cars, buses and special-use vehicles.

Therefore, according to growing number of futurists, the main question is only “when” automated vehicles will take over lead in urban mobility. Nevertheless, this chapter is taking more critical approach and allows to ask a question starting with

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"whether", backed by innovation economics. Therefore, the key question to be analysed in this analysis is whether the transport in future cities will be fully or incrementally autonomous which determines the core setup of future smart cities. In the case of radical change (current human-driven vehicles are like horses that will be opted out from everyday urban traffic by more superior automated vehicles), today's cities' transport systems need to be fully upgraded both physically and virtually—future smart cities would look like the ones in the futuristic movies. On the other hand, in the case of incremental change (e.g. trains, trams and metros being fully automated and open-road vehicles having partially automated functions—something already happening today), autonomous vehicles will take over mainly closed-traffic and offer some automation options for human drivers that still remain in control in open-road traffic—therefore, smart cities of future will still look similar to cities of today.

In other words, this analysis is based on analysing two possible scenarios:

1. **Revolution:** future smart cities will have fully autonomous traffic.
2. **Evolution:** future smart cities will be only incrementally autonomous.

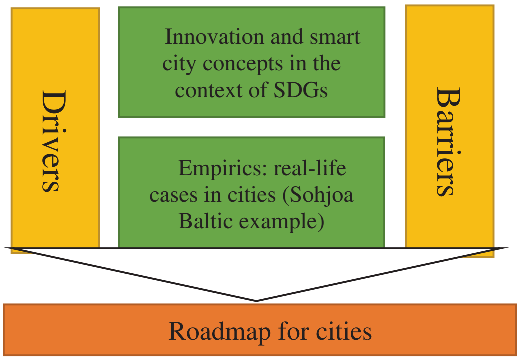
This chapter is set in the following logic. Firstly, autonomous vehicles in the context of smart city concept are analysed. Secondly, barriers and enablers of fully autonomous public urban transport system are evaluated. Thirdly, an empirical overview of cities introducing robot buses follows. Finally, a roadmap for smart city policymakers implementing (or non-implementing) autonomous vehicles is provided.

2 Conceptual Approach

This chapter aims to develop an empirical roadmap for the public sector (mainly cities) on how to implement automated transport in the urban context. This is a theory-driven and empirics-tested approach, meaning that innovation concepts and smart city frameworks will be mapped with examples from the real-life urban cases. It is expected that smart city (and smart mobility) aims to solve actual real-life global problems, and thus United Nations sustainable development goals (SDGs) in the case of urbanisation will be analysed (see Fig. 10.1). As a framework, main drivers and barriers will be analysed in order to provide public sector decision-makers an adequate picture of negative and positive effects of the automated urban transport.

The main research question is to understand under which conditions can we expect the revolution scenario (future cities having fully autonomous transport) and under which conditions can we have an evolution scenario (future cities being incrementally autonomous). Therefore, this is rather a visionary chapter with the aim to analyse what are the conditions (or drivers and barriers) to different scenarios. For this, real-life cases will be analysed, and the empirical part is partially based on the

Fig. 10.1 Conceptual framework



European Union-funded project Sohjoa Baltic (Baltic Sea Interreg project #R073) and its deliverables that tests automated buses in six cities across Europe.

2.1 The Scope and Role of Autonomous Vehicles in the Smart City Concept

This section analyses the role of autonomous vehicles within the innovation economics and smart city domains. In this analysis, autonomous vehicles are seen as potentially superior technology vehicles that aim to replace human-driven vehicles. As mentioned earlier, this process is not automatic. In other words, it is possible that autonomous vehicle is mainly twenty-first-century hype technology with incremental changes (evolution scenario); alternatively, in the case of most extreme revolution scenario, autonomous vehicles are as radical as introduction of personal computers and/or Internet that has significantly changed how we work and live. How do we know which scenario is more probable? For this, we will look into innovation research.

In order to analyse take-up of new technologies, it is important to make a distinction between invention and innovation [3]. Inventions can occur any time but not all of them will be turned into innovations. According to Perez [2], inventions (solutions that are technically feasible) significantly outnumber actual innovations. Innovations need to be economically profitable and socially acceptable before they can widely diffuse. A famous example is BETA technology that was superior to VHS video cassettes but never made it to replace VHS that already dominated the market [4]. Therefore, autonomous vehicles are currently in the status of being inventions that aim to innovate the transport system but their wider success depends on whether they are economically better and socially acceptable. To put it simply, innovations like autonomous vehicles need to have a strong business case and they also need to be widely accepted by people before they can fully diffuse. This will be central to the analysis in the next sections.

In order to understand the effect of automated transport for smart cities, we need to understand first what the concept of smart cities is, especially the role of mobility within this concept. Although smart city as a research area is still developing, it is often categorised via six dimensions, introduced by Giffinger and Haindlmaier [5]. This "smart city wheel" has spread to academia, cities and business sector and is taken over by the European Commission (see for example the report written by Manville et al. [6]).

Without doubt, smart city research has clear focus on the smart mobility (e.g. [7]) and smart mobility is an integral part of most research-based smart city frameworks (e.g. [5, 8–10]). Also empirically, smart city initiatives tend to be often in the field of mobility and environment (e.g. [6, 11]). In this chapter, we use the United Nations University (UNU-EGOV)-proposed smart city definition by Estevez et al. [12], according to which a smart city is:

> "*a city which […] solves multidimensional and complex problems […] aiming to achieve sustainable economic, social and environmental development*".

According to UNU-EGOV smart sustainable city framework (see Fig. 10.2), autonomous vehicles contribute to solving various transport-related problems and aim to make urban mobility smarter (e.g. via transport systems, accessibility and infrastructure). Automation of vehicles can also contribute indirectly to the smart environment domain offering more energy-efficient and economical ways for urban transit, and is interlinked with other domains.

2.2 Scope of Analysis

It is also important to define the scope of this analysis: In other words—what do we mean by autonomous vehicles in the urban context? In this analysis we mainly analyse the potential use of automated small buses with a purpose to offer alternatives

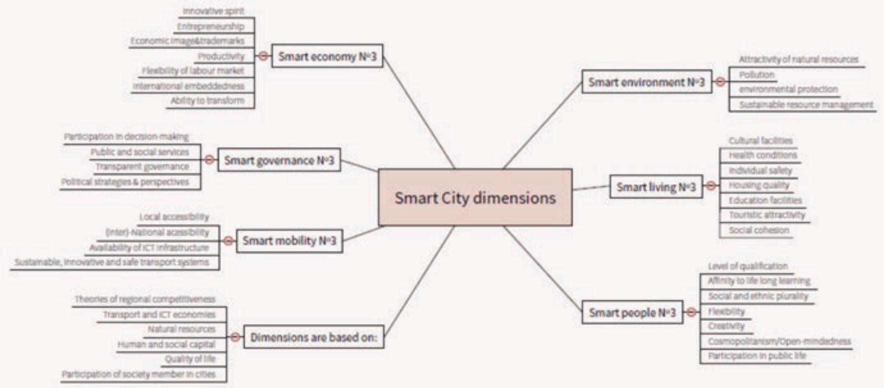


Fig. 10.2 Smart city dimensions by United Nations University

to the last mile transport in cities. This chapter mainly covers the developments of small electric minibuses and their testings on the urban roads, because this is already an ongoing process in many cities globally. In addition, we also track the developments of private cars as they can be used as shared cars in the urban environment.

Cities all over the world are entering the race in terms of who can introduce more robots on their streets. Google launched its self-driving car project in 2009 and has real-life testing experience in California's complex city streets, the average testing mileage reaching over 5000 km per day.[1] Volvo is planning a large-scale test with 100 cars in Gothenburg.[2] Beijing recently announced that it has earmarked 33 road sections with a total length of 105 km for testing autonomous cars.[3] In addition, significant number of cities perform tests with procuring market-ready solutions (such as EasyMile and Navya shuttles) and applying them in urban traffic (with most testing sites in the cities of Europe: Helsinki, Paris, Stockholm, Sion, Toulouse, Wageningen, Lausanne, Tallinn, Trikala, Berlin and others but also in the USA: Texas, Florida and Las Vegas; in Australia: Darwin and South Perth; in Asia: Nanjing, Singapore and Taipei). In addition, there are tens of urban road pilots planned for the next years to come.

In this analysis, it is crucial to distinguish between development stages of automated vehicles, as they apply differently. The most accepted approach among the automated mobility community is proposed by the SAE (Society of Automotive Engineers) International, a global standardisation organisation (see Fig. 10.3). According to SAE, there are the following levels of automation:

SAE 0: NO AUTOMATION (vehicle can provide driving-assist features)
SAE 1: DRIVING AUTOMATION ASSISTANCE (either steering OR braking assisted but not at the same time)
SAE 2: PARTIAL DRIVING AUTOMATION (steering AND braking assisted together as support feature only; human driver must supervise)
SAE 3: CONDITIONAL DRIVING AUTOMATION (automation of full driving task with human fallback; driver must respond promptly when alerted)
SAE 4: CONDITIONAL DRIVING AUTMATION (full automation in predetermined conditions; human must drive when system is not engaged)
SAE 5: FULL DRIVING AUTOMATION (human never has to drive unless he/she wants to)

This chapter does not analyse in depth the use of automated metros, trains, drones, boats, delivery robots, heavy-good vehicles, etc. (grey boxes on graph below) in order to limit the unit of analysis with most commonly spread vehicles globally (cars and buses) which could most radically change the future urban environments when applied on urban roads (see Fig. 10.4). Nevertheless, there are significant developments in these areas. For example, Massachusetts Institute of

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[1] https://techcrunch.com/2018/04/13/waymo-reportedly-applies-to-put-autonomous-cars-on-california-roads-with-no-safety-drivers/?guccounter=1

[2] https://www.agvegroup.com/volvo-cars-drive-program-100-self-driving-cars-gothenburg

[3] http://www.ecns.cn/business/2018-07-05/detail-ifyvvuhv1809109.shtml?TrucksFoT

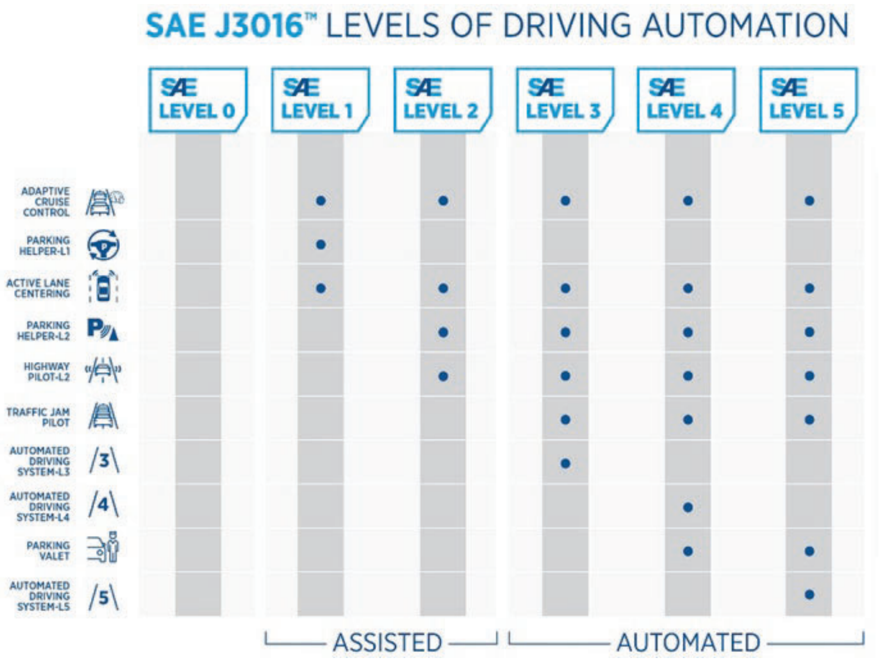

Fig. 10.3 Levels of driving automation. Source: SAE International

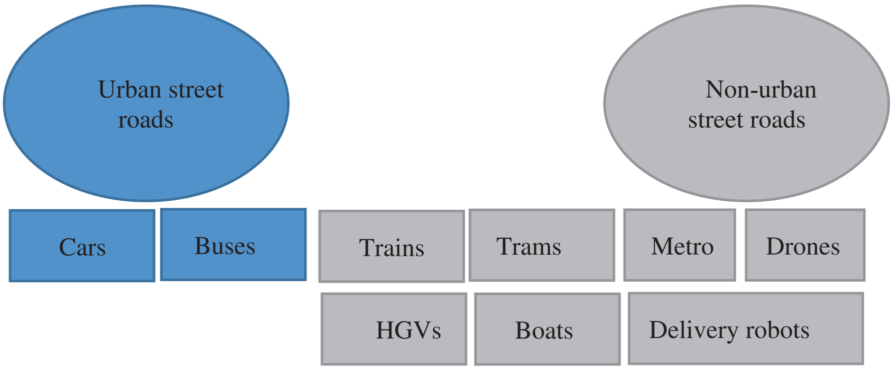

Fig. 10.4 Main focus: cars and buses on urban streets (in blue)

Technology (MIT) and the City of Amsterdam are planning to pilot a fleet of autonomous boats in Amsterdam canals[4] and former Skype founders plan to revolutionise urban deliveries (e.g. food and postal packages) with piloting delivery robots on pedestrian streets in several cities (mainly London, Tallinn and San Francisco).[5]

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[4] http://senseable.mit.edu/roboat

[5] https://www.starship.xyz

Plus, automation of railroad-based traffic (subways, trams) is already a reality in many cities with the most advantage that city environments can remain largely unchanged.

As this chapter has access to empirical data in planning and conducting actual last-mile automated transport pilots with small electric cars in the six European urban streets, more focus is put to the minibuses (around eight passengers) that could also be seen as hybrid vehicles between buses and cars. These pilots are mainly SAE levels 3–4 with potential to be upgraded to SAE 5. Thus, this analysis focuses on SAE levels 3–5.

2.3 Automated Transport and Sustainable Development Goals

How can we estimate whether autonomous vehicles contribute to the progress or regress of global urban development and whether they contribute to solve or create complex problems, following the UNU smart city definition? One way to tackle this, continuing with UNU-EGOV smart city-proposed smart city framework, is to analyse the globally agreed urban development goals and try to estimate how much automated transport can or cannot influence them. According to the United Nations sustainable development goals (SDGs), one of the global challenges is to make cities inclusive, safe, resilient and sustainable (goal # 11—sustainable cities and communities). Table 10.1 maps UN sustainable goals with the potential of autonomous vehicles.

The effect can be positive (helping to solve the goal) or negative (contributing negatively to achieving the goal). Therefore, it is very crucial to stress that introduction of automated transport is not a linear positive process per se: in some cases, this can have positive consequences whereas weak implementations can also lead to negative consequences. Therefore, it is crucial to analyse the potential positive and negative effects.

3 Barriers and Enablers of Autonomous Public Urban Transport System

In order to answer the question whether autonomous vehicles are radically or just incrementally changing the future, we need to analyse how acceptable they are economically and socially, following the innovation adaption theory by Carlota Perez. This will be pursued via key barrier and driver analysis. If automated vehicles would be introduced fully, urban congestion, traffic accidents and traffic pollution could be minimised, at least theoretically. In other words, there could be less lethal traffic accidents, less traffic jams and cleaner air. According to the Fédération Internationale de l’Automobile (FIA), every day 3500 people die on the roads globally. When

Table 10.1 Mapping of sustainable development goals and automated vehicles

Sustainable cities and communities	The estimated potential of autonomous vehicles
By 2030, ensure access for all to adequate, safe and affordable housing and basic services and upgrade slums	Limited to moderate effect: enhanced mobility improves access to basic services, especially for people living in slums, and reduces the time spent in congestion
By 2030, provide access to safe, affordable, accessible and sustainable transport systems for all, improving road safety, notably by expanding public transport, with special attention to the needs of those in vulnerable situations, women, children, persons with disabilities and older persons	Moderate to very strong effect: fully automated transport could be, at least theoretically, safer, more accessible and sustainable, and there is potential to reduce the costs of transit when implemented full scale In addition, automated transport could also give special attention to the needs of vulnerable situations
By 2030, enhance inclusive and sustainable urbanisation and capacity for participatory, integrated and sustainable human settlement planning and management in all countries	No effect to limited effect: it depends how inclusive and participatory is the process of introducing automated transport for cities. It can help connecting the most vulnerable communities
Strengthen efforts to protect and safeguard the world's cultural and natural heritage	No effect to negative strong effect. Autonomous transport has no effect on protecting the heritage to strong negative effect on non-protecting it (fully automated transport requires reconstruction of urban environments)
By 2030, significantly reduce the number of deaths […] and decrease the direct economic losses […] caused by disasters […] with a focus on protecting the poor and people in vulnerable situations	Limited to moderate effect (both negative and positive). Autonomous vehicles can be designed to be resilient to natural disaster and protect most vulnerable people, but that depends deeply on how they are designed
By 2030, reduce the environmental impact of cities, including by paying special attention to air quality and municipal and other waste management	Up to strong effect. Automated transport can effectively decrease urban congestions and CO_2 emissions by reducing the number of vehicles on cities
By 2030, provide universal access to safe, inclusive and accessible, green and public spaces, in particular for women and children, older persons and persons with disabilities	The effect can range from strong positive to strong negative depending on how the automated transport is implemented. In the positive scenario with smaller number of cars in cities and also parking lots—the access to green and public spaces is enhanced. In the negative cases, reconstructing the cities for autonomous vehicles could also limit this access
Support positive economic, social and environmental links between urban, peri-urban and rural areas by strengthening national and regional development planning	No effect to limited positive or negative effect. This depends on how the automated transport is implemented. If this is planned on the regional levels, then it has positive effect on linkage urban, peri-urban and rural areas. If not, it can introduce mobility silos, thus having a negative effect

(continued)

Table 10.1 (continued)

Sustainable cities and communities	The estimated potential of autonomous vehicles
By 2020, substantially increase the number of cities and human settlements adopting and implementing integrated policies and plans towards inclusion, resource efficiency, mitigation and adaptation to climate change, resilience to disasters, and develop and implement […] holistic disaster risk management at all levels	Limited effect to moderate effect. Depending on how successful the implementation of automated transport is, it can diffuse to limited number of global cities (limited effect) to a majority of cities (strong effect). In any case, automated transport contributed to wiser use of resources
Support least developed countries […] in building sustainable and resilient buildings utilising local materials	No effect

autonomous vehicles take it over, this could be rapidly minimised close to 0, at least theoretically. Automated vehicles coupled with sharing economy concepts would be a very effective measure against large inefficiencies of private cars in cities for two reasons:

1. Significant number of private cars have single driver only.
2. Most of the time, private cars are parked.

According to the much debated OECD [13] study,[6] when autonomous vehicles are coupled with shared economy, nearly the same mobility can be delivered with 10% of the cars exemplified in the case of Lisbon, the capital of Portugal. In other words, it is possible to simulate that one non-stop self-driving shared taxi is as effective in offering mobility as nine private cars in current urban setting. The effect comes from the logic that cars would have more than a single passenger on average and automated cars can be driving non-stop instead of being parked. In the case of larger cities, the MIT Senseable City Lab has modelled earlier based on New York that taxi sharing could reduce the number of trips by 40% with only minimal inconvenience to the passengers [14].

On the barrier side, automated vehicles on public roads require a significant upgrade of urban infrastructure with substantial costs and serious rebuilding involved in already regulated urban environment. Plus, maybe even more importantly, urban citizens would lose a significant fraction of their everyday freedoms such as owning and driving a car for the city traffic purpose and also freedom to take risks and make mistakes in everyday situations (such as exceed speeding limits, cross the street with red lights, park or stop on a wrong place)—driving skill becomes as handwriting skill in a modern computerised office. In this radical scenario, this would have a significant labour market effect as well—number of transport jobs will be effectively substituted by artificial intelligence.

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[6] https://www.itf-oecd.org/sites/default/files/docs/15cpb_self-drivingcars.pdf

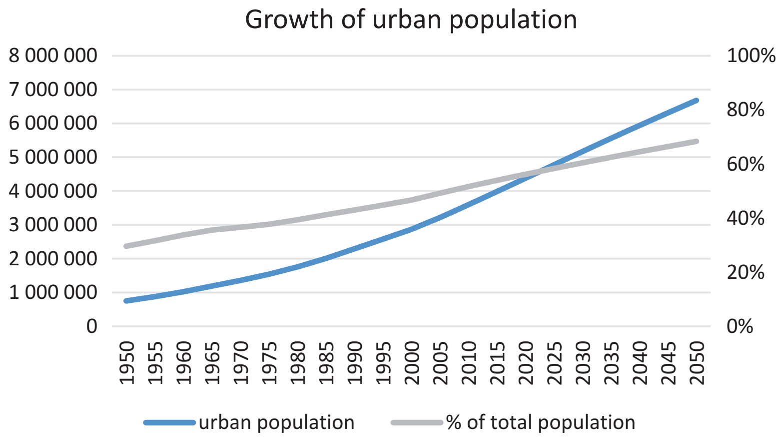


Fig. 10.5 Historical and estimated urban population growth. Source: United Nations. World Urbanization Prospects: The 2018 Revision

3.1 Key Driver: Urbanisation

According to the United Nations World Urbanisation Prospects [15], the urban population of the world has grown rapidly since 1950, having increased from 751 million to 4.2 billion in 2018 (whereas total population, including rural areas, has grown from 2.5 to 7.2 billion). Continuing population growth and urbanisation are projected to add 2.5 billion people to the world's urban population by 2050, with almost 90% of this growth happening in Asia and Africa (see global growth in Fig. 10.5).

Globally, more people live in urban areas than in rural areas, with 55% of the world's population residing in urban areas in 2018. In 1950, 30% of the world's population was urban, and by 2050 68% of the world's population is projected to be urban. More people in cities means also more traffic that needs to be dealt with (e.g. according to Washburn and Sindhu [16], one of the aims of smart city initiatives is to reduce congestion in cities). In the case of urbanisation, significantly more vehicles in cities create real demand for smart mobility solutions. One effective solution is shared automated mobility that can decrease the number of vehicles in cities rapidly.

3.2 Key Driver: Technology

It is very difficult to estimate when and if one technology becomes superior to the current technology and thus has potential to either radically replace previous technology or offer a strong competition. In any case, this is not a momentous situation but it takes significant amount of resources and time to develop new technologies and next it takes time and effort to bring them to the market. For example, landline telephone was replaced by the mobile phones and mobile phones are being replaced by smartphones, although this diffusion takes time and it can be described as a geological sediment where new technologies compete successfully with older ones, although old ones will stay as alternative in place. The same logic applies to TVs and smart TVs, watches and smartwatches, and vehicles. This following subsection analyses the maturity of electric automated minibuses in the case of urban traffic.

The key to understanding autonomous driving is to understand that vehicles need to be equipped with a large number of sensors that provide real-time data to making autonomous decisions. In the case of current minibus pilots, these decision options are pre-programmed, thus making automated minibuses like trams with "virtual trails". When the minibus is put into traffic, their trajectory needs to be recorded several times using sensors and cameras and later the minibus just continues this operation autonomously while reporting continuously on the localisation of the minibus based on analysing sensor and visual data. If everything goes smoothly, minibus can continue this for unlimited number of times without interruption. In the case of unplanned (or unprogrammed) events, the control of the minibus needs to be taken over by human drivers, either via computer on-board or then remotely by computer via Internet. Therefore, the automated minibuses have three ways to control the movement of vehicle:

1. Automated control following the pre-programmed trajectory
2. On-board human control via computer
3. Remote control via Internet and computer

According to Ainsalu et al. [17], automated vehicles are equipped with various sensors that provide data on velocity (based on encoder sensors of mechanical motion that generates digital signals in response to motion) and most importantly geographic position. The vehicles are being constantly localised in real time via a combination of satellites (e.g. global navigation satellite system, GNSS) and odometer sensors. As satellite localisation requires a direct connection between a spot on earth and satellites, in the case of disrupted connection (e.g. being indoors or between tall urban buildings), odometers help to position the vehicle. Automated vehicles also need to constantly report on their exact pose and for this GNSS are integrated often with inertial measurement units (IMUs) that help to measure vehicle orientation using specific sensors (accelerometer, gyroscope and magnetometer). Vehicles have also cameras on-board, and there is an approach to use visual cameras (front and back camera) to improve global positioning (generate a map and estimate robot location based on visual data), although this technique is still developing. The analysis of the surrounding environment is performed via cameras and 3D sensors with main goal to detect objects on the road. The most common sensors are radars in bumper (both front and rear) to detect the distance between vehicle and objects. In addition, automatic minibuses have LIDAR (light detection and ranging) that can estimate the distance between the vehicle and object via emitting a light wave (see Fig. 10.6).

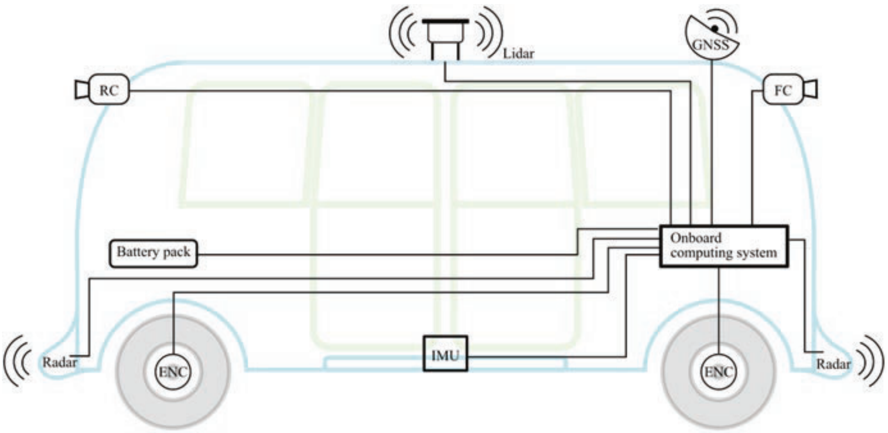


Fig. 10.6 Typical sensors in automated minibuses. Source: Ainsalu et al. (2018) [17]

One can also argue that current-day technology is also a barrier. The sensor technology is far from being as adaptive as expected for real-time decision-making. In this perspective, the current city pilots have experienced the following weaknesses, based on first pilots by EasyMile and Navya minibuses:

1. In the case of unexpected objects (e.g. bicycle passing by), the vehicle is pre-programmed for full stop. Therefore, the speed is often limited to up to 20 km/h in order to avoid any accidents caused by the full stop. The full stop is usually followed by manual on-board control of the vehicle.
2. Strong sensitivity to everyday weather conditions (e.g. drop of rain or falling tree leaves because of wind) too often requires manual takeover.
3. Changes in the visual surrounding environment (e.g. real estate developments) can also stop the vehicle unexpectedly.
4. Sensors and cameras are not developed well enough to follow the simple traffic rules (e.g. there are difficulties in reading the traffic lights and also giving permission to cross the road in the case of pedestrian crossings).
5. In practice, front radar can be too limited, e.g. ignoring higher heavy goods vehicles.

3.3 Key Driver: Market Solutions

Although there are several companies developing market solutions for automated vehicles, there are rather limited options for cities that wish to purchase or lease the buses. Only a limited number of companies (mainly Navya and EasyMile, see Fig. 10.7, but also RDM Autonomous) can deliver buses at this stage, although there are several companies aiming to enter the market soon (e.g. Waymo and General

Fig. 10.7 Main solutions on the market: EasyMile and Navya buses

Motors, Local Motors) or in a few years from now (Apple, Volkswagen Sedric, Robomart). Therefore, the main providers are the following:

EasyMile EZ10. The EZ10 has been the most common demonstrator of autonomous buses. The EZ10 is a battery-powered autonomous electric vehicle designed by Ligier and marketed by EasyMile. It seats up to six people and allows six more passengers to ride standing, or can accommodate a wheelchair. It has been piloted in cities in Finland, Estonia, Norway, the Netherlands, California in the USA and other places. It can operate in metro mode, bus mode and on-demand mode, although the on-demand mode has not been demonstrated on open roads before. With pre-programed routes the on-demand mode can utilise only what has been thought to the vehicle during the programming. EZ10 runs on virtual tracks that are predefined, and needs only light infrastructure to operate (e.g. enough visual cues on road side and possibly local GPS for better positioning). Ligier is a French company.

NAVYA ARMA. NAVYA launched ARMA in October 2015. It is 100% electric and autonomous driverless shuttle that can transport up to 15 passengers and safely drive up to 45 km/h. NAVYA has similar driving modes as EZ10. NAVYA was the vehicle used in the Swiss PostBus demonstration in open roads in 2016 in Sion. NAVYA is a French company.

Local Motors Olli. Local Motors is a US-based company with offices in Europe (Berlin). Olli is a self-driving vehicle designed by Urban Mobility Challenge: Berlin 2030 winner Edgar Sarmiento, and built by Local Motors. The company positions it as “more than a selfdriving vehicle—a platform for new ways of using and thinking around transportation”. It demonstrates integration to Watson, and some parts are 3D printed. Autonomy and fleet management are similar to others.

3.4 Key Barrier: Legal Set-Up

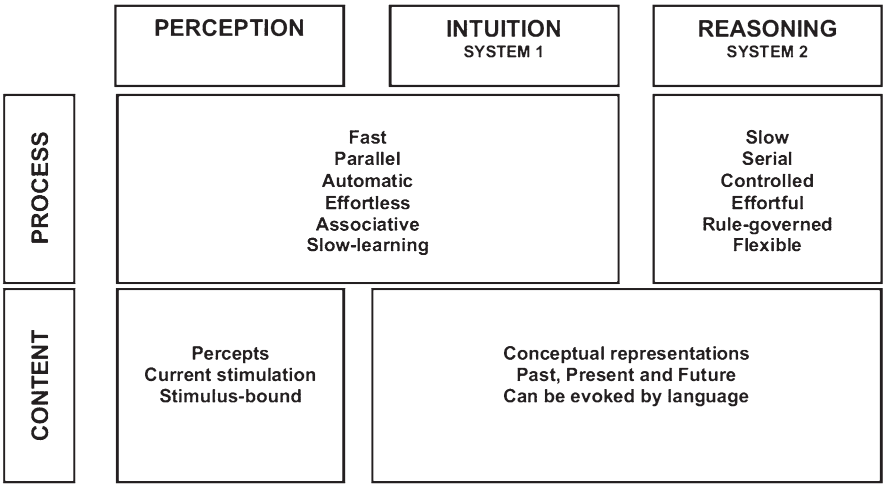
From the legal perspective, it is important to distinguish automated driving levels (see Fig. 10.3). In the case of SAE levels 1–2 (driving assistance and partial driving automation), very limited legal innovation is needed, as human still stays fully responsible for driving as today. In the case of SAE 3–5 (conditional driving automation to full driving automation) applied on open streets, significant to radical legal changes are expected. In the longer run, this could even require adding third juridical type throughout the legal system. Currently, driving responsibility (and all other responsibilities) is defined via private or business individuals. In the case of fully automated driving, as is debated, there might be a need of adding robot (or artificial intelligence) individual. In the case of ongoing automated driving pilots applied on open urban streets, very often they are legally constructed as testings of new vehicles, especially when on SAE levels above 3. SAE 5 on urban streets has not been tested; it is legally too complex. In other words, usually SAE3 vehicles on open urban roads have testing licences and human driver as legally responsible. In the case of robot buses, the following laws should be analysed (based on [17]):

- Vehicle registration law (how new vehicles can be registered and put in use; what kind of technical inspections should be carried out and what kind of requirements the vehicle needs to meet; what kind of additional documents should be provided; for example, in Europe, Road Administrations would like to see vehicles following registration regulations in most important parts: how the seats are installed, safety windows, break acceleration, door-closing force, emergency lights, reflectors, lights used in car traffic and where they are installed, kill switch in the bus—based on EU Directive 2007/46)
- Human driver regulations (automated driverless vehicle often cannot obtain a car registration due to its non-compliance regional law (e.g. EU UNECE rules) or local traffic acts; the way to overcome this, in the case of SAE3 vehicles, is to state that every vehicle must have a responsible driver, but in testing automated vehicles the driver can be either inside or outside the vehicle)
- Special testing permit regulations (in many countries, testing automated driving is possible using a test plate certificate, usually up to SAE levels 3–4; these vehicles must have a driver either within the vehicle or acting remotely, who is responsible for the vehicle and takes control of it if necessary; testing can take place on public roads or off-road. Usually testing permissions are given by Road Administrations for a few months, with possibility to extend them; when applying for a test plate certificate, it is often needed to describe how their stewards/safety drivers will be trained)
- Passenger transportation permit (in the case of involving passengers in testings, there is a need to obtain a taxi or passenger transport permission)
- Driver's licence (due to the need for having a human driver, he/she also needs to have a driving licence; the type of driving licence is determined according to the weight and length of the vehicle as well as the number of passengers; typically, no special licence is needed for automated vehicles)

- Liability law and insurance (one should also follow regulations on product liability, e.g. European Directive 85/374/EEC; the use of automated vehicles within public road traffic up to SAE levels 3/4 raises no special insurance requirements, e.g. traffic liability insurance is a must)
- Criminal law (the main question is whether criminal liability applies only to driver and/or also to manufacturer or any legal entity)

3.5 Key Barrier: Human Acceptance

As mentioned before, innovations need to be also socially acceptable which is often ignored in urban traffic modelling and planning. In 2002, a decision researcher Daniel Kahneman won the Nobel Prize in Economics for a series of work (co-authored with Amos Tversky) proving that people tend to think irrationally, especially in making economical decisions. This chapter is not about rationality analysis but it is clear that the assumption that people are rational is still too often assumed by the traffic, ICT and urban planners, and this can be challenged, similarly to economic decisions. How else can we explain that 3500 people die on roads every day globally,[7] considering that most (if not all) accidents are unintentional—most people do not commute with a purpose to "kill someone" or to "be killed". When using the Kahenman's model (see also Fig. 10.8) people tend to make mistakes when they make intuitive decisions.



	PERCEPTION	INTUITION SYSTEM 1	REASONING SYSTEM 2
PROCESS	Fast Parallel Automatic Effortless Associative Slow-learning		Slow Serial Controlled Effortful Rule-governed Flexible
CONTENT	Percepts Current stimulation Stimulus-bound	Conceptual representations Past, Present and Future Can be evoked by language	

Fig. 10.8 Human rationality and irrationality. Source: Kahneman (2011) [18]

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[7] https://www.fia.com/3500lives

People-driven urban traffic is full of mistakes. For example, in a midsized European city Tallinn, journalists discovered that 500 traffic mistakes were made during every 60 min in one midsized traffic junction[8] (mainly cars ignoring “no left turn” signs, bus lines, straight lines and also pedestrians crossing the street in wrong place or with red light on); this observation could be continued with stopping and parking mistakes or non-attentive driving (e.g. reading emails on smartphone). This happens in all cities globally every hour with smaller or bigger adjustments.

On the other hand, the logic of autonomous vehicles is that they are programmed to strictly follow all the rules—artificial intelligence or simply a code recorded for driving will most probably avoid at least most mistakes that could lead to unintentional consequences. In other words, it is very probable that autonomous cars and buses would be strictly programmed to actually follow all the traffic rules and this makes it more complicated to have mixed open roads (e.g. both driver-driven and autonomous vehicles on urban roads)—automated vehicles have difficulties in understanding and predicting human behaviour as it often varies and does not follow rules. Therefore, fully rational and automated revolution scenario can take place when opting out human drivers and this might not be socially acceptable. On the other hand, the fact that humans make more mistakes than pre-programmed automated vehicles (at least theoretically) can also make this a strong argument and a driver, once this is accepted socially.

3.6 Key Barrier: Economic Costs

Continuing with Perez [2], in addition to being socially acceptable, novel superior innovations also need to be economically beneficial. Currently, automated vehicles on open roads have no economic advantage, rather the opposite. In most cases, automated minibuses have an innovation and city marketing purpose whereas they do not pass the cost-effectiveness test. Putting a self-driving shuttle in service is significantly more expensive (initiate setup €40–50 00, a monthly rental cost of automated EasyMile or Navya minibus is around €15 000 per bus + costs of drivers’ salary) whereas one could lease a human-driven shuttle bus for manifold lower price.

This is also the rationale why most pilots are funded by the competitive R&D funds—it is harder for cities to procure such solutions using local taxpayers’ money. At the same time, as the sensor technology is still improving, these buses in operations are capped with speed limit of up to 20 km/h; at the same time regular shuttles can operate following city’s speed limits. Nevertheless, there are plenty of empirical examples of superior technologies being more expensive (e.g. smart TVs, electric cars) which still make it very successful in the market. According to Rogers ([19], Fig. 10.9), the key to success is to get a small group of people (innovators) using the

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[8] http://ekspress.delfi.ee/kuum/autojuhtide-anarhia-tallinna-sudalinna-ristmikul-eiratakse-liiklusmarke-500-korda-tunnis?id=82689315 (in Estonian)

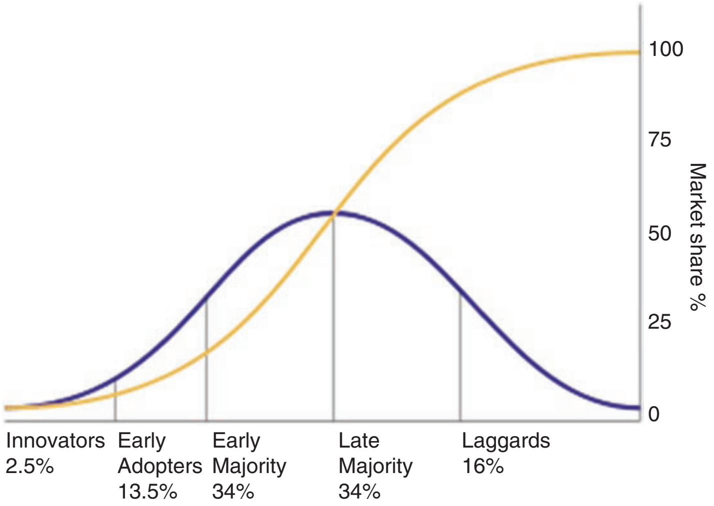

Fig. 10.9 The diffusion of innovations (with successive groups of consumers adopting the new technology (shown in blue), its market share (yellow) will eventually reach the saturation level). Source: Rogers [19]

novel innovations that will be followed by early adaptors, early and late majority and then laggards. Most importantly, innovations do not gain market share linearly but rather exponentially with the first steps being the hardest.

4 Overview of Autonomous Vehicle Initiatives

To date, there are first closed-road pilots conduced all over Europe (e.g. Warsaw, Brussels, Bordeaux, Lean, Trikala, Milan) and globally (e.g. in China[9] and the USA[10]) and first limited trials in the real-life traffic (e.g. in Helsinki and Gelderland). On the other hand, there are no full city-district and no city-level demonstrations and there are no fully automated driving pilots on urban roads (SAE 5 level).

In reality, when zoomed into pilots, evolution scenario tends to be more probable that mimics the development path of technology and regulations. As described in the barrier and enabler section, the current technology is too limited with some fundamental challenges that can actually leave the entry of fully autonomous cars and buses on the urban streets as hype. As the first public tests indicate, the urban

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[9] https://www.weforum.org/agenda/2018/07/chinese-internet-giant-baidu-has-just-rolled-out-self-driving-buses

[10] http://icities4greengrowth.in/casestudy/pittsburgh-smart-traffic-control-pittsburgh-united-states-america

automated reality is far from letting self-driving cars onto pubic roads with three main weaknesses:

1. Sensor- and image-recognition technology is not advanced enough.
2. All driver's regulation is centred in individual (human) drivers instead of systems/robots.
3. Autonomous vehicles have difficulties in operating in open traffic.

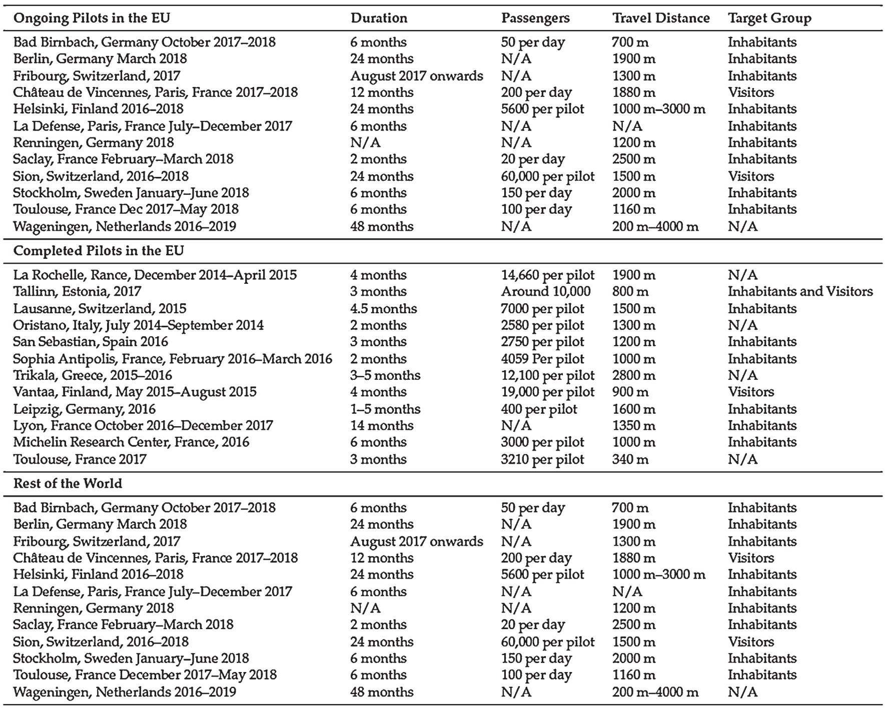
If the first limitation could be seen as technological barrier and second legal barrier which can be at least theoretically solved (or then proven to be non-solvable) then the latter is a fundamental problem that is very difficult to solve without separating autonomous cars and human-driven cars. Namely as first pilots indicate on open roads (e.g. following projects like City2mobile, Sohjoa and others), robot buses tend to be too slow, require manual operators coupled with virtual ones (= driver with a joystick in the bus coupled with a supervisor behind screen) and are inflexible. This has led to the situation that without manual and virtual operators, robot buses in open environment would be stopped in most cases due to either passing-by cars, pedestrians or even small change in physical environment (e.g. close-by construction) or weather conditions (sometimes a drop of rain can stop the vehicle). Therefore, there are no fully automated market-ready solutions for open-road traffic but rather a pre-programed route automation on low speed with actual drivers involved and responsible.

In order to understand the rationale and design of the automated robot bus pilots in the urban contexts, the following section describes one pan-European project and its aims based on the Sohjoa Baltic project documents and deliverables. Firstly, Sohjoa Baltic project team has developed a state-of-the-art report (of which the author of this chapter was one of the contributors, see [17]) listing all known robot bus urban pilots carried out (Fig. 10.10) and also in preparation (see Fig. 10.11). The next section provides in-depth overview of Sohjoa Baltic project for more detailed understanding of how these pilots are planned, mainly based on the project application plan (of which the author of this chapter was one of the contributors).

4.1 Sohjoa Baltic Project

This section is based on the Sohjoa Baltic project proposal and deliverables, co-authored or accessible to the author of this chapter.

The lack of citywide coverage by public transport system increases the automobile dependency for commuters leading to severe congestion on roads, road fatalities, deteriorating air quality and vast CO_2 emissions. Currently public transport is not able to offer competitive option alongside private cars for flexible, on-demand type of operation, and especially the gap in the last-mile connectivity becomes a major barrier to use public transport. The challenge of transition from private cars to public transportation can be addressed by changing the structure of public transport with autonomous operation, introducing safer, attractive, innovative,

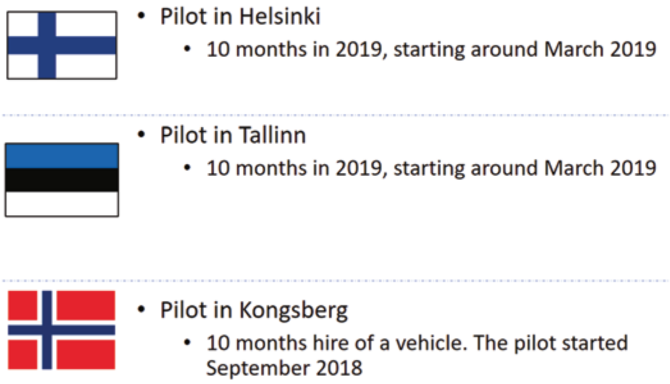


Ongoing Pilots in the EU	Duration	Passengers	Travel Distance	Target Group
Bad Birnbach, Germany October 2017–2018	6 months	50 per day	700 m	Inhabitants
Berlin, Germany March 2018	24 months	N/A	1900 m	Inhabitants
Fribourg, Switzerland, 2017	August 2017 onwards	N/A	1300 m	Inhabitants
Château de Vincennes, Paris, France 2017–2018	12 months	200 per day	1880 m	Visitors
Helsinki, Finland 2016–2018	24 months	5600 per pilot	1000 m–3000 m	Inhabitants
La Defense, Paris, France July–December 2017	6 months	N/A	N/A	Inhabitants
Renningen, Germany 2018	N/A	N/A	1200 m	Inhabitants
Saclay, France February–March 2018	2 months	20 per day	2500 m	Inhabitants
Sion, Switzerland, 2016–2018	24 months	60,000 per pilot	1500 m	Visitors
Stockholm, Sweden January–June 2018	6 months	150 per day	2000 m	Inhabitants
Toulouse, France Dec 2017–May 2018	6 months	100 per day	1160 m	Inhabitants
Wageningen, Netherlands 2016–2019	48 months	N/A	200 m–4000 m	N/A
Completed Pilots in the EU				
La Rochelle, Rance, December 2014–April 2015	4 months	14,660 per pilot	1900 m	N/A
Tallinn, Estonia, 2017	3 months	Around 10,000	800 m	Inhabitants and Visitors
Lausanne, Switzerland, 2015	4.5 months	7000 per pilot	1500 m	Inhabitants
Oristano, Italy, July 2014–September 2014	2 months	2580 per pilot	1300 m	N/A
San Sebastian, Spain 2016	3 months	2750 per pilot	1200 m	Inhabitants
Sophia Antipolis, France, February 2016–March 2016	2 months	4059 Per pilot	1000 m	Inhabitants
Trikala, Greece, 2015–2016	3–5 months	12,100 per pilot	2800 m	N/A
Vantaa, Finland, May 2015–August 2015	4 months	19,000 per pilot	900 m	Visitors
Leipzig, Germany, 2016	1–5 months	400 per pilot	1600 m	Inhabitants
Lyon, France October 2016–December 2017	14 months	N/A	1350 m	Inhabitants
Michelin Research Center, France, 2016	6 months	3000 per pilot	1000 m	Inhabitants
Toulouse, France 2017	3 months	3210 per pilot	340 m	N/A
Rest of the World				
Bad Birnbach, Germany October 2017–2018	6 months	50 per day	700 m	Inhabitants
Berlin, Germany March 2018	24 months	N/A	1900 m	Inhabitants
Fribourg, Switzerland, 2017	August 2017 onwards	N/A	1300 m	Inhabitants
Château de Vincennes, Paris, France 2017–2018	12 months	200 per day	1880 m	Visitors
Helsinki, Finland 2016–2018	24 months	5600 per pilot	1000 m–3000 m	Inhabitants
La Defense, Paris, France July–December 2017	6 months	N/A	N/A	Inhabitants
Renningen, Germany 2018	N/A	N/A	1200 m	Inhabitants
Saclay, France February–March 2018	2 months	20 per day	2500 m	Inhabitants
Sion, Switzerland, 2016–2018	24 months	60,000 per pilot	1500 m	Visitors
Stockholm, Sweden January–June 2018	6 months	150 per day	2000 m	Inhabitants
Toulouse, France December 2017–May 2018	6 months	100 per day	1160 m	Inhabitants
Wageningen, Netherlands 2016–2019	48 months	N/A	200 m–4000 m	N/A

Fig. 10.10 List of ongoing and competed robot bus pilots in urban environment. Source: Ainsalu et al. [17]

Adelaide, Australia (N/A)
Calgary, Canada (2018)
Copenhagen, Denmark (2018)
Gainesville, U.S. (2018)
Gothenburg, Sweden (2018)
Hamburg, Germany (2018)
Knoxville, U.S. (2018)
London, U.K. (N/A)
Gjøvik, Norway (2018)
Drammen, Norway 2020
Tallinn, Estonia (2019, 2020–2022)
Vienna, Austria (2019)
Gdansk, Poland (2019)
Oslo & Gjesdal, Norway (2018, 2019)
San Francisco, U.S. (2020)
Stavanger, Norway (2018)
Sydney, Australia (2018)
Christchurch Airport, New Zealand (2018)
Melbourne, Australia (2018)
Ann Arbor, Michigan, U.S. (2018)
Shenzhen, China (2018)
Kongsberg, Norway (2018–2019)
Vejle, Denmark (2019)
Koppl, Austria (2018–2020)
Helsinki, Finland (2018, 2019, 2020)

Fig. 10.11 List of future pilots in urban environment. Source: Ainsalu et al. [17]



- Pilot in Helsinki
  - 10 months in 2019, starting around March 2019
- Pilot in Tallinn
  - 10 months in 2019, starting around March 2019
- Pilot in Kongsberg
  - 10 months hire of a vehicle. The pilot started September 2018

Fig. 10.12 Large-scale pilots of Sohjoa Baltic project

energy-efficient and improved service. Autonomous transport promotes the usage of urban public transportation including automated driverless electric minibuses as part of the public transport chain especially for first/last-mile trips. Through large-scale pilots in three European cities (see Fig. 10.12) and also 1-month demonstrations in three additional cities (see Fig. 10.15), the project brings institutionalised knowledge and competence on organising environmentally friendly and smart automated public transport solutions as well as providing guidelines on the organisational setup needed for running such a service in an efficient way.

Automated buses will not be optimal everywhere for next few years until technology maturation; therefore Sohjoa Baltic specifically intends to find out first suitable applications and development paths. As all of the development can't be done in laboratories, experiments on the roads are required to bring meaningful data to the discussion. The pilots will act as a proof that the concept is capable to work in transnational environments and can be replicated.

The Sohjoa Baltic project seeks to enhance environmentally friendly transport systems in urban areas by increasing the capacity of urban transport actors, by working out a joint vision, policy and business recommendations as well as short-, medium- and long-term action plan on removing existing barriers and facilitating public transport. These outputs will be used by urban planning authorities, urban transport authorities, companies providing public transport, traffic safety authorities and private sector innovation, service developers and academic and research institutions. This is supported by the increased awareness and improved acceptance of the current and new users of public transportation.

The project aims to provide a toolkit for cities to start the shift towards eco-friendly urban transport. Through the need for developing autonomy and successful paradigm shift from private cars to public transport, traffic will change, emissions will be reduced as well as regional development and consistency will be improved in urban surroundings.

Despite moderately well-executed public transportation, average occupancy of the vehicles in the cities is low, for example about 20% in Finland. In some participant countries (e.g. Poland) the use of public transport has even decreased in the last few years. Instead of mere base traffic, travel chain should be seen as a whole and provide options where the so-called last-mile journey has been resolved. A large part of the traffic between the cities is made with passenger cars because public transportation can't offer competitive alternatives for the last mile. This was proven for instance by the former Kutsuplus service in Finland, which demonstrated that public transport is not able to offer competitive options alongside private cars, even in densely populated regions for flexible, on-demand type of operation.

Automatic vehicles themselves do not solve traffic problems such as traffic congestions and vast CO_2 emissions. Traffic problems can be solved by increasing the modal share of the public transportation (see also Fig. 10.13). The relative efficiency of public transport modes compared to passenger cars is much higher, which means less deteriorated air quality and fewer CO_2 emissions. In addition cars take up a disproportionate amount of space compared to the number of people transported which leads to traffic capacity problems especially in densely populated areas. By using public transportation, more space is released to the housing and parks. Also traffic congestions decrease and traffic safety improves.

As part of the many vehicles featuring self-driving capabilities, automated last-mile public transportation will be among first services. A clear service and cost benefit for automated last-mile public transportation exist, but the products are still developing and slowly entering the market through closed areas such as factories,

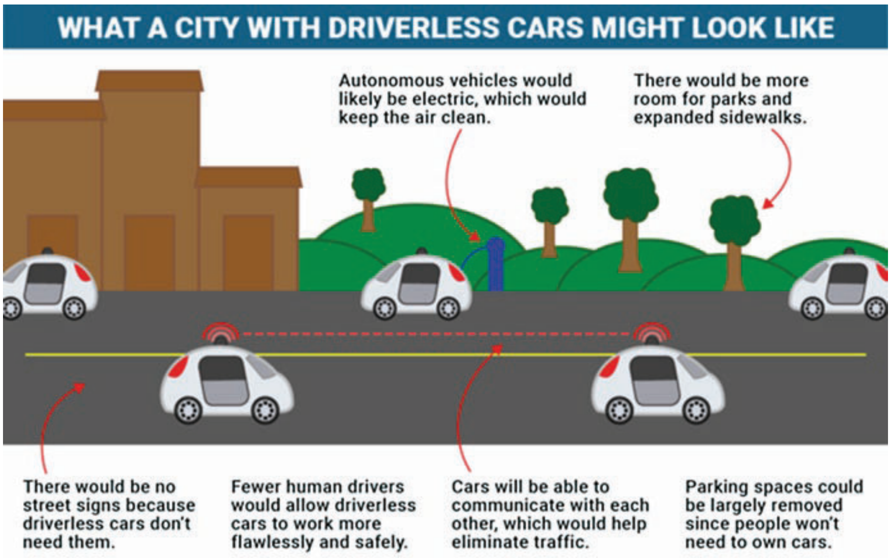


Fig. 10.13 The potential environmental effect of fully autonomous driving. Source: Chris Dixon; Business Insider

amusement parks and zoos. When technology develops through closed-area operations and open-road pre-commercial pilots, it is evident that the next automation area will be in the last-mile public transportation. For pre-commercial autonomous demonstrations, several countries have the legal framework (such as Finland and Norway, which are also piloting cities in the project) and several are undergoing the legal framework to allow autonomous demonstrations and testing in the traffic (such as Sweden and Estonia). This can later lead to full operation in traffic.

Currently, public transportation is very diverse in many countries, some regions are moving rapidly towards electrified fleets, but some are still running conventional fleets, Norway and Poland as opposed examples. When the use of public transport increases, also the desire and the need to develop the fleet increase. In combination with the growing use of low-emission public transportation vehicles such as biogas and hybrid buses, not to mention the rail traffic, energy consumption savings can be achieved by integrating electric automated last-mile public transportation to the travel chain. The energy needed to operate electric vehicles can be produced completely CO_2 free, depending on the electricity production. Even further energy consumption savings can be achieved by flexible and optimised automated local fleet leading to a truly environmentally friendly urban mobility.

Competitiveness of public transport can be best promoted by increasing the supply, affecting the travel time and reducing prices. Automated operation will change the consistency of public transport, introducing innovative, energy-efficient and improved service. However, to achieve this change, it is necessary to solve the gaps associated to operational, regional, public transportation planning, legal, economical, technological, user acceptance, risk analysis and benchmarking aspects of such services.

Main target groups of the project are urban planning authorities, urban transport authorities, companies providing public transport, traffic safety authorities and private-sector innovation and international. These target groups share the need to better understand how to enable the shift to automated public transportation and how their operating environment will be affected. Also, an important need for the target groups is to promote and then take advantage from the promotion of environmentally friendly urban mobility as well as increase the awareness of how to set up the automated operation and what are the benefits or risks for cost, emissions, service quality, safety, technology and other mobility provider's perspectives. Main need of the users of public transport is to have affordable, yet efficient, public transportation mobility chain service locally.

The European project CityMobil2 (CM2) demonstrated the technical feasibility of automated last-mile transport and fostered the adoption of such new transport systems. From the EU side CM2 has been a milestone on which to build new research and demonstration activities. Last-mile automated transport is now a market issue and the way in which automation will contribute to public and shared transport still remains open.

One of the purposes of Sohjoa Baltic is to remove the barriers identified by the CM2 project.

Barriers like missing marketing and communication strategy to increase the overall acceptance of the automated road transport systems (ARTS), and specifically:

- To increase the level of awareness of the ARTS
- To increase the level of awareness of the benefits of the ARTS
- To correct perceptions that individuals might have for the ARTS in comparison with the conventional transport system

4.1.1 Large-Scale Pilots

Under this group of activities three real-life automated bus pilots will be implemented (Helsinki, Kongsberg and Tallinn). All the pilots will be planned, implemented and evaluated jointly with co-creation activity. Three cities selected for large-scale pilots have unique piloting conditions: all cities have four seasons, including the large variation in daylight (from 6.5 h in December to 19 h in June) and the winters are cold and snowy. The large-scale pilots are meant for the cities where automated bus piloting has already been done (e.g. Finland and Norway) or will be done before the launch of this project.

There has been experiments in Finland, Norway and Estonia. Next the large-scale demonstrations are logical continuation in the selected cities where piloting will be taken to the next level:

1. Automated buses will run for longer period in one location (typically it has been for a day/week but in the case of large-scale demonstrations, it will be at least 1 month in one location). See Tallinn's route in Fig. 10.14.
2. The pilots will be integrated with the city transport network (previous short pilots have been conducted in isolation) and cross-border mobility solutions will be mapped.
3. New mobility options including automated vehicles can be sustained; the next step is to integrate them as part of everyday fleet operated, provided that the outcomes of our pilots are successful.
4. There is effective knowledge sharing between partnering cities, including rotation of operators, if proven necessary.

It should also be noted that large-scale pilots will work in line with small-scale pilots (in Zemgale, Gdansk, Vejle) so that these cities can learn from the best practices.

The large-scale pilots are planned to start late 2018 (Norway) or 2019 (Estonia and Finland) and run throughout the entire year with the following characteristics:

1. Buses will be in operation up to 9 months in each city, mostly in real-life traffic on open roads.
2. Buses will stay in one predefined location for minimum 1 month, so passengers can incorporate them to their everyday mobility plan and create demand for sustaining this service.

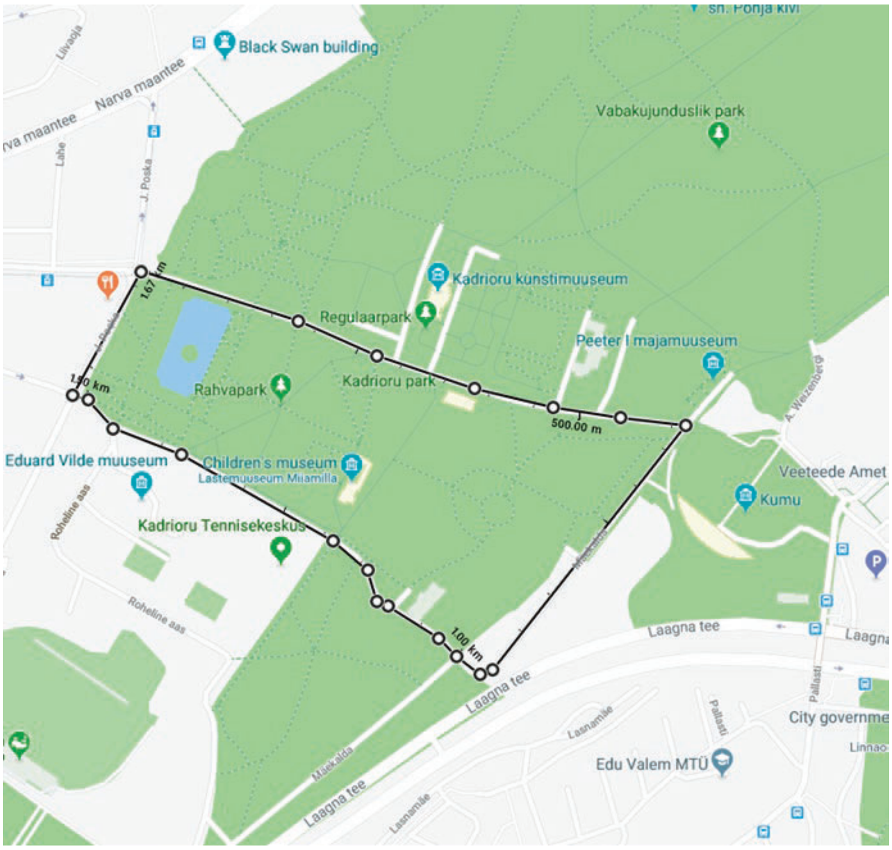


Fig. 10.14 Initial route planned in Tallinn starting 2019

3. During the pilots, buses will be projected to operate up to 10 h a day and 6 days a week.

The planning, implementation and evaluation of these pilots will be done mutually in the consortium and this will be effectively documented for other cities' replications.

4.1.2 Small-Scale Pilots

The small-scale pilots (showcases, see Fig. 10.15) are likely to last for 1 month with the possibility of setting up more than one bus route within this period. The showcases serve as pilots for transport operators from countries which have no current legislation on the autonomous transport in place and for the cities where the automated bus piloting hasn't been tested yet. After the large-scale pilots in Helsinki,

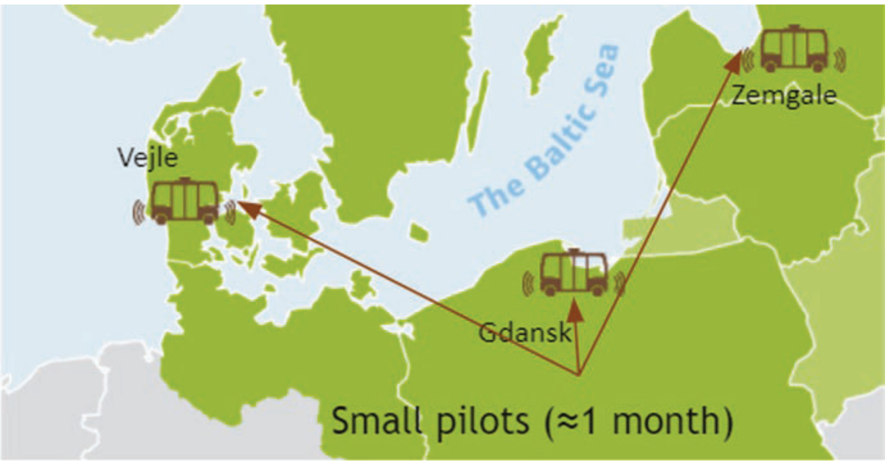


Fig. 10.15 Sohjoa Baltic small pilots

Kongsberg and Tallinn at least three showcases will be organised in Gdansk, Zemgale and Vejle with the following characteristics:

1. While the large-scale pilots test the automated buses in different weather conditions, the showcases raise the awareness of automated transport and have a significant marketing impact.
2. Hosts of the small-scale pilots learn from each other and from the hosts of the large-scale pilots. They work in partnership to plan and organise successful showcases and to evaluate it.
3. To benefit from cross-marketing it is planned to include the small-scale pilots in other significant events, e.g. the European Mobility Week; therefore the buses won't have to be integrated in the city's transport network.
4. The small-scale pilots are planned between August 2019 and February 2020.

Both types of demonstrations will prove that this solution is capable to work in transnational environment and can be replicated:

1. While the small-scale pilots are local, the concept can be implemented in any urban environment that fits the requirements defined in the project.
2. The transnational experience can be extended by a live video streaming of the small-scale pilots from inside of the vehicle so that anyone could be a virtual passenger of the automated bus and the transport providers could better understand the automated intelligent public transport.
3. Hosts of the small-scale pilots will invite local politicians as well as transport providers from other cities and regions in their countries to extend the local character of the demonstrations and share the experience of the automated intelligent transport solutions.
4. Through both large- and small-scale pilots the projects bring competence on provision of the eco-friendly and smart automated transport solutions and guidelines on the logistics and technicalities of running a service.

The urban planning and transport authorities and transport providers will be involved in the development of the transnational roadmap to automated last-mile public transportation. Consequently all the project partners, authorities and users involved will develop best practices for knowledge exchange and will collate both training and technical guidelines for operators.

Small-scale pilots raise the awareness of the public to the concept of the automated transport and allow the users of automated transport to experience it.

5 Concluding Roadmap for Cities

The first automated bus pilots can already be analysed in order to help cities to decide whether and how to start using the automated fleet on open urban roads.

Based on driver and barrier analysis and empirical examples of the previous section a conceptual framework for implementing autonomous vehicles is proposed in Fig. 10.16. The framework encompasses four main components: input, transformation, output and outcome and each of those components is composed by elements. The input component consists of (1) urbanisation, (2) technology and (3) market. The transformation component consists of (4) regulation, (5) cultural and (6) economic. The component output consists of (7) evolution and (8) revolution and finally the component outcome consists of achievement of the (9) SDGs.

The framework is directed at policymakers on three levels:

- Local government (e.g. cities)
- Central government (central and federal governments)
- Regional government (multiple areas/countries)

It should be noted that the aim of this chapter is not to predict the future; it is rather to analyse under which conditions future cities can have fully automated vehicles on public urban roads, that is, how the revolution scenario can realise. On the other hand, there are clear reasons to argue that the evolution scenario is more probable as fully automated transport assumes radical rebuilding of cities. Nevertheless, both scenarios are possible, although their probabilities are rather dynamic, changing across time and locations. In other words, the probability to introduce automated fleet is expected to increase over time and applies more to novel or more adaptive cites.

There are clear incentives for introducing automated vehicles on open urban roads. Firstly, in the area of urbanisation, the cities just need to cope with increased

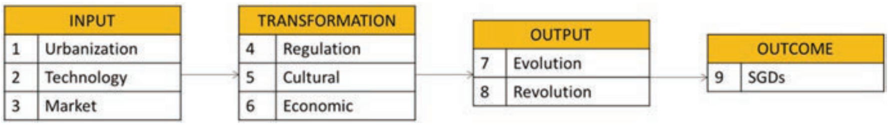


Fig. 10.16 Framework to implement autonomous vehicle initiatives

congestion and thus automated and shared urban transport can effectively traffic smoother, reducing the need of vehicles up to ten times for the same number of trips. Secondly, there is already more than a decade of technology advancement which has intensified over the past years. The breaking point will be when automated vehicles prove to be superior to human driven. Thirdly, already first market solutions like EasyMile and Navya vehicles are available for all cities, and the demand tends to be higher than supply.

As explained in the innovation's entry barriers to the market, there are also examples when superior technologies do not reach mainstream, mainly due to social non-acceptance and economic costs. Therefore, there are also lock-ins or disincentives that can block automated vehicles from becoming a mainstream: firstly, the current legal system that needs to be upgraded with third legal person: artificial intelligence; secondly, humans as collective life freedoms related to open traffic and human driving and there can be logical resistance towards giving this ability to drive away to robots; and thirdly, automated vehicles need to get much cheaper compared to the current solutions on the market.

To conclude, the aim of cities pursuing to become smart should not be technology driven but should be to help solving actual global challenges on the broader level. Thus, this analysis maps United Nations smart sustainable goals with potential and threats of automated vehicles in the case of urban development.

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